NSW ROADS AND MARITIME SERVICES

HW1 Princes Highway, Bulli - Traffic modelling

Options assessment report

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EXECUTIVE SUMMARY

WSP | Parsons Brinckerhoff was commissioned by NSW Roads and Maritime Services to develop an Aimsun traffic microsimulation model to assess the existing and future operational performances of the HW1 Princes Highway corridor in Bulli, NSW, between Sturdee Avenue in the north and Hospital Road in the south.

A base model was developed in Aimsun using traffic surveys from March 2016 in order to establish a baseline for the future year modelling. The 2016 weekday AM, weekday PM and Saturday base models were calibrated and validated to the criteria defined by the Roads and Maritime *Traffic Modelling Guidelines (2013)*. These base models (and associated documentation) were submitted to Roads and Maritime and subsequently approved as fit-for-purpose in the future year modelling of the study area.

The 'do-minimum' modelling indicated that without these treatment options, the southbound queue in particular on the Princes Highway, would extend past Hobart Street in future year 2036. This level of congestion would approximately double the southbound travel time on the Princes Highway and significantly affect the local amenity of the corridor. The forecast level of queuing and travel time by 2036 indicated that there were key capacity pinch points on the Princes Highway corridor, including the one-lane section of the Princes Highway (impacted by on-street parking during the peak periods), the Princes Highway/Molloy Street roundabout and right-turn movements on the Princes Highway corridor in shared through/right turn lanes at key intersections.

To mitigate the impact of the pinch points identified in the 'do-minimum' assessment, the improvement options were assessed in six scenarios in future years 2026 and 2036. The assessment was undertaken in the following three stages, with the peak period clearways on Princes Highway (between Park Road and Station Street) and widening of on-ramp lanes to Memorial Drive implemented in all scenarios.

- Stage 1 assessment (Scenario 1–3) – Princes Highway/Molloy Street:
  - Revised roundabout lane allocation, traffic signalisation and consolidation with Memorial Drive off-ramp were assessed.
  - Scenario 1, revising roundabout lane allocation to provide two through lanes to Memorial Drive, was deemed as the preferred option, based upon the overall balance of infrastructure cost and network benefit.
- Stage 2 assessment (Scenario 4 and 5) – Princes Highway/Park Road and Princes Highway/ Station Street intersections:
  - 'No right turn' treatment and traffic signalisation at Princes Highway/Station Street intersection were assessed.
  - Scenario 4, which bans the northbound right turn at Princes Highway/Station Street intersection, was deemed as the preferred option based on the traffic performance and vehicle queuing results. To complement this treatment, a right-turn phase at the downstream Princes Highway/Park Road intersection is provided.
- Stage 3 assessment (Scenario 6) – Princes Highway/Point Street intersection:
  - The provision of a northbound right-turn bay at the intersection of Princes Highway/Point Street was assessed and the results demonstrated that it would provide an appreciable improvement to corridor safety and efficiency.

Based upon the outcomes of the abovementioned assessment, the preferred scenario is **Scenario 6** based on the network performance, corridor efficiency and safety outcomes. In summary, Scenario 6 includes the following treatments:

- → Peak period clearways on the Princes Highway, between Park Road and Station Street.
- → Two on-ramp lanes to Memorial Drive.
- → Two through lanes at Princes Highway/Molloy Street roundabout to Memorial Drive.
- → A 'No Right Turn' from Princes Highway (south) to Station Street and to complement this with a right-turn phase from Princes Highway (south) to Park Road.
- → A northbound right-turn bay at Princes Highway/Point Street.

Based on the traffic modelling results, Scenario 6 would provide significant improvements in travel time, network delay and corridor safety/efficiency, compared to the 'do-minimum' scenario in both future years 2026 and 2036. The improvements in 2036 are summarised below.

- → VHT in network statistics are 21%, 26% and 5% lower in respective AM, PM and Saturday peak periods.
- → Number of vehicle stops in network statistics are 24%, 29% and 10% lower in respective AM, PM and Saturday peak periods.
- → Northbound travel time is improved by 20% (approximately 35 seconds), 19% (35 seconds) and 6% (10 seconds) in respective AM, PM and Saturday peak hours.
- → Southbound travel time is improved by 49% (approximately 3 minutes and 30 seconds), 19% (3 minutes and 40 seconds) and 10% (20 seconds) in respective AM, PM and Saturday peak hours.
- → Under this corridor arrangement, the intersections on the Princes Highway corridor operate at an acceptable LoS (of LoS D or better).

A rapid economic assessment was undertaken for Scenario 1, 2, 4 and 6. Although Scenario 6 has the highest costs based on preliminary estimation, the rapid economic assessment results indicate that it is economically viable with the Benefit-Cost Ratio (BCR) of 11.9 and a positive Net Present Value (NPV) of approximately $42.3M.

An indicative prioritisation of the improvement options is summarised below. Overall, this prioritisation of works is based upon the relative impact of the different pinch points upon the efficiency and safety of the Princes Highway corridor in Bulli over the medium to long term.

1. Critical corridor elements (with pre-2026 implementation):
   a) Peak period clearways on the Princes Highway, between Park Road and Station Street
   b) Provision of two on-ramp lanes to Memorial Drive AND reallocation of lanes at the Princes Highway/Molloy Street roundabout to provide two through lanes to Memorial Drive
2. Right-turn management:
   a) 'No Right Turn' from Princes Highway (south) into Station Street AND implement protected right-turn signal phase at Princes Highway/Park Road
   b) Provision of a channelized right-turn bay at Princes Highway/Point Street.

Based upon the 'do-minimum' assessment, the critical corridor elements listed as Priority 1 should be undertaken prior to 2026. The right-turn management measures are considered to be cost effective from a traffic performance perspective. This is because they can be implemented at any time and would provide an immediate improvement to the operation of the Princes Highway corridor.

1 Introduction

1.1 Background

NSW Roads and Maritime Services (Roads and Maritime) commissioned WSP | Parsons Brinckerhoff to develop an Aimsun microsimulation traffic model for the purpose of assessing the existing and future operational performances of the HW1 Princes Highway corridor in Bulli, NSW, between Sturdee Avenue in the north and Hospital Road in the south. Figure 1.1 illustrates the study area along the Princes Highway Corridor.

In 2012, Roads and Maritime carried out a traffic study to investigate the improvement options of traffic operations through this section of the Princes Highway. The previous study recommended to retain the on-street car parking in the short term and suggested further investigations to improve other pinch points along the corridor.

The purpose of this WSP | Parsons Brinckerhoff commission is to assist Roads and Maritime to develop a program of works required to maintain efficient and safe traffic flow along the route in the future years. To achieve this purpose, a microsimulation traffic model is required to develop and assess the existing and future year traffic operational performances along the route and develop improvement options to maintain efficient and safe travel.

1.2 Modelling objectives

The key objectives of the microsimulation traffic modelling at the subject corridor are to:

- Replicate the existing conditions in the base model including known congestion and travel patterns and assess current and future traffic performances along the route and at key intersections
- Identify the treatment options to alleviate traffic congestion and improve travel time by assessing the performance of the route and key intersections in the base and future year scenarios
- Develop a preferred package of works to improve traffic operation and maintain road safety on the route
- Support the future business case development by providing the relevant statistical model outputs into Cost Benefit analysis.

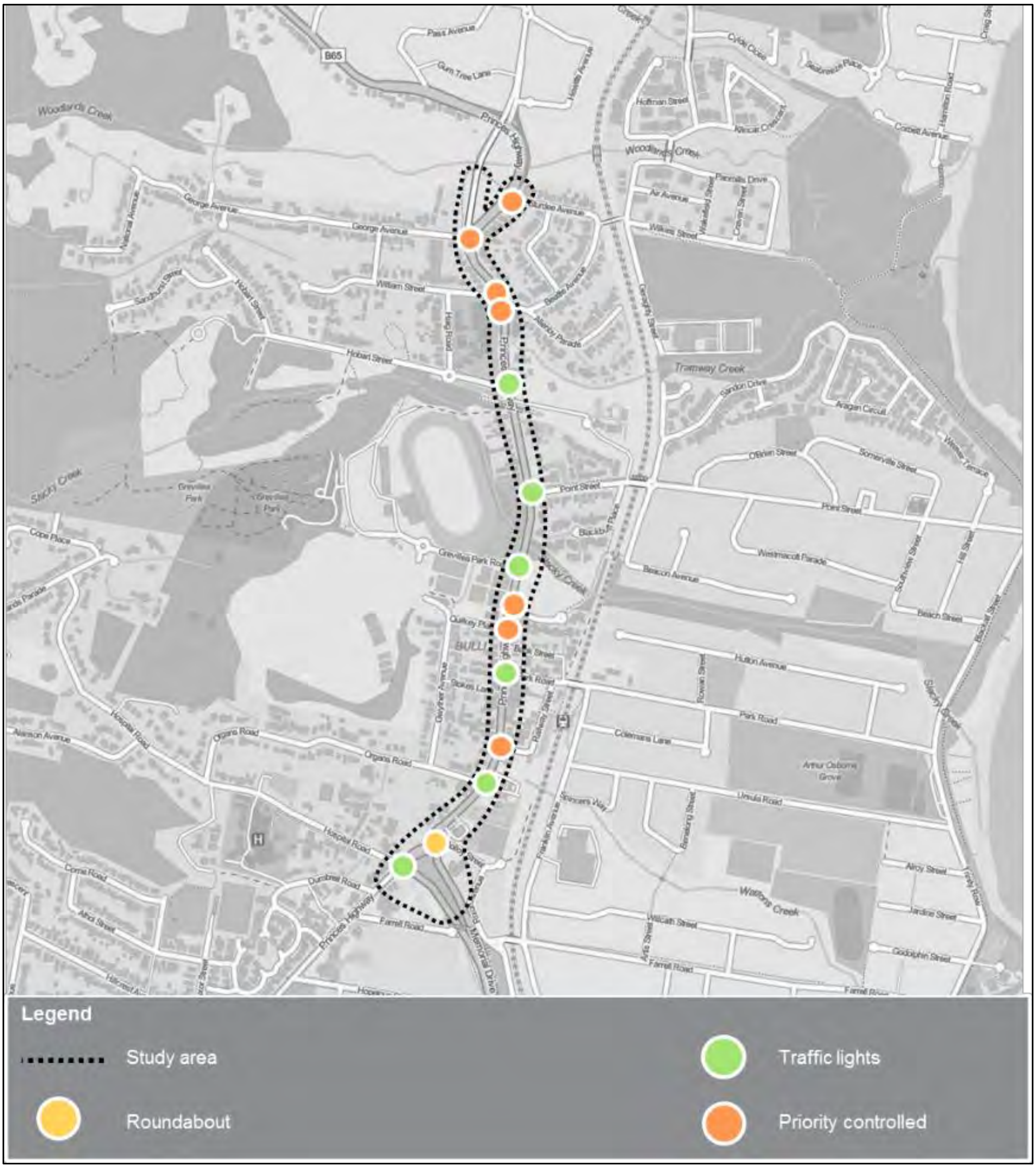


Figure 1.1 Study area

1.3 Summary of base model calibration/validation results

The outcomes of the calibration and validation of the 2016 base models, compared to the requirements of the Roads and Maritime *Traffic Modelling Guidelines (2013)*, are summarised in Table 1.1. This comparison confirms that the 2016 base models prepared for the Princes Highway, Bulli Aimsun modelling meet the relevant requirements of the Roads and Maritime guideline. As a consequence, the base models are deemed fit-for-purpose in regards to their use to assess the proposed improvement works along the Princes Highway corridor in Bulli, NSW.

Table 1.1 Base model calibration/validation summary

Criteria		Meets criteria?		
		Weekday AM model	Weekday PM model	Saturday model
Model calibration				
Intersection turning counts	100% of all 60 turning counts are below GEH 5	Yes	Yes	Yes
	Difference in flow within 10 for observed flows of < 100 vph	Yes (1)	Yes (1)	Yes (1)
	Difference in flow within 10% for observed flows of 100–999 vph	Yes	Yes (1)	Yes
	Difference in flow within 100 for observed flows of 1,000–1,999 vph	Yes	Yes	Yes
Model validation				
Travel time	Difference within 1 minute or 15%, for all of the routes	Yes	Yes	Yes
Queue lengths	Comparable for all of the key movements	Yes	Yes	Yes
Model stability				
Model variability	Reasonable level of variability	Yes	Yes	Yes
Vehicle release blocking	Vehicle release blocking not observed	Yes	Yes	Yes

(1) A total of approximately 10 intersection movements have a flow difference of 10–20 vehicles/hour compared to the criteria

1.4 Options modelling assumptions and methodology

The methodology adopted for the assessment of options is summarised in Figure 1.2. The results from the Aimsun microsimulation models have been obtained at the following three levels of detail:

→ Network wide: vehicle stops, travel delays and travel distance statistics of the entire Bulli study area, considering it covers the study objectives of both through traffic movements on the Princes Highway and local area traffic (e.g. in and out of Bulli town centre).

- Corridor level: travel time performance and queue length along the Princes Highway.
- Local and intersection level: local intersection traffic delay and queue length at local street sections.

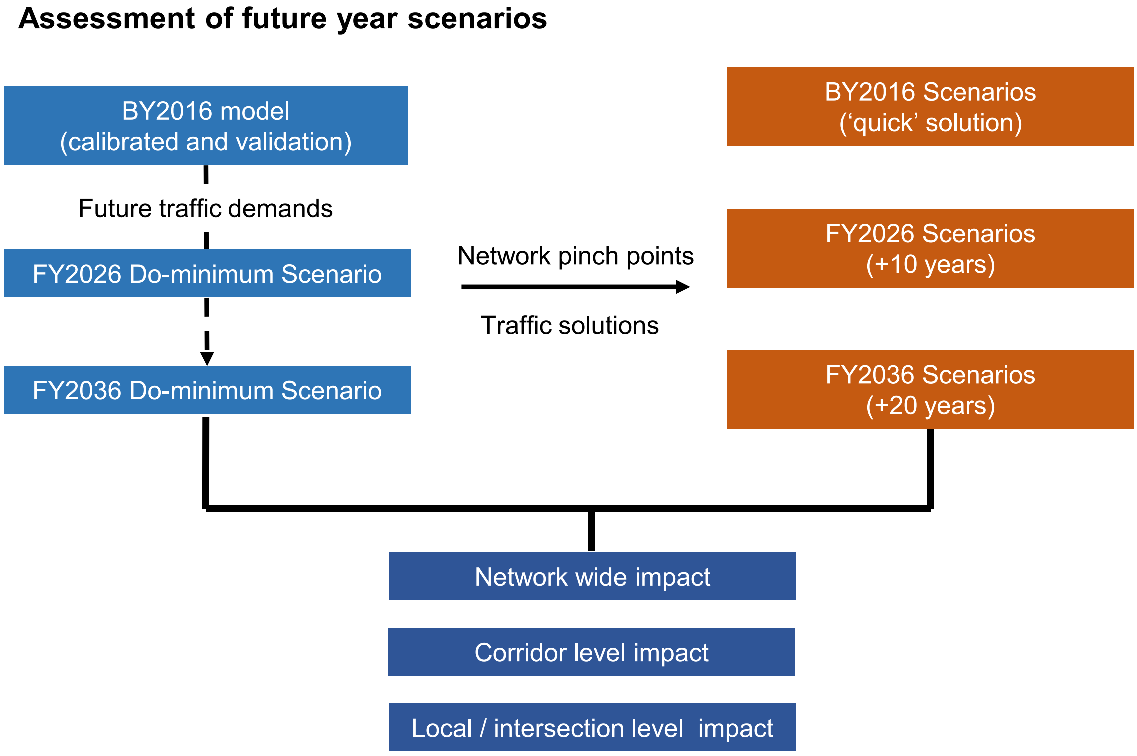


Figure 1.2 Assessment of future year options

1.5 Report structure

This report is structured as follows:

- Section 2 summarise the methodology and the results of the future year traffic estimation
- Section 3 summarises the outcomes of the 'do minimum' corridor assessment
- Section 4 outlines the options and scenarios assessed
- Section 5 to 7 detail the assessment results of each scenario
- Section 8 discusses the crash reduction analysis undertaken
- Section 9 summarises the economic assessment undertaken
- Section 10 outlines the key conclusions of this report.

2 Future traffic demands

2.1 Overview

The future traffic demands were estimated for the purpose of assessing the future road network performance. The following data sources and references have been reviewed to undertake the traffic demand estimation:

- Population and employment forecasts sourced from the NSW Transport and Performance Analytics (TPA) website
- Forecast traffic growth from the Roads and Maritime TRACKS model for 2011, 2021 and 2036
- Historical AADT traffic growth at Roads and Maritime traffic count stations
- Bulli Pass Strategic Review (Roads and Maritime, October 2015).

In addition to background traffic growth, the traffic flows associated with approved/committed developments within the study area have also been considered.

The following sections summarise the findings regarding the traffic growth rates for the Bulli study area. Detailed documentation and justification for the traffic growth rate assumptions are provided in the '*Bulli & Thirroul future traffic growth assumptions*' memorandum attached in Appendix A. The memorandum was submitted to Roads and Maritime in May 2016 and was subsequently approved for use as part of the future year modelling.

2.2 Background traffic growth assumptions

Table 2.1 summarises the annual background traffic growth rate within the study area, as agreed with Roads and Maritime for use as part of the future year modelling. These growth rates are based upon the review and analysis of the above data and reference documents.

Table 2.1 Proposed future traffic annual growth by corridor

ANNUAL GROWTH RATE	WEEKDAY AM PEAK		WEEKDAY PM PEAK		SATURDAY PEAK	
	Short term (2016–2021)	Long term (2021–2036)	Short term (2016–2021)	Long term (2021–2036)	Short term (2016–2021)	Long term (2021–2036)
Bulli Pass	1.4%	0.5%	1.4%	0.5%	1.4%	0.5%
Princes Highway (south)	1.4%	0.7%	1.4%	0.5%	1.4%	0.5%
Memorial Drive	1.4%	0.5%	1.4%	0.5%	1.4%	0.5%
Lawrence Hargrave Drive	0.4%	0.5%	0.5%	0.5%	0.5%	0.5%
Other side streets	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%

The traffic growth will be applied to both directions of each road based upon the origin/destination centroid. This is based upon the TRACKS model outputs which indicate that traffic growth is expected to be similar in both directions of travel, particularly over the long term.

2.3 Committed traffic generating developments

The following traffic generating developments have been approved and are expected to have an impact upon the future year traffic volumes within the study area:

- Sandon Point residential subdivision
- Bulli Brickworks.

In total, these developments are estimated to generate approximately 400 vehicle trips during the weekday AM and PM peak periods. For the purposes of modelling, the average trip generation rate of the weekday AM and PM peak periods will also be applied during the Saturday peak period. This is due to limited guidance from the *Guide to Traffic Generating Developments v2.2 (2002)* and *TDT 2013/04a* for the relevant land uses during the weekend peak period.

2.4 Estimated future midblock flows

Table 2.2 summarises the total future midblock traffic volumes for the modelling year 2026 and 2036, based up on the proposed traffic growth rates discussed in sections 2.2 and 2.3. These midblock flows indicate the following:

- There is a significant increase (of approximately 20%) in the directional midblock flows on the Princes Highway during all peak periods
- The estimated future traffic demand would exceed the expected midblock capacity for one lane for urban areas of 1,000 vehicles/hour/lane
- The 2036 traffic demand, particularly approaching the Molloy Street roundabout, is likely to exceed the capacity of the roundabout
- The impact of the proposed residential developments at Bulli Brickworks and Sandon Point would cause the critical peak period to change from the weekday PM to the weekday AM peak. This is due to the high proportion of outbound trips during the AM peak period from these developments, which would add around 125 vehicles/hour to the southbound flow.

Table 2.2 Estimated future midblock traffic demand (veh/hr)

Road		AM peak hour			PM peak hour			Saturday peak hour		
		2016	2026	2036	2016	2026	2036	2016	2026	2036
Northbound										
Princes Highway	North of Hobart Street	1,230	1,420	1,500	1,320	1,420	1,500	1,330	1,460	1,530
Princes Highway	North of Memorial Drive	1,050	1,240	1,310	1,290	1,520	1,590	1,180	1,370	1,440
Princes Highway	South of Hospital Road	510	600	650	480	550	570	570	630	660
Memorial Drive	East of Princes Highway	780	900	960	1,060	1,260	1,320	830	980	1,020
Southbound										
Princes Highway	North of Hobart Street	1,410	1,600	1,690	1,590	1,810	1,890	1,300	1,460	1,530
Princes Highway	North of Memorial Drive	1,460	1,740	1,840	1,510	1,710	1,790	1,320	1,540	1,620
Princes Highway	South of Hospital Road	510	600	650	670	760	800	530	600	630
Memorial Drive	East of Princes Highway	1,130	1,360	1,430	910	1,040	1,100	890	1,040	1,090

The details of the methodology used in estimating the future traffic growth was documented in memorandum *Bulli and Thirroul traffic growth assumptions* (Appendix A). This memorandum was issued to Roads and Maritime in May 2016. Roads and Maritime has since approved WSP **|** Parsons Brinckerhoff use of the proposed traffic growth rates in the future year traffic modelling.

3 Future 'Do-minimum' assessment

3.1 Overview

As agreed with Roads and Maritime, there are no infrastructure upgrades currently under construction or due for completion within the project scope. As a result, the road network modelled in the future year 'do-minimum' scenario is identical to the existing road network. The results of future do-minimum scenarios have been used as a reference case to compare the impact of the proposed traffic options.

The future year traffic demands and the corresponding traffic signal adjustments have been applied in the 'do minimum' scenarios. The applied traffic signal adjustments were based on the results from SIDRA Intersection modelling.

3.2 Network queuing

The key model pinch points are summarised in Table 3.1, including snapshots of the network queuing identified in the future 'do-minimum' modelling for the weekday AM, weekday PM and Saturday peak periods.

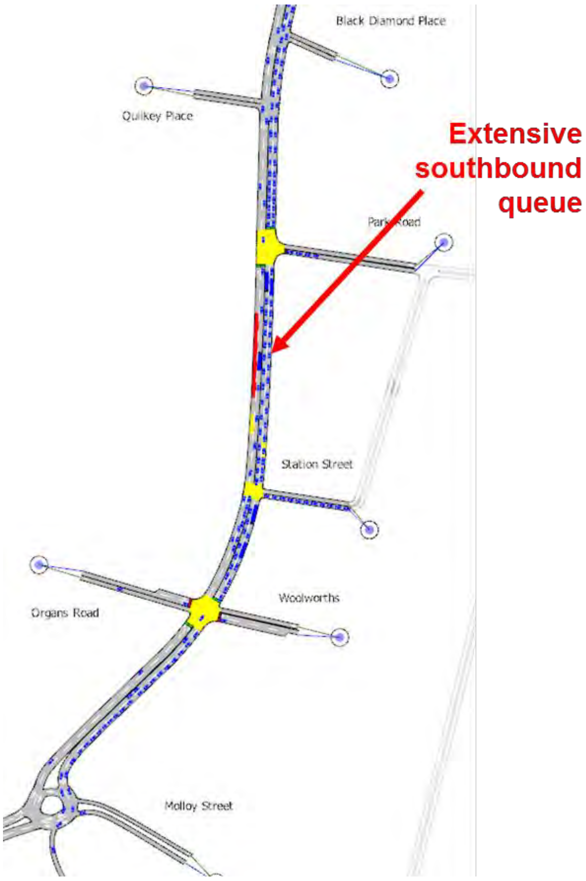
Overall, these model screenshots indicate that without any additional infrastructure works on the Princes Highway corridor, there will not be sufficient road capacity to accommodate the future year demand. In particular, the two key constraints which impact upon the performance of the network are:

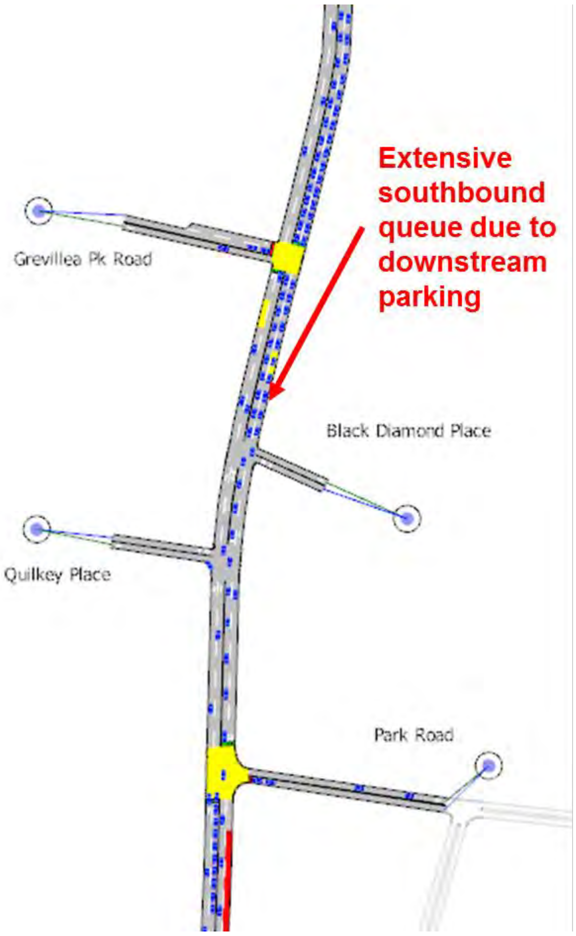
- Roundabout at Princes Highway/Molloy Street:
  - This roundabout provides one southbound lane to Memorial Drive and two southbound lanes to the Princes Highway, although the dominant movement is to Memorial Drive
  - This geometry forces a significant proportion of vehicles to change to the kerbside lane to be able to continue through into Memorial Drive
  - During the 2026 AM peak period, the southbound queue extending from this intersection would extend past Point Street. By the 2036 AM peak period, this queue would extend past Beattie Avenue
- On-street car parking on Princes Highway (southbound), south of Park Road:
  - This on-street car parking reduces the southbound capacity on the Princes Highway and forces vehicles into a single lane through the Bulli Town Centre. This is most evident during the PM peak period
  - During the 2026 PM peak period, the southbound queue extending from Park Road, would extend almost to Point Street. By the 2036 PM peak period, this queue would extend to the vicinity of Beattie Avenue.

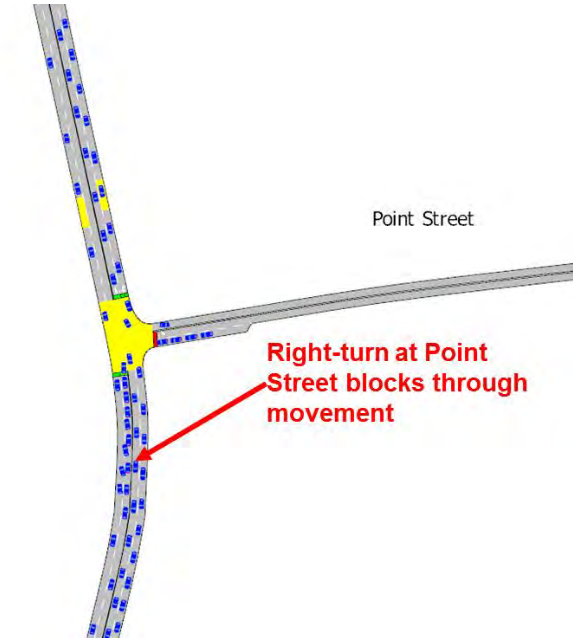
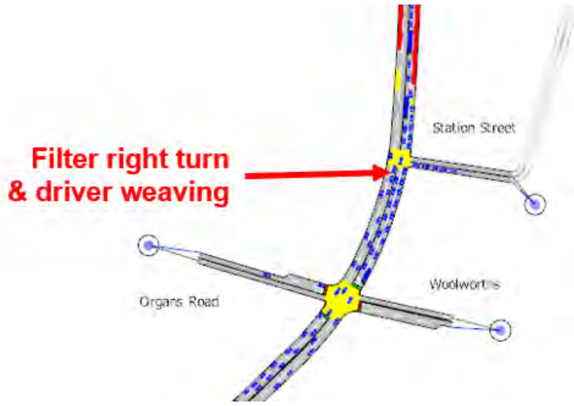
The impact of these constraints is most evident in the extent of the southbound moving queues during each of the modelled weekday peak periods. The impact during the Saturday peak period, whilst observed, is considered to be less significant compared to that during the weekday peak periods.

Figure 3.1–Figure 3.3 inclusive provide an indication of the network queuing during each of the respective peak periods.

Table 3.1 Summary of model queuing observations

Constraint	Impact	Model screenshot	Peak periods affected		
			AM	PM	SAT
Roundabout at Molloy Street	→ Single lane to Memorial Drive has limited capacity to accommodate future demand. → Causes extensive southbound queues upstream as traffic attempts to merge into kerbside lane.	 [Screenshot from 2036 AM model]	✓	✓	~

Constraint	Impact	Model screenshot	Peak periods affected		
			AM	PM	SAT
No provision for a southbound clearway south of Park Road	→ Reduces corridor capacity by restricting vehicles to one lane during critical periods of demand.	 [Screenshot from 2036 PM model]	n/a	✓	~

Constraint	Impact	Model screenshot	Peak periods affected		
			AM	PM	SAT
No provision of right-turn bays at key intersections (such as Point Street)	→ Causes queuing in the median lane. → Reduces corridor capacity by forcing vehicles into the kerbside lane. → This also creates safety issues due to the need for vehicle weaving and lane changing.	 [Screenshot from 2036 PM model]	✓	✓	✓
No provision of right-turn signal phases (such as at Park Road)	→ Traffic currently diverts via right-turn into Station Street. → This also causes weaving conflicts due to the downstream on-street parking.	 [Screenshot from 2036 SAT model]	~	✓	✓

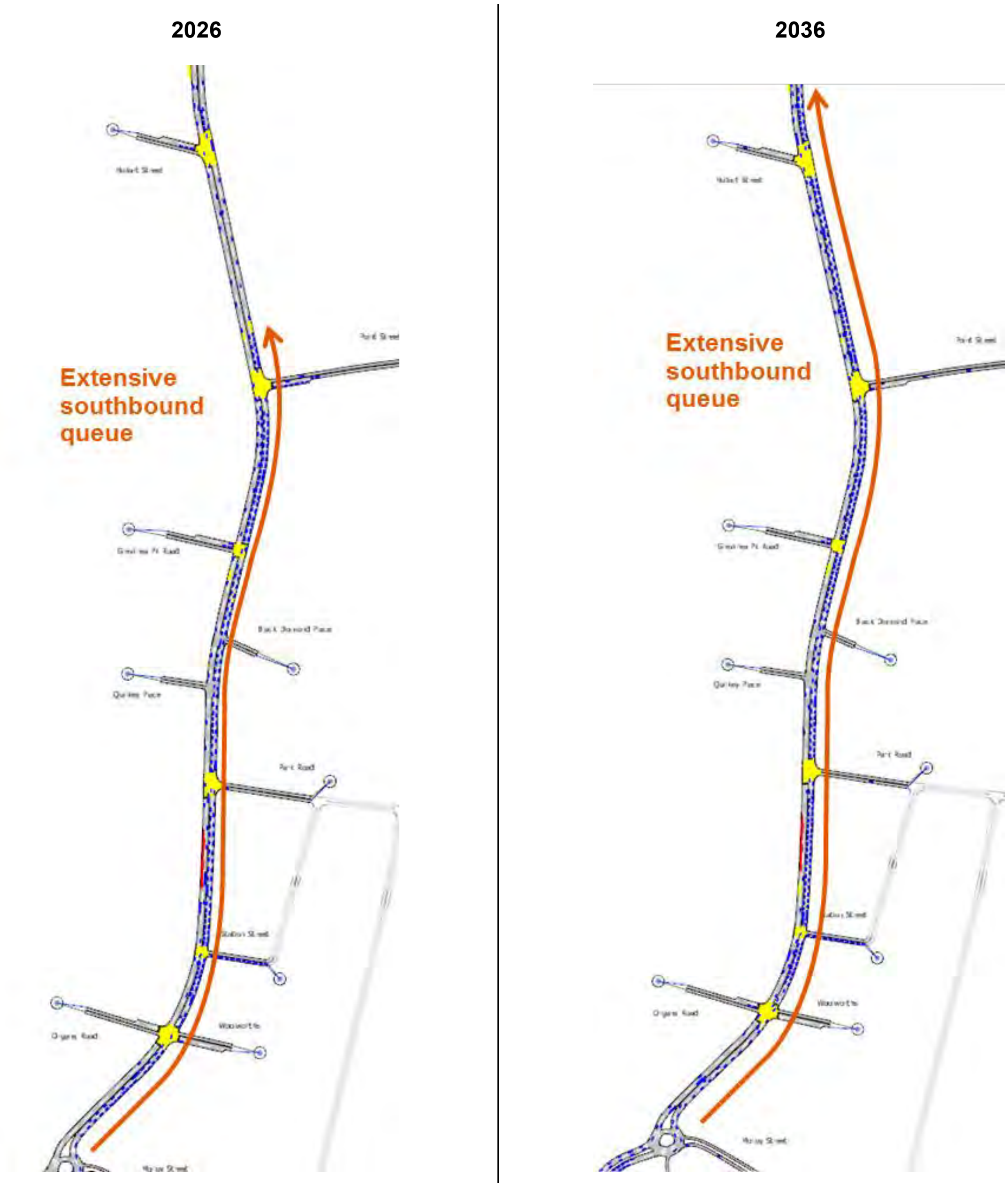


Figure 3.1 Model queuing – weekday AM peak ‘do minimum’ scenario

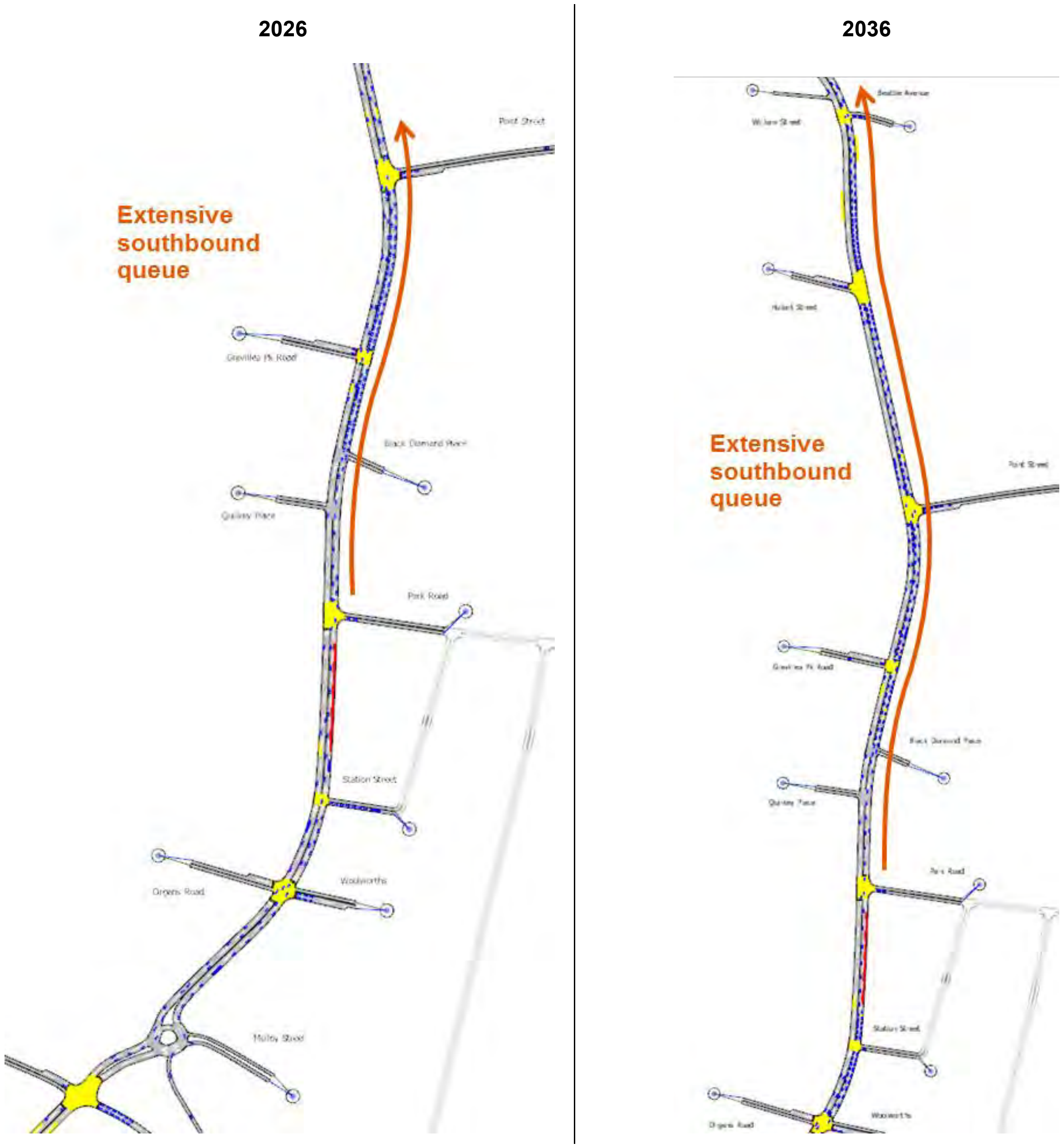


Figure 3.2 Model queuing – weekday PM peak ‘do minimum’ scenario

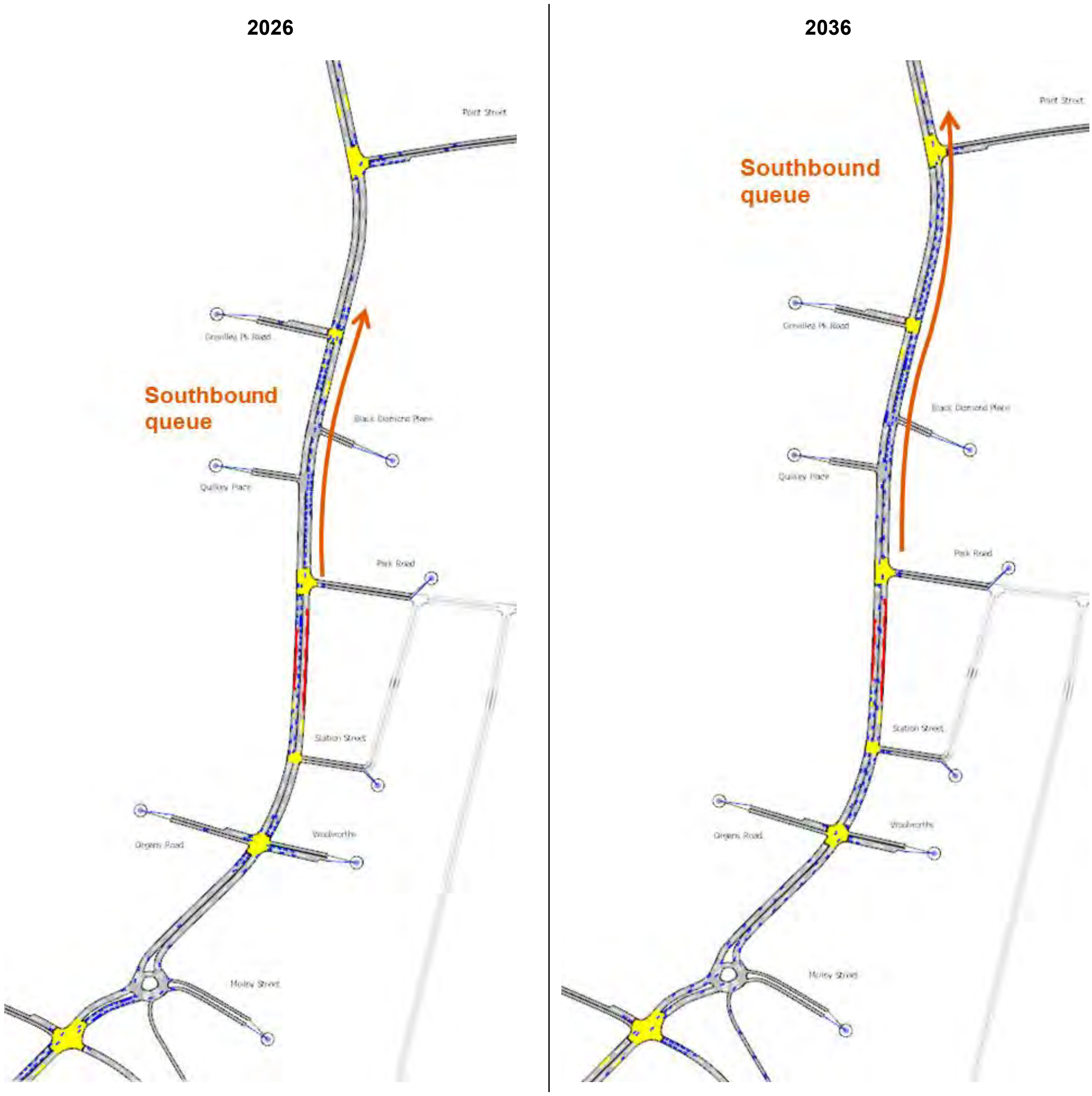


Figure 3.3 Model queuing – Saturday peak 'do minimum' scenario

3.3 Travel time

The travel time results for the 'do-minimum' scenarios were collected for each of the modelled peak periods. The travel times on the Princes Highway corridor during 2026 and 2036 are summarised in Table 3.2.

These travel time results indicate that over the next 20 years, there is expected to be a significant increase in the southbound travel time on the Princes Highway corridor. This is most evident during the weekday AM and PM peak periods, where there is a 90–130% increase in travel time. This is primarily a consequence of pinch points at the Molloy Street roundabout, and during the PM peak approaching the on-street parking near Park Road.

Travel times in the northbound direction increase more consistently, at around 15–25% over the 20 year period across the three modelled periods.

Table 3.2 Princes Highway corridor – travel time comparison – future 'do-minimum' scenarios

Year	Weekday AM peak	Weekday PM peak	Saturday peak
Northbound – Hospital Road to Beattie Avenue			
2016	2:27	2:26	2:12
2026	2:50	2:40	2:23
2036	3:02	3:09	2:31
% Difference (2016–2036)	***+20%***	***+25%***	***+15%***
Southbound – Beattie Avenue to Hospital Road			
2016	3:07	3:18	2:43
2026	5:54	4:47	2:48
2036	7:10	6:14	3:09
% Difference (2016–2036)	***+130%***	***+90%***	***+15%***

(1) Travel times are reported for the peak one hour of each peak period

3.4 Network statistics

The network statistics for the future year 'do-minimum' models are summarised in Table 3.3. These statistics indicate the following:

- The number of vehicle stops will approximately double by 2036 compared to 2016 in all peak periods
- The average network delay will approximately double by 2036 compared to 2016 in the weekday AM and PM peak periods. The Saturday peak is expected to experience a 50% increase
- There is a significant proportion of unreleased trips, particularly during the AM peak which is related to the capacity constraint at the Molloy Street roundabout. These unreleased trips begin to appear in the 2026 AM peak period and therefore indicate that the design life of the existing intersection will be reached before 2026.

It is noted that the VHT, network speed, network delay and vehicle stops values are likely to be under-reported as a result of the number of unreleased trips.

Table 3.3 General network statistics – 'do-minimum' model comparison

	Weekday AM			Weekday pm			Saturday		
	2016	2026	2036	2016	2026	2036	2016	2026	2036
Vehicle kilometres travelled (km)	9,485	10,685	11,015	11,047	12,597	12,912	10,062	11,524	12,107
Vehicle hours travelled (hrs)	301	430	487	370	506	641	304	389	422
Average network speed (km/h)	32	25	23	30	25	20	33	30	29
Average network delay (sec/km)	114	178	208	132	180	247	106	139	147
Vehicle stops	12,176	19,405	22,051	16,427	24,768	31,474	12,343	16,913	19,081
Completed trips	6,766	7,755	8,022	8,221	9,517	9,775	7,466	8,678	9,109
Incomplete trips	331	579	663	390	518	733	267	362	390
Unreleased trips	0	79	128	0	0	27	0	24	23

3.5 Intersection performance and link delay

3.5.1 Overview

The Roads and Maritime *Guide to Traffic Generating Developments* v2.2 (2002) provides a guideline for the interpretation of Level of Service (LoS) results for different intersection configurations. These LoS results are determined on the basis of the Average Vehicle Delay (AVD) and is summarised in Table 3.4.

Table 3.4 Level of service criteria

LoS	Traffic signals/roundabout	Give way/Stop/T-junction	Average Delay (sec/veh)
A	Good operation	Good operation	Less than 14
B	Good operation, with acceptable delays and spare capacity	Acceptable delays and spare capacity	15 to 28
C	Satisfactory	Satisfactory, but crash study required	29 to 42
D	Operating near capacity	Near capacity and crash study required	43 to 56
E	At capacity; at signals, incidents will cause excessive delays	At capacity, requires alternative control mode	57 to 70
F	Unsatisfactory and requires additional capacity. Roundabouts require alternative control mode	Unsatisfactory and requires additional capacity	More than 70

Source: Roads and Maritime, Guide to Traffic Generating Developments v2.2 (2002)

- The LoS for signalised intersections is determined on the basis of the weighted average (by vehicles) for all intersection approach delays.
- The LoS for roundabouts is determined by the critical performing movement.
- The LoS for priority-controlled intersections is determined by the critical performing movement. It should be noted that high delay on the side streets for a small number of vehicles can be misleading in some circumstances to determine the overall intersection performance. As a result, high delay for a small number of vehicles may be justified (in the absence of safety or operational concerns).

3.5.2 Aimsun level of service

The operation and performance of each intersection was assessed using the average delay time outputs from the Aimsun model. The performance of the following intersections have been assessed:

- Princes Highway/Beattie Avenue
- Princes Highway/Hobart Street
- Princes Highway/Point Street
- Princes Highway/Grevillea Park Road
- Princes Highway/Park Road
- Princes Highway/Station Street
- Princes Highway/Organs Road
- Princes Highway/Molloy Street
- Princes Highway/Hospital Road/Memorial Drive.

The results of the intersection performance analysis are summarised in Table 3.5 and Table 3.6. These results are the average across the five seed values for each respective peak period.

It is noted that, in the context of the corridor and the relatively close spacing of most intersections (100–200 m between roundabouts or signalised intersections), intersection LoS does not always provide a complete measure of intersection performance. This is due to the observations within the Aimsun model that queuing extends through the next signalised intersection and therefore part of the delay is attributed to the upstream intersection. A notable example of this is the southbound queue at the roundabout at Princes Highway/Molloy Street, which exhibits a queue extending through the intersection of Princes Highway/Organs Road.

3.5.2.1 Weekday AM peak

The results of the intersection analysis indicate that during the weekday AM peak period, most intersections would operate at LoS D or better. The exceptions to this are:

- Princes Highway/Beattie Avenue (2036 only)
- Princes Highway/Station Street (2026 and 2036)
- Princes Highway/Organs Road (2036 only).

The intersections of Princes Highway/Beattie Avenue and Princes Highway/Station Street are priority controlled intersections and therefore the LoS is determined based upon the critical movement. The critical movement in both instances is the right-turn from the side-street (Beattie Avenue and Station Street). These movements are relatively low and less than 20 vehicles/hour. Whilst these movements are expected to have a high delay as a result of the heavy southbound movement on the Princes Highway (over 1,500 vehicles/hour), the low demand also means that the reported delay may be skewed by the observation of a couple of vehicles which arrive at the start of a large platoon. Furthermore, as the demand for these movements is low, an outcome of LoS E/F is considered acceptable in the interest of the prioritising the primary movements on the corridor.

These intersections also showed an unsatisfactory performance (LoS E/F) for the right-turn from Princes Highway (south) into the side street. This is mostly related to the extensive southbound queue on the Princes Highway, which impacts upon the available gaps for filtering vehicles. This result is considered conservative (worst case) as in reality cooperative driver behaviour is expected at these intersections to enable right-turning vehicles to enter/exit side streets when the mainline queue extends past the side street. This was driver behaviour was observed by WSP | Parsons Brinckerhoff staff during the existing situation at the intersection of Princes Highway/Station Street.

The poor LoS outcome at the intersection of Princes Highway/Organs Road is a product of the extensive southbound queue on the Princes Highway which originates from the Molloy Street roundabout. As a result, the poor LoS outcome is considered to be a consequence of the downstream capacity constraint which limits the discharge capacity at Princes Highway/Organs Road.

Whilst the remaining intersections were found to operate at LoS D or better, it is noted that the model shows an extensive southbound queue on the Princes Highway (Figure 3.1), which extends past Point Street in 2026 and past Beattie Avenue in 2036. As a result, the performance of the signalised intersections and roundabout on the corridor should be interpreted in the context of the queues observed in the model (section 3.2).

3.5.2.2 Weekday PM peak

The results of the intersection analysis indicate that during the weekday AM peak period, most intersections would operate at LoS C or better. The exceptions to this are:

- Princes Highway/Beattie Avenue
- Princes Highway/Station Street.

Similarly to the weekday AM peak period, the critical movement at the intersection of Princes Highway/ Beattie Avenue was the right-turn from Beattie Avenue. This movement has a relatively low demand of less than 20 vehicles/hour and the reported delay may be skewed by the observation of a couple of vehicles which arrive at the start of a large platoon. Furthermore, as the demand for these movements is low, an outcome of LoS E/F is considered acceptable in the interest of the prioritising the primary movements on the corridor.

At the intersection of Princes Highway/Station Street, the critical movement is the right-turn from Princes Highway (south). Like the weekday AM peak period, this is due to the southbound traffic flow on the Princes Highway of over 1,500 vehicles/hour which limits the number of available gaps for filtering vehicles.

It is noted that there is no demand for the right-turn from Station Street, which reflects the existing situation and is most likely a consequence of the difficulty of undertaking this manoeuvre during the PM peak period.

3.5.2.3 Saturday peak

The results of the intersection analysis indicate that during the Saturday peak period, most intersections would operate at LoS C or better. The exception to this is the intersection of Princes Highway/Station Street.

Like the weekday peak periods, the critical movement at this intersection is the right-turn from Station Street. This movement has a demand of less than five vehicles/hour and therefore adverse delay on this movement is considered an acceptable outcome in the interest of the prioritising the primary movements on the corridor. In addition, with demand being less than five vehicles/hour it is possible that the reported average delay may be skewed by a single vehicle which experiences an unusually high delay. This may occur if the modelled vehicle arrives at the intersection at the start of a relatively large platoon of traffic on the primary movement.

Table 3.5 Level of service summary – 'Do-minimum' – 2026

Intersection	Control type	2026 AM		2026 PM		2026 SAT	
		Delay (S)	LoS	Delay (S)	LoS	Delay (S)	LoS
Princes Highway/Beattie Avenue	Priority	55	D	33	C	27	B
Princes Highway/Hobart Street	Signalised	24	B	14	B	7	A
Princes Highway/Point Street	Signalised	21	B	25	B	13	A
Princes Highway/Grevillea Park Road	Signalised	18	B	23	B	13	A
Princes Highway/Park Road	Signalised	42	C	28	B	17	B
Princes Highway/Station Street	Priority	> 100	F	54	D	43	D (1)
Princes Highway/Organs Road	Signalised	53	D	24	B	16	B
Princes Highway/Molloy Street	Roundabout	38	C	20	B	18	B
Princes Highway/Hospital Road	Signalised	28	B	29	C	27	B

(1) Demand less than 20 vehicles/hour and therefore not a holistic sample of average delay

Table 3.6 Level of service summary – 'Do-minimum' – 2036

Intersection	Control type	2036 AM		2036 PM		2036 SAT	
		Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS
Princes Highway/Beattie Avenue	Priority	89	F (1)	> 100	F (1)	28	B
Princes Highway/Hobart Street	Signalised	34	C	35	C	7	A
Princes Highway/Point Street	Signalised	32	C	40	C	14	A
Princes Highway/Grevillea Park Road	Signalised	25	B	28	C	14	A
Princes Highway/Park Road	Signalised	45	D	35	C	20	B
Princes Highway/Station Street	Priority	> 100	F (1)	89	F	85	F (1)
Princes Highway/Organs Road	Signalised	57	E	26	B	16	B
Princes Highway/Molloy Street	Roundabout	37	C	22	B	21	B
Princes Highway/Hospital Road	Signalised	33	C	30	C	28	B

(2) Demand less than 20 vehicles/hour and therefore not a holistic sample of average delay

4 Preliminary traffic options

4.1 Introduction

The Princes Highway, Bulli traffic modelling workshop was undertaken on 10 May 2016. At this workshop, Roads and Maritime and WSP | Parsons Brinckerhoff staff held discussions about the preliminary design options based upon the 2026 and 2036 'do-minimum' traffic models.

The key options proposed for further assessment were:

- Peak directional clearways during peak periods
- Provision of two on-ramp lanes to Memorial Drive
- Reconfiguration of the Princes Highway/Molloy Street roundabout
  - Realignment of lanes to provide two lanes to Memorial Drive, or
  - Conversion to traffic lights, or
  - Conversion to traffic lights and consolidation with the Memorial Drive off-ramp
- Right-turn bays and right-turn bans
- Amendments to signal phasing at the intersection of Princes Highway/Park Road
- New traffic lights at of Princes Highway/Station Street.

These options are summarised in the following sections.

4.2 Clearways

Clearways are proposed on the Princes Highway corridor between Park Road and Station Street in order to provide two lanes of capacity on the entire study corridor. The proposed clearway arrangement would supplement the existing clearway arrangements in this section of the corridor. As the remainder of the Princes Highway corridor operates under a clearway or is otherwise under No Parking/Stopping restrictions, the proposed clearways would provide two lanes of capacity along the entire study corridor when in operation.

The proposed clearway operation is summarised in Table 4.1 and the on-street car parking that would be impacted by the clearway is presented on Figure 4.1. The proposed operation times during the weekday peak periods are aligned with the existing clearway times. However an additional clearway is proposed during the Saturday peak period for the southbound direction only. Given that existing directional clearways are in operation, the proposed clearways would require the removal of an additional 13 car parking spaces during the peak periods.

The following benefits are expected as a result of the proposed clearways:

- Remove the southbound pinch-point at Park Road during the weekday PM and Saturday peak period
- Improve the safety and operation in the northbound direction during the weekday AM peak period by reducing the number of lane changing manoeuvres associated with weaving around right-turning traffic at Park Road and Station Street.

It is noted that there are no changes to the road geometry required to accommodate the expanded clearway provisions.

Table 4.1 Proposed clearway arrangements – Princes Highway, between Park Road and Station Street

Direction	Weekday AM peak (6.30 am–9.30 am)	Weekday PM peak (3.00 pm–6.00 pm)	Saturday peak (11.00 am–1.00 pm)
Northbound	✓	Existing	
Southbound	Existing	✓	✓

Figure 4.1 Existing on-street car parking impacted by clearway

4.3 Two lanes to Memorial Drive and reconfiguration of the Princes Highway/ Molloy Street roundabout

As indicated previously, the existing and future 'do minimum' model results show that the intersection of Princes Highway/Molloy Street would become a critical pinch point on the corridor during peak periods, particularly for the southbound flow. As a result, the resolution of this pinch point is important for maintaining the satisfactory future operation of the Princes Highway corridor in Bulli.

In consultation with Roads and Maritime, three different options have been assessed for the reconfiguration of this roundabout. The following sections detail the proposed options and the road geometry changes.

It is noted that all of the proposed options incorporate two lanes for the Memorial Drive on-ramp. The additional lane for the on-ramp is to accommodate the dominant flow at the roundabout, that being to Memorial Drive. This would require the widening of the existing culvert (located south of the intersection) to accommodate the additional lane.

4.3.1 Layout 1 – revised allocation of existing lanes

The proposed Layout 1 would involve the least amount of changes to the intersection footprint and consist of:

- Additional lane for the on-ramp to Memorial Drive (total of two lanes)
- Amendment to road line markings to allow the following movements:
  - Both southbound lanes to travel to the Memorial Drive on-ramp
  - Median lane to travel to Princes Highway (south).

The proposed layout is summarised on Figure 4.2.

Figure 4.2 Revised lane allocation at Princes Highway/Molloy Street

4.3.2 Layout 2 – traffic lights

The proposed Layout 2 would involve converting the roundabout into traffic lights, whilst utilising the existing intersection footprint. As part of this, the road geometry changes consist of:

- Additional lane for the on-ramp to Memorial Drive (total of two lanes)
- 50 metre right-turn bay on Molloy Street
- Right-turn bays on Princes Highway (south) of 35 metres (to Memorial Drive) and 50 metres (to Molloy Street)
- Realignment of the intersection and approach roads.

The proposed layout is summarised on Figure 4.3 and the preliminary signal phasing is summarised on Figure 4.4.

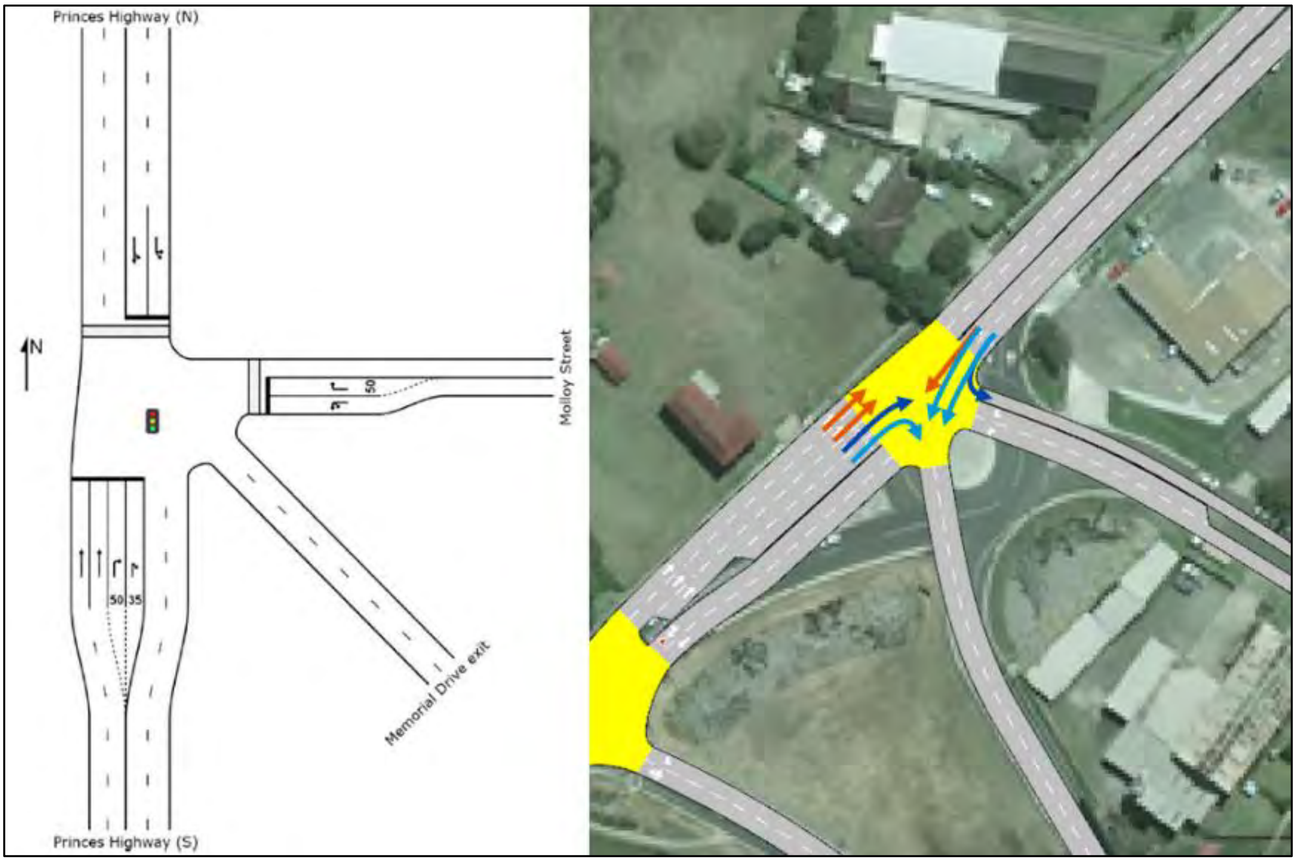


Figure 4.3 Traffic lights layout at Princes Highway/Molloy Street

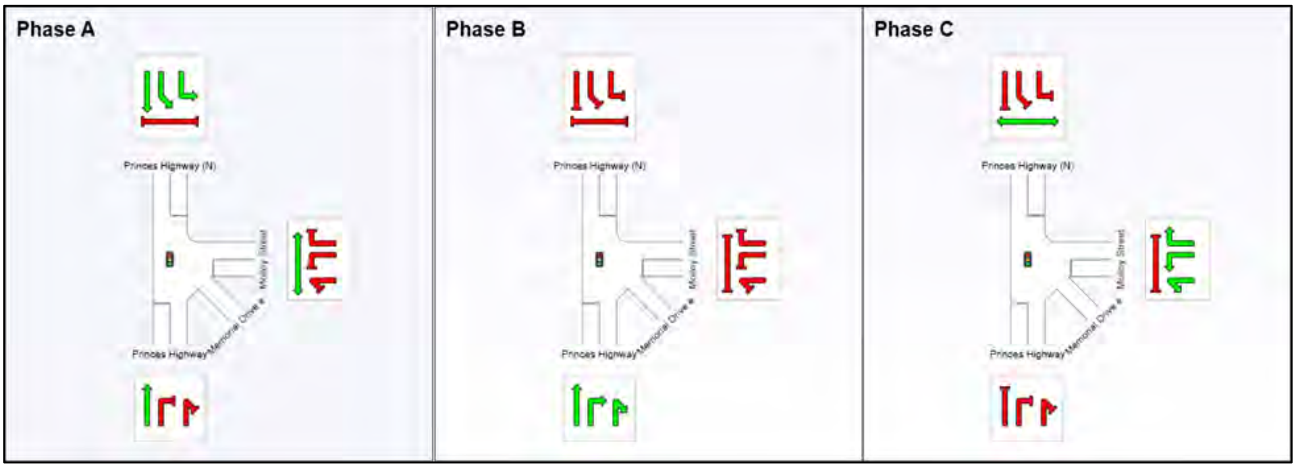


Figure 4.4 Preliminary signal phasing

4.3.3 Layout 3 – traffic lights and consolidation with Memorial Drive off-ramp

The proposed Layout 3 builds on Layout 2 with conversion of the roundabout into traffic lights, whilst also incorporating the Memorial Drive off-ramp. As part of this, the road geometry changes (compared to the existing) consist of:

→ 100 metre and 75 metre short lanes on Princes Highway (north) to separate traffic travelling to Princes Highway (south) from traffic to Memorial Drive

→ Additional lane for the on-ramp to Memorial Drive (total of two lanes)

→ 50 metre right-turn bay on Molloy Street

→ Right-turn bays on Princes Highway (south) of 35 metres (to Memorial Drive) and 50 metres (to Molloy Street)

→ Three lane approach on Memorial Drive, incorporating a 50 metre right-turn lane for traffic to Molloy Street

→ Realignment of the intersection and approach roads.

The proposed layout is summarised on Figure 4.5, whilst Figure 4.6 provides a preliminary signal phasing arrangement. It is noted that due to the intersection geometry/configuration, an unconventional signal phasing arrangement is proposed and its introduction would require significant detail design development to limit potential safety impacts. This is because the phase regards:

→ movements between Princes Highway (north) and Memorial Drive as the ‘through’ movement

→ movements between Princes Highway (north) and Princes Highway (south) as part of the ‘diamond’ phase.

In particular, the ‘diamond phase’ envisages that the northbound traffic from Memorial Drive to Molloy Street and visa versa operating at the same time. As a result, southbound traffic on the Princes Highway would have vehicles travelling ‘towards’ them on both sides.

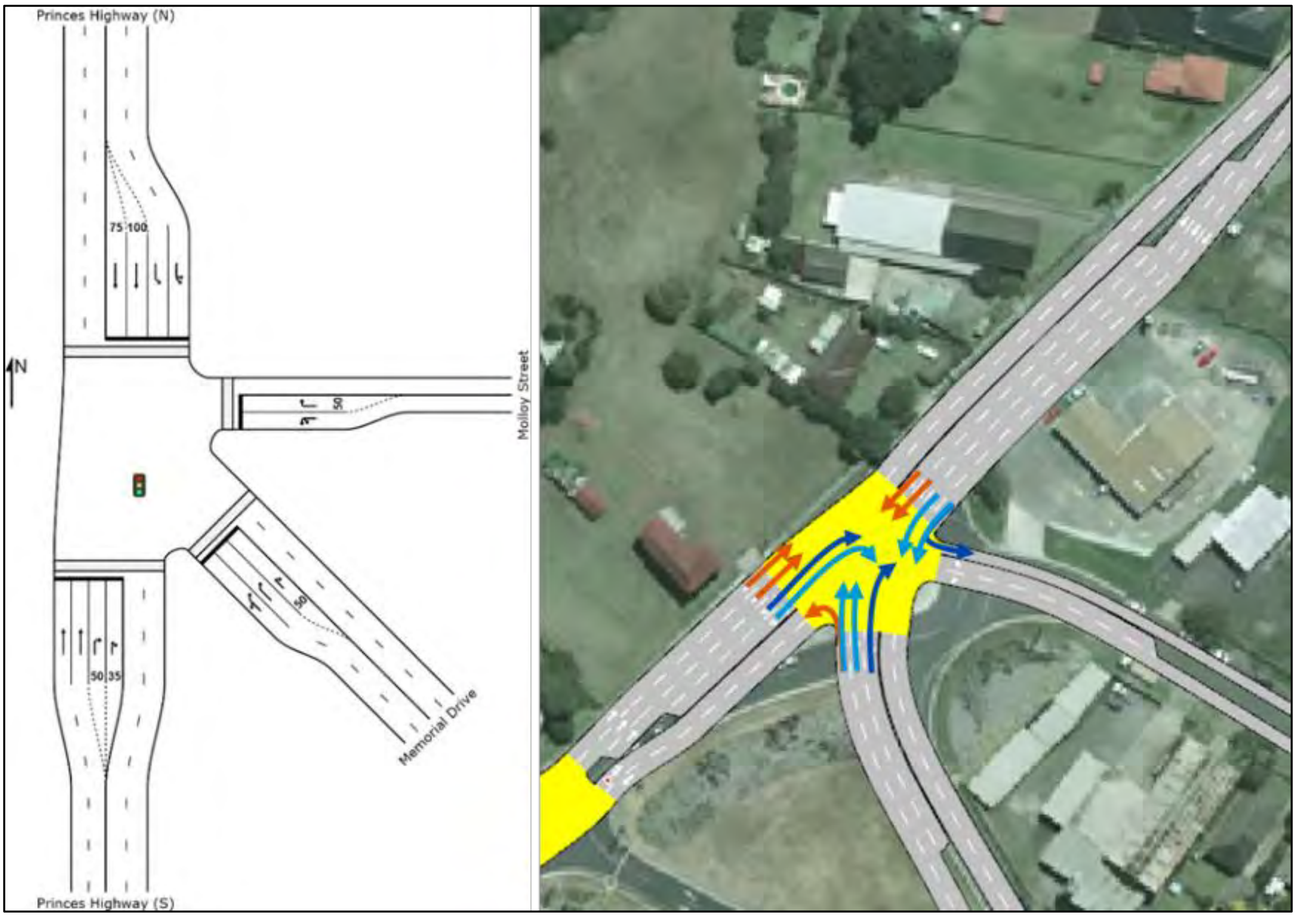


Figure 4.5 Consolidated intersection layout at Princes Highway/Molloy Street

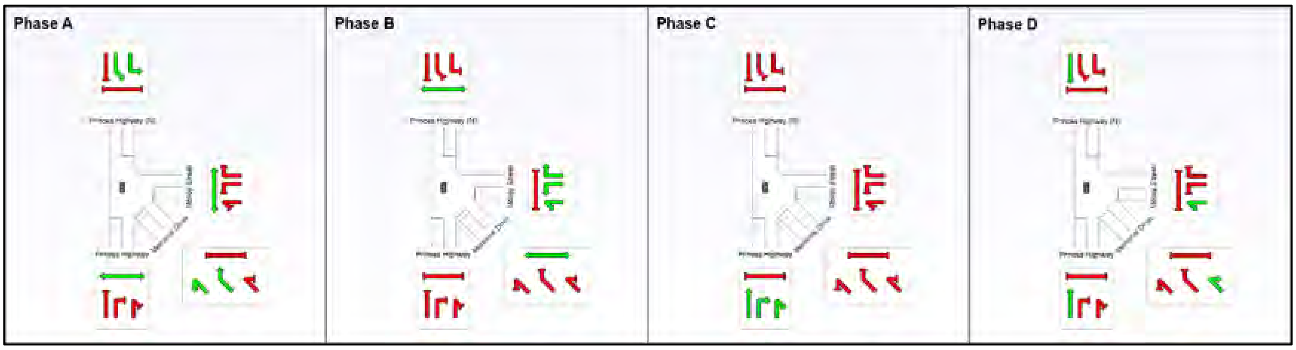


Figure 4.6 Preliminary signal phasing

4.4 Right-turn bays/bans

4.4.1 Overview of right-turn demand

Locations for right turn bays and bans have been identified based upon the estimated future turning movements and the operational efficiency of the corridor. In particular, locations where the right-turn demand is greater than 100 vehicles/hour have been identified for consideration of these treatments. The estimated right-turn demand in the 2036 peak periods is summarised on Figure 4.7.

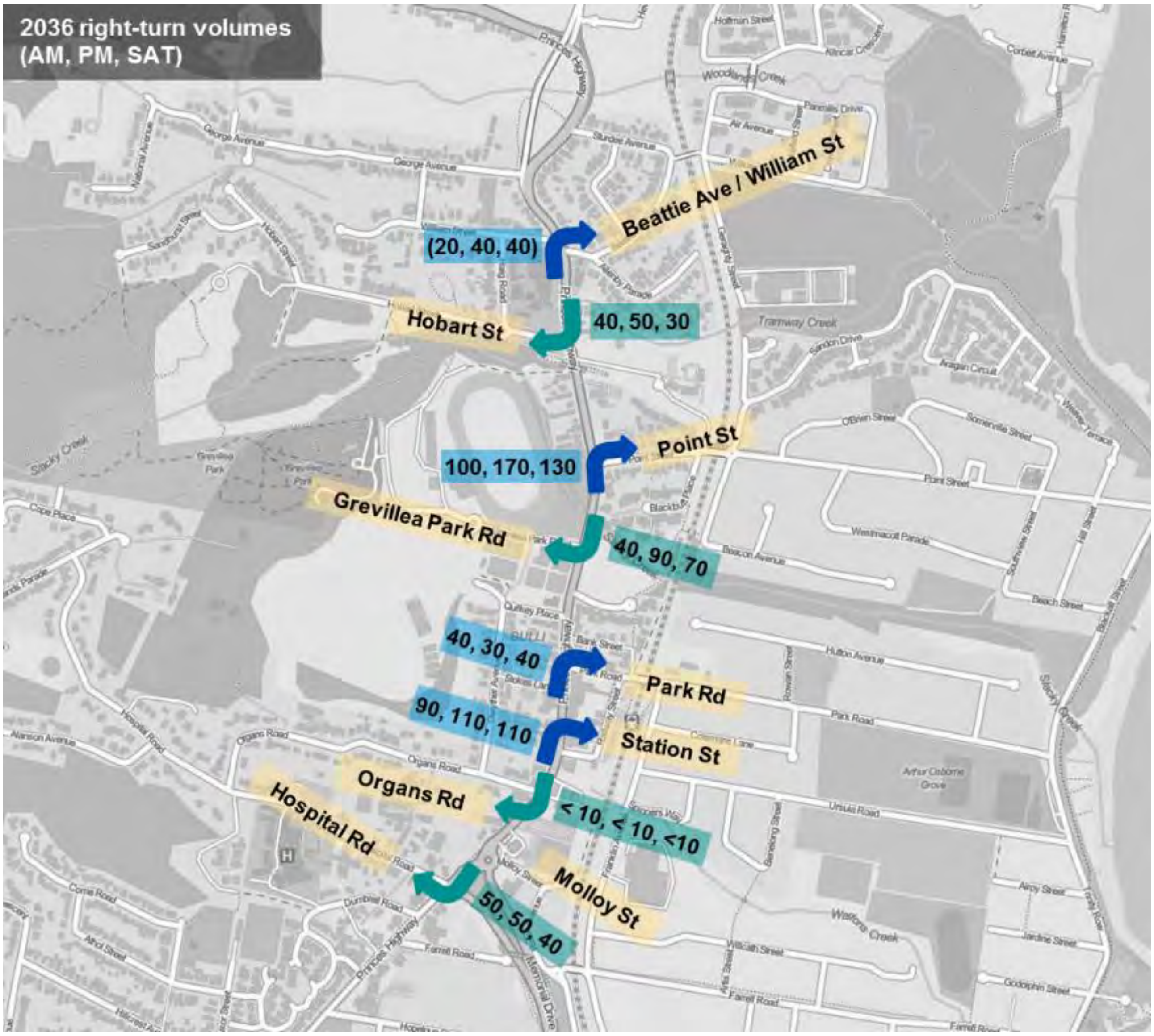


Figure 4.7 Estimated right-turn demand (2036)

4.4.2 Proposed right-turn management

Based upon the estimated future right-turn demand, the following right-turn bays/bans have been proposed:

- Right-turn bay:
  - Princes Highway (northbound) at Point Street (Figure 4.8)
- Right-turn ban:
  - Princes Highway (northbound) at Station Street.

It is noted that the proposed right-turn ban at Station Street is expected to move this right-turn demand to the Park Road intersection. The additional right-turn demand at Princes Highway/Park Road will be supplemented by changes in the signal configuration, as discussed in section 4.4.3. Roads and Maritime have advised that due to restrictions regarding property boundaries and heritage listings, it would not be possible to accommodate a right-turn bay at the intersection of Princes Highway/Park Road.

At the intersection of Princes Highway/Point Street, a 75 metre right-turn bay has been assumed for the purposes of modelling, as depicted in Figure 4.8.

Figure 4.8 Right turn bay at Princes Highway/Point Street

4.4.3 Signal phasing at Princes Highway/Park Road

As a result of the right-turn ban proposed at Princes Highway/Station Street, signal phasing changes are proposed for the traffic lights at Princes Highway/Park Road. The existing signal phasing at Princes Highway/Park Road is summarised on Figure 4.9 and consists of a basic two phase arrangement that accommodates the right turn movements from the Princes Highway by filtering through the opposing traffic stream.

The proposed signal phasing arrangement would incorporate a 'trailing right-turn' phase, to facilitate right turn movements into Park Road. Filtering right turns would continue to be permitted during the primary (prince Highway) signal phase. This would be similar to the arrangement currently utilised at other intersections along the Princes Highway corridor through Bulli.

The existing and proposed traffic signal phasing arrangements are summarised in Figure 4.9 and Figure 4.10 respectively.

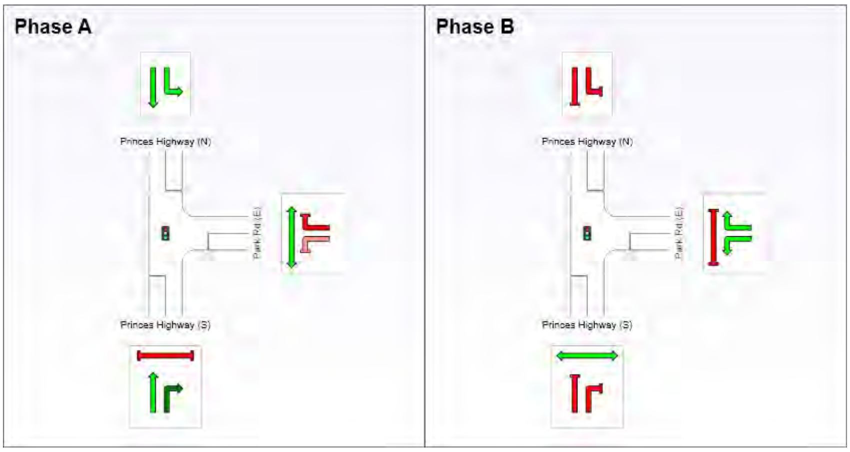


Figure 4.9 Existing phase structure – Princes Highway/Park Road

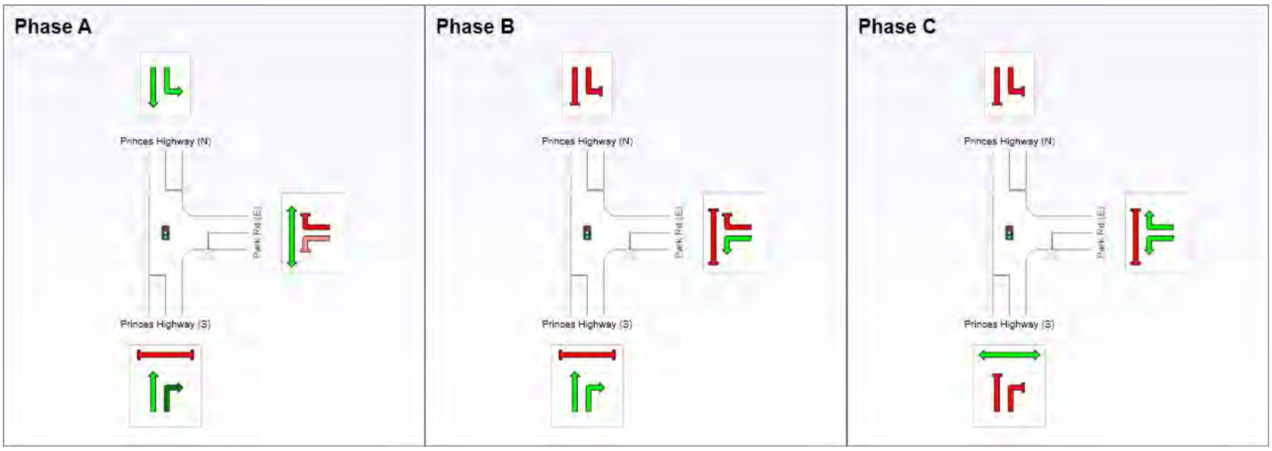


Figure 4.10 Proposed phase structure – Princes Highway/Park Road

4.5 Traffic lights at Princes Highway/Station Street

Traffic lights have been proposed at the intersection of Princes Highway/Station Street in order to facilitate the movement of traffic to/from Station Street. This has been proposed as an alternative scheme for managing the right-turn demand at this intersection. The intersection layout would be consistent with the existing intersection footprint. The layout and phasing is similar to the existing operation at the intersection of Princes Highway/Park Road.

The proposed intersection layout is described in Figure 4.11 and the phasing arrangement in Figure 4.12. As agreed with Roads and Maritime, a separate right-turn phase was not modelled as part of this scenario.

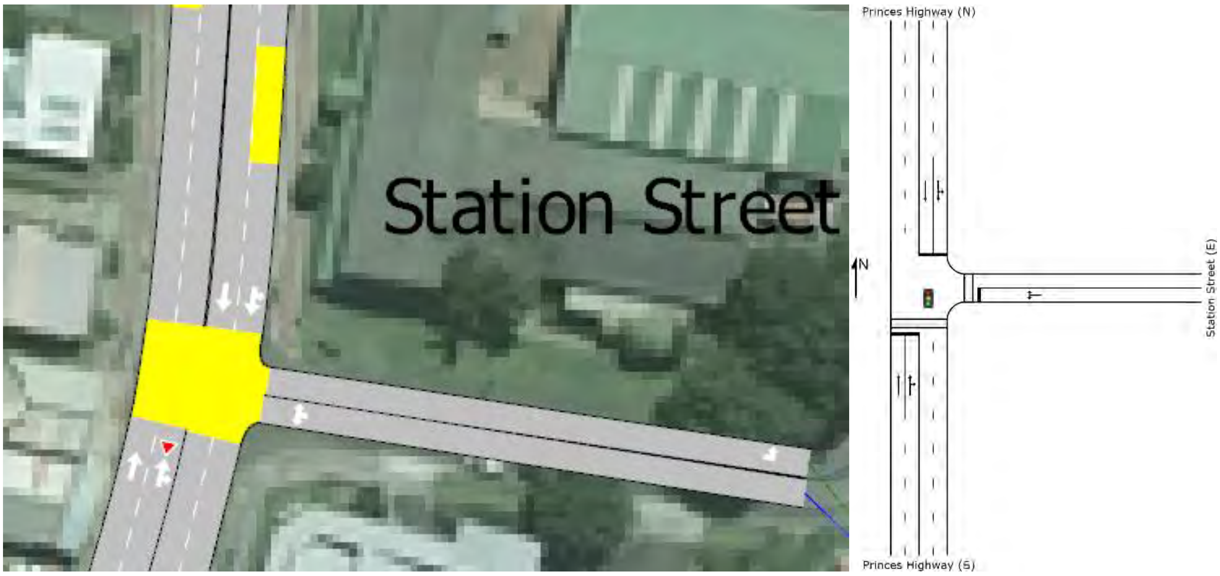


Figure 4.11 Signalised intersection layout at Princes Highway/Station Street

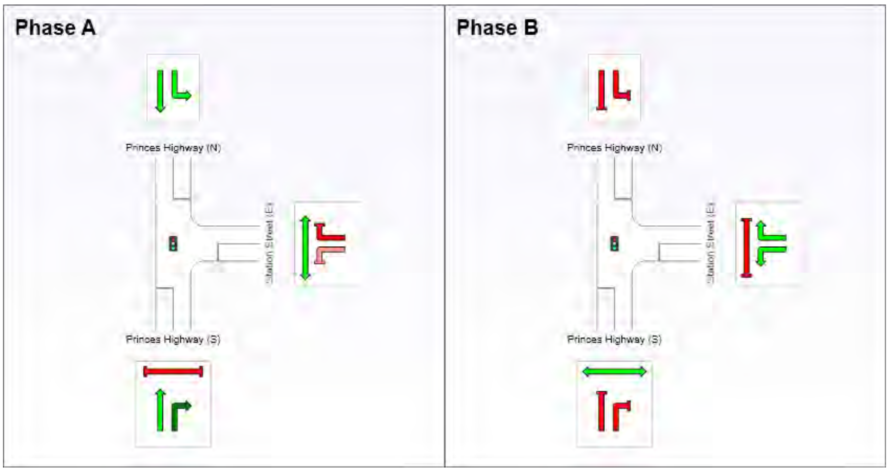


Figure 4.12 Proposed phase structure – Princes Highway/Station Street

4.6 Summary of modelling scenarios

Overview

The traffic management options discussed above were incorporated into a series of modelling scenarios, combining selected options to assess their cumulative impact. These scenarios were agreed with Roads and Maritime and are summarised in Table 4.2.

The scenarios were developed using a multi-stage approach, in order to identify preferred treatments for the different pinch-points along the Princes Highway corridor. This multi-stage approach is summarised on Figure 4.13.

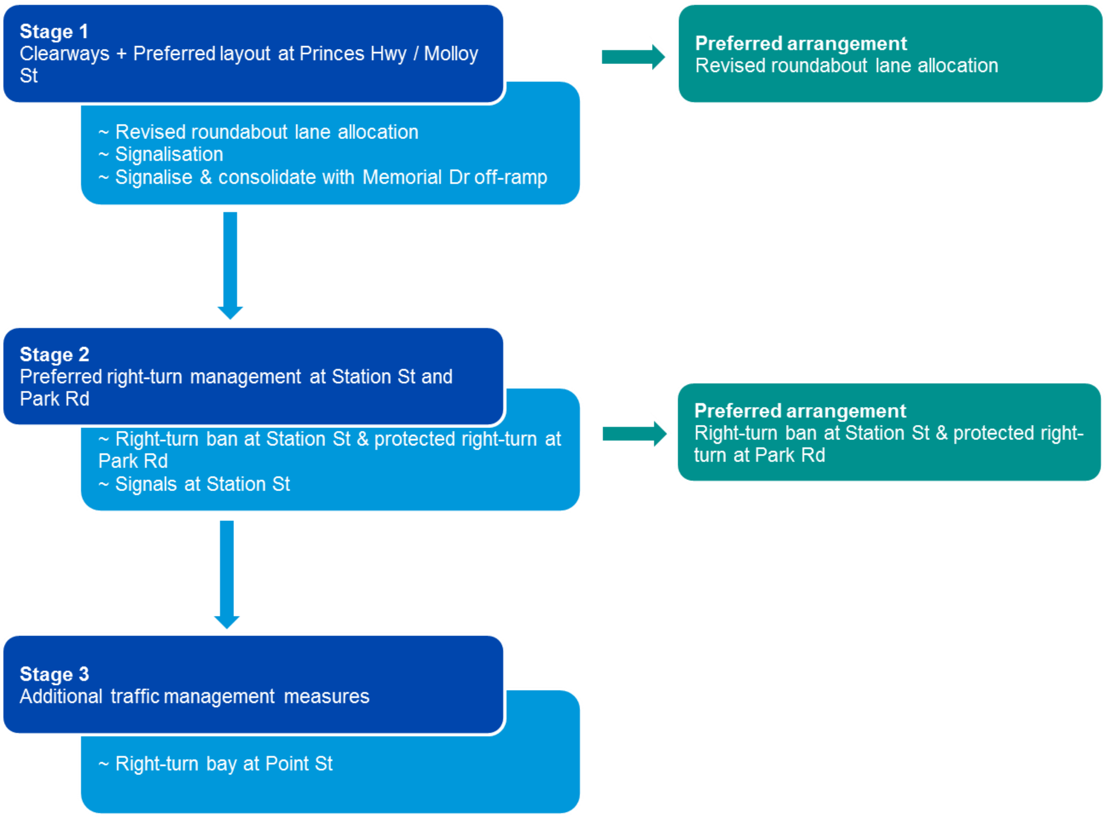


Figure 4.13 Multi-stage model development process

Preferred intersection layout – Princes Highway/Molloy Street

Following the modelling of Scenarios 1–3, the model results were supplied to Roads and Maritime in order to select a preferred option to carry forward for Scenarios 4–6. Based upon the modelling results (to be discussed in subsequent sections) and discussions with Roads and Maritime, the preferred option was Scenario 1 (maintaining the roundabout and providing two through lanes to Memorial Drive). The reasons for the selection of this option as the preferred layout will be discussed in sections 5 and 9.

Preferred right-turn treatment – Princes Highway/Park Road and Princes Highway/Station Street

Following the modelling of Scenarios 4–5, the model results were supplied to Roads and Maritime in order to select a preferred option to carry forward for Scenario 6. Based upon the modelling results (to be discussed in subsequent sections) and discussions with Roads and Maritime, the preferred option was Scenario 4 (right-turn ban at Station Street and providing a protected right-turn phase at Park Road). The reasons for the selection of this option as the preferred layout will be discussed in section 6 and 9.

Table 4.2 Summary of modelling scenarios

	Clearway Princes Highway	Molloy Street roundabout revised lane allocation	Molloy Street roundabout converted to traffic signal	Molloy Street consolidation with Hospital Road	Right turn ban to Station Street and provide right turning phase from Princes Highway to Park Road	Traffic signals at Station Street	Right turn bay for right turning traffic from Princes Highway to Point Street	Demand years modelled
Stage 1 assessment – preferred Princes Highway/Molloy Street layout								
Scenario 1	✓	✓						→ 2026 → 2036
Scenario 2	✓		✓					→ 2026 → 2036
Scenario 3	✓			✓				→ 2026 → 2036
Stage 2 assessment – preferred right-turn management at Station Street and Park Road								
Scenario 4	✓	✓			✓			→ 2026 → 2036
Scenario 5	✓	✓				✓		→ 2026 → 2036
Stage 3 assessment – other traffic management schemes								
Scenario 6	✓	✓			✓		✓	→ 2026 → 2036

(1) All the scenarios were modelled for the weekday AM, weekday PM and Saturday peak periods
(2) The preferred option at Princes Highway/Molloy Street was Scenario 1 and this layout was carried forward for Scenarios 4–6
(3) The preferred option at Princes Highway/Station Street was Scenario 4 and this was carried forward for Scenario 6

5 Stage 1 modelling assessment

5.1 Overview

As described in Table 4.2, Stage 1 has been modelled through three different layout options for the intersection of Princes Highway/Molloy Street. This intersection was identified as the key pinch point in the future year ‘do minimum’ modelling, whereby traffic demand would exceed the capacity of the existing intersection layout.

5.1.1 Scenario 1 – revised roundabout lane allocation

Scenario 1 has been modelled using the forecast 2026 and 2036 traffic demands including the following network reconfiguration options:

- Clearways on the Princes Highway between Park Road and Station Street (as per Table 4.1)
- Revised lane allocation at the Princes Highway/Molloy Street roundabout (as per Figure 4.2)
- Additional on-ramp lane to Memorial Drive.

These changes are summarised in Figure 5.1.

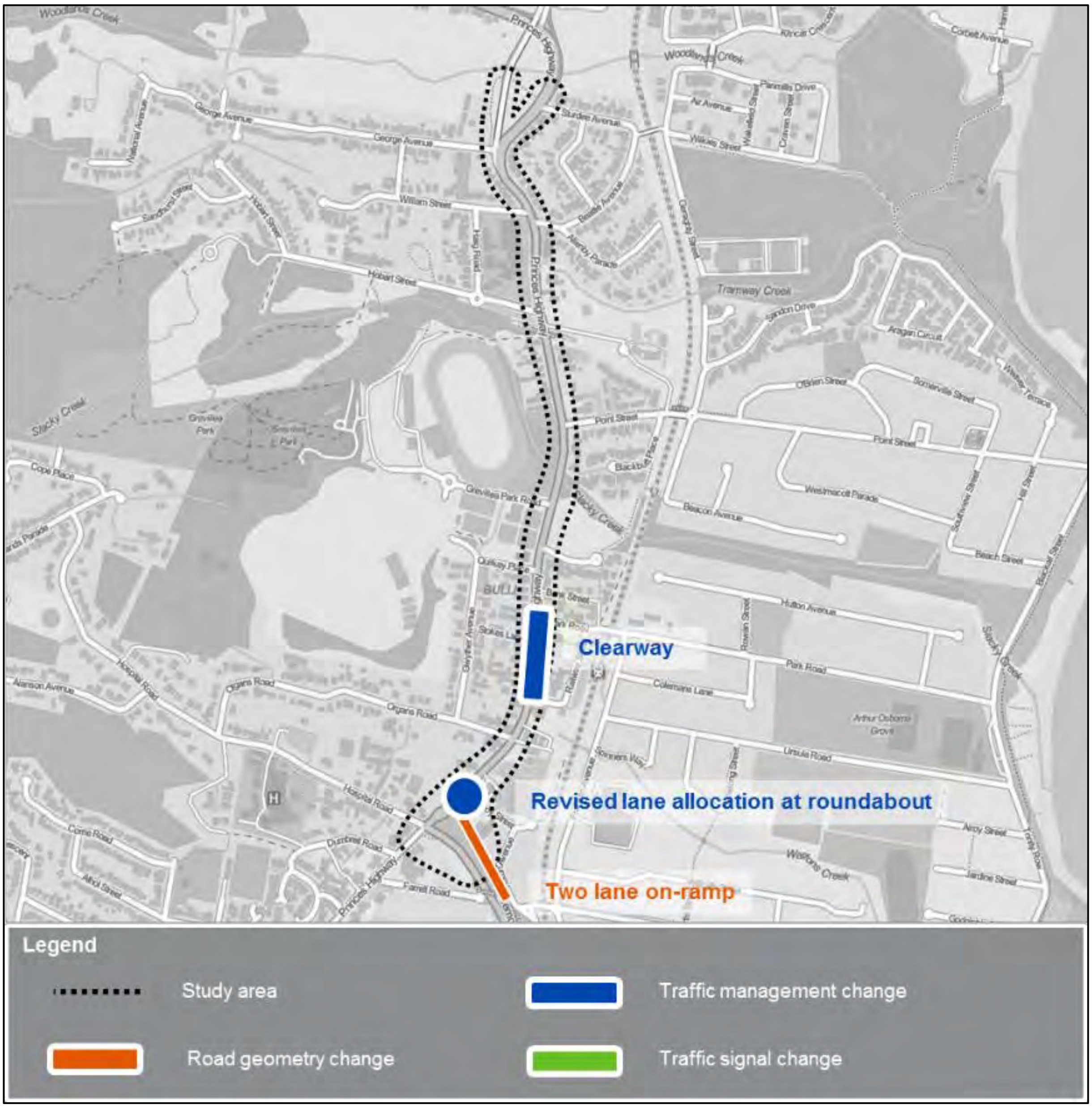


Figure 5.1 Scenario 1 network amendments

5.1.2 Scenario 2 – conversion of intersection to traffic lights

As proposed in Table 4.2, Scenario 1 has been modelled using the forecast 2026 and 2036 traffic demands including the following network reconfiguration options:

- Clearways on the Princes Highway between Park Road and Station Street (as per Table 4.1)
- Conversion of the Princes Highway/Molloy Street roundabout to traffic lights (as per Figure 4.3)
- Additional on-ramp lane to Memorial Drive.

These changes are summarised in Figure 5.2.

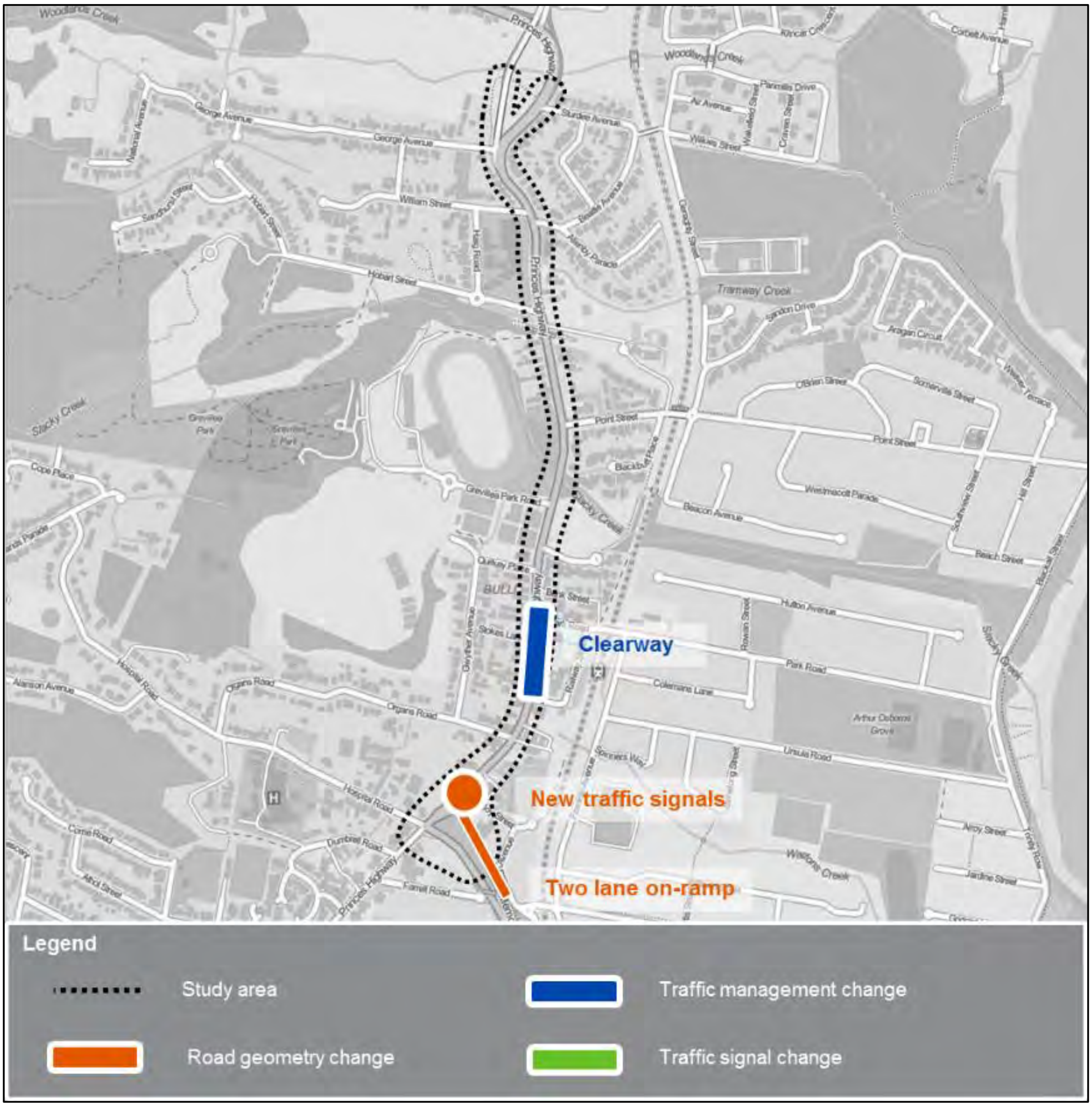


Figure 5.2 Scenario 2 network amendments

5.1.3 Scenario 3 – signalisation and consolidation with Memorial Drive off-ramp

As proposed in Table 4.2, Scenario 1 has been modelled using the forecast 2026 and 2036 traffic demands including the following network reconfiguration options:

- Clearways on the Princes Highway between Park Road and Station Street (as per Table 4.1)
- Conversion of the Princes Highway/Molloy Street roundabout to traffic lights and consolidation with the Memorial Drive off-ramp (as per Figure 4.5)
- Additional on-ramp lane to Memorial Drive.

These changes are outlined in Figure 5.3.

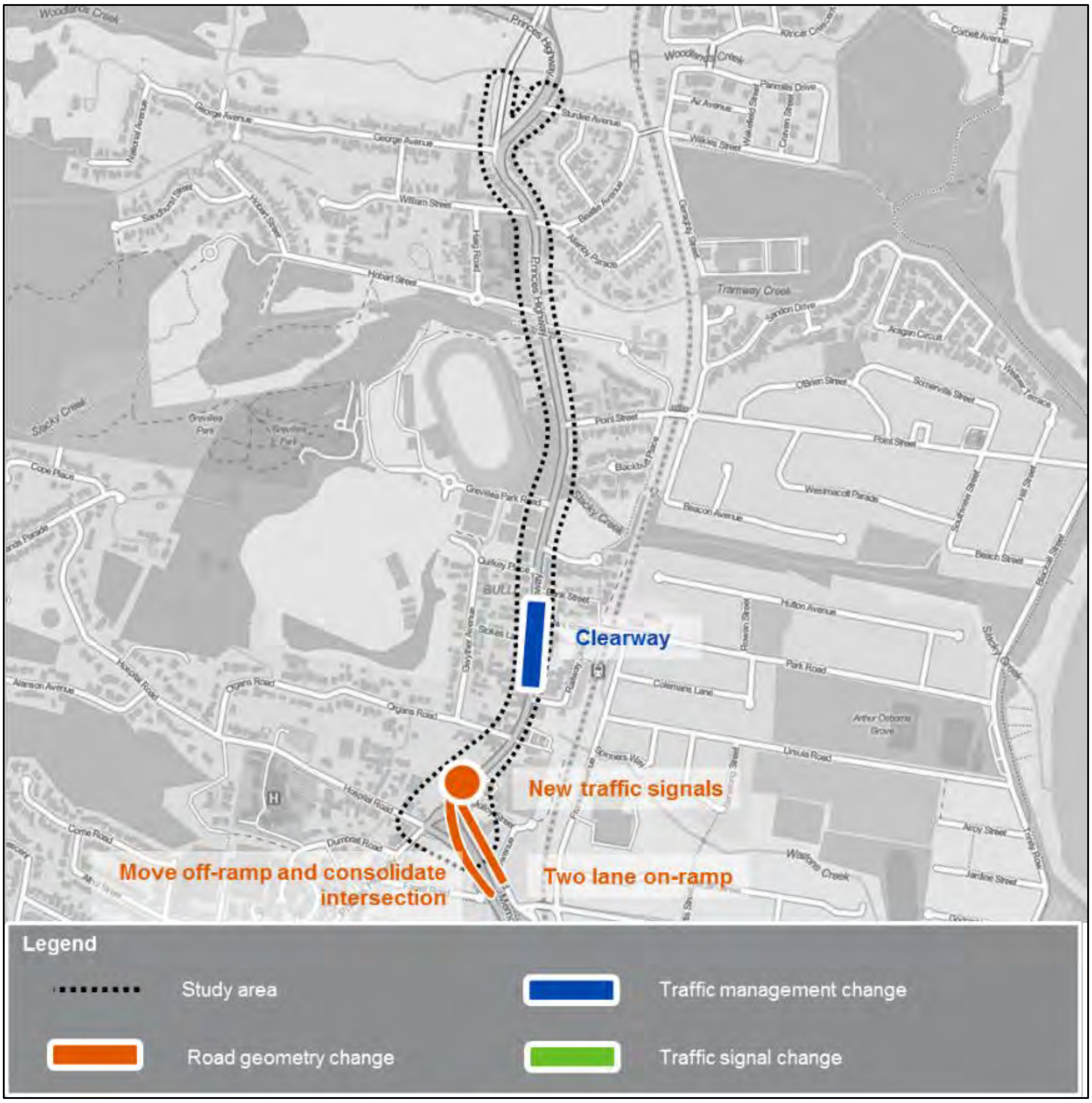


Figure 5.3 Scenario 3 network amendments

5.2 Network performance

5.2.1 Network statistics

The network statistics are summarised in Table 5.1–Table 5.3. The results indicate the following:

- VHT and vehicle stops during the weekday peak periods are significantly reduced (> 25%) by 2036 in all of the scenarios
- Vehicle throughput increases in all of the scenarios by around 5% during the 2036 AM peak period and around 2% during the 2036 PM peak period
- The increase in vehicle kilometres travelled in all scenarios is a consequence of the decrease in unreleased trips in the model network. As a result, the model is able to capture the kilometres travelled of these previously unreleased trips
- The improvement in average delay and vehicle stops during the Saturday peak period is around 5% and relatively small compared to the weekday peak periods.

Comparing the performance of the different scenarios, Scenario 2 shows similar levels of average delay and vehicle stops compared to Scenario 3. At the same time, Scenario 2 shows an additional improvement of around 5% in average delay and vehicle stops compared to Scenario 1. This indicates that the modelled traffic demand could be accommodated by either providing an additional through lane at the Molloy Street roundabout to Memorial Drive or signalising the existing intersection (and also providing two lanes to Memorial Drive).

Summary tables

Table 5.1 Comparison of network performance statistics – Stage 1 scenarios vs Do-minimum (AM peak)

Performance indicators	2026				2036			
	Base	Scenario 1	Scenario 2	Scenario 3	Base	Scenario 1	Scenario 2	Scenario 3
Vehicle kilometres travelled (km)	10,685	3%	3%	2%	11,015	5%	5%	4%
Vehicle hours travelled (hrs)	430	-20%	-19%	-19%	487	-22%	-24%	-24%
Average network speed (km/h)	25	+7	+7	+7	23	+8	+9	+8
Average network delay (sec/km)	178	-37%	-32%	-32%	209	-41%	-39%	-39%
Vehicle stops	19,405	-24%	-21%	-20%	22,111	-24%	-26%	-25%
Completed trips	7,755	2%	3%	3%	8,023	5%	5%	5%
Incomplete trips	413	-154	-194	-188	488	-244	-256	-260
Unreleased trips	79	-79	-79	-79	127	-127	-127	-127

(1) Scenario values refer to the model outputs for the scenario being assessed
(2) Difference comparisons are versus the ‘do-minimum’ model for the same future year demand (i.e. positive value indicates the scenario value is higher than the ‘do-minimum’).

Table 5.2 Comparison of network performance statistics – Stage 1 scenarios vs Do-minimum (PM peak)

Performance indicators	2026				2036			
	Base	Scenario 1	Scenario 2	Scenario 3	Base	Scenario 1	Scenario 2	Scenario 3
Vehicle kilometres travelled (km)	12,574	1%	1%	1%	12,907	2%	2%	2%
Vehicle hours travelled (hrs)	502	-13%	-12%	-12%	641	-26%	-26%	-24%
Average network speed (km/h)	25	+4	+4	+4	20	+8	+8	+7
Average network delay (sec/km)	178	-20%	-21%	-17%	247	-37%	-37%	-33%
Vehicle stops	24,461	-15%	-16%	-12%	31,569	-26%	-28%	-23%
Completed trips	9,501	1%	1%	1%	9,769	2%	2%	1%
Incomplete trips	304	-65	-60	-61	404	-151	-151	-128
Unreleased trips	0	0	0	0	27	-27	-27	-27

(1) Scenario values refer to the model outputs for the scenario being assessed
(2) Difference comparisons are versus the ‘do-minimum’ model for the same future year demand (i.e. positive value indicates the scenario value is higher than the ‘do-minimum’).

Table 5.3 Comparison of network performance statistics – Stage 1 scenarios vs Do-minimum (SAT peak)

Performance indicators	2026				2036			
	Base	Scenario 1	Scenario 2	Scenario 3	Base	Scenario 1	Scenario 2	Scenario 3
Vehicle kilometres travelled (km)	11,549	0%	0%	-1%	12,127	0%	0%	-1%
Vehicle hours travelled (hrs)	379	-6%	-3%	-6%	412	-6%	-5%	-7%
Average network speed (km/h)	30	+2	+1	+1	29	+2	+2	+2
Average network delay (sec/km)	126	-9%	2%	-2%	135	-11%	-2%	-5%
Vehicle stops	17,004	-7%	-3%	-5%	19,097	-8%	-6%	-8%
Completed trips	8,705	0%	0%	0%	9,131	0%	0%	0%
Incomplete trips	169	-3	+3	+4	175	-4	+4	0
Unreleased trips	0	0	0	0	0	0	0	0

(1) Scenario values refer to the model outputs for the scenario being assessed
(2) Difference comparisons are versus the ‘do-minimum’ model for the same future year demand (i.e. positive value indicates the scenario value is higher than the ‘do-minimum’).

5.2.2 Network queuing

The queueing on the Princes Highway corridor, with a focus on the impact of the Molloy Street roundabout pinch point, is described in Figure 5.4. These queues have been presented for the 2036 AM and PM peak periods, which represent the most critical peaks for the Molloy Street roundabout.

Overall, the depicted queues indicate that under all scenarios a significant reduction in the southbound queue on the Princes Highway would be achieved. The primary reason for this reduction in the queue length is the provision of an additional approach lane to Memorial Drive, which reflects the dominance of this movement at this intersection during all peak periods. As a result, the additional capacity provides significant relief for the southbound movement on the Princes Highway.

The provision of a southbound clearway during the PM peak period also significantly reduces the queue on the Princes Highway, allowing the traffic demand to reach the Molloy Street roundabout. The release of this pinch-point during the PM peak period does not result in any significant impacts at the Molloy Street roundabout, and is no worse than the impact during the AM peak period.

Comparing the scenarios, Scenario 2 appears to offer the greatest improvement in queuing at the Molloy Street roundabout. In Scenario 2, the southbound queue is generally between Station Street and Organs Road. Compared to Scenario 1, this is generally a shorter back-of-queue, given that Scenario 1 will typically extend to Station Street and intermittently beyond Station Street. Overall, this is not considered to be a significant difference in the back-of-queue, with a difference in the order of around 50 metres in 2036.

Scenario 3 shows a similar level of queuing compared to Scenario 2. However it is noted that a significant intersection footprint is required for this level of queuing.

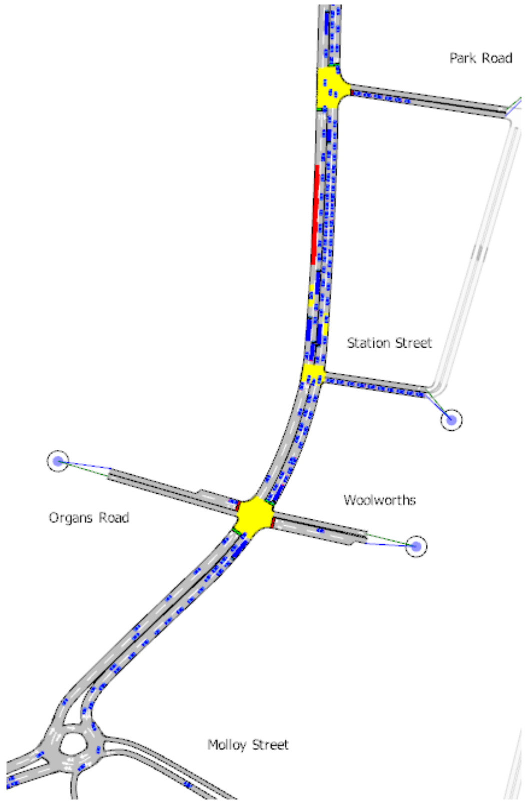
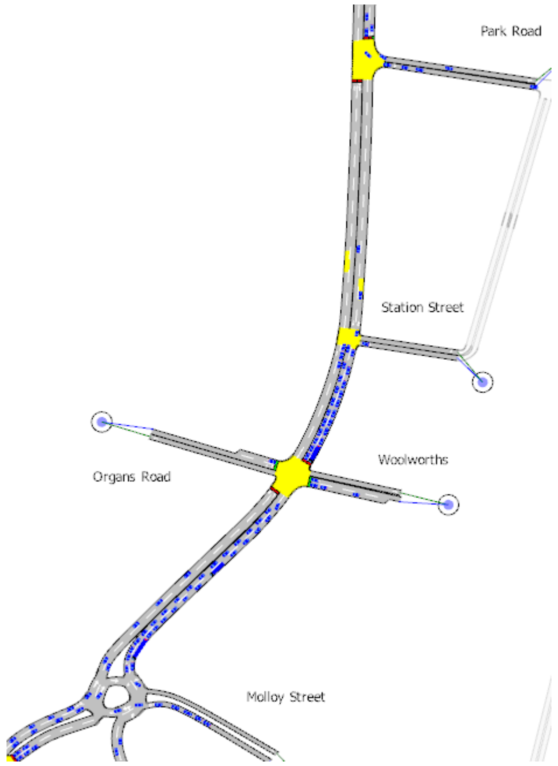
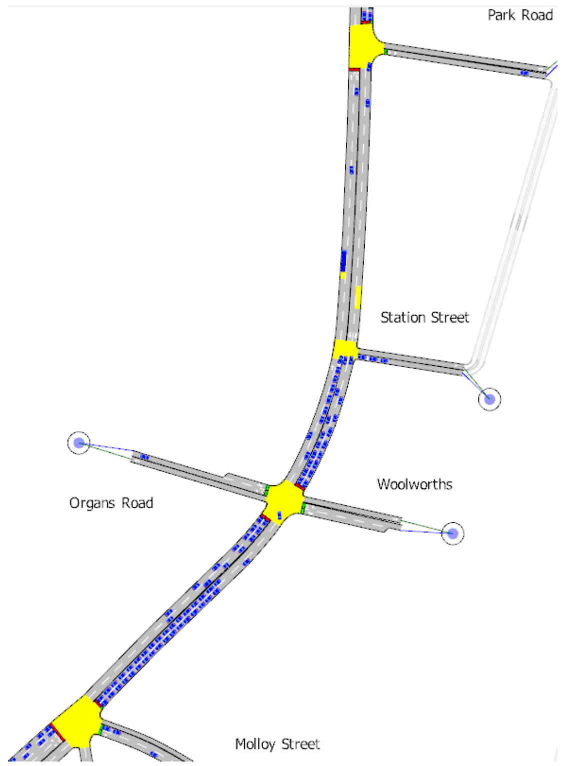
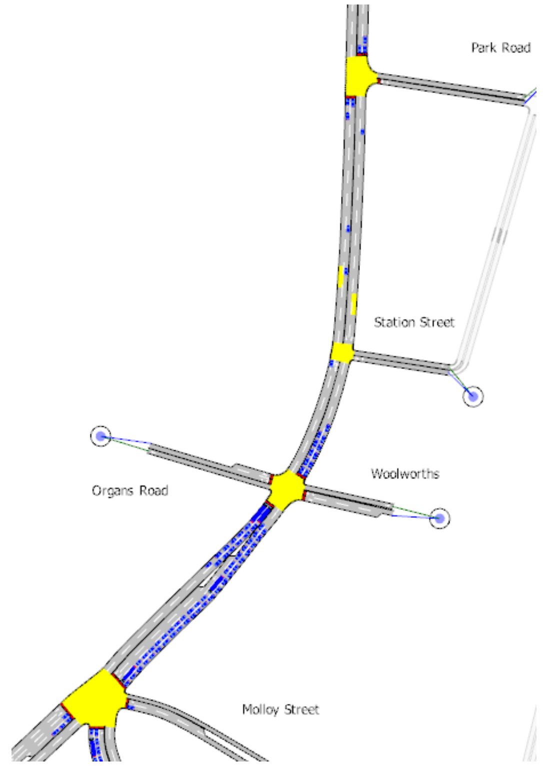
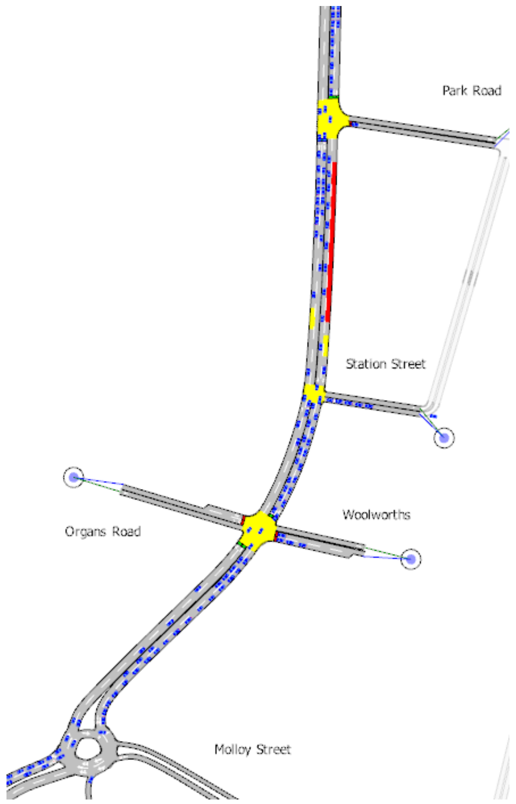
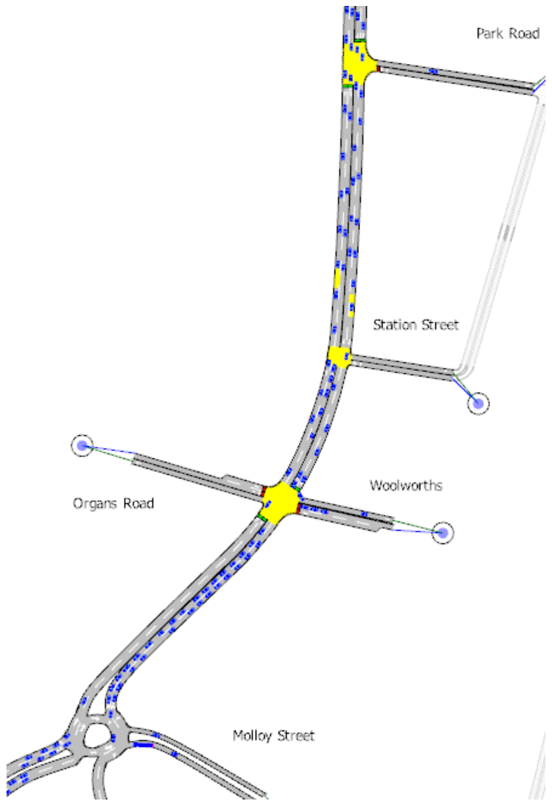
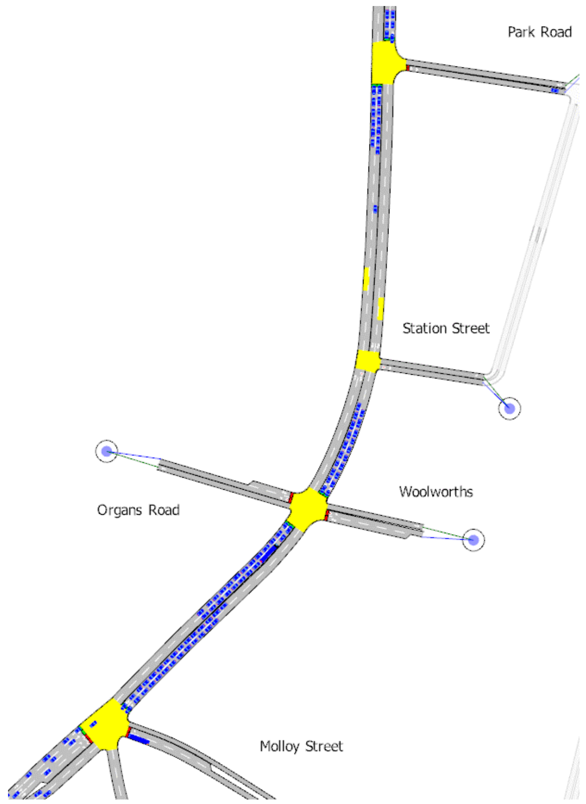
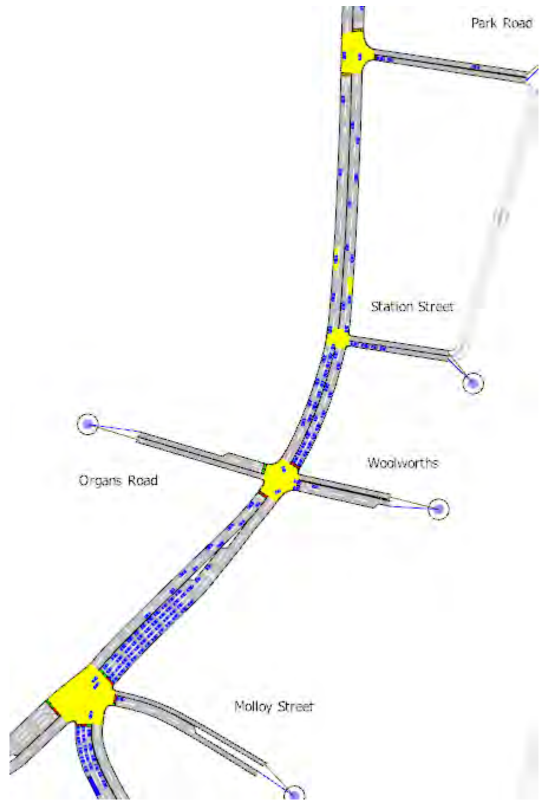
	‘Do-minimum’	Scenario 1	Scenario 2	Scenario 3
2036 AM				
2036 PM				

Figure 5.4 Comparison of network queuing | Scenarios 1–3

5.3 Travel time

The travel time results for Scenarios 1–3 are summarised in Table 5.4 and a percentage difference comparison to the ‘do-minimum’ modelling is summarised in Table 5.5. These results indicate that there are significant travel time benefits in the southbound direction in all scenarios. This benefit is around 50% during the 2036 weekday AM and PM peak periods, and around 15% during the 2036 Saturday peak period. Scenarios 2 and 3 show the largest improvement in travel time, with an improvement of around 5–10% higher compared to Scenario 1.

The improvement in travel time is lower in the northbound direction and comparable across Scenarios 1 and 2; being in the order of 20% during the 2036 weekday AM and PM peak periods, and approximately 5% during the 2036 Saturday peak period. The exception to this is in the results for the Scenario 3 northbound travel time, which typically shows an increase in travel time compared to the ‘do-minimum’ scenario. This is primarily a consequence of the increase in travel time in the section of the Princes Highway from Hospital Road to Molloy Street. This increase in travel time is due to the traffic signals being coordinated for the Memorial Drive off-ramp, which is the dominant approach under this scenario. As a result, the increase in northbound travel time in this section negates any travel time benefits on the remainder of the corridor.

Graphical comparisons of the travel times are presented at Appendix B.

Table 5.4 Travel time results – Stage 1 modelling vs Do-minimum

Performance indicators	2026				2036			
	Base	Scenario 1	Scenario 2	Scenario 3	Base	Scenario 1	Scenario 2	Scenario 3
AM peak period								
Northbound	2:50	2:24	2:25	2:55	3:02	2:26	2:28	2:59
Southbound	5:54	3:05	2:44	2:50	7:10	3:23	2:50	2:56
PM peak period								
Northbound	2:40	2:34	2:32	3:05	3:09	2:37	2:37	3:09
Southbound	4:47	3:26	2:59	2:56	6:14	3:34	3:09	3:07
Saturday peak period								
Northbound	2:22	2:19	2:30	2:59	2:35	2:25	2:32	3:02
Southbound	2:57	2:41	2:29	2:37	3:08	2:44	2:33	2:40

(1) Travel time measured between Hospital Road and Beattie Avenue in both directions
(2) Scenario values refer to the model outputs for the scenario being assessed
(3) Difference comparisons are versus the ‘do-minimum’ model for the same future year demand (i.e. positive value indicates the scenario value is higher than the ‘do-minimum’).

Table 5.5 Comparison of travel time results – Stage 1 modelling vs Do-minimum

Performance indicators	2026			2036		
	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
AM peak period						
Northbound	-15%	-15%	+3%	-20%	-19%	-2%
Southbound	-48%	-54%	-52%	-53%	-60%	-59%
PM peak period						
Northbound	-4%	-5%	+16%	-17%	-17%	0%
Southbound	-28%	-37%	-39%	-43%	-49%	-50%
Saturday peak period						
Northbound	-2%	+5%	+26%	-7%	-2%	+17%
Southbound	-9%	-16%	-11%	-13%	-18%	-15%

5.4 Intersection performance and link delay

The intersection LoS results are summarised in Table 5.6–Table 5.8 inclusive. These results indicate that the intersections along the Princes Highway corridor operate satisfactorily at LoS D or better in each of Scenarios 1–3. The release of the pinch point at the Molloy Street roundabout does not appear to have resulted in any significant downstream impacts at the intersection of Princes Highway/Hospital Road.

It is noted that the intersection of Princes Highway/Station Street operates at LoS D/E during some of the future year scenarios. The intersection performance at these location is governed by the critical movement of the right-turn from the side street, which has a demand of less than five vehicles/hour. As a result of the relatively low demand for this movement, it is possible for the reported delay to be skewed by one or two vehicles arriving at the start of a large platoon on the primary corridor. The right-turn demand is most likely generated by drivers unfamiliar to the road network who otherwise would have utilised the traffic lights at Park Road to undertake this manoeuvre. Furthermore, as the demand for these movements is low, an outcome of LoS E is considered acceptable in the interest of the prioritising the primary movements on the corridor.

Overall, there are few notable differences in intersection LoS between the three scenarios. The primary differences in the intersection LoS are:

- Princes Highway/Molloy Street operates at LoS C under Scenarios 1/3 and LoS B under Scenario 2 during the 2036 AM peak:
  - This reflects the additional capacity afforded by the traffic lights and the ability for the traffic lights to better balance the competing demands at the intersection
  - The performance of Scenario 3 is complicated by the need to balance the competing demands of Princes Highway (southern approach) and the Memorial Drive off-ramp.
- Princes Highway/Hospital Road operates at LoS B under Scenarios 1/2 and LoS A under Scenario 3 during 2036:
  - The improved performance under Scenario 3 is due to the consolidation of the Memorial Drive off-ramp with the intersection of Princes Highway/Molloy Street, resulting in the Princes Highway/ Hospital Road intersection becoming a T-intersection in this scenario
  - As a result of relocating the Memorial Drive off-ramp, Scenario 3 with a lower intersection demand.

Table 5.6 Level of Service summary – Stage 1 modelling vs 'Do-minimum' – AM peak period

	2026 AM								2036 AM							
	Base		Scenario 1		Scenario 2		Scenario 3		Base		Scenario 1		Scenario 2		Scenario 3	
Intersection	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS
Princes Highway/Beattie Avenue	55	D(1)	40	C	37	C	36	C	89	F(1)	41	C	41	C	42	C
Princes Highway/Hobart Street	24	B	16	B	16	B	16	B	34	C	17	B	17	B	17	B
Princes Highway/Point Street	20	B	12	A	13	A	12	A	32	C	13	A	13	A	13	A
Princes Highway/Grevillea Park Road	17	B	9	A	8	A	8	A	25	B	9	A	9	A	9	A
Princes Highway/Park Road	39	C	8	A	8	A	9	A	45	D	9	A	9	A	9	A
Princes Highway/Station Street	> 100	F(1)	42	C	40	C	34	C	> 100	F(1)	66	E(1)	49	D(1)	36	C
Princes Highway/Organs Road	53	D	11	A	11	A	10	A	57	E	15	B	12	A	11	A
Princes Highway/Molloy Street	35	C	27	B	22	B	36	C	37	C	39	C	22	B	38	C
Princes Highway/Hospital Road	30	C	27	B	26	B	10	A	33	C	28	B	27	B	10	A

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

Table 5.7 Level of Service summary – Stage 1 modelling vs 'Do-minimum' – PM peak period

	2026 PM								2036 PM							
	Base		Scenario 1		Scenario 2		Scenario 3		Base		Scenario 1		Scenario 2		Scenario 3	
Intersection	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS
Princes Highway/Beattie Avenue	33	C	32	C	33	C	31	C	> 100	F(1)	37	C	35	C	34	C
Princes Highway/Hobart Street	14	B	11	A	12	A	12	A	35	C	12	A	13	A	13	A
Princes Highway/Point Street	25	B	16	B	13	A	14	A	40	C	17	B	14	A	15	B
Princes Highway/Grevillea Park Road	23	B	10	A	10	A	11	A	28	C	11	A	11	A	11	A
Princes Highway/Park Road	28	B	9	A	8	A	8	A	35	C	9	A	9	A	9	A
Princes Highway/Station Street	54	D(1)	23	B	36	C	37	C	89	F(1)	47	D	42	C	38	C
Princes Highway/Organs Road	24	B	17	B	19	B	15	B	26	B	20	B	21	B	16	B
Princes Highway/Molloy Street	20	B	20	B	17	B	37	C	22	B	26	B	18	B	39	C
Princes Highway/Hospital Road	29	C	29	C	29	C	8	A	30	C	30	C	30	C	8	A

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

Table 5.8 Level of Service summary – Stage 1 modelling vs 'Do-minimum' – Saturday peak period

	2026 Saturday								2036 SAT							
	Base		Scenario 1		Scenario 2		Scenario 3		Base		Scenario 1		Scenario 2		Scenario 3	
Intersection	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS
Princes Highway/Beattie Avenue	27	B	25	B	28	B	28	B	28	B	27	B	29	C	28	B
Princes Highway/Hobart Street	7	A	8	A	8	A	9	A	7	A	10	A	10	A	8	A
Princes Highway/Point Street	13	A	10	A	10	A	11	A	14	A	12	A	12	A	11	A
Princes Highway/Grevillea Park Road	13	A	9	A	8	A	8	A	14	A	9	A	9	A	9	A
Princes Highway/Park Road	17	B	7	A	7	A	7	A	20	B	7	A	8	A	8	A
Princes Highway/Station Street	43	D(1)	27	B	29	C	34	C	85	F(1)	33	C	40	C	31	C
Princes Highway/Organs Road	16	B	10	A	14	A	14	A	16	B	12	A	18	B	13	A
Princes Highway/Molloy Street	18	B	15	B	16	B	37	C	21	B	20	B	20	B	35	C
Princes Highway/Hospital Road	27	B	28	B	25	B	7	A	28	B	31	C	27	B	8	A

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

5.5 Conclusion

A summary comparison of the performance of Scenarios 1–3 is presented on Figure 5.5. Overall, the following findings have been made:

- Network statistics:
  - Scenarios 2 and 3 result in the largest improvements in VHT and vehicle stops, with an improvement of around 25% compared to the 2036 ‘do-minimum’ scenario
  - Scenario1 would also result in a significant improvement in VHT and vehicle stops, albeit 5% smaller than Scenarios 2 and 3. The improvement in Scenario 1 is around 20% compared to the ‘do-minimum’
- Model queuing:
  - Scenarios 2 and 3 would result in the largest improvement in the southbound queuing at the intersection of Princes Highway/Molloy Street
  - The typical back of-queue in 2036 for Scenarios 2 and 3 would be between Station Street and Organs Road
  - Under Scenario 1, the typical back of queue would extend to Station Street, and intermittently beyond Station Street
  - The difference in queuing between the scenarios is expected to be around 50 metres
- Corridor travel time:
  - Scenarios 2 and 3 result in the largest improvements in southbound travel time, with an improvement of around 60% compared to the 2036 AM ‘do-minimum’ scenario
  - Scenario 1 would also result in a significant improvement in southbound travel time, albeit smaller than Scenarios 2 and 3. The improvement in Scenario 1 is around 55% compared to the 2036 AM ‘do-minimum’ scenario
- Intersection LoS:
  - Intersection LoS is generally similar across Scenarios 1–3, with the major intersections (signalised or roundabouts) along the Princes Highway corridor operating satisfactorily at LoS D or better in all scenarios
  - The priority-controlled intersection of Princes Highway/Station Street would operate at LoS D/E in the 2036 AM peak period. This is due to the critical movement being identified as the right-turn exit from Station Street even though it generates a demand of less than 5 vehicles/hour:
    - As a result of the low demand, the reported delay may be skewed by a large delay experienced by one or two vehicles which arrive at the intersection during the start of a large platoon
    - Overall, as the demand at this intersection is low, an outcome of LoS E/F for this movement is considered acceptable in the interest of prioritising the movements along the Princes Highway corridor
    - Furthermore, it is possible for this small number of right turn vehicles to undertake the manoeuvre at the Park Road traffic signals
- Scenario 3 signal operation:
  - The proposed layout and signal phasing for the consolidated intersection of Princes Highway/ Molloy Street/Memorial Drive is considered to be unconventional. This is due to the treatment of the Princes Highway–Memorial Drive movements as the primary movements and the Princes

Highway through movements (northbound and southbound) as the ‘right-turn’ movements in a diamond phasing arrangement

- The diamond phasing arrangement would result in the southbound through movement on the Princes Highway operating at the same time as the northbound through movement on the Princes Highway and the right-turns from Memorial Drive to Molloy Street. This would cause the southbound through movement to observe ‘oncoming traffic’ on both sides of the vehicle
- Whilst the proposed diamond phasing arrangement is workable from a modelling perspective, there are potential safety implications as a result of this phasing arrangement and detailed engineering design would be required to mitigate the safety hazards.

Overall, Scenarios 1 and 2 were considered to offer the best ‘value for money’ at improving the operation of the Princes Highway corridor in Bulli and as a consequence both scenarios were carried forward for economic assessment (the results of this analysis are detailed in section 9). Based upon the economic assessment and the relatively similar network performance outcomes, it was determined in consultation with Roads and Maritime that Scenario 1 be the preferred scenario to be progressed to the Stage 2 modelling phase.

Comparison between Scenario and 'Do Minimum' in 2036

	Network improvement		Travel time improvement		Approach delay at Molloy St			
Scenario 1	**AM peak**							
	Vehicle kilometres travelled	↑ 5%	Northbound	↓ -20%	Princes Hwy (N)	34 sec	LoS B	↓ -1 sec
	Vehicle hours travelled	↓ -22%			Molloy St	37 sec	LoS B	↑ +2 sec
	Avg network speed	↑ 35%	Southbound	↓ -53%	Princes Hwy (S)	5 sec	LoS A	↓ -1 sec
	Number of stops	↓ -24%						
	PM peak							
	Vehicle kilometres travelled	↑ 2%	Northbound	↓ -17%	Princes Hwy (N)	26 sec	LoS B	↑ +4 sec
	Vehicle hours travelled	↓ -26%			Molloy St	20 sec	LoS B	↑ +1 sec
	Avg network speed	↑ 38%	Southbound	↓ -43%	Princes Hwy (S)	6 sec	LoS A	~ 0 sec
	Number of stops	↓ -26%						
	SAT peak							
	Vehicle kilometres travelled	~ 0%	Northbound	↓ -7%	Princes Hwy (N)	15 sec	LoS B	↓ -3 sec
	Vehicle hours travelled	↓ -6%			Molloy St	18 sec	LoS B	↑ +1 sec
	Avg network speed	↑ 7%	Southbound	↓ -13%	Princes Hwy (S)	6 sec	LoS A	↑ +1 sec
	Number of stops	↓ -8%						
Scenario 2	**AM peak**							
	Vehicle kilometres travelled	↑ 5%	Northbound	↓ -19%	Princes Hwy (N)	17 sec	LoS B	↓ -18 sec
	Vehicle hours travelled	↓ -24%			Molloy St	63 sec	LoS D	↑ +28 sec
	Avg network speed	↑ 38%	Southbound	↓ -60%	Princes Hwy (S)	9 sec	LoS A	↑ +3 sec
	Number of stops	↓ -26%						
	PM peak							
	Vehicle kilometres travelled	↑ 2%	Northbound	↓ -17%	Princes Hwy (N)	16 sec	LoS B	↓ -6 sec
	Vehicle hours travelled	↓ -29%			Molloy St	50 sec	LoS C	↑ +31 sec
	Avg network speed	↑ 43%	Southbound	↓ -49%	Princes Hwy (S)	7 sec	LoS A	↑ +1 sec
	Number of stops	↓ -32%						
	SAT peak							
	Vehicle kilometres travelled	~ 0%	Northbound	↓ -2%	Princes Hwy (N)	17 sec	LoS B	↓ -1 sec
	Vehicle hours travelled	↓ -5%			Molloy St	45 sec	LoS C	↑ +28 sec
	Avg network speed	↑ 5%	Southbound	↓ -18%	Princes Hwy (S)	8 sec	LoS A	↑ +3 sec
	Number of stops	↓ -6%						
Scenario 3	**AM peak**							
	Vehicle kilometres travelled	↑ 4%	Northbound	↓ -2%	Princes Hwy (N)	34 sec	LoS B	↓ -1 sec
	Vehicle hours travelled	↓ -24%			Molloy St	31 sec	LoS B	↓ -4 sec
	Avg network speed	↑ 36%	Southbound	↓ -59%	Princes Hwy (S)	31 sec	LoS B	↑ +25 sec
	Number of stops	↓ -25%			Memorial Dr	24 sec	LoS B	↓ -2 sec
	PM peak							
	Vehicle kilometres travelled	↑ 1%	Northbound	~ 0%	Princes Hwy (N)	31 sec	LoS B	↑ +9 sec
	Vehicle hours travelled	↓ -30%			Molloy St	33 sec	LoS B	↑ +14 sec
	Avg network speed	↑ 44%	Southbound	↓ -50%	Princes Hwy (S)	31 sec	LoS B	↑ +25 sec
	Number of stops	↓ -32%			Memorial Dr	28 sec	LoS B	↑ +4 sec
	SAT peak							
	Vehicle kilometres travelled	↓ -1%	Northbound	↑ 17%	Princes Hwy (N)	29 sec	LoS B	↑ +11 sec
	Vehicle hours travelled	↓ -7%			Molloy St	33 sec	LoS B	↑ +16 sec
	Avg network speed	↑ 6%	Southbound	↓ -15%	Princes Hwy (S)	29 sec	LoS B	↑ +24 sec
	Number of stops	↓ -8%			Memorial Dr	24 sec	LoS B	↑ +3 sec

Figure 5.5 Summary comparison of Scenarios 1–3 (vs ‘Do-minimum’)

(1) Network statistics are reported for the full two hour peak period
(2) Travel times and approach delays are for the peak one hour
(3) Comparison for Memorial Drive approach delay is against the Princes Highway/Hospital Road intersection in the base scenario

6 Stage 2 Modelling assessment

6.1 Overview

As described in Table 4.2, Stage 2 has been modelled through two different options for the management of right-turns on the Princes Highway at Station Street and Park Road. These right-turn movements were identified as contributing to potential safety hazards and inefficiencies in the northbound operation of the Princes Highway.

Based upon the outcomes of the economic assessment (refer to section 9), it was determined in consultation with Roads and Maritime that Scenario 1 be the preferred scenario to be progressed to the Stage 2 assessment.

6.1.1 Scenario 4 – Right-turn ban and protected right-turn signal phase

As proposed in Table 4.2, Scenario 4 has been modelled using the forecast 2026 and 2036 traffic demands. This scenario builds upon Scenario 1 to also include the following network reconfiguration options:

→ ‘No right turn’ from Princes Highway to Station Street

→ Provision of a right-turn phase at the Princes Highway/Park Road intersection.

This is summarised on Figure 6.1.

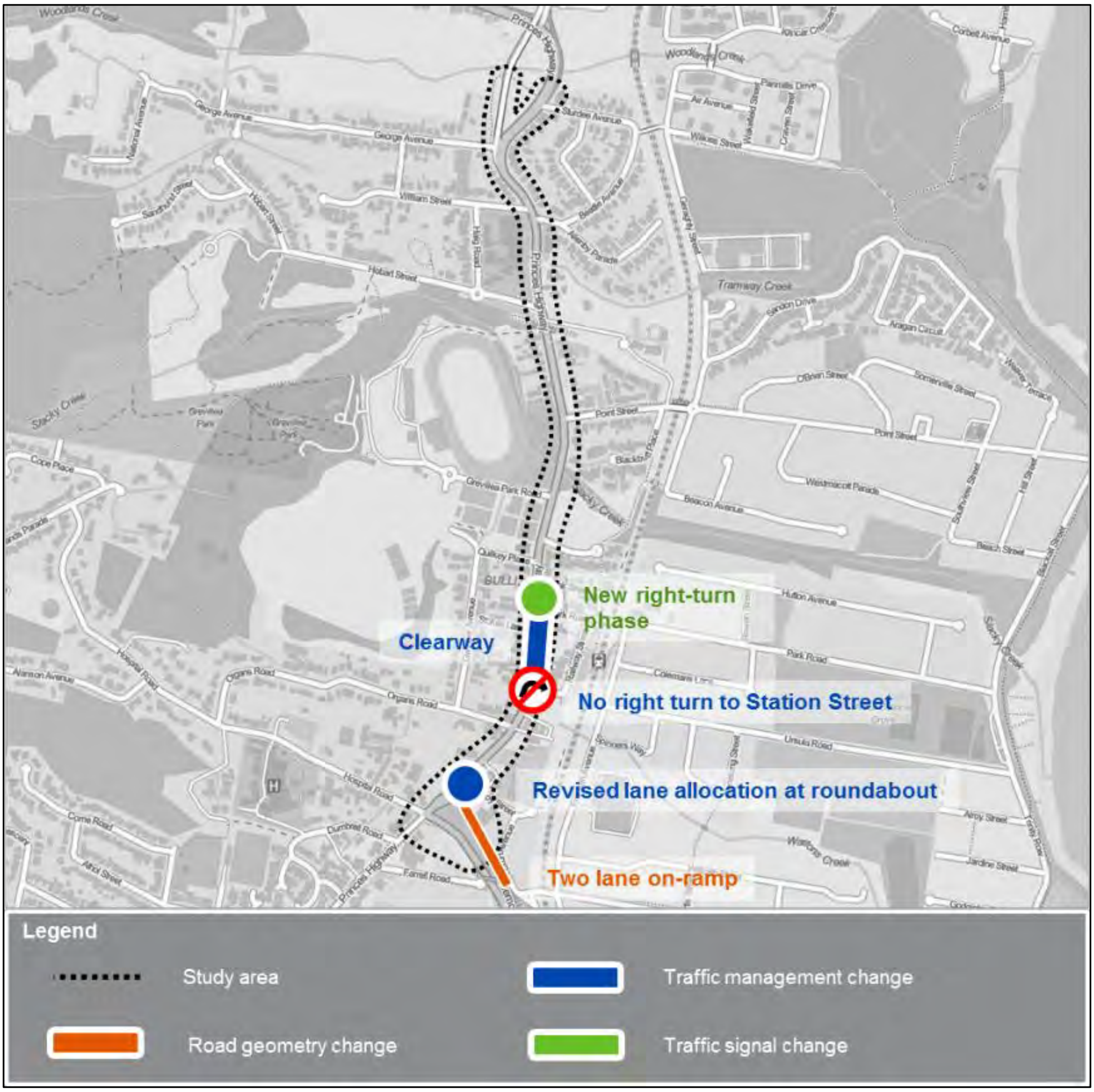


Figure 6.1 Scenario 4 network amendments

6.1.2 Scenario 5 – Traffic lights at Princes Highway/Station Street

As indicated in Table 4.2, Scenario 5 has been modelled using the forecast 2026 and 2036 traffic demands. This scenario builds upon Scenario 1 by also providing new traffic signals at the Princes Highway/ Station Street. At this stage, the new traffic signals would not include a right-turn phase for the northbound right-turn from Princes Highway (south) to Station Street. As a result, right-turning traffic would be required to filter-turn through oncoming traffic in a similar manner to that currently required (2016) at the intersection of Princes Highway/Park Road.

The corridor configuration assessed is summarised in Figure 6.2.

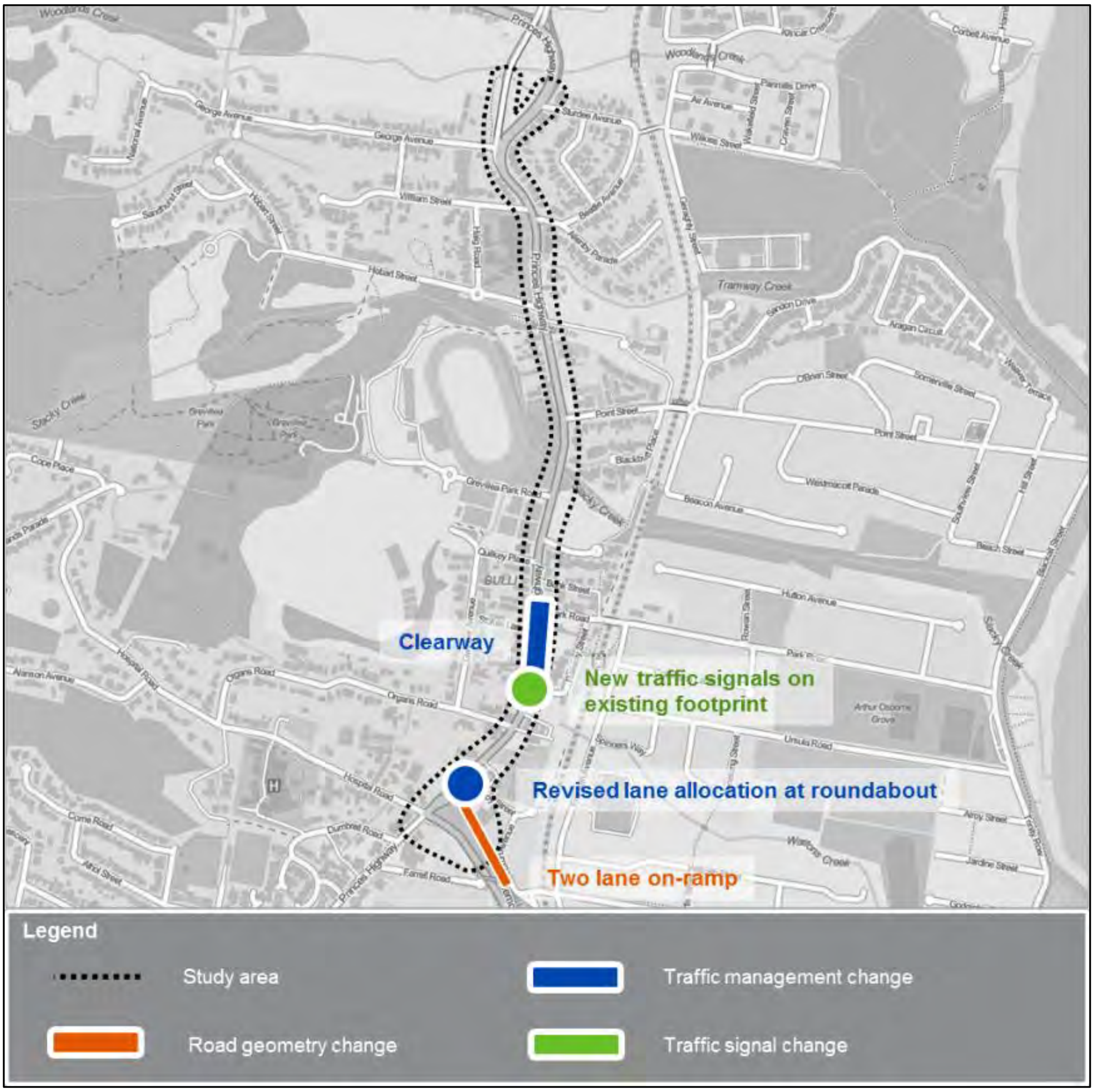


Figure 6.2 Scenario 5 network amendments

6.2 Network performance

6.2.1 Network statistics

The network statistics for each of the peak periods are summarised in Table 6.1 to Table 6.3 and compared to the results achieved for Scenario 1 (the preferred scenario from Stage 1):

- VHT is slightly increased by 3–5% by 2036, with vehicle stops showing a similar trend:
  - Scenario 4 has a lower VHT compared to Scenario 5 in 2036. However there is no significant difference between the two scenarios
  - The increase in VHT in Scenario 4 is a direct consequence of holding the southbound through movement at the traffic lights of Princes Highway/Park Road, in order to accommodate the new right-turn phase. The change in VHT is a trade-off between increasing delay for the southbound through movement and reducing delay (and increasing safety) for the northbound right-turn at this intersection
  - The increase in VHT in Scenario 5 is a direct consequence of the new traffic lights, which increases the delay for the Princes Highway through movement in both directions by providing guaranteed green time for the Station Street movements
- The increase in VHT generally correlates with a similar increase in vehicle stops, as more traffic is required to stop at traffic lights under both Scenarios 4 and 5. Having said this, in Scenario 4, there is a small decrease in total vehicle stops in the PM peak period. This is a net result of the trade-off between the decrease in stops for the northbound right-turn at Park Road, and the increase in stops for the southbound through movement at Princes Highway/Park Road.
- Vehicle throughput is similar across all scenarios.

Table 6.1 Comparison of network performance statistics – Stage 2 Scenarios vs Scenario 1 (AM peak)

Performance indicators	2026			2036		
	Scenario 1	Scenario 4	Scenario 5	Scenario 1	Scenario 4	Scenario 5
Vehicle kilometres travelled (km)	10,955	+1%	+1%	11,527	0%	0%
Vehicle hours travelled (hrs)	346	+2%	+2%	377	+4%	+5%
Average network speed (km/h)	32	0	0	31	-1	-1
Average network delay (sec/km)	113	+1%	+5%	123	+6%	+11%
Vehicle stops	14,653	+1%	+6%	16,753	+3%	+8%
Completed trips	7,948	+1%	+1%	8,389	0%	0%
Incomplete trips	259	-24	-18	244	+20	+32
Unreleased trips	0	0	0	0	0	0

(1) Scenario values refer to the model outputs for the scenario being assessed
(2) Difference comparisons are versus the Scenario 1 model for the same future year demand (i.e. positive value indicates the scenario value is higher than the Scenario 1).

Table 6.2 Comparison of network performance statistics – Stage 2 Scenarios vs Scenario 1 (PM peak)

Performance indicators	2026			2036		
	Scenario 1	Scenario 4	Scenario 5	Scenario 1	Scenario 4	Scenario 5
Vehicle kilometres travelled (km)	12,661	0%	0%	13,171	0%	0%
Vehicle hours travelled (hrs)	438	+1%	+1%	475	+1%	+3%
Average network speed (km/h)	29	0	0	28	0	-1
Average network delay (sec/km)	141	0%	+4%	155	0%	+7%
Vehicle stops	20,909	-2%	+3%	23,337	-2%	+4%
Completed trips	9,560	0%	0%	9,941	0%	0%
Incomplete trips	239	+5	+4	253	+0	+23
Unreleased trips	0	0	0	0	0	0

(1) Scenario values refer to the model outputs for the scenario being assessed
(2) Difference comparisons are versus the Scenario 1 model for the same future year demand (i.e. positive value indicates the scenario value is higher than the Scenario 1).

Table 6.3 Comparison of network performance statistics – Stage 2 Scenarios vs Scenario 1 (Saturday peak)

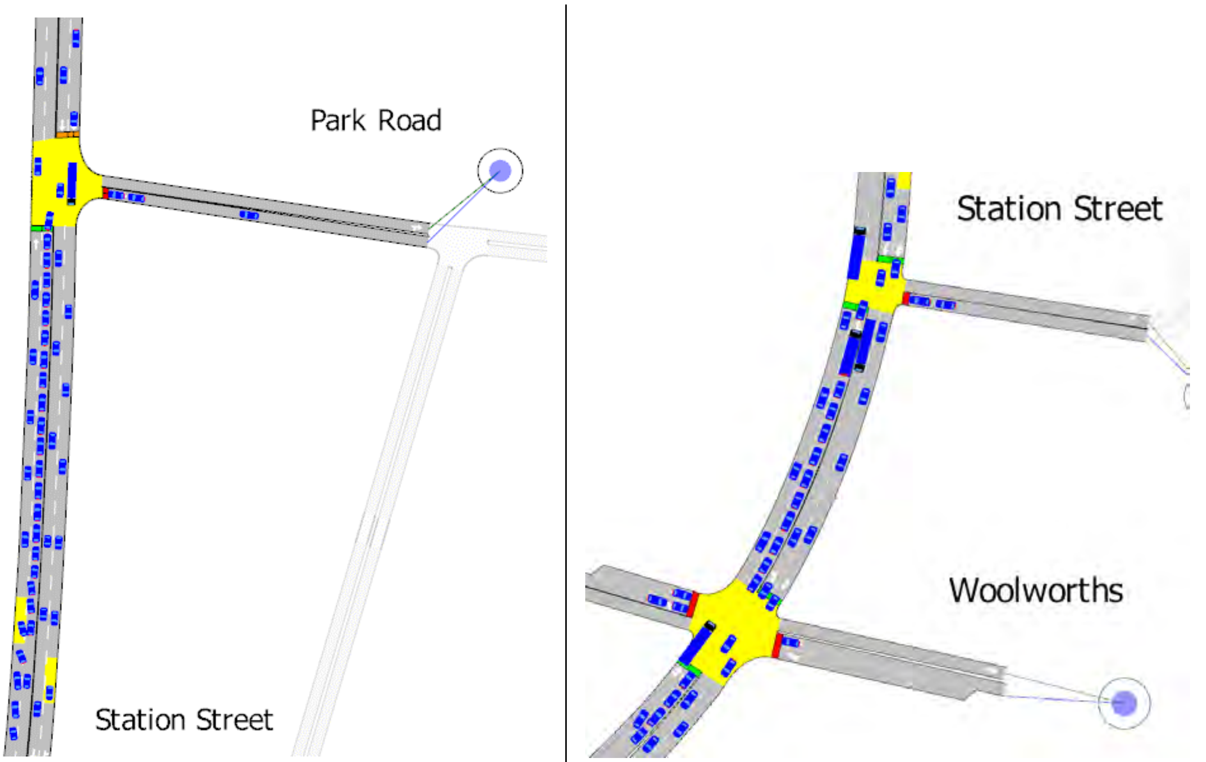
Performance indicators	2026			2036		
	Scenario 1	Scenario 4	Scenario 5	Scenario 1	Scenario 4	Scenario 5
Vehicle kilometres travelled (km)	11,501	+1%	0%	12,117	0%	0%
Vehicle hours travelled (hrs)	358	+2%	+1%	386	+2%	+1%
Average network speed (km/h)	32	-1	0	31	-1	0
Average network delay (sec/km)	115	+2%	+4%	120	+2%	+4%
Vehicle stops	15,842	0%	0%	17,538	0%	0%
Completed trips	8,694	0%	0%	9,127	0%	0%
Incomplete trips	166	+4	+1	170	+6	+3
Unreleased trips	0	0	0	0	0	0

(1) Scenario values refer to the model outputs for the scenario being assessed
(2) Difference comparisons are versus the Scenario 1 model for the same future year demand (i.e. positive value indicates the scenario value is higher than the Scenario 1).

6.2.2 Network queuing

The proposed arrangements for managing the right-turn demand to Park Road and Station Street would result in an increase in queue length at Park Road in Scenario 4 and at Station Street in Scenario 5. The typical queues under these scenarios are summarised on Figure 6.3. Overall, the following observations were made:

- Scenario 4:
  - There is an increase in queueing in the northbound median lane at the Princes Highway/Park Road intersection, which extends approximately 90 metres during the peak periods. This queue was not observed to extend past Station Street and mostly clears out during the right-turn phase (typically no more than two vehicles which wait for the next cycle)
  - The queue in the median lane also includes some northbound through vehicles which have been caught behind the right-turning vehicle/s and either are waiting to change lanes or waiting to clear during the right turn phase.
- Scenario 5:
  - The provision of an additional signalised intersection at Princes Highway/Station Street was observed in the model to cause southbound traffic to “bunch up” on approach to the intersection. This leads to reduction in the number of available gaps for right-turning vehicles to undertake filter turns
  - The reduced number of available gaps was observed to increase the northbound queuing in the median lane at Station Street, which occasionally extended past Organs Road. In previous scenarios, this queue typically did not extend past Organs Road.



Scenario 4	Scenario 5

Figure 6.3 Typical weekday peak period northbound right-turn queues

It is noted that as a result of the reduced green time for the southbound movement at Park Road, the southbound queue length increases by around 50 metres and extends to about Black Diamond Place. As a result of the increased size of the platoon of southbound traffic at Princes Highway/Park Road, the model shows downstream impacts at the intersection of Princes Highway/Molloy Street. This bunching increases the size of the platoon released from the intersection of Princes Highway/Park Road and therefore results in an increase in the southbound queue length at Princes Highway/Molloy Street. As indicated by Figure 6.4, the southbound back of queue is between Park Road and Station Street during the 2036 AM peak period, and would intermittently extend to Park Road during the peak 15 minutes of the AM peak period.

This queueing on the Princes Highway corridor is presented in Figure 6.4.

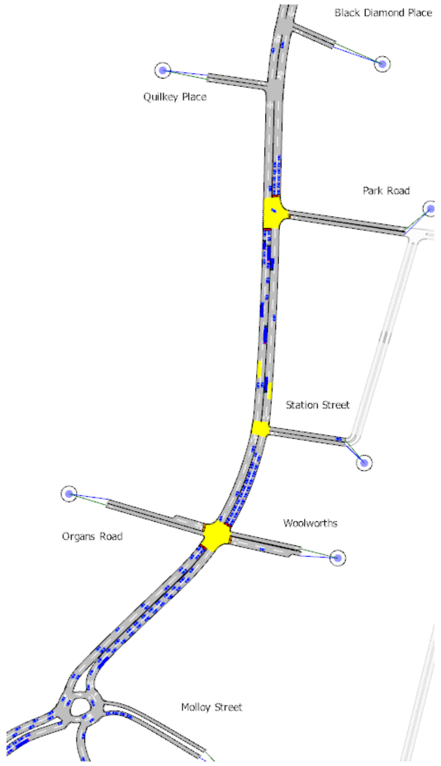
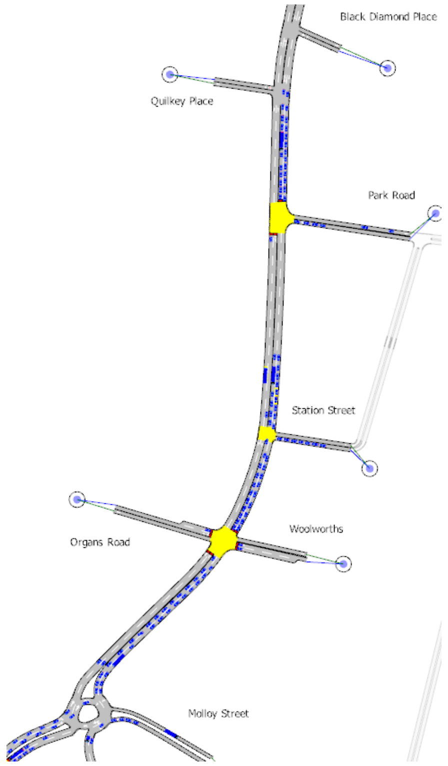
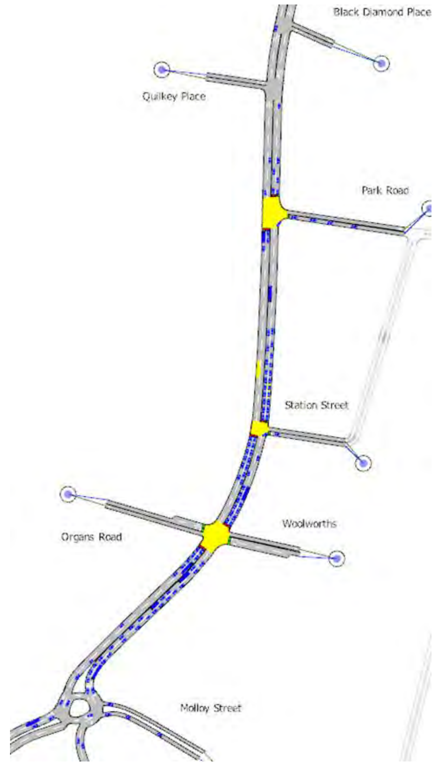
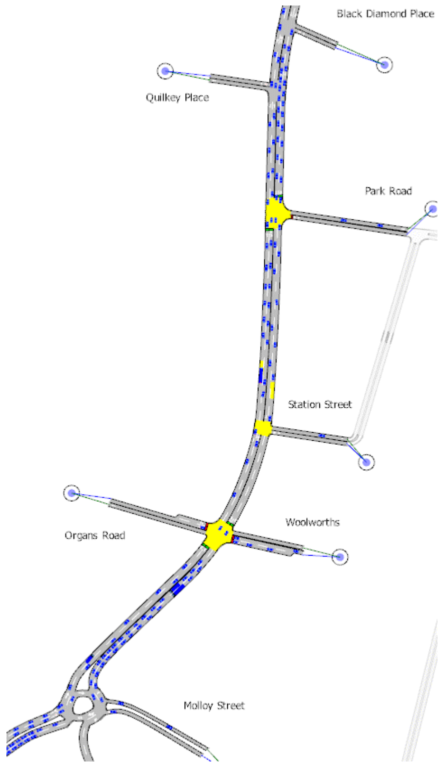
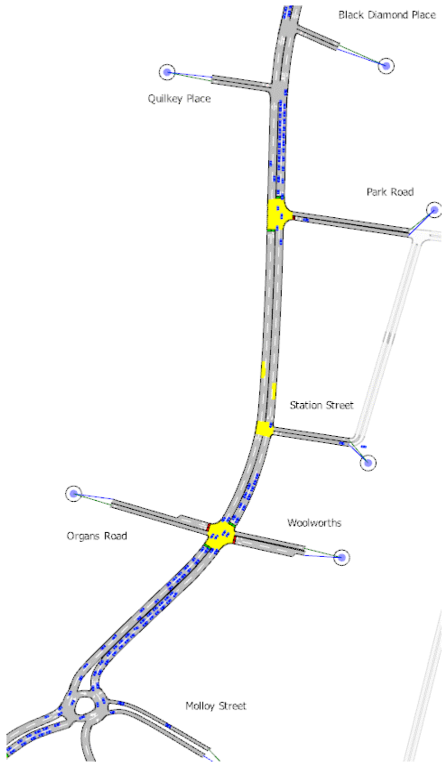
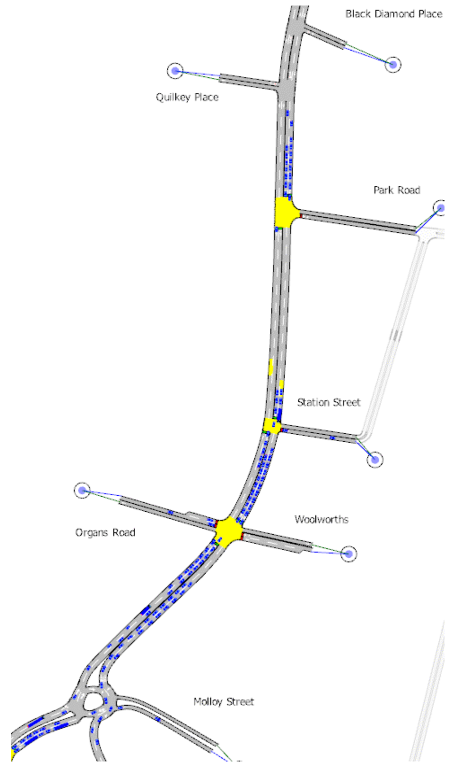
	Scenario 1	Scenario 4	Scenario 5
2036 AM			
2036 PM			

Figure 6.4 Comparison of queuing | Scenarios 4–5

6.3 Travel time

The travel time results for Scenarios 4 and 5 are summarised in Table 6.4 and as a percentage difference comparison to Scenario 1 is summarised in Table 6.5. These results indicate the following:

- Scenario 4, typically has a 5–15 seconds better travel time for the assessed peak periods than the results achieved for Scenario 5 in 2036
- There is no significant change in the northbound travel time as a result of the revised traffic signal phasing at Princes Highway/Park Road, with the difference to Scenario 1 being in the order of 5 seconds. This difference is considered spurious and is attributed to the variation across the different simulation seed runs
- There is an increase in southbound travel time in the AM peak period and a small decrease in the PM peak period compared to Scenario 1:
  - The increase in travel time is attributed to the increase in delay at the traffic lights at Princes Highway/Park Road
  - During the PM peak period, whilst southbound vehicles experience an increase in delay on the approach to Park Road, the increased delay allows additional time for the downstream queue at Princes Highway/Molloy Street to clear and therefore improve travel time downstream of Park Road
  - This effect is also observed in the AM peak period. However the downstream travel time improvement is smaller and does not outweigh the additional delay at Park Road.

Table 6.4 Comparison of travel time results – Stage 2 modelling vs Do-minimum and Scenario 1

Performance indicators	2026				2036			
	Base	Scenario 1	Scenario 4	Scenario 5	Base	Scenario 1	Scenario 4	Scenario 5
AM peak period								
Northbound	2:50	2:24	2:26	2:29	3:02	2:26	2:31	2:38
Southbound	5:54	3:05	3:13	3:09	7:10	3:23	3:49	3:47
PM peak period								
Northbound	2:40	2:34	2:36	2:39	3:09	2:37	2:38	2:55
Southbound	4:47	3:26	3:14	3:09	6:14	3:34	3:32	3:39
Saturday peak period								
Northbound	2:22	2:19	2:25	2:19	2:35	2:25	2:30	2:23
Southbound	2:57	2:41	2:44	2:41	3:08	2:44	2:49	2:46

(1) Travel time measured between Hospital Road and Beattie Avenue in both directions
(2) Scenario values refer to the model outputs for the scenario being assessed
(3) Difference comparisons are versus the 'do-minimum' model for the same future year demand (i.e. positive value indicates the scenario value is higher than the 'do-minimum')

Table 6.5 Comparison of travel time results – Stage 2 modelling scenarios vs Scenario 1

Performance indicators	2026		2036	
	Scenario 4	Scenario 5	Scenario 4	Scenario 5
AM peak period				
Northbound	+0:02	+0:05	+0:05	+0:12
Southbound	+0:08	+0:04	+0:27	+0:24
PM peak period				
Northbound	+0:02	+0:04	+0:01	+0:18
Southbound	-0:12	-0:17	-0:02	+0:04
Saturday peak period				
Northbound	+0:06	+0:00	+0:05	-0:02
Southbound	+0:03	-0:01	+0:05	+0:02

6.4 Intersection performance and link delay

The intersection LoS results are summarised in Table 6.6 to Table 6.8. These results indicate that the intersections along the Princes Highway corridor operate satisfactorily at LoS D or better in each of Scenarios 4 and 5.

The primary difference in intersection LoS between Scenarios 4 and 5 is at the intersection of Princes Highway/Station Street. This difference is a consequence of the change in traffic control from priority control under Scenario 4 to traffic control signals under Scenario 5. Under Scenario 5, the traffic signal operation allows Station Street traffic to be released on regular intervals, therefore reducing the delay at this intersection compared to Scenario 4. This also assists in managing the impact of the small number of right-turn vehicles from Station Street (less than 5 vehicles/hour) upon the operational performance of Station Street approach to the intersection.

The results also indicate that the changes to the traffic signal operation in Scenario 4 at the intersection of Princes Highway/Park Road has not significantly affected the intersection performance compared to Scenario 1. Under Scenario 4, the LoS of this intersection is expected to be LoS B, which is than the LoS A achieved under Scenario 1. The increase in average delay at this intersection is a direct consequence of the changes to the phase timings which has increased the delay for the southbound through movement.

As with previous scenarios, Scenario 4 was found to operate at LoS F at the intersection of Princes Highway/Station Street during some future year scenarios where the critical movement of the right-turn from the side street, which has a demand of less than five vehicles/hour. As a result of the relatively low demand for this movement, it is possible for the reported delay to be skewed by one or two vehicles which arrive at the start of a large platoon on the primary traffic corridor. This right-turn demand most likely represents unfamiliar drivers who could otherwise have utilised the traffic signals at Park Road to undertake this manoeuvre. Furthermore, as the demand for these movements is low, an outcome of LoS F is considered acceptable in the interest of the prioritising the primary movements on the corridor.

Table 6.6 Level of service summary – Stage 2 modelling vs 'Do-minimum' – AM peak period

	2026 AM								2036 AM							
	Base		Scenario 1		Scenario 4		Scenario 5		Base		Scenario 1		Scenario 4		Scenario 5	
Intersection	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS
Princes Highway/Beattie Avenue	55	D	40	C	39	C	37	C	89	F(1)	41	C	38	C	40	C
Princes Highway/Hobart Street	24	B	16	B	16	B	17	B	34	C	17	B	17	B	18	B
Princes Highway/Point Street	20	B	12	A	13	A	13	A	32	C	13	A	13	A	13	A
Princes Highway/Grevillea Park Road	17	B	9	A	9	A	6	A	25	B	9	A	10	A	8	A
Princes Highway/Park Road	39	C	8	A	16	B	9	A	45	D	9	A	19	B	12	A
Princes Highway/Station Street	> 100	F	42	C	24	B	9	A	> 100	F	66	E(1)	> 100	F(1)	20	B
Princes Highway/Organs Road	53	D(1)	11	A	8	A	13	A	57	E	15	B	18	B	27	B
Princes Highway/Molloy Street	35	C	27	B	26	B	27	B	37	C	39	C	39	C	41	C
Princes Highway/Hospital Road	30	C	27	B	28	B	28	B	33	C	28	B	28	B	28	B

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

Table 6.7 Level of service summary – Stage 2 modelling vs 'Do-minimum' – PM peak period

	2026 PM								2036 PM							
	Base		Scenario 1		Scenario 4		Scenario 5		Base		Scenario 1		Scenario 4		Scenario 5	
Intersection	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS
Princes Highway/Beattie Avenue	33	C	32	C	32	C	33	C	> 100	F(1)	37	C	35	C	35	C
Princes Highway/Hobart Street	14	B	11	A	12	A	12	A	35	C	12	A	13	A	13	A
Princes Highway/Point Street	25	B	16	B	14	A	13	A	40	C	17	B	14	A	15	B
Princes Highway/Grevillea Park Road	23	B	10	A	11	A	11	A	28	C	11	A	11	A	12	A
Princes Highway/Park Road	28	B	9	A	16	B	7	A	35	C	9	A	17	B	10	A
Princes Highway/Station Street	54	D(1)	23	B	17	B	11	A	89	F(1)	47	D(1)	43	D(1)	18	B
Princes Highway/Organs Road	24	B	17	B	13	A	17	B	26	B	20	B	16	B	28	B
Princes Highway/Molloy Street	20	B	20	B	21	B	21	B	22	B	26	B	24	B	26	B
Princes Highway/Hospital Road	29	C	29	C	30	C	31	C	30	C	30	C	33	C	33	C

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

Table 6.8 Level of service summary – Stage 2 modelling vs 'Do-minimum' – Saturday peak period

	2026 Saturday								2036 SAT							
	Base		Scenario 1		Scenario 4		Scenario 5		Base		Scenario 1		Scenario 4		Scenario 5	
Intersection	Delay (s)	Los	Delay (s)	Los	Delay (s)	Los	Delay (s)	Los	Delay (s)	Los	Delay (s)	Los	Delay (s)	Los	Delay (s)	Los
Princes Highway/Beattie Avenue	27	B	25	B	26	B	27	B	28	B	27	B	29	C	29	C
Princes Highway/Hobart Street	7	A	8	A	8	A	9	A	7	A	10	A	8	A	9	A
Princes Highway/Point Street	13	A	10	A	10	A	10	A	14	A	12	A	11	A	11	A
Princes Highway/Grevillea Park Road	13	A	9	A	8	A	8	A	14	A	9	A	9	A	9	A
Princes Highway/Park Road	17	B	7	A	12	A	6	A	20	B	7	A	13	A	7	A
Princes Highway/Station Street	43	D(1)	27	B	26	B	7	A	85	F(1)	33	C	15	B	7	A
Princes Highway/Organs Road	16	B	10	A	9	A	10	A	16	B	12	A	9	A	10	A
Princes Highway/Molloy Street	18	B	15	B	16	B	17	B	21	B	20	B	19	B	20	B
Princes Highway/Hospital Road	27	B	28	B	27	B	28	B	28	B	31	C	28	B	28	B

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

6.5 Conclusion

A summary comparison of the performance of Scenarios 4–5 (versus Scenario 1) is presented on Figure 6.5. Overall, the following findings have been made:

- General network operation:
  - Despite there being no clear improvements in the operational efficiency of Scenarios 4/5 over Scenario 1, it is noted that Scenario 4 has the potential to significantly improve the level of safety of the Princes Highway corridor around the Bulli Town Centre
  - The 'No Right Turn' at Station Street and subsequent protected right-turn phase at Park Road (Scenario 4) provides the following advantages:
    - Increased queue space for the northbound right-turn queue, which minimises the risk of this queue interfering with signalised intersections (such as at Princes Highway/Organs Road). This would most likely reduce the risk of rear-end crashes within this section of the corridor
    - Providing a right-turn phase at Princes Highway/Park Road would most likely reduce the risk of aggressive driver behaviour with respect to the selection of appropriate gaps for filter turns. This is on the basis that the provision of a signal controlled right-turn would enable drivers to take less risk when making filter turns in the knowledge that a non-conflicting signal controlled turn will follow the through phase.
- Network statistics:
  - VHT, vehicle stops and trip completion rates are comparable between the two scenarios.
- Model queuing:
  - Under Scenario 4, the northbound right-turn queue at Princes Highway/Park Road would extend approximately 90 metres in the median lane:
    - This queue is not expected to extend past Station Street and would mostly clear out during the right-turn phase (typically there would be no more than two vehicles required to wait for the next cycle)
    - The protected right-turn phase would also reduce the available green time for the southbound through movement, which results in the southbound queue at Princes Highway/Park Road extending to around Black Diamond Place
  - Under Scenario 5, the traffic lights would cause southbound traffic to 'bunch up' and reduce the available gaps for right-turn traffic to Station Street:
    - As a result, the northbound right-turn queue on the Princes Highway would increase and is expected to extend past the intersection of Princes Highway/Organs Road.
- Corridor travel time:
  - Scenario 4 has an improved travel time impact compared to Scenario 5, where Scenario 4 typically has a 5–15 second lower travel time during the peak periods
  - Overall, both scenarios are generally expected to increase southbound corridor travel times on the Princes Highway as a result of the revised signal phasing (in Scenario 4) and new traffic signals (in Scenario 5).
- Intersection LoS:
  - Intersection LoS is generally similar across Scenarios 4–5, with the major intersections (signalised or roundabouts) along the Princes Highway corridor operating satisfactorily at LoS D or better in all scenarios

- The priority-controlled intersections of Princes Highway/Station Street would operate at LoS D/E in the 2036 AM peak period in Scenario 4. This is due to the critical movement of the right-turn exit from Station Street which has a demand of less than five vehicles/hour. It should be noted that he LoS performance is determined by the worst performing movement at a priority controlled intersection:
  - As a result of the low demand, the reported delay may be skewed by a large delay experienced by one or two vehicles which arrive at the intersection during the start of a large platoon
  - Overall, as the demand at this intersection is low, an outcome of LoS E/F for this movement is considered acceptable in the interest of prioritising the movements along the Princes Highway corridor
  - Furthermore, it is possible for this small number of right turn vehicles to undertake the manoeuvre at the traffic lights at Park Road.
- The intersection LoS of Princes Highway/Station Street improves to LoS B in Scenario 5 as a result of the signalisation of this intersection. The traffic light operation allows traffic from Station Street to be released at regular intervals, and therefore reduces average delay at this intersection compared to Scenario 4. However it is noted that the demand for the critical movement under previous scenarios has a demand of less than five vehicles/hour.

In the context of the potential improvements in road safety on the corridor, it was agreed with Roads and Maritime to select Scenario 4 for economic assessment, which is discussed in detail in section 9.

Comparison between Scenario and 'Scenario 1' in 2036

Scenario	Peak	Network improvement		Travel time improvement		Approach delay at Park Rd				Approach delay at Station St			
Scenario 4	AM peak	Vehicle kilometres travelled	~ 0%	Northbound	↑ 3%	Princes Hwy (N)	21 sec	LoS B	↑ +15 sec	Princes Hwy (N)	11 sec	LoS A	↑ +6 sec
		Vehicle hours travelled	↑ 4%			Park Rd	42 sec	LoS C	~ 0 sec	Station St	81 sec	LoS F	↑ +20 sec
		Avg network speed	↓ -4%	Southbound	↑ 13%	Princes Hwy (S)	10 sec	LoS A	↑ +2 sec	Princes Hwy (S)	1 sec	LoS A	↓ -3 sec
		Number of stops	↑ 3%										
	PM peak	Vehicle kilometres travelled	~ 0%	Northbound	↑ 1%	Princes Hwy (N)	17 sec	LoS B	↑ +9 sec	Princes Hwy (N)	5 sec	LoS A	↓ -2 sec
		Vehicle hours travelled	↑ 1%			Park Rd	37 sec	LoS C	~ 0 sec	Station St	43 sec	LoS D	↓ -4 sec
		Avg network speed	~ 0%	Southbound	↓ -1%	Princes Hwy (S)	13 sec	LoS A	↑ +2 sec	Princes Hwy (S)	1 sec	LoS A	↓ -3 sec
		Number of stops	↓ -2%										
	SAT peak	Vehicle kilometres travelled	~ 0%	Northbound	↑ 4%	Princes Hwy (N)	12 sec	LoS A	↑ +8 sec	Princes Hwy (N)	2 sec	LoS A	↑ +1 sec
		Vehicle hours travelled	↑ 2%			Park Rd	42 sec	LoS C	↑ +1 sec	Station St	15 sec	LoS B	↓ -1 sec
		Avg network speed	↓ -2%	Southbound	↑ 3%	Princes Hwy (S)	20 sec	LoS B	↑ +5 sec	Princes Hwy (S)	8 sec	LoS A	~ 0 sec
		Number of stops	~ 0%										
Scenario 5	AM peak	Vehicle kilometres travelled	~ 0%	Northbound	↑ 8%	Princes Hwy (N)	11 sec	LoS A	↑ +5 sec	Princes Hwy (N)	21 sec	LoS B	↑ +16 sec
		Vehicle hours travelled	↑ 5%			Park Rd	42 sec	LoS C	~ 0 sec	Station St	67 sec	LoS E	↑ +6 sec
		Avg network speed	↓ -5%	Southbound	↑ 12%	Princes Hwy (S)	20 sec	LoS B	↑ +12 sec	Princes Hwy (S)	13 sec	LoS A	↑ +9 sec
		Number of stops	↑ 8%										
	PM peak	Vehicle kilometres travelled	~ 0%	Northbound	↑ 11%	Princes Hwy (N)	10 sec	LoS A	↑ +2 sec	Princes Hwy (N)	16 sec	LoS B	↑ +9 sec
		Vehicle hours travelled	↑ 3%			Park Rd	37 sec	LoS C	~ 0 sec	Station St	43 sec	LoS D	↓ -4 sec
		Avg network speed	↓ -3%	Southbound	↑ 2%	Princes Hwy (S)	21 sec	LoS B	↑ +10 sec	Princes Hwy (S)	16 sec	LoS B	↑ +12 sec
		Number of stops	↑ 4%										
	SAT peak	Vehicle kilometres travelled	~ 0%	Northbound	↓ -1%	Princes Hwy (N)	4 sec	LoS A	~ 0 sec	Princes Hwy (N)	2 sec	LoS A	↑ +1 sec
		Vehicle hours travelled	↑ 1%			Park Rd	41 sec	LoS C	~ 0 sec	Station St	61 sec	LoS E	↑ +45 sec
		Avg network speed	↓ -1%	Southbound	↑ 1%	Princes Hwy (S)	16 sec	LoS B	↑ +1 sec	Princes Hwy (S)	10 sec	LoS A	↑ +2 sec
		Number of stops	~ 0%										

Figure 6.5 Summary comparison of Scenarios 4–5 (vs Scenario 1)

(1) Travel times and approach delays are for the peak one hour
(2) Network statistics are reported for the full two hour peak period.

7 Stage 3 Modelling assessment

7.1 Overview

Based upon the outcomes of the economic assessment discussed in section 9 and the safety benefits of the different scenarios, it was agreed with Roads and Maritime to carry forward Scenario 4 for the Stage 3 assessment.

As indicated in Table 4.2, Stage 3 focusses on additional “minor” traffic management measures. As part of this, Scenario 6 builds upon Scenario 4 to also include a right-turn bay at the Princes Highway/Point Street intersection.

For the purposes of modelling, it has been assumed that this right-turn bay would be 75 metres long.

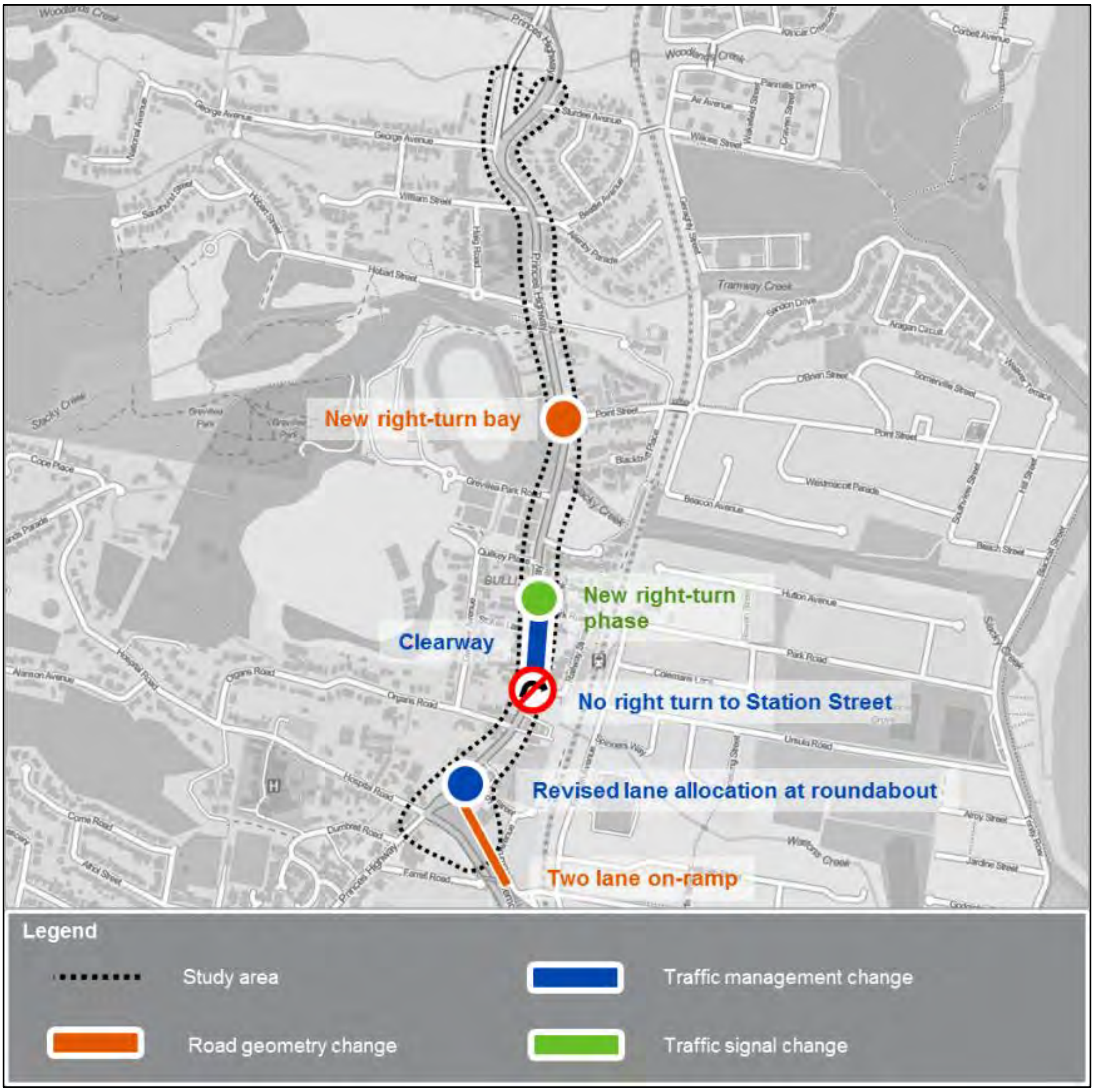


Figure 7.1 Scenario 6 network amendments

7.2 Network performance

7.2.1 Network statistics

The network statistics are summarised in Table 7.1 to Table 7.3 as a comparison of the results achieved for Scenario 4 (the preferred scenario from Stage 2):

- VHT has decreased by 1–2% by 2036, with vehicle stopes showing a similar trend:
  - This decrease is directly related to the reduced congestion associated with the right-turning vehicles at Point Street increasing the northbound capacity of the Princes Highway
- Vehicle throughput and VKT are similar across all scenarios, and reflects the modest improvement to network efficiency as a result of the right-turn bay.

Table 7.1 Comparison of network performance statistics – Stage 3 Scenario vs Scenario 4 (AM peak)

Performance indicators	2026		2036	
	Scenario 4	Scenario 6	Scenario 4	Scenario 6
Vehicle kilometres travelled (km)	11,045	0%	11,523	0%
Vehicle hours travelled (hrs)	353	-1%	393	-2%
Average network speed (km/h)	31	0	29	1
Average network delay (sec/km)	114	-1%	131	-4%
Vehicle stops	14,793	-2%	17,291	-3%
Completed trips	8,009	0%	8,374	0%
Incomplete trips	236	-2	264	-8
Unreleased trips	0	0	0	0

(1) Scenario values refer to the model outputs for the scenario being assessed
(2) Difference comparisons are versus the Scenario 4 model for the same future year demand (i.e. positive value indicates the scenario value is higher than the Scenario 4).

Table 7.2 Comparison of network performance statistics – Stage 3 Scenario vs Scenario 4 (PM peak)

Performance indicators	2026		2036	
	Scenario 4	Scenario 6	Scenario 4	Scenario 6
Vehicle kilometres travelled (km)	12,707	0%	13,209	0%
Vehicle hours travelled (hrs)	441	-1%	477	-1%
Average network speed (km/h)	29	0	28	0
Average network delay (sec/km)	141	0%	154	-1%
Vehicle stops	20,576	-2%	22,847	-2%
Completed trips	9,556	0%	9,936	0%
Incomplete trips	244	-5	254	-5

Performance indicators	2026		2036	
	Scenario 4	Scenario 6	Scenario 4	Scenario 6
Unreleased trips	0	0	0	0

(1) Scenario values refer to the model outputs for the scenario being assessed
(2) Difference comparisons are versus the Scenario 4 model for the same future year demand (i.e. positive value indicates the scenario value is higher than the Scenario 4).

Table 7.3 Comparison of network performance statistics – Stage 3 Scenario vs Scenario 4 (SAT peak)

Performance indicators	2026		2036	
	Scenario 4	Scenario 6	Scenario 4	Scenario 6
Vehicle kilometres travelled (km)	11,568	0%	12,134	0%
Vehicle hours travelled (hrs)	366	-1%	393	-1%
Average network speed (km/h)	32	0	31	0
Average network delay (sec/km)	117	-1%	122	-1%
Vehicle stops	15,811	-2%	17,527	-2%
Completed trips	8,698	0%	9,114	0%
Incomplete trips	170	-1	176	-4
Unreleased trips	0	0	0	0

(1) Scenario values refer to the model outputs for the scenario being assessed
(2) Difference comparisons are versus the Scenario 4 model for the same future year demand (i.e. positive value indicates the scenario value is higher than the Scenario 4).

7.2.2 Network queuing

The proposed right-turn bay at the intersection of Princes Highway/Point Street would result in an improvement in vehicle queuing in the northbound median lane. This is a direct result of the right-turn bay which prevents through vehicles from being delayed behind right-turning vehicles, and consequentially adding to the queue length.

The maximum queue observed in the model at the Princes Highway/Point Street is presented on Figure 7.2. This figure indicates that a 75 metre right-turn bay will generally be sufficient to accommodate the right-turn queue demand during the modelled peak periods.

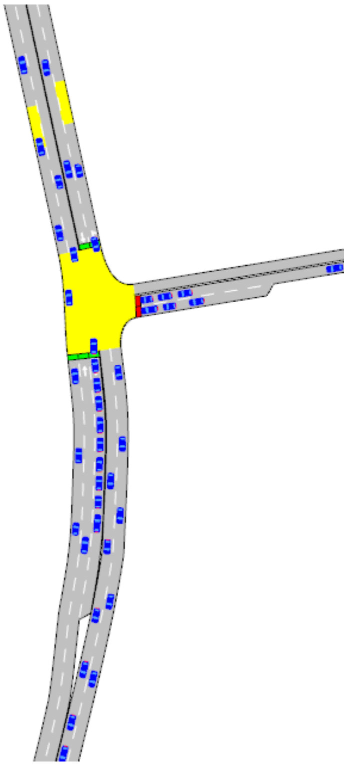


Figure 7.2 Typical maximum back of queue – Princes Highway/Point Street (2036 PM)

7.3 Travel time

The travel time results for Scenario 6 are summarised in Table 7.4 and the percentage difference as a comparison to Scenario 4 is summarised in Table 7.5. These results indicate that the proposed right-turn bay would reduce the northbound travel time in 2036 by an additional 2–4% compared to Scenario 4. This is a direct result of the right-turn bay which diminishes the congestion previously experienced at Princes Highway/Point Street, where no right turn bay currently exists.

Table 7.4 Comparison of travel time results – Scenario 6 vs Do-minimum and Scenario 4

Performance indicators	2026			2036		
	Base	Scenario 4	Scenario 6	Base	Scenario 4	Scenario 6
AM peak period						
Northbound	2:50	2:26	2:23	3:02	2:31	2:25
Southbound	5:54	3:13	3:13	7:10	3:49	3:41
PM peak period						
Northbound	2:40	2:36	2:31	3:09	2:38	2:33
Southbound	4:47	3:14	3:14	6:14	3:32	3:33
Saturday peak period						
Northbound	2:22	2:25	2:21	2:35	2:30	2:26
Southbound	2:57	2:44	2:44	3:08	2:49	2:50

(1) Travel time measured between Hospital Road and Beattie Avenue in both directions
(2) Scenario values refer to the model outputs for the scenario being assessed
(3) Difference comparisons are versus the ‘do-minimum’ model for the same future year demand (i.e. positive value indicates the scenario value is higher than the ‘do-minimum’).

Table 7.5 Comparison of travel time results – Stage 3 modelling vs Scenario 4

Performance indicators	2026	2036
	Scenario 6	Scenario 6
AM peak period		
Northbound	-2%	-4%
Southbound	0%	-4%
PM peak period		
Northbound	-4%	-4%
Southbound	0%	0%
Saturday peak period		
Northbound	-3%	-3%
Southbound	0%	0%

7.4 Intersection performance and link delay

The intersection LoS results are summarised in Table 7.6 to Table 7.8. These results indicate that, similar to Scenario 4, the intersections along the Princes Highway corridor operate satisfactorily at LoS D or better in Scenario 6.

As with previous scenarios, Scenario 6 was found to operate at LoS F at the intersection of Princes Highway/ Station Street during some future year scenarios. As discussed previously this is primarily a consequence of the delays experienced by motorists attempting to turn right out of Station Street. Even though this movement is generally less than five vehicles per hour, the delay is such that it skews the overall intersection delay. As motorists have an alternative means of exiting onto the Princes Highway at the signalised Park Road intersection, the LoS F outcome is considered acceptable in the interest of the prioritising the primary movements on the corridor.

The results also indicate that the right-turn bay at Princes Highway/Point Street would result in a small decrease in average delay at this intersection. This intersection would continue to operate satisfactorily at LoS A/B during the 2036 peak periods.

Table 7.6 Level of service summary – Stage 3 modelling vs 'Do-minimum' – AM peak period

	2026 AM						2036 AM					
	Base		Scenario 4		Scenario 6		Base		Scenario 4		Scenario 6	
Intersection	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**
Princes Highway/Beattie Avenue	55	D(1)	39	C	37	C	> 100	F(1)	38	C	39	C
Princes Highway/Hobart Street	24	B	16	B	16	B	38	C	17	B	16	B
Princes Highway/Point Street	21	B	13	A	11	A	39	C	13	A	12	A
Princes Highway/Grevillea Park Road	18	B	9	A	9	A	32	C	10	A	10	A
Princes Highway/Park Road	42	C	16	B	16	B	52	D	19	B	19	B
Princes Highway/Station Street	> 100	F(1)	24	B	26	B	> 100	F(1)	> 100	F(1)	89	F(1)
Princes Highway/Organs Road	53	D	8	A	8	A	57	E	18	B	15	B
Princes Highway/Molloy Street	38	C	26	B	26	B	37	C	39	C	38	C
Princes Highway/Hospital Road	28	B	28	B	27	B	29	C	28	B	28	B

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

Table 7.7 Level of service summary – Stage 3 modelling vs 'Do-minimum' – PM peak period

	2026 PM						2036 PM					
	Base		Scenario 4		Scenario 6		Base		Scenario 4		Scenario 6	
Intersection	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**
Princes Highway/Beattie Avenue	40	C	32	C	32	C	44	D(1)	35	C	33	C
Princes Highway/Hobart Street	15	B	12	A	12	A	23	B	13	A	12	A
Princes Highway/Point Street	35	C	14	A	12	A	35	C	14	A	12	A
Princes Highway/Grevillea Park Road	30	C	11	A	11	A	29	C	11	A	12	A
Princes Highway/Park Road	33	C	16	B	16	B	34	C	17	B	17	B
Princes Highway/Station Street	48	D	17	B	15	B	41	C	43	D	42	C
Princes Highway/Organs Road	25	B	13	A	13	A	21	B	16	B	17	B
Princes Highway/Molloy Street	21	B	21	B	20	B	21	B	24	B	25	B
Princes Highway/Hospital Road	30	C	30	C	31	C	31	C	33	C	32	C

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

Table 7.8 Level of service summary – Stage 3 modelling vs ‘Do-minimum’ – Saturday peak period

	2026 Saturday						2036 SAT					
	Base		Scenario 4		Scenario 6		Base		Scenario 4		Scenario 6	
Intersection	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**
Princes Highway/Beattie Avenue	31	C	26	B	27	B	33	C	29	C	29	C
Princes Highway/Hobart Street	7	A	8	A	8	A	6	A	8	A	8	A
Princes Highway/Point Street	13	A	10	A	9	A	13	A	11	A	9	A
Princes Highway/Grevillea Park Road	12	A	8	A	8	A	7	A	9	A	9	A
Princes Highway/Park Road	15	B	12	A	12	A	17	B	13	A	13	A
Princes Highway/Station Street	36	C	26	B	26	B	38	C	15	B	13	A
Princes Highway/Organs Road	17	B	9	A	9	A	17	B	9	A	9	A
Princes Highway/Molloy Street	19	B	16	B	16	B	23	B	19	B	19	B
Princes Highway/Hospital Road	27	B	27	B	28	B	25	B	28	B	28	B

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

7.5 Conclusion

7.5.1 Overview

A summary comparison of the performance of Scenario 6 (versus Scenario 4) is presented on Figure 7.3. Overall, the following findings have been made:

- Network statistics:
  - VHT and vehicle stops are around 2% lower following the implementation of the right-turn bay at Princes Highway/Point Street
  - VKT and trip completion rates is comparable to Scenario 4
- Model queuing:
  - The right-turn bay reduces disruption to the northbound traffic flow on the Princes Highway by removing the potential need to change lanes around right-turning vehicles at the Princes Highway/Point Street intersection
  - The model indicates that a 75 metre right-turn bay may be sufficient to accommodate the 2036 right-turn demand
- Corridor travel time:
  - Northbound travel time is improved by around 4% following the implementation of the right-turn bay, as a result of improving the corridor efficiency at the Princes Highway/Point Street intersection
  - Southbound travel time is generally comparable
- Intersection LoS:
  - Intersection LoS is generally similar between Scenarios 4 and 6, with the major intersections (signalised or roundabouts) along the Princes Highway corridor operating satisfactorily at LoS D or better in all scenarios
  - The priority-controlled intersections of Princes Highway/Station Street would operate at LoS F in the 2036 AM peak period in Scenarios 4 and 6. This is due to the critical movement of the right-turn exit from Station Street which has a demand of less than 5 vehicles/hour:
    - As a result of the low demand, the reported delay may be skewed by a large delay experienced by a couple of vehicles which arrive at the intersection during the start of a large platoon
    - Overall, as the demand at this intersection is low, an outcome of LoS E/F for this movement is considered acceptable in the interest of prioritising the movements along the Princes Highway corridor
    - Furthermore, it is possible for this small number of right turn vehicles to undertake the manoeuvre at the traffic lights at Park Road.

Overall, it is considered that the proposed right-turn bay at Princes Highway/Point Street offers an appreciable level of benefit to the operation and safety of the Princes Highway corridor.

Comparison between Scenario 6 and 'Scenario 4' in 2036

	Network improvement			Travel time improvement		Approach delay at Point Street				
	AM peak									
Scenario 6	Vehicle kilometres travelled	~	0%	Northbound	↓ -4%	Princes Hwy (N)	11 sec	LoS A	~	0 sec
	Vehicle hours travelled	↓	-2%			Point Street	37 sec	LoS C	~	0 sec
	Avg network speed	↑	2%	Southbound	↓ -4%	Princes Hwy (S)	3 sec	LoS A	↓	-3 sec
	Number of stops	↓	-3%							
	PM peak									
	Vehicle kilometres travelled	~	0%	Northbound	↓ -4%	Princes Hwy (N)	14 sec	LoS A	~	0 sec
	Vehicle hours travelled	↓	-1%			Point Street	38 sec	LoS C	~	0 sec
	Avg network speed	↑	1%	Southbound	~ 0%	Princes Hwy (S)	3 sec	LoS A	↓	-5 sec
	Number of stops	↓	-2%							
	SAT peak									
	Vehicle kilometres travelled	~	0%	Northbound	↓ -3%	Princes Hwy (N)	8 sec	LoS A	~	0 sec
	Vehicle hours travelled	↓	-1%			Point Street	47 sec	LoS D	↑	+1 sec
	Avg network speed	↑	1%	Southbound	~ 0%	Princes Hwy (S)	3 sec	LoS A	↓	-3 sec
	Number of stops	↓	-2%							

Figure 7.3 Summary comparison of Scenario6 (vs Scenario 4)

(1) Travel times and approach delays are for the peak one hour
(2) Network statistics are reported for the full two hour peak period.

7.5.2 Prioritisation of works

As the final scenario assessed as part of this commission, an indicative prioritisation of the improvement options is summarised below. Overall, this prioritisation of works is based upon the relative impact of the different pinch points upon the efficiency and safety of the Princes Highway corridor in Bulli over the medium to long term.

3. Critical corridor elements (with pre-2026 implementation):
   a) Peak period clearways on the Princes Highway, between Park Road and Station Street
   b) Provision of two on-ramp lanes to Memorial Drive
   c) Reallocation of lanes at the Princes Highway/Molloy Street roundabout to provide two through lanes to Memorial Drive. This should occur after the provision of two on-ramp lanes to Memorial Drive
4. Right-turn management:
   a) ‘No Right Turn’ from Princes Highway (south) into Station Street AND installation of a right-turn signal phase at the Princes Highway/Park Road intersection
   b) Provision of a channelized right-turn bay at the Princes Highway/Point Street intersection.

Based upon the ‘do minimum’ assessment in section 3, the critical corridor elements listed as Priority 1 should be undertaken prior to 2026. Without the Priority 1 works, the southbound queue on the Princes Highway is expected to extend to Point Street by 2026 and past Hobart Street by 2036.

The right-turn management measures are considered to be cost effective from a traffic performance perspective. This is because they can be implemented at any time and would provide an immediate improvement to the operation of the Princes Highway corridor.

8 Crash reduction analysis

8.1 Crash reduction analysis – impacts of treatment options

8.1.1 Existing crash trends

The crash data analysis was undertaken to establish a baseline for the pre-treatment rate of crashes on the Princes Highway corridor. This analysis was also used to identify the number of crashes that would be affected by each upgrade option. The crash data included all reported crashes that occurred within the study area for the 10 year period between 1 January 2005 and 31 December 2014.

The existing crash statistics for the above 10 year period is summarised in Table 8.1. This data represents the baseline for analysing the forecast crash rates post implementation of the treatment option.

Table 8.1 Summary of crash data (January 2005–December 2014)

Crashes		Counts (%)		Casualties		Counts (%)	
Fatal		1	1%	Killed		1	1%
Injury	Serious	23	17%	Injured	Seriously	28	36%
	Moderate	16	12%		Moderately	19	25%
	Minor/other	15	11%		Minor/other	25	33%
	Uncategorised	4	3%		Uncategorised	4	5%
Non-casualty		77	57%	**Total number of casualties**		**77**	
Total number of crashes		**136**					

8.1.2 Methodology

For the purposes of the crash reduction analysis, it has been assumed that the future year crash trends (including frequency and crash type) will remain relatively unchanged without any proposed treatments in place. The impacts to road safety would therefore be assumed to occur as a direct result of the upgrade of the Princes Highway corridor.

The Roads and Maritime *Accident Reduction Guide Part 1: Accident Investigation and Prevention (2004)* was used as a guide for the forecasting the changes in crash frequency as a result of the proposed treatment option/s.

Table 8.2 Impact upon road safety of treatments

Location	Treatment	Crashes in location by DCA	Percentage reduction	Impact upon road safety
Princes Highway between Park Road and Station Street	Clearway (peak periods) (treatment ID: 103)	→ DCA 301 (rear-end collisions): ▪ 1x injury crash ▪ 5x non-casualty crashes → DCA 305 (side swipe): ▪ 1x non-casualty crash → DCA 401 (parking manoeuvre): ▪ 1x injury crash → DCA 001 (pedestrian, near side): ▪ 1x injury crash.	→ U-turns (DCA 207–304): –20% → Rear ends (DCA 301–303): –20% → Manoeuvring (DCA 401–409): –20% → Hit parked vehicles (DCA 601): –50% → Hit pedestrians (DCA 001–008 and 901–902): –30%.	This would reduce the potential for hitting parked vehicles by removing these vehicles from the corridor. This also reduces rear-ends by reducing the need for vehicles to slow-down to avoid parking areas.
Memorial Drive on-ramp	Widening of bridge (treatment ID: 96)	→ DCA 803 (off-right bend into object): ▪ 1x non-casualty crash → DCA 804 (off-left bend into object): ▪ 1x injury crash ▪ 1x non-casualty crash.	→ Head-on (DCA 201–501): –40% → Overtake in same direction (DCA 503–506): –40% → Hit pedestrians (DCA 001–008 and 901–902): –40% → Permanent obstruction (DCA 605): –40% → Off carriageway on straight (DCA 701–702, 706–709, 502): –40% → Off straight and hit object (DCA 703–704): –40% → Out of control on straight (DCA 705, 502): –40% → Off carriageway on curve (DCA 801–802): –40% → Off curve and hit object (DCA 803–804): –40% → Out of control on curve (DCA 805): –40%.	The Roads and Maritime guideline does not directly assess the impact of road widening upon crash rates. For the purposes of analysis, the 'bridge widening' treatment was used to assess the additional southbound travel lane. This treatment also reflects the widening of the existing bridge north of Farrell Road. The widening of the bridge/carriageway contributes to a reduction in crashes by increasing the available road width for driving and therefore reduces the chance of drivers leaving the carriageway.

Location	Treatment	Crashes in location by DCA	Percentage reduction	Impact upon road safety
Intersection of Princes Highway/Molloy Street	New traffic lights (no filter) (treatment ID: 4)	→ DCA 101 (crossing traffic): ▪ 2x non-casualty crashes → DCA 104 (adjacent right/through): ▪ 4x injury crashes ▪ 5x non-casualty crashes → DCA 202 (opposing right/through): ▪ 2x non-casualty crashes → DCA 300 (same direction, uncategorised): ▪ 1x injury crash → DCA 301 (rear end): ▪ 1x injury crash → DCA 302 (rear end/left turn): ▪ 1x non-casualty crash → DCA 303 (rear end/right turn): ▪ 2x injury crashes → DCA 306 (lane change, right): ▪ 1x non-casualty crash → DCA 307 (lane change, left): ▪ 2x non-casualty crashes → DCA 406 (emerging from driveway): ▪ 1x non-casualty crash → DCA 704 (right off carriageway into object): ▪ 1x non-casualty crash → DCA 706 (left turn): ▪ 1x non-casualty crash → DCA 801 (off carriageway at right bend): ▪ 1x injury crash → DCA 804 (off left bend into object): ▪ 1x non-casualty crash	→ Adjacent approaches of intersections (DCA 101–109): –60% → Opposing vehicles turning (DCA 202–206): –90% → Rear ends (DCA 301–303): +40% → Hit pedestrians (DCA 001–008 and 901–902): –10%.	This would reduce the risk of intersection crashes by controlling the entry of vehicles from the different approaches. However traffic lights may cause an increase in rear-end collisions due to the potential for sudden/sharp braking by some vehicles on approach to the traffic lights.
Intersection of Princes Highway/Station Street	No Right Turn from Princes Highway (south) (treatment ID: 23)	→ DCA 003 (pedestrian, far side): ▪ 1x injury crash → DCA 104 (adjacent right/through): ▪ 1x non-casualty crash	→ Adjacent approaches of intersections (DCA 101–109): –70% → Opposing vehicles turning (DCA 202–206): –70% → Rear ends (DCA 301–303): –70% → Parallel lanes turning manoeuvres (DCA 308–309): –70%.	This would reduce the risk of intersection crashes by removing the potential for vehicles to turn right. This also removes filtering vehicles queued on the carriageway and therefore reduces rear-end collisions and those associated with lane changing.

Location	Treatment	Crashes in location by DCA	Percentage reduction	Impact upon road safety
	New traffic lights (no filter) (treatment ID: 4)	→ DCA 202 (opposing right/through): ▪ 1x injury crash → DCA 301 (rear end): ▪ 1x non-casualty crash → DCA 302 (rear end/left turn): ▪ 1x injury crash → DCA 303 (rear end/right turn): ▪ 2x injury crashes ▪ 1x non-casualty crash → DCA 704 (right off carriageway into object): ▪ 2x non-casualty crashes → DCA 803 (off right bend into object): ▪ 1x injury crash.	Refer to above discussion for Princes Highway/Molloy Street.	Refer to above discussion for Princes Highway/Molloy Street.
Intersection of Princes Highway/Park Road	Introduce right-turn phase (with filter) (treatment ID: 25)	→ DCA 003 (pedestrian, far side): ▪ 1x injury crash → DCA 201 (opposing head-on): ▪ 1x injury crash → DCA 301 (rear end): ▪ 2x non-casualty crashes → DCA 303 (rear end/right turn): ▪ 1x injury crash ▪ 1x non-casualty crash → DCA 305 (side swipe): ▪ 1x injury crash → DCA 601 (parked vehicle): ▪ 1x non-casualty crash.	→ Opposing vehicles turning (DCA 202–206): +10%.	This would increase the risk of crashes involving opposing turns as a result of maintaining the filter movement.
Intersection of Princes Highway/Point Street	Protected right-turn lane, painted S-lane (treatment ID: 29)	→ DCA 104 (adjacent right/through): ▪ 2x non-casualty crashes → DCA 201 (opposing head-on): ▪ 1x non-casualty crash → DCA 202 (opposing right/through): ▪ 1x non-casualty crash → DCA 301 (rear end): ▪ 1x injury ▪ 1x non-casualty crash → DCA 302 (rear end/left turn): ▪ 1x injury crash → DCA 305 (side swipe): ▪ 1x non-casualty crash → DCA 307 (lane change to left): ▪ 2x non-casualty crashes	→ Adjacent approaches of intersections (DCA 101–109): –15% → Opposing vehicles turning (DCA 202–206): –40% → Rear ends (DCA 301–303): –60% → Lane change (DCA 305–307): –40% → Parallel lanes turning manoeuvres (DCA 308–309): –40% → Overtake in same direction (DCA 503–506): –70%.	This would reduce crashes related to intersections, rear ends and lane changing by providing right-turn vehicles with a separate lane from the through lanes.

8.2 Predicted crash rate

Table 8.3 summarises the estimated number of crashes under the 'do minimum' scenario compared to each of the scenarios modelled for the Princes Highway corridor in Bulli. These estimates are based upon the historical crash data for the 10 year period between January 2005 and December 2014, and assumes that the rate of crashes would remain the same in the future if no improvement works are undertaken. Crash reduction rates have been derived from the Roads and Maritime guideline *Accident Reduction Guide Part 1: Accident Investigations and Prevention (2004)* and have been applied to reflect the estimated benefits of each treatment option.

Table 8.3 Predicted annual crash rate with proposed improvements

		Stage 1			Stage 2		Stage 3
Crash type	**Do minimum**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**
Fatal	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Injury	5.7	5.6	5.5	5.5	5.4	5.8	5.4
Non-casualty	7.8	7.7	7.1	7.1	7.5	7.7	7.3
Overall	**13.6**	**13.4**	**12.7**	**12.7**	**13.0**	**13.6**	**12.9**

The crash reduction forecasts indicate the following:

- Under the Stage 1 modelling scenarios, the signalisation of the intersection of Princes Highway/ Molloy Street would lead towards a lower rate of crashes (by 0.7 crashes/year) compared to modifying the existing roundabout configuration.
- Under the Stage 2 modelling scenarios, the implementation of a right-turn ban from the Princes Highway (south) into Station Street, and subsequent addition of a right-turn phase at Princes Highway/ Park Road, would result in a greater crash reduction (by 0.6 crashes/year) compared to signalising the intersection of Princes Highway/Station Street:
  - The implementation of the right-turn ban into Station Street and right-turn phase at Princes Highway/Park Road would further reduce the rate of crashes compared to Scenario 1 by around 0.4 crashes/year. This reduction in crash rate supports the decision to carry forward Scenario 4 as the preferred scenario into the Stage 3 modelling (compared to Scenarios 1 or 5).
- Under the stage 3 modelling scenario, the implementation of the right-turn bay at Princes Highway/ Point Street would further reduce the rate of crashes compared to Scenario 4 by around 0.1 crashes/year.
- Overall, there would be a net decrease in the crash rate in all scenarios assessed (except for Scenario 5) compared to the 'do minimum' scenario:
  - The minimal change in crash rate under Scenario 5 is based upon the trade-off between the increase in rear-end collisions at new traffic lights and the reduction in crashes between opposing movements.

9 Economic assessment

9.1 Overview

As part of the options assessment, a high level 'rapid economic appraisal' has been undertaken. This economic appraisal has been used to provide a preliminary estimate of the expected costs and benefits of selected options. This estimate of the expected future costs and benefits has been used by Roads and Maritime as part of selecting their preferred scenario at each stage of the modelling process.

The assumptions and details of the economic assessment are documented at Appendix C memorandum *HW1 Princes Highway at Bulli rapid economic appraisal.*

The base case and four scenarios were assessed for AM and PM peak hours in all three modelling years. The following traffic modelling results of the base case and the four scenarios were used as inputs to the economic appraisal:

- Total vehicle hours travelled (VHT) – to inform travel time benefit assessment
- Total vehicle kilometre travelled (VKT) – to inform vehicle operating cost and emission cost assessment
- Total number of stops – to inform vehicle operating cost assessment.

The above statistics were extracted separately for light vehicles (cars), heavy vehicles (trucks), and buses.

The traffic model used for the project is a corridor model, and does not model the effects that the increasing congestion along the corridor in the future (e.g. 2036) may cause the diversion of traffic to adjacent corridors or to a different mode. As a result, the actual congestion in the future may not be as severe as what is indicated by the traffic modelling. The modelling indicates that the Princes Highway corridor would become very congested during the peak periods of 2026. In order to minimise the risk of overstating the project benefits, only the 2016 and 2026 model results have been used to inform the economic assessment. This has been undertaken on the assumption that the benefits will initially grow until 2026 and will then remain at a similar level over the remaining years of the appraisal period.

9.2 Summary of results

A brief summary of the cost-benefit analysis is presented in Table 9.1. These results indicate that all of the scenarios assessed are economically viable with the Benefit-Cost Ratio (BCR) exceeding 10 and a positive Net Present Value (NPV). Overall, the cost-benefit analysis indicates the following:

- Scenario 2 provides the highest NPV (around $48.3 million):
  - This indicates that there is a net benefit (discounted for inflation and opportunity cost) as a result of implementing the proposal.
- Scenario 1 has the highest BCR (around 18.2):
  - This indicates that for every dollar in economic cost, there is around $18.20 in economic benefit as a result of implementing the proposal.
- Travel time savings comprise a significant proportion of the economic benefit in all of the scenarios.

Table 9.1 Summary of cost-benefit analysis

	Scenario 1	Scenario 2	Scenario 4	Scenario 6
PV capital cost	$2,286,900	$3,032,900	$2,848,500	$3,469,100
PV net maintenance cost	$274,200	$363,600	$341,500	$415,900
PV total cost	**$2,561,100**	**$3,396,600**	**$3,190,000**	**$3,885,000**
PV travel time benefit	$41,848,200	$46,365,800	$39,388,500	$40,772,400
PV vehicle operation cost savings	$6,331,200	$6,657,100	$6,210,700	$6,673,000
PV emission savings	$6,800	$46,500	-$38,100	-$37,100
PV crash cost savings	$136,500	$316,200	$409,500	$426,800
Clearway disbenefit	-$1,691,100	-$1,691,100	-$1,691,100	-$1,691,100
PV total benefit	**$46,631,600**	**$51,694,500**	**$44,279,500**	**$46,143,900**
NPV	**$44,070,500**	**$48,297,900**	**$41,089,500**	**$42,259,000**
BCR	**18.2**	**15.2**	**13.9**	**11.9**

(1) PV stands for 'Present Value'
(2) Reported values have been rounded.

10 Summary and conclusions

10.1 Project context

WSP | Parsons Brinckerhoff was commissioned by NSW Roads and Maritime Services to develop an Aimsun traffic microsimulation model to assess the existing and future operational performances of the HW1 Princes Highway corridor in Bulli, NSW, between Sturdee Avenue in the north and Hospital Road in the south.

This traffic microsimulation model has been developed to assist Roads and Maritime in preparing a program of works to maintain safe and efficient traffic flow along the Princes Highway corridor in Bulli in the future years.

10.2 2016 base model calibration/validation

A base model was developed in Aimsun using traffic surveys from March 2016 in order to establish a baseline for the future year modelling. The 2016 weekday AM, weekday PM and Saturday base models were calibrated and validated to the criteria defined by the Roads and Maritime *Traffic Modelling Guidelines (2013)*. These base models (and associated documentation) were submitted to Roads and Maritime and subsequently approved as fit-for-purpose in the future year modelling of the study area.

10.3 'Do-minimum' assessment

The 'do-minimum' modelling indicated that without these treatment options, the southbound queue in particular on the Princes Highway, would extend past Hobart Street in 2036. This level of congestion would approximately double the southbound travel time on the Princes Highway and significantly affect the local amenity of the corridor.

The forecast level of queuing and travel time by 2036 indicated that there were key capacity pinch points on the Princes Highway corridor. These pinch points included:

- On-street car parking during the peak periods, which reduces the corridor capacity to one lane in the affected direction
- Roundabout at Princes Highway/Molloy Street, which is also required to accommodate a demand of over 1000 vehicles/hour travelling to Memorial Drive in a single lane
- Right-turn movements on the Princes Highway corridor in shared through/right-turn lanes at key intersections.

10.4 Improvement options assessed

Based upon the 'do-minimum' assessment, the improvement options in Table 10.1 for the Princes Highway corridor were assessed.

Table 10.1 Corridor treatment scenarios assessed

	Clearway Princes Highway	Molloy Street roundabout revised lane allocation	Molloy Street roundabout converted to traffic signal	Molloy Street consolidation with Hospital Road	Right turn ban to Station Street and provide right turning phase from Princes Highway to Park Road	Traffic signals at Station Street	Right turn bay for right turning traffic from Princes Highway to Point Street
Stage 1 assessment – preferred Princes Highway/Molloy Street layout							
Scenario 1	✓	✓					
Scenario 2	✓		✓				
Scenario 3	✓			✓			
Stage 2 assessment – preferred right-turn management at Station Street and Park Road							
Scenario 4	✓	✓			✓		
Scenario 5	✓	✓				✓	
Stage 3 assessment – other traffic management schemes							
Scenario 6	✓	✓			✓		✓

10.5 Key assessment outcomes and preferred scenario

The preferred treatment scenario is **Scenario 6**, based on the following key assessment outcomes of three stages.

General corridor requirements

Overall, the Princes Highway corridor required the following improvements to provide medium to long term improvement of the corridor:

- Peak period clearways on the Princes Highway, between Park Road and Station Street
- Two on-ramp lanes to Memorial Drive.

The above options are critical to mitigating the key pinch points on the corridor and allowing for the safe and efficient movement of vehicles on the corridor into the future. These treatments are provided in all the assessed scenarios.

Stage 1 assessment (Scenario 1–3) – Princes Highway/Molloy Street roundabout

The reconfiguration of the roundabout at Princes Highway/Molloy Street to provide two through lanes to Memorial Drive would provide significant improvement to southbound traffic on the Princes Highway corridor. The resultant southbound queue in 2036 is expected to extend back to around Station Street, and therefore the intersection would show similar levels of queuing to the existing (2016) situation. The signalisation of this intersection (with and without consolidation with the Memorial Drive roundabout) would result in slightly shorter queues compared to the roundabout, such that the queues would typically extend to between Organs Road and Station Street. Under all scenarios, the southbound travel time in 2036 would be around 40–50% lower during the weekday peak periods compared to the 'do-minimum' assessment.

Despite the greater capacity offered by the signalisation of the intersection, the overall balance of infrastructure cost and network benefit indicated that the preferred improvement option at this intersection was to **reallocate lanes at the roundabout to provide two through lanes to Memorial Drive**. It is noted that this is complemented by the provision of two on-ramp lanes to Memorial Drive. As a result, Scenario 1 was carried forward to Stage 2 assessment.

Stage 2 assessment (Scenario 4 and 5) – Princes Highway/Park Road and Princes Highway/ Station Street intersections

As a result of the improvement in corridor safety and efficiency, the preferred improvement option for managing the right-turn movements at Princes Highway/Park Road and Princes Highway/Station Street is to **provide a 'No Right Turn' from Princes Highway (south) to Station Street** and to complement this with a **right-turn phase from Princes Highway (south) to Park Road.**

The signalisation of the intersection of Princes Highway and Station Street was also considered. However it was determined that this had the potential to cause the 'bunching up' of southbound traffic and therefore reduce the number of gaps available for right-turning vehicles to filter. This reduction in available gaps resulted in a lengthening of the northbound right-turn queue into Station Street, which occasionally extended past Organs Road. This was not considered to be a desirable outcome for the Princes Highway corridor in terms of safety or operational efficiency. As a result, Scenario 4 was carried forward to Stage 3 assessment.

Stage 3 assessment (Scenario 6) – Princes Highway/Point Street intersection

The provision of a right-turn bay at the intersection of Princes Highway/Point Street was assessed. It is considered that the provision of this northbound right-turn bay would provide an appreciable improvement to corridor safety and efficiency. In particular, the right-turn bay reduces the impact of the right-turn queue at this intersection interacting with the northbound through traffic on the Princes Highway corridor. As a result, it is recommended to **provide a right-turn bay at Princes Highway/Point Street (Scenario 6)**. The Aimsun modelling indicated that a 75 metre right-turn bay may be sufficient to accommodate the right-turn demand.

The amendments to the corridor of Scenario 6 are summarised below and presented in Figure 10.1:

- Peak period clearways on the Princes Highway, between Park Road and Station Street
- Two on-ramp lanes to Memorial Drive.
- Two through lanes at Princes Highway/Molloy Street roundabout to Memorial Drive.
- A 'No Right Turn' from Princes Highway (south) to Station Street and to complement this with a right-turn phase from Princes Highway (south) to Park Road.
- A northbound right-turn bay at Princes Highway/Point Street.

The microsimulation modelling results demonstrate that Scenario 6 would provide significant improvements in travel time, network delay and corridor safety/efficiency, compared to the 'do-minimum' scenario in both future years 2026 and 2036. The improvements in 2036 are summarised below:

- VHT in network statistics are 21%, 26% and 5% lower in respective AM, PM and Saturday peak periods.
- Number of vehicle stops in network statistics are 24%, 29% and 10% lower in respective AM, PM and Saturday peak periods.
- Northbound travel time is improved by 20% (approximately 35 seconds), 19% (35 seconds) and 6% (10 seconds) in respective AM, PM and Saturday peak hours.
- Southbound travel time is improved by 49% (approximately 3 minutes and 30 seconds), 19% (3 minutes and 40 seconds) and 10% (20 seconds) in respective AM, PM and Saturday peak hours.
- Under this corridor arrangement, the intersections on the Princes Highway corridor operate at an acceptable LoS (of LoS D or better).

In addition, the network performance results of Scenario 6 show marginal difference to those of Scenario 1 and Scenario 4 (preferred scenario of Stage 1 and 2), whilst Scenario 6 improves the safety and operational efficiency of northbound right turn movements at Princes Highway/Park Road, Princes Highway/ Station Street, and Princes Highway/Point Street intersections.

Although Scenario 6 has the highest costs based on preliminary estimation, the rapid economic assessment results indicate that it is economically viable with the Benefit-Cost Ratio (BCR) of 11.9 and a positive Net Present Value (NPV) of approximately $42.3M.

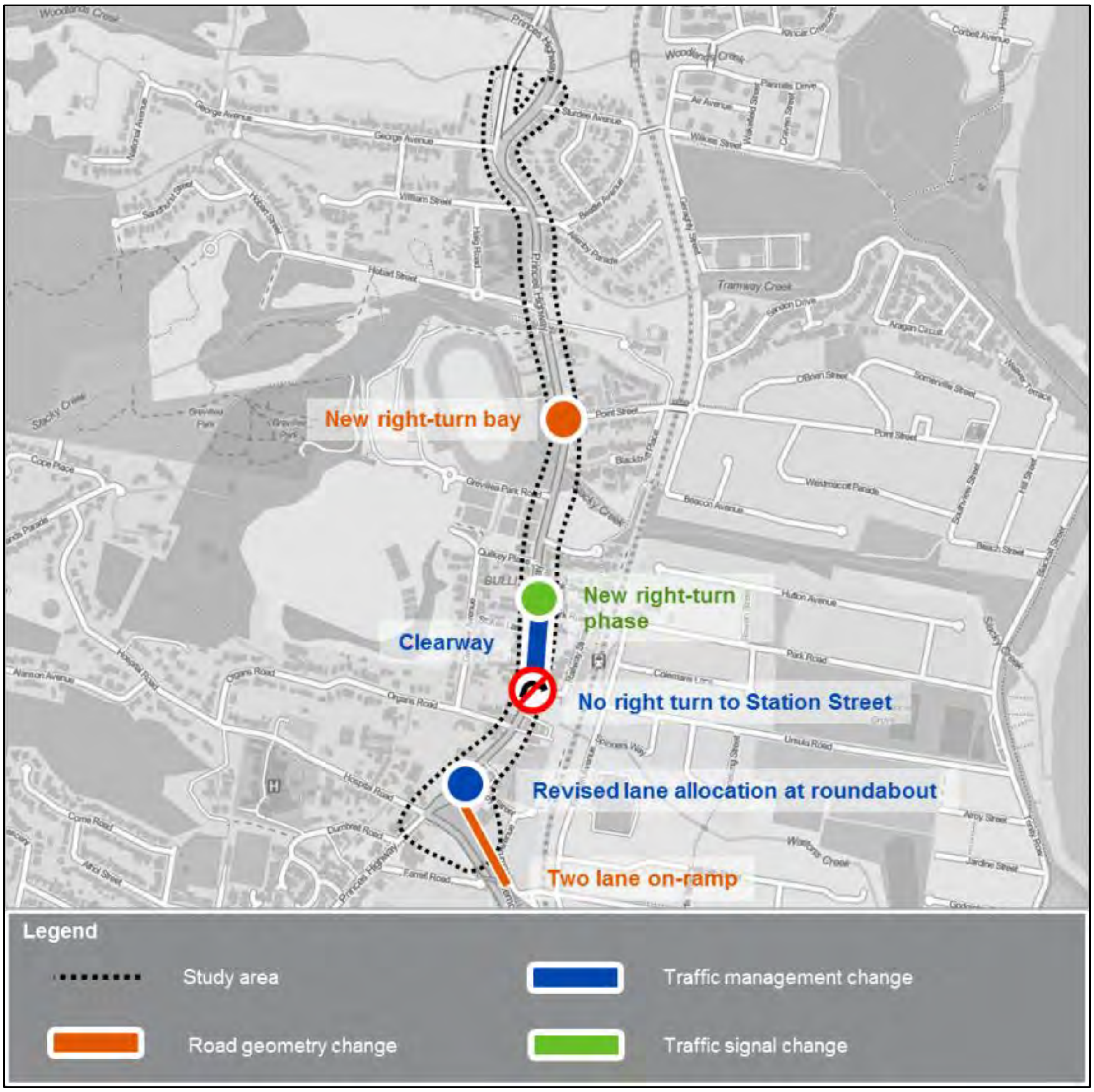


Figure 10.1 Preferred scenario corridor amendments (Scenario 6)

Prioritisation of works

An indicative prioritisation of the improvement options is summarised below. Overall, this prioritisation of works is based upon the relative impact of the different pinch points upon the efficiency and safety of the Princes Highway corridor in Bulli over the medium to long term.

1. Critical corridor elements (with pre-2026 implementation):
   a) Peak period clearways on the Princes Highway, between Park Road and Station Street
   b) Provision of two on-ramp lanes to Memorial Drive AND reallocation of lanes at the Princes Highway/Molloy Street roundabout to provide two through lanes to Memorial Drive

2. Right-turn management:

  a) 'No Right Turn' from Princes Highway (south) into Station Street AND implement protected right-turn signal phase at Princes Highway/Park Road

  b) Provision of a channelized right-turn bay at Princes Highway/Point Street.

Based upon the 'do-minimum' assessment, the critical corridor elements listed as Priority 1 should be undertaken prior to 2026. Without the Priority 1 works, the southbound queue on the Princes Highway is expected to extend to Point Street by 2026 and past Hobart Street by 2036.

The right-turn management measures are considered to be cost effective from a traffic performance perspective. This is because they can be implemented at any time and would provide an immediate improvement to the operation of the Princes Highway corridor.

Appendix A

FUTURE TRAFFIC GROWTH ASSUMPTIONS MEMORANDUM

MEMO

TO: s74 Scope

FROM:

SUBJECT: **Bulli & Thirroul future traffic growth assumptions**

OUR REF: 2196958A-ITP-MEM-002-RevA.docx

DATE: **4 May 2016**

1. INTRODUCTION

WSP | Parsons Brinckerhoff was commissioned by New South Wales Roads and Maritime Services (Roads and Maritime) to undertake traffic modelling of the following corridors:

- Princes Highway, Bulli
- Lawrence Hargrave Drive, Thirroul.

This modelling project was commissioned to assess the existing and future operational performance and identify future improvement options for the above two corridors in the future years 2026 and 2036.

This technical memorandum has been prepared to document the following assumptions:

- Future year background traffic growth
- Future year development traffic.

As part of preparing this memorandum, the following data sources and references have been reviewed:

- Population and employment forecasts sourced from the NSW Bureau of Statistics and Analytics (BSA) website
- Forecast traffic growth from the Roads and Maritime TRACKS model for 2011, 2021 and 2036
- Historical AADT traffic growth at Roads and Maritime traffic count stations
- Bulli Pass Strategic Review (Roads and Maritime, October 2015).

2. BACKBROUND TRAFFIC GROWTH ANALYSIS

2.1 Population and employment

The population and employment forecasts from the NSW Bureau of Transport Statistics for the following suburbs have been analysed for the period 2011–2036:

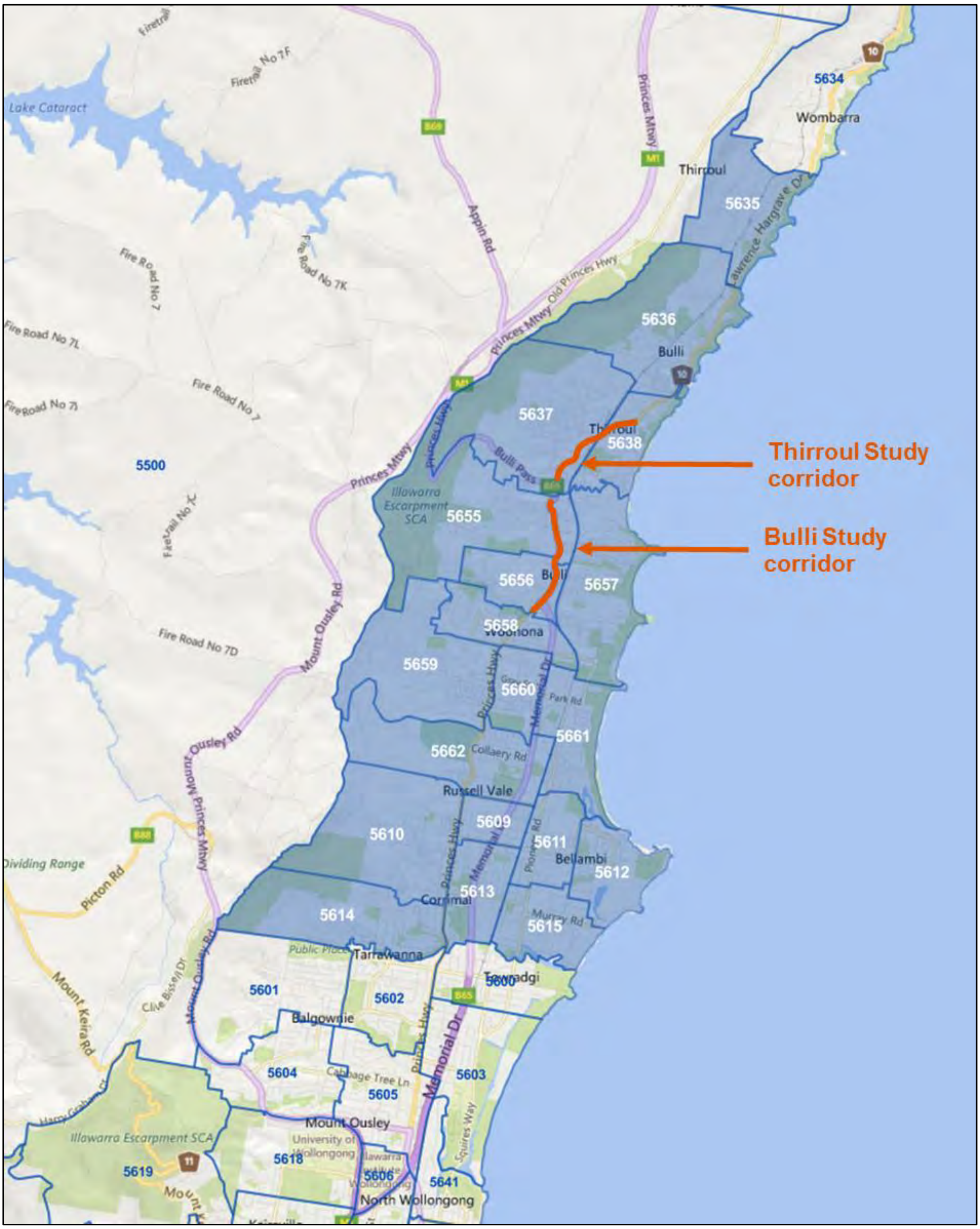
- **Austinmer**
- **Thirroul**
- **Bulli**
- **Russell Vale**
- **Bellambi**
- **Corrimal**
- **Towradgi.**

These suburbs comprise a total of 16 travel zones (based on 2011 Travel Zone Geography) which are shown in Figure 2.1. These specific suburbs have been chosen based upon the expected catchment for the Lawrence Hargrave Drive, Princes Highway and Memorial Drive corridors which are most likely to impact traffic demand within and travelling through the Bulli and Thirroul area. The wide network connectivity to the Princes Motorway means that the area selected covers between the southern-most suburb, Towradgi and the northern-most suburb, Austinmer.

The population and employment forecasts are summarised in Table 2.1, with the selected travel zones shown in Figure 2.1. The population, employment and workforce forecasts show a steady rate of growth over the five year intervals between 2011 and 2036. Overall, the data indicates that the short and long term growth rates in population and employment within the study corridor are approximately 0.5% p.a. It is noted that the growth rate for the local workforce is expected to be slower, at approximately 0.2% p.a. which indicates that the population is gaining an increasing percentage of retirees.

Table 2.1 Population & employment forecast growth (per annum)

FROM	2011	2016	2021	2026	2031	2011	2021
TO	**2016**	**2021**	**2026**	**2031**	**2036**	**2021**	**2036**
Population	0.3%	0.7%	0.4%	0.4%	0.3%	0.5%	0.4%
Employment	0.4%	0.6%	0.5%	0.6%	0.6%	0.5%	0.6%
Workforce	0.0%	0.6%	0.2%	0.1%	0.2%	0.4%	0.1%



Source: NSW Bureau of Statistics and Analytics (BSA) & Bing Maps

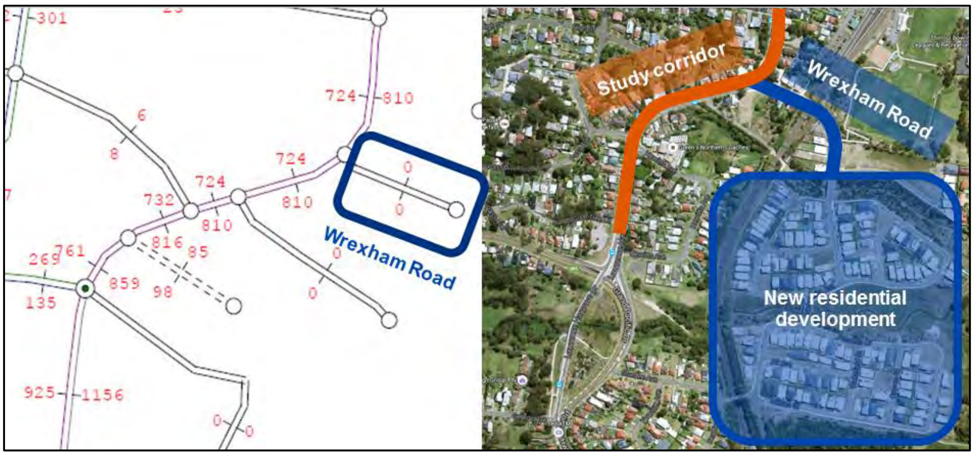
Figure 2.1 2011 Travel zones selected

2.2 TRACKS model forecasts

2.2.1 Overview

The Roads and Maritime WOLSH06 TRACKS model is a strategic model of the traffic flows within the wider Wollongong and Illawarra region. As part of this project, Roads and Maritime provided the relevant link flow diagrams for the Princes Highway corridor in Bulli and the surrounding areas. An example of the link flow diagram is presented in Figure 2.2. It is noted that the link flow diagrams do not distinguish between light vehicles and heavy vehicles. The TRACKS model outputs were provided for 2011, 2021 and 2036 for one hour AM and PM peak periods. As part of the analysis, future year modelling horizons 2026 and 2036 were agreed with Roads and Maritime.

It is noted that TRACKS link flow plots indicate that within the Thirroul study area, there is no zone connector defined for Wrexham Road in any modelling scenarios. However the aerial images from Google Earth indicate that there has been recent residential development work in this area, as indicated on Figure 2.2.



Source: TRACKS WM36NL link plot & Google Maps

Figure 2.2 TRACKS model link flows (2036 AM), Wrexham Road development

Similar issues exist in the Bulli study area. TRACKS does not include the proposed residential development site west of Grevillea Park Road, as shown in the Figure 2.3.

Figure 2.3 TRACKS model link flows (2036 AM), Grevillea Park Road development

2.2.2 Link flow traffic growth

Princes Highway and Memorial Drive – Bulli

It was noted that the 2011 TRACKS link flows were significantly higher than 2016 traffic counts on Princes Highway and Memorial Drive, as shown in Table 2.5.

Table 2.2 TRACKS 2011 link flows vs 2016 traffic counts – Bulli

SECTION	AM PEAK		PM PEAK	
	TRACKS 2011	Traffic counts 2016	TRACKS 2011	Traffic counts 2016
Princes Highway, North of Memorial Drive	3,200	2,100	3,300	2,500
Princes Highway, North of Park Road	3,200	2,200	3,300	2,600
Princes Highway, North of Hobart Street	2,900	2,300	3,000	2,600
Princes Highway, South of Hospital Road	1,100	700	1,200	1,000
Memorial Drive, East of Princes Highway	2,200	1,600	2,300	1,900

It is noted that over the longer term (2021–2036), the TRACKS model growth rates on both corridors are comparable to the BSA population and employment growth forecasts of 0.5% p.a.

Table 2.3 TRACKS model link flow growth (per annum) – Bulli

SECTION	2011–2021			2021–2036		
	NB	SB	TOTAL	NB	SB	TOTAL
Princes Highway – AM	0.6%	1.2%	0.9%	0.8%	0.5%	0.7%
Princes Highway – PM	1.0%	0.7%	0.8%	0.5%	0.5%	0.5%
Memorial Drive – AM	0.7%	1.4%	1.1%	0.6%	0.3%	0.5%
Memorial Drive – PM	1.1%	0.6%	0.8%	0.4%	0.4%	0.4%

Lawrence Hargrave Drive – Thirroul

Not surprisingly, 2016 traffic counts on Lawrence Hargrave Drive are higher than those from the 2011 TRACKS model, as shown in Table 2.4.

Table 2.4 TRACKS 2011 link flows vs 2016 traffic counts – Thirroul

SECTION	AM PEAK		PM PEAK	
	TRACKS 2011	Traffic counts 2016	TRACKS 2011	Traffic counts 2016
Lawrence Hargrave Drive, north of Raymond Road	1,300	1,300	1,400	1,500
Lawrence Hargrave Drive, south of Railway Parade	1,400	1,500	1,500	1,700
Lawrence Hargrave Drive, south of Wrexham Road	1,500	1,900	1,500	2,000

Based upon the TRACKS link flow plots, the model suggests that the traffic growth rate will be comparable in both directions with a slight decline in growth rate over the longer term, as shown in Table 2.5. It is noted that over both short and long term, the TRACKS model growth rate on Lawrence Hargrave Drive is similar to the BSA population and employment forecast growth 0.5% p.a.

Table 2.5 TRACKS model link flow growth (per annum)

SECTION	2011–2021			2021–2036		
	NB	SB	TOTAL	NB	SB	TOTAL
Lawrence Hargrave Drive – AM	0.5%	0.4%	0.4%	0.3%	0.2%	0.3%
Lawrence Hargrave Drive – PM	0.6%	0.3%	0.5%	0.5%	0.3%	0.4%

2.3 Historical traffic growth

2.3.1 Overview

The AADT midblock traffic counts at the locations in Table 2.6 have been reviewed as part of estimating the historical traffic growth within the study area.

Table 2.6 Permanent count station locations

STATION ID	ROAD	COUNT TYPE	YEARS COVERED
07747	Bulli Pass	Vehicles	2012–2015 (ADT)
07766	Princes Highway, north of Bellambi Lane, Russell Vale (south of project area)	Vehicles	1990, 1992–2009 2010–2015 (ADT)
07801	Memorial Drive, south of Towradgi Road, Towradgi	Vehicles	1990, 1992–2006 2007–2011, 2015 (ADT)
07749	Princes Highway, north of Hobart Street, Bulli	Vehicles	1990, 1992, 1994, 1997, 1998, 2000, 2003, 2005

It is noted that the Memorial Drive (formerly the Northern Distributor) connection to Bulli was opened in 2009. In addition, the analysis of the historical AADT volumes indicated individual years where there were significant fluctuations in traffic volumes. This would most likely be related to the opening of new links or road upgrades and the redistribution of traffic between the Princes Highway and Memorial Drive connection at Bulli roundabout.

The only available historical traffic counts are at Lawrence Hargrave Drive, Clifton, which is significantly north of the Thirroul study area. As a consequence the counts at this location were not used.

2.3.2 Growth analysis

This historical traffic growth analysis summarised in Table 2.7 indicates that prior to 2005, the traffic growth on the Princes Highway and Memorial Drive ranged between 0.5–1.7% p.a.

Over the recent 10-year period, there was a significant amount of traffic growth on the Princes Highway (1.8% p.a.) and Memorial Drive (1.4% p.a.). The traffic growth on the Bulli Pass was calculated as being between 0.8% and 1.4% p.a. A historical growth of 1.4% p.a. on Bulli Pass was used in the *Bulli Pass Strategic Review* (Roads and Maritime, October 2015).

Table 2.7 AADT/ADT annual growth at Roads and Maritime count stations

STATION ID	ROAD	10-YEAR GROWTH UP TO 2005	RECENT 10-YEAR GROWTH
Bulli study area or surrounding			
07749	Princes Highway, north of Hobart Street	1.4%	-
07766	Princes Highway, north of Bellambi Lane, Russell Vale (1)	0.5%	1.8%
07801	Memorial Drive, south of Towradgi Road, Towradgi (1)	1.7%	1.4%
07.747	Bulli Pass	3.3%	0.8%–1.4%(2)
No count station is located within Thirroul study area			

(1) south of Bulli study area
(2) 1.4% was used in the *Bulli Pass Strategic Review*

The peak period traffic growth rates for 2010–2015 were also calculated and are shown in Table 2.8. The historical peak hour traffic growth trend, following the completion of the Memorial Drive extension to Bulli, indicates that whilst the growth for Princes Highway is negligible, the traffic growth on Memorial Drive and Bulli Pass are higher, at around 2–3% p.a. The traffic growth on the Saturday peak period is mostly consistent with the weekday trends for the Princes Highway, Memorial Drive and Bulli Pass.

It was recommended that the available recent 10-year traffic growth rate be adopted to forecast the future traffic demands for the modelling exercise, whilst the peak hour growth rate (with limited data range) be used as a sensitivity test if required.

Table 2.8 Recent peak hour traffic growth – Weekday/weekend (per anum)

STATION ID	ROAD	AFTER 2010		
		Weekday AM peak	Weekday PM peak	Saturday peak
Bulli study area				
07747	Bulli Pass (1)	3.2%	2.8%	2.4%
07766	Princes Highway, north of Bellambi Lane, Russell Vale (2)	-0.4%	0.1%	-0.4%
07801	Memorial Drive, south of Towradgi Road, Towradgi (3)	2.1%	2.1%	2.7%
No count station is located within Thirroul study area				

(1) Traffic growth for these sites are 2012–2015 due to no data being available for 2010 and 2011
(2) Traffic growth for these sites are 2010–2014 as the 2015 dataset is limited to five days
(3) 2015 data is incomplete with only southbound traffic, use ADT growth instead

2.4 Conclusion and recommendation of background traffic growth

The comparison of the forecast and historical traffic growth results from the various sources is summarised in Table 2.9.

Table 2.9 Comparison of traffic forecast and historical trends

AVERAGE ANNUAL GROWTH RATE		WEEKDAY AM PEAK	WEEKDAY PM PEAK	SATURDAY PEAK
BSA Population and Employment forecasts	Bulli and Thirroul catchment area	Short term: 0.5% Long term: 0.5%		
TRACK models **Short term: 2011–2021** **Long term: 2021–2036**	Princes Highway	Long term: 0.7%	Long term: 0.5%	n/a
	Memorial Drive	Long term: 0.5%	Long term: 0.4%	
	Lawrence Hargrave Drive	Short term: 0.4% Long term: 0.3%	Short term: 0.5% Long term: 0.4%	
Historical traffic growth (10-year growth)	Bulli Pass	1.4%	1.4%	1.4%
	Princes Highway north of Hobart Street	1.4%	1.4%	1.4%
	Memorial Drive, Towradgi	1.4%	1.4%	1.4%

Based upon an assessment of the available information the recommendations for the future year traffic growth rates are summarised in Table 2.10. Overall, it is proposed that:

- The TRACKS model results, historical growth rate and the BSA population and employment forecast, which is greater, will be applied for short term growth (up to 2021)
- The TRACKS model results and the BSA population and employment forecast, which is greater, will be applied for long term growth
- For any locations where the annual growth was indicated as being negative, the BSA population and employment growth is used as a conservative assessment for the future year scenario.

Table 2.10 Recommended future background traffic growth rates (per annum)

ANNUAL GROWTH RATES	WEEKDAY AM PEAK		WEEKDAY PM PEAK		SATURDAY PEAK	
	Short term (before 2021)	Long term (after 2021)	Short term (before 2021)	Long term (after 2021)	Short term (before 2021)	Long term (after 2021)
Bulli Pass	1.4%	0.5%	1.4%	0.5%	1.4%	0.5%
Princes Highway	1.4%	0.7%	1.4%	0.5%	1.4%	0.5%
Memorial Drive	1.4%	0.5%	1.4%	0.5%	1.4%	0.5%
Lawrence Hargrave Drive	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Other side streets	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%

BSA – highlighted in 'yellow'; TRACKS results – highlighted in 'blue'; Historical AADT/ADT – highlighted in 'green

3. DEVELOPMENT TRAFFIC

The traffic impact assessments for the approved and committed developments within the Bulli and Thirroul study areas have been provided by Roads and Maritime. As part of this, the following reports have been provided:

- Thirroul study area:
  - Sandon Point residential subdivision (2007, 2008 and 2009)
- Bulli study area:
  - Sturdee Avenue seniors housing and residential care facility (2006)
  - Bulli Brickworks residential development (2012).

As discussed in section 2.2, the proposed developments at Bulli Brickworks (accessing via Grevillea Park Road) and Sandon Point (accessing via Wrexham Road) have not been included in the TRACKS models. In addition, these developments are of sufficient scale that the application of background traffic growth rates on the existing flows for these roads would not be sufficient to reflect the expected traffic demand generated by these developments.

As a result of the split between the model coverage areas, the additional trips applied to one study area (e.g. Thirroul) is proposed to be applied to the second study area (e.g. Bulli) as additional through trips. These trips will be distributed according to the origin-destination survey commissioned as part of these studies.

For the purposes of modelling the Saturday peak period, it is proposed to utilise the same trip generation and distribution as the weekday peak period. Where trip generation rates differ between the AM and PM peak periods, an average of the two will be utilised. This is in the absence of guidance in the *Guide to Traffic Generating Developments v2.2 (2002)* and *TDT 2013/04a* regarding weekend trip generation for low density residential areas and wellness/recreation centres.

Overall, it is considered that the application of the weekday peak period trip generation rates during the Saturday peak will be sufficient to provide a fit for purpose model of the future year scenarios and the impact of the proposed developments.

3.1 Sandon Point residential subdivision

The proposed Sandon Point residential subdivision consists of the following development yield:

- 167 low-density dwellings
- 14 medium density townhouses
- 80 medium density apartment units
- 232 seniors living retirement dwellings
- 102 assisted care dwellings.

Based upon this development yield, the following peak period trip generation would result:

- AM peak: 270 vehicle trips/hour
- PM peak: 332 vehicle trips/hour.

The majority of the trips generated by the development are expected to access and egress the site via Wrexham Road according to the distribution in Table 3.1. However, the abovementioned reports also identify a connection to Point Street, and that trips to/from Wollongong would utilise this link. As a result, the number of trips entering/exiting via Wrexham Road would reduce to:

- AM peak: 211 vehicle trips/hour
- PM peak: 279 vehicle trips/hour.

The difference in trips to the estimated site trip generation is assumed to travel via Point Street. As no entry/exit splits have been defined in the traffic assessment for the Point Street movements, the following splits are proposed:

- AM peak: 20% entry/80% exit
- PM peak: 80% entry/20% exit.

These splits are consistent with those applied for the Wrexham Road trip distribution and are generally consistent with the industry standard applied to residential developments as part of traffic impact assessments.

The reporting does not identify a more detailed trip distribution other than vehicles travelling north or south on Lawrence Hargrave Drive. The forecast traffic volumes of some movements are lower than the corresponding existing traffic volumes.

As a result, it is proposed to distribute these additional trips to match the forecast traffic volumes, whilst maintaining the existing traffic level in other directions. The modelled traffic volumes related to this development are summarised in Table 3.2.

Table 3.1 Forecast trip distribution in RMS report – Sandon Point

ORIGIN-DESTINATION (TRIPS)	AM – IN	AM – OUT	PM – IN	PM – OUT
Lawrence Hargrave Drive (north)	95	80	98	140
Lawrence Hargrave Drive (south)	11	25	26	15
Point Street (Bulli)	14	55	42	11

Source: Traffic access to Sandon Point – Intersection of Lawrence Hargrave Drive & Wrexham Road, Thirroul, Christopher Hallam & Associates (2009)

Table 3.2 Modelled trip distribution – Sandon Point

ORIGIN-DESTINATION (TRIPS)	AM – IN	AM – OUT	PM – IN	PM – OUT	SAT-IN	SAT-OUT
Lawrence Hargrave Drive (north)	95	80	98	140	97	110
Lawrence Hargrave Drive (south)	17	63	72	28	45	46
Point Street (Bulli)	14	55	42	11	28	33

Source: Traffic access to Sandon Point – Intersection of Lawrence Hargrave Drive & Wrexham Road, Thirroul, Christopher Hallam & Associates (2009) & Austraffic 2016 traffic survey

3.2 Bulli Brickworks

The proposed Bulli Brickworks consists of the following development yield:

- 250 low-density dwellings
- 4,000 m^2 GFA wellness and recreation centre.

This proposed development would generate approximately 230 vehicle trips/hour during the AM and PM peak periods. The trip distribution utilised as part of the traffic assessment is summarised in Table 3.3.

Table 3.3 Modelled trip distribution – Bulli Brickworks development

ORIGIN-DESTINATION (TRIPS)	AM – IN	AM – OUT	PM – IN	PM – OUT	SAT-IN	SAT-OUT
Princes Highway (north)	30	70	70	30	50	50
Princes Highway (south)	30	70	70	30	50	50
Point Street	5	10	10	5	8	8
Park Road	5	10	10	5	8	8

Source: Transport report for proposed residential/mixed use development, Bulli, Colston Budd Hunt & Kafes (2012)

This trip distribution indicates that the majority of trips are expected to travel on the Princes Highway to/from the site, via Grevillea Park Road. However, the trip distribution only covers the section of the Princes Highway between Point Street and Park Road. As a result, it does not identify whether drivers will be travelling to the specific destinations. Thus, the 2016 OD survey results were used as the key indicator for the following destination split:

- Lawrence Hargrave Drive or Bulli Pass (to the north)
- Princes Highway or Memorial Drive (to the south).

Other than the reported distribution to Point Street and Park Road, it is proposed to apply the existing trip distributions to the aforementioned roads (i.e. based upon the origin-destination surveys commissioned as part of this study).

3.3 Sturdee Avenue residential care facility

It is noted that the traffic study undertaken for the Sturdee Avenue residential care facility identified that the additional trip generation of the site (compared to the existing land use) is approximately 15 additional trips during the peak periods. As a result, the impact of this development is expected to be incorporated within the background traffic growth assumptions and as such no additional traffic is proposed to be assigned to the Sturdee Avenue or Beattie Avenue travel zones.

4. CONCLUSION AND RECOMMENDATION

Table 4.1 summarises the total future background traffic growth for the future modelling year 2026 and 2036, based on the annual growth rate recommended in Table 2.10. The traffic growth will be applied to both directions of each corridor by each origin zone on the basis that both TRACKS results show similar traffic growth in both directions, particularly over the long term.

Table 4.1 Proposed cumulative future traffic growth (by modelling years)

2016 CUMULATIVE TRAFFIC GROWTH DEMANDS	WEEKDAY AM PEAK		WEEKDAY PM PEAK		SATURDAY PEAK	
	2026	2036	2026	2036	2026	2036
Bulli Pass	10%	16%	10%	16%	10%	16%
Princes Highway	11%	19%	10%	16%	10%	16%
Memorial Drive	10%	16%	10%	16%	10%	16%
Lawrence Hargrave Drive	5%	10%	5%	10%	5%	10%
Other side streets	5%	10%	5%	10%	5%	10%

In relation to the proposed traffic generating developments within the Thirroul and Bulli study areas, it is proposed that the approved trip generation rates and distributions be applied for the Sandon Point residential subdivision and Bulli Brickworks developments.

These developments, combined, are estimated to generate approximately 400 vehicle trips during the weekday AM and PM peak periods. For the purposes of modelling, this trip generation rate will also be applied during the Saturday peak period due to limited guidance from the *Guide to Traffic Generating Developments v2.2 (2002)* and *TDT 2013/04a* for the relevant land uses.

The predicted future traffic volumes at the midblock locations along Princes Highway and Memorial Drive were summarised in Table 4.2 and Table 4.3. The future traffic volumes considered both background traffic growth and the development traffic from Sandon Point and Bulli Brickworks.

Table 4.2 Predicted future year midblock volumes – Bulli 2026

Section – Future year 2026		AM peak hour			PM peak hour			SAT peak hour		
		NB	SB	Total	NB	SB	Total	NB	SB	Total
Princes Highway	North of Memorial Drive	1,240	1,740	2,980	1,520	1,670	3,180	1,370	1,550	2,920
Princes Highway	North of Park Road	1,340	1,750	3,080	1,580	1,750	3,330	1,490	1,480	2,970
Princes Highway	North of Hobart Street	1,420	1,600	3,020	1,420	1,810	3,240	1,460	1,460	2,920
Princes Highway	South of Hospital Road	600	610	1,210	540	760	1,300	630	600	1,220
Memorial Drive	East of Princes Highway	910	1,360	2,280	1,260	1,040	2,300	980	1,040	2,020

Table 4.3 Predicted future year midblock volumes – Bulli 2036

Section – Future year 2036		AM peak hour			PM peak hour			SAT peak hour		
		NB	SB	Total	NB	SB	Total	NB	SB	Total
Princes Highway	North of Memorial Drive	1,310	1,840	3,150	1,590	1,750	3,340	1,440	1,620	3,060
Princes Highway	North of Park Road	1,410	1,840	3,250	1,650	1,840	3,490	1,560	1,550	3,110
Princes Highway	North of Hobart Street	1,500	1,680	3,180	1,500	1,900	3,400	1,530	1,530	3,060
Princes Highway	South of Hospital Road	650	650	1,290	570	800	1,370	660	620	1,280
Memorial Drive	East of Princes Highway	960	1,430	2,390	1,320	1,090	2,410	1,020	1,090	2,120

The predicted future traffic volumes at the midblock locations along Lawrence Hargrave Drive were summarised in Table 4.4 and Table 4.5. The future traffic volumes considered both background traffic growth and the development traffic from Sandon Point and Bulli Brickworks.

Table 4.4 Predicted future year midblock volumes – Thirroul 2026

Section – future year 2026		AM peak hour			PM peak hour			SAT peak hour		
		NB	SB	Total	NB	SB	Total	NB	SB	Total
Lawrence Hargrave Drive	South of Princes Street	840	1,300	2,140	1,390	920	2,310	1,220	1,140	2,360
Lawrence Hargrave Drive	South of Phillip Street	960	1,260	2,220	1,360	1,020	2,380	1,250	1,180	2,430
Lawrence Hargrave Drive	South of Raymond Road	710	980	1,690	1,100	800	1,900	1,130	1,000	2,130
Lawrence Hargrave Drive	South of Mary Street	510	850	1,360	860	630	1,490	890	890	1,780

Table 4.5 Predicted future year midblock volumes – Thirroul 2036

Section – future year 2036		AM peak hour			PM peak hour			SAT peak hour		
		NB	SB	Total	NB	SB	Total	NB	SB	Total
Lawrence Hargrave Drive	South of Princes Street	880	1,360	2,240	1,460	960	2,420	1,280	1,200	2,480
Lawrence Hargrave Drive	South of Phillip Street	1,000	1,320	2,320	1,420	1,070	2,490	1,310	1,230	2,540
Lawrence Hargrave Drive	South of Raymond Road	740	1,030	1,770	1,140	840	1,980	1,180	1,040	2,220
Lawrence Hargrave Drive	South of Mary Street	530	890	1,420	890	660	1,550	930	930	1,860

Following review and agreement with Roads and Maritime, WSP | Parsons Brinckerhoff will input the proposed future year traffic growth rates in the future year traffic modelling.

s74 Scope [redacted]

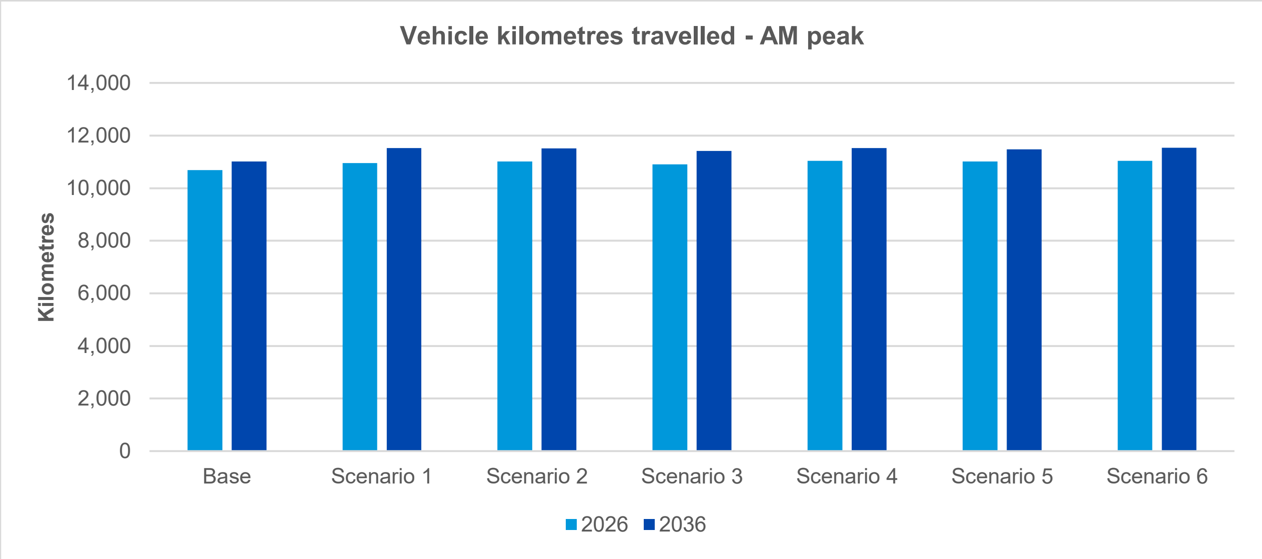
Transport Modeller Principal Transport Engineer

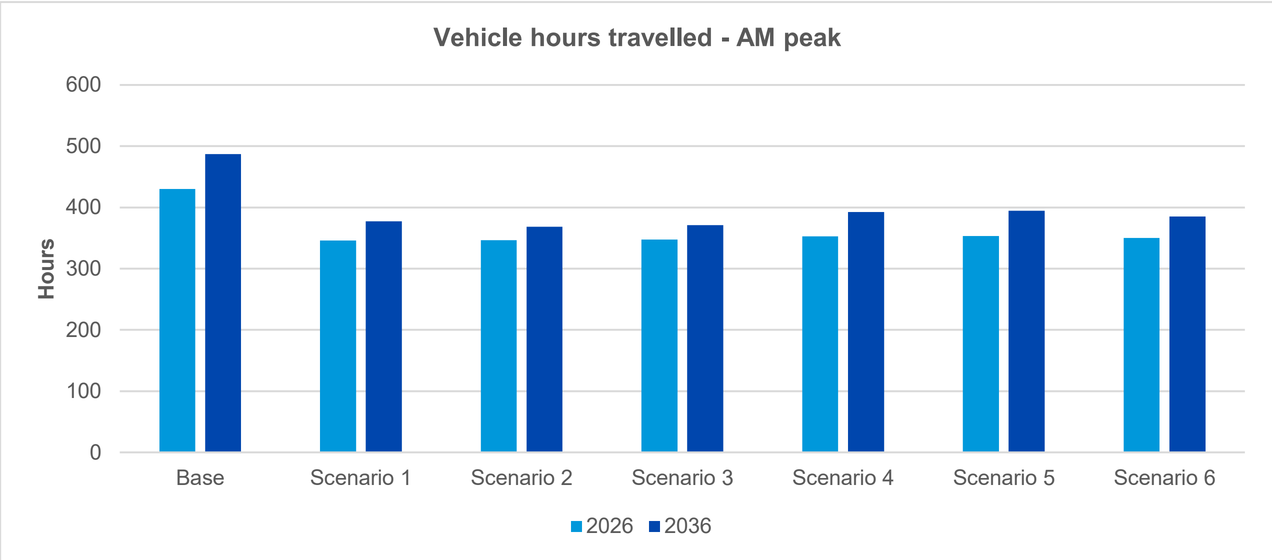
Appendix B

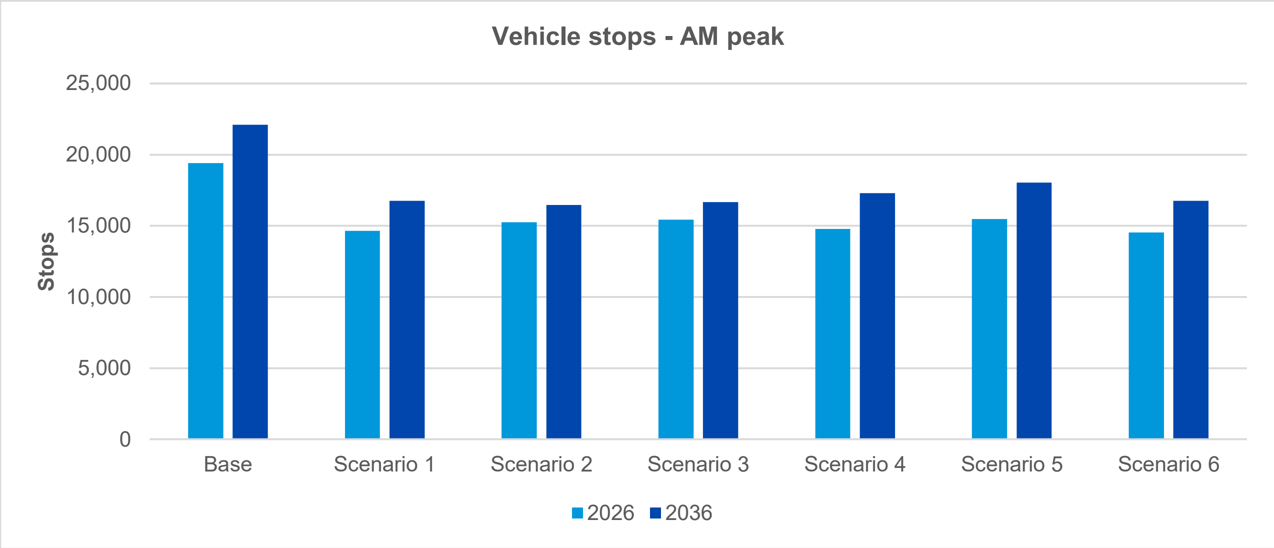
DETAILED COMPARISON OF MODEL RESULTS

Network statistics

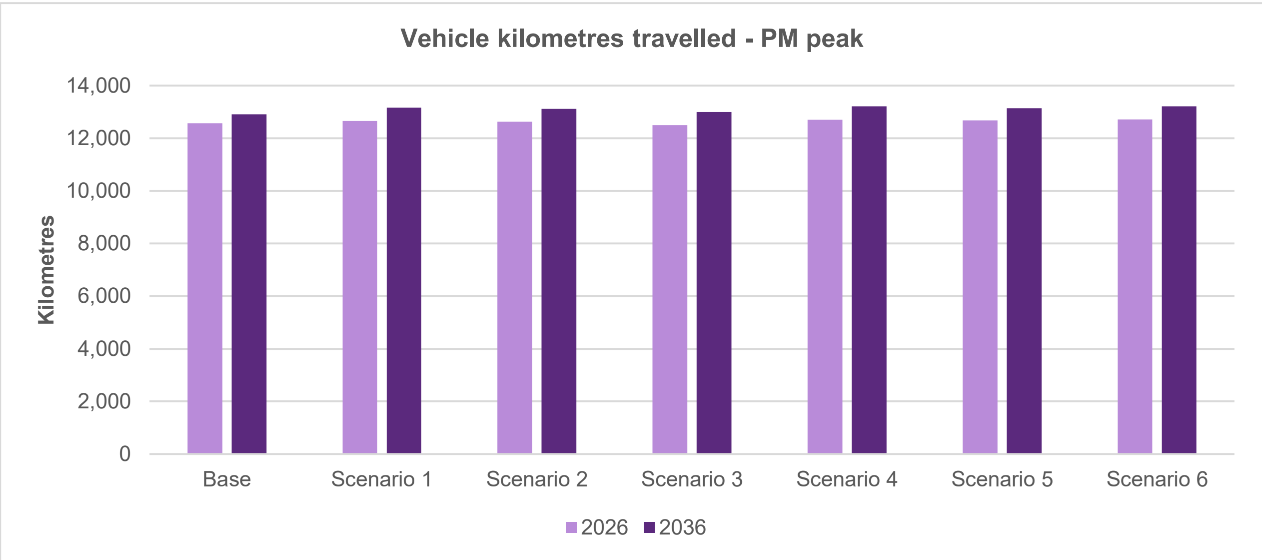
Weekday AM peak

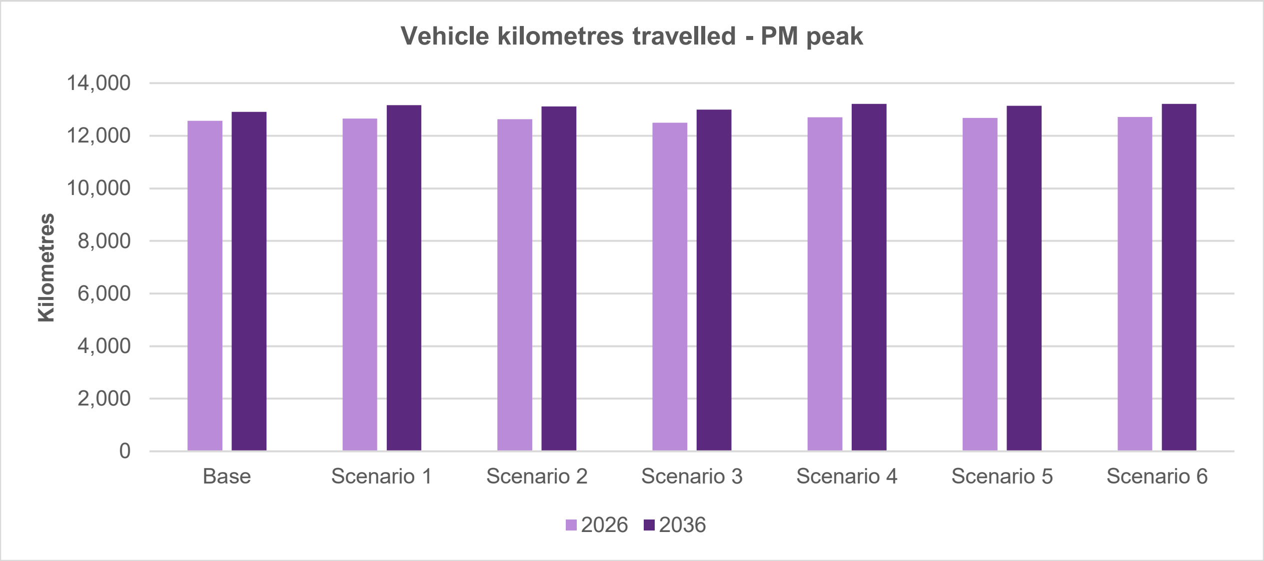


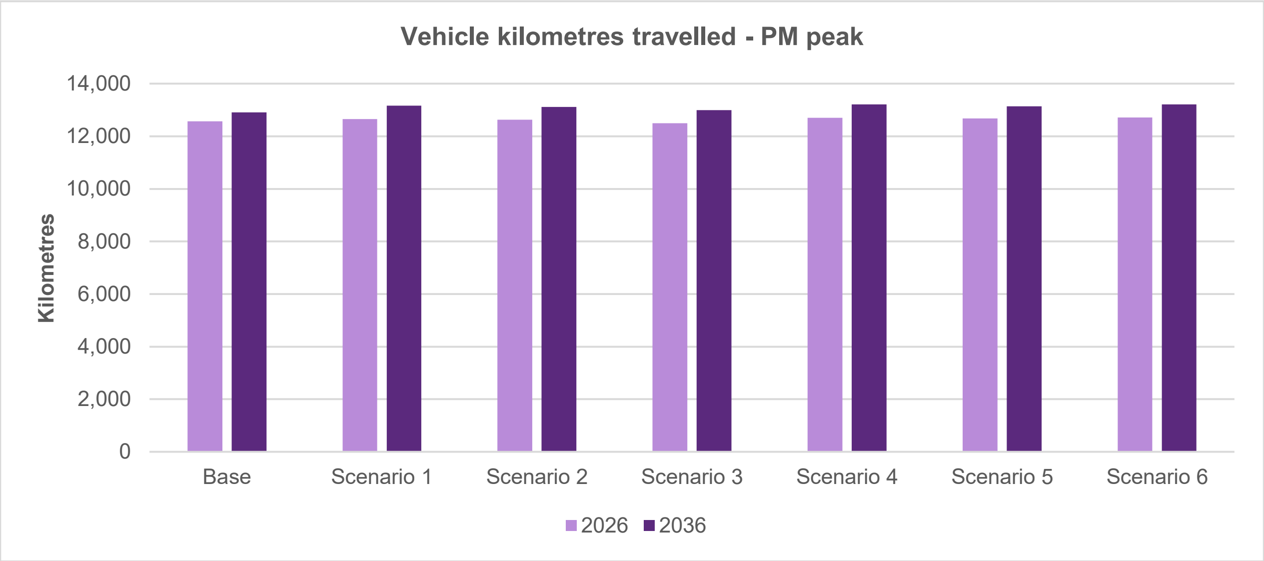




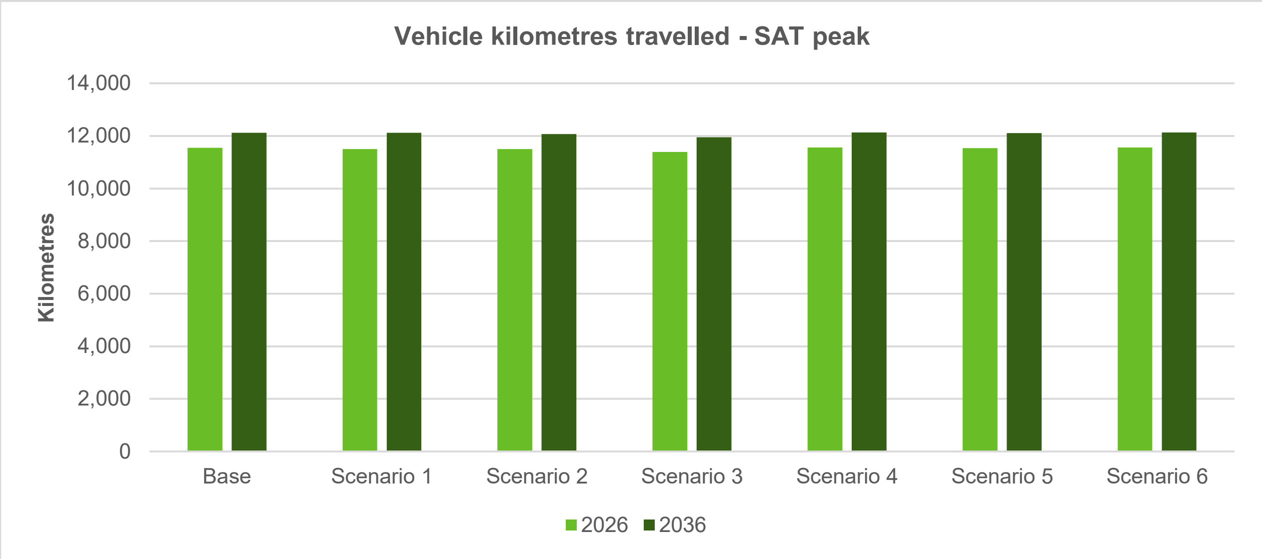
Weekday PM peak

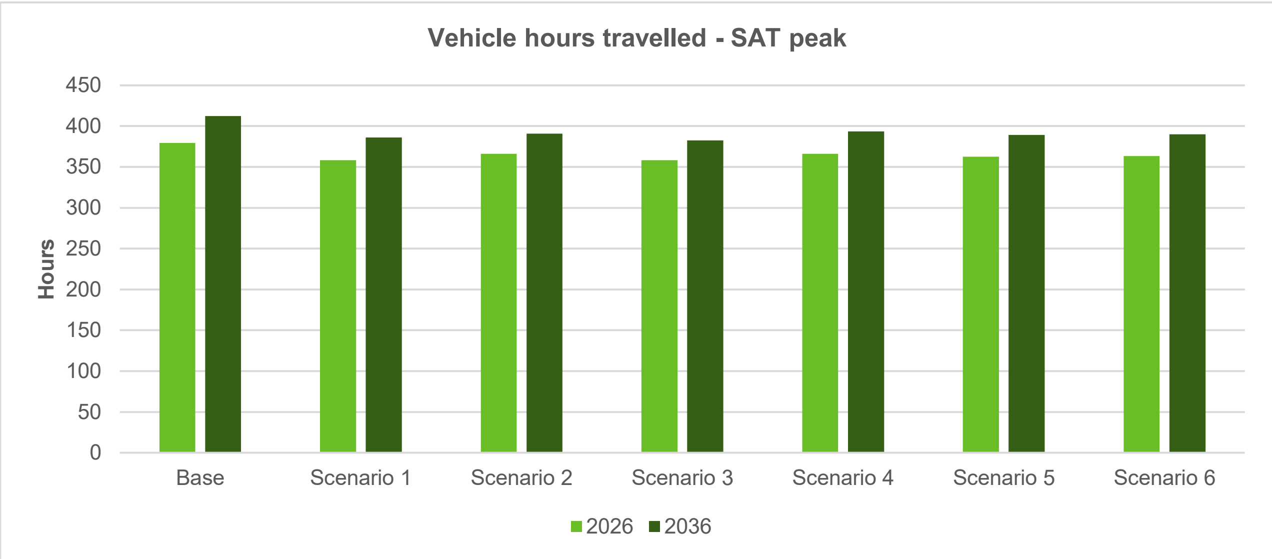


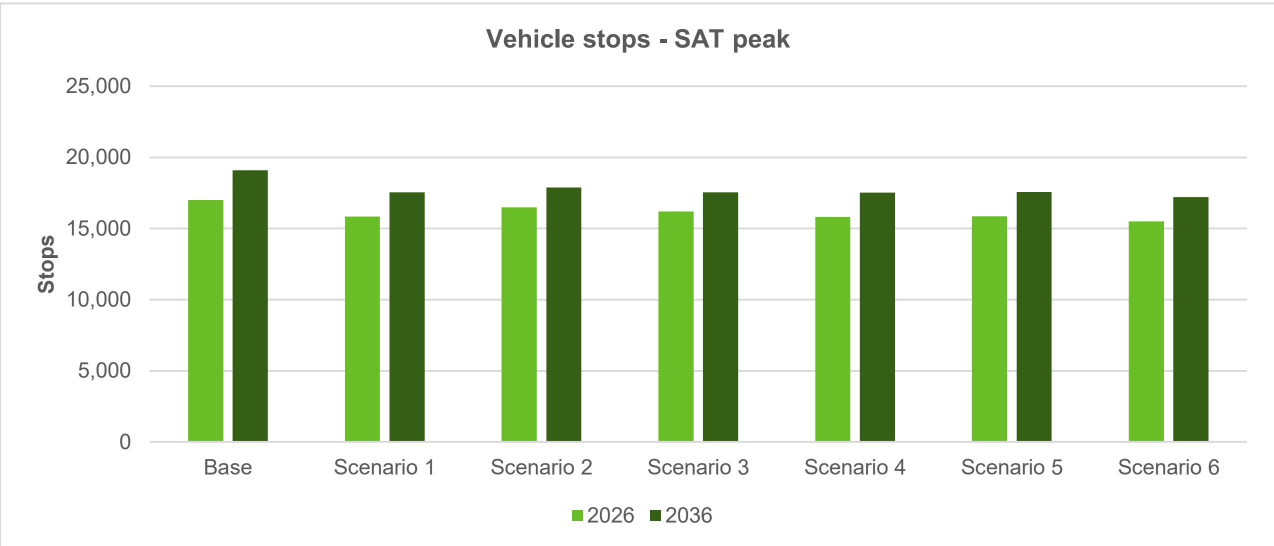

Vehicle kilometres travelled - PM peak
Kilometres
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Base
Scenario 1
Scenario 2
Scenario 3
Scenario 4
Scenario 5
Scenario 6
2026
2036


Vehicle kilometres travelled - PM peak
Kilometres
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Base
Scenario 1
Scenario 2
Scenario 3
Scenario 4
Scenario 5
Scenario 6
2026
2036

Saturday peak

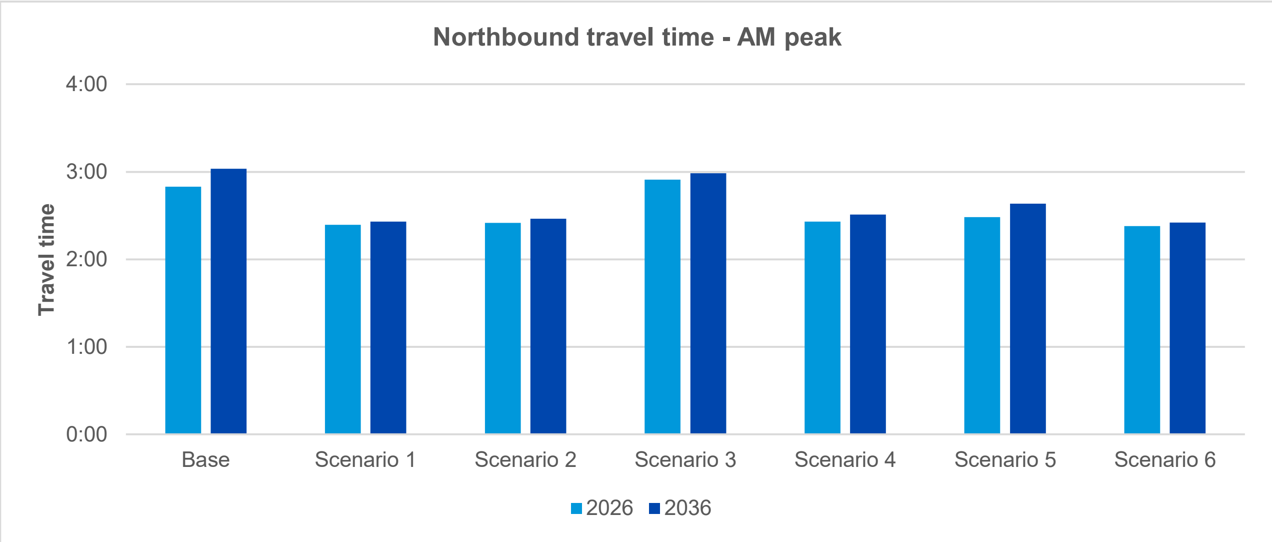


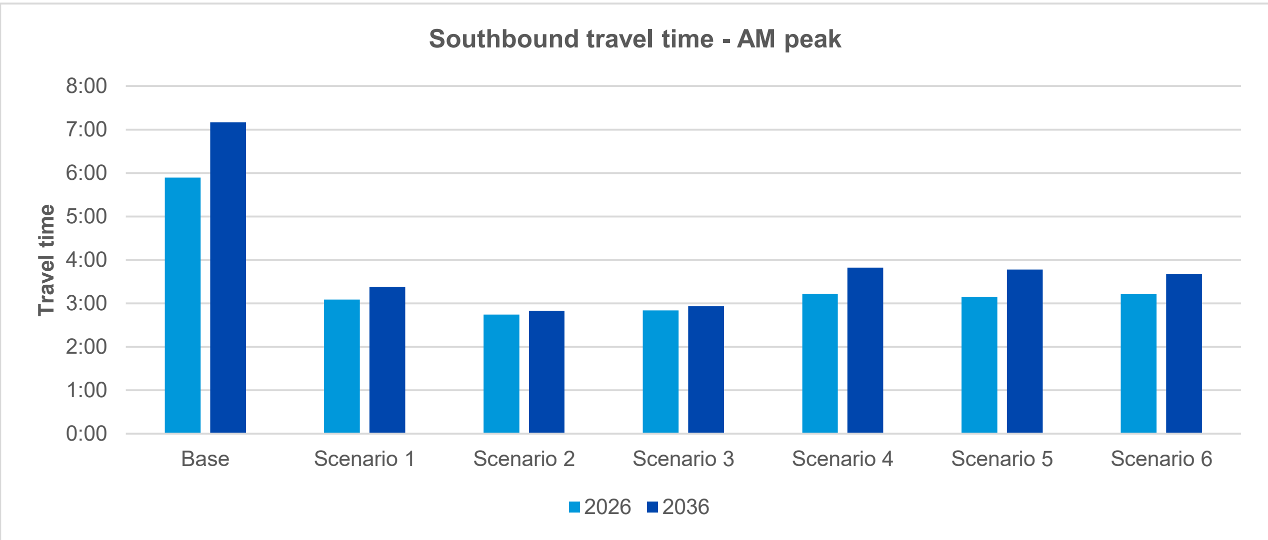




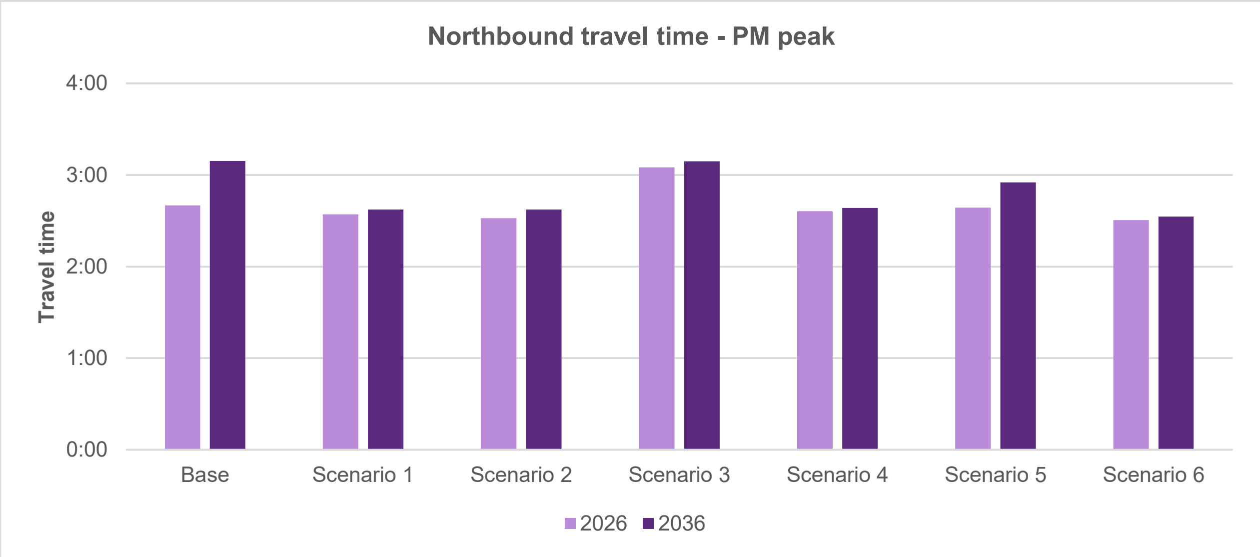
Travel time

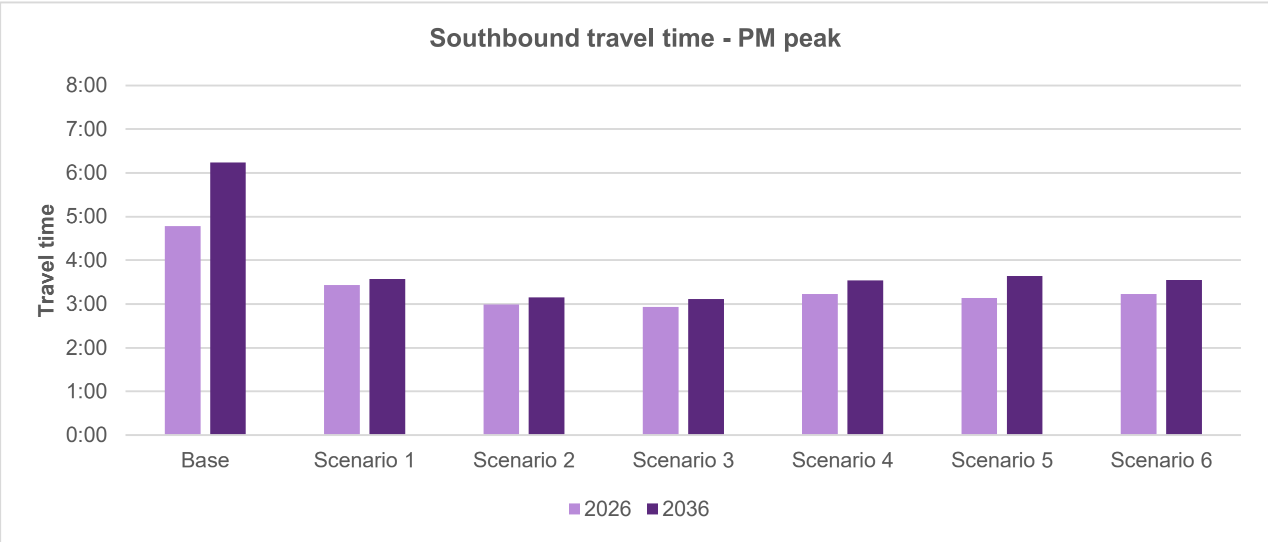
Weekday AM peak



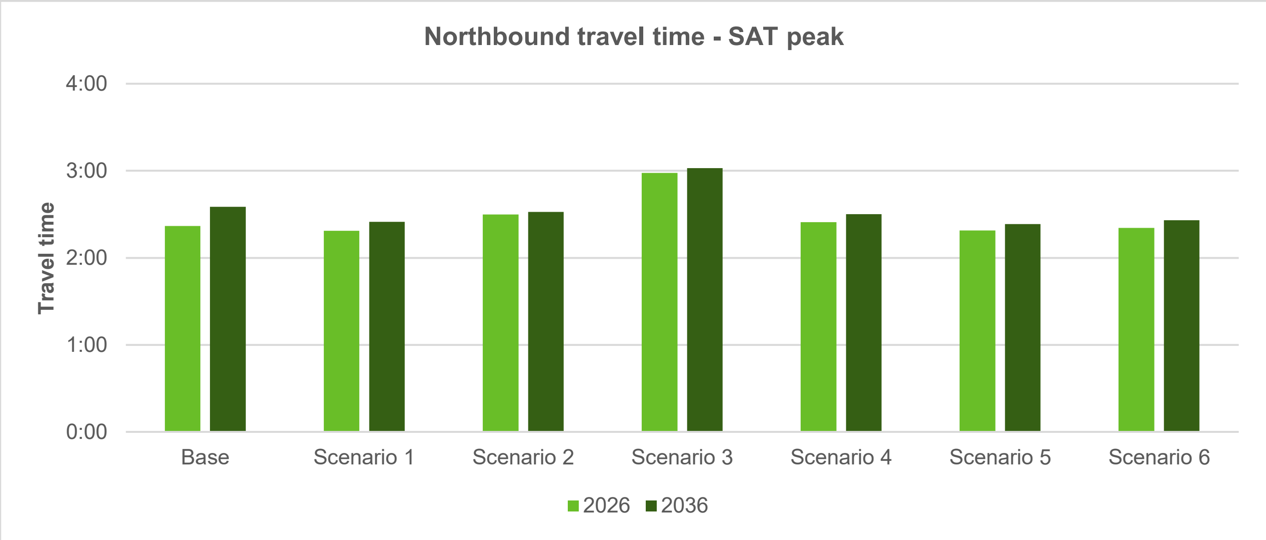


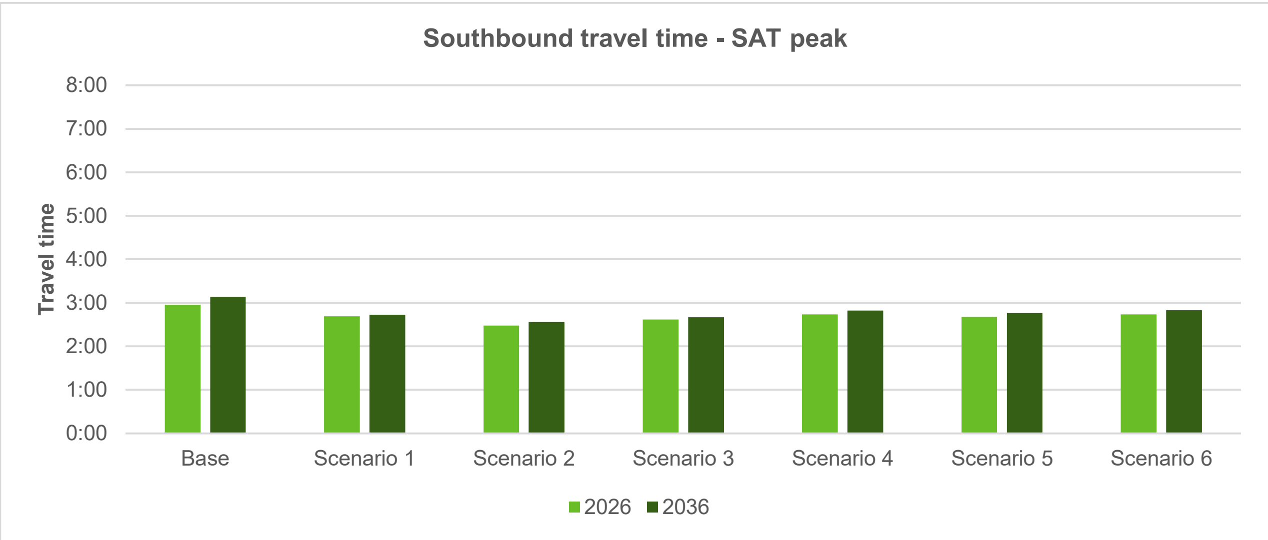
Weekday PM peak





Saturday peak





Level of Service

Table B.1 Level of Service summary – 'Do-minimum' – 2026

	2026 AM				2026 PM				2026 SAT			
	7.00 am–8.00 am		8.00 am–9.00 am		4.00 pm–5.00 pm		5.00 pm–6.00 pm		11.00 am–12.00 pm		12.00 pm–1.00 pm	
Intersection	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**
Princes Highway /Beattie Avenue	27	B	55	D(1)	33	C	33	C	27	B	27	B
Princes Highway/ Hobart Street	8	A	24	B	10	A	14	A	7	A	6	A
Princes Highway/ Point Street	11	A	20	B	15	B	25	B	13	A	12	A
Princes Highway/ Grevillea Park Road	10	A	17	B	13	A	23	B	13	A	18	B
Princes Highway/ Park Road	9	A	39	C	24	B	28	B	17	B	14	A
Princes Highway/ Station Street	17	B	> 100	F(1)	39	C	54	D	43	D	64	E(1)
Princes Highway/ Organs Road	9	A	53	D	20	B	24	B	16	B	14	A
Princes Highway/ Molloy Street	20	B	35	C	25	B	20	B	18	B	20	B
Princes Highway/ Hospital Road	28	B	30	C	29	C	29	C	27	B	24	B

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

Table B.2 Level of Service summary – ‘Do-minimum’ – 2036

	2036 AM				2036 PM				2036 SAT			
	7.00 am–8.00 am		8.00 am–9.00 am		4.00 pm–5.00 pm		5.00 pm–6.00 pm		11.00 am–12.00 pm		12.00 pm–1.00 pm	
Intersection	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**
Princes Highway/ Beattie Avenue	25	B	89	(1)	41	C	> 100	F(1)	28	B	28	B
Princes Highway/ Hobart Street	8	A	34	C	14	A	35	C	7	A	6	A
Princes Highway/ Point Street	12	A	32	C	24	B	40	C	14	A	13	A
Princes Highway/ Grevillea Park Road	10	A	25	B	22	B	28	B	14	A	15	B
Princes Highway/ Park Road	10	A	45	D	31	C	35	C	20	B	15	B
Princes Highway/ Station Street	39	C	> 100	F(1)	83	F	89	F	85	F(1)	61	E(1)
Princes Highway/ Organs Road	9	A	57	E	25	B	26	B	16	B	16	B
Princes Highway/ Molloy Street	23	B	37	C	28	B	22	B	21	B	21	B
Princes Highway/ Hospital Road	29	C	33	C	29	C	30	C	28	B	24	B

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

Table B.3 Level of Service summary – Scenario 1 – 2026

	2026 AM				2026 PM				2026 SAT			
	7.00 am–8.00 am		8.00 am–9.00 am		4.00 pm–5.00 pm		5.00 pm–6.00 pm		11.00 am–12.00 pm		12.00 pm–1.00 pm	
Intersection	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**
Princes Highway/ Beattie Avenue	27	B	40	C	31	C	32	C	29	C	25	B
Princes Highway/ Hobart Street	9	A	16	B	10	A	11	A	10	A	8	A
Princes Highway/ Point Street	10	A	12	A	13	A	16	B	11	A	10	A
Princes Highway/ Grevillea Park Road	11	A	9	A	10	A	10	A	8	A	9	A
Princes Highway/ Park Road	5	A	8	A	10	A	9	A	7	A	7	A
Princes Highway/ Station Street	19	B	42	C	27	B	23	B	40	C	27	B
Princes Highway/ Organs Road	5	A	11	A	16	B	17	B	12	A	10	A
Princes Highway/ Molloy Street	11	A	27	B	27	B	20	B	16	B	15	B
Princes Highway/ Hospital Road	26	B	27	B	29	C	29	C	30	C	28	B

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

Table B.4 Level of Service summary – Scenario 1 – 2036

	2036 AM				2036 PM				2036 SAT			
	7.00 am–8.00 am		8.00 am–9.00 am		4.00 pm–5.00 pm		5.00 pm–6.00 pm		11.00 am–12.00 pm		12.00 pm–1.00 pm	
Intersection	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**
Princes Highway /Beattie Avenue	26	B	41	C	32	C	37	C	27	B	29	C
Princes Highway/ Hobart Street	10	A	17	B	10	A	12	A	10	A	8	A
Princes Highway/ Point Street	10	A	13	A	14	A	17	B	12	A	11	A
Princes Highway/ Grevillea Park Road	11	A	9	A	10	A	11	A	9	A	9	A
Princes Highway/ Park Road	6	A	9	A	10	A	9	A	7	A	7	A
Princes Highway/ Station Street	21	B	66	E(1)	41	C	47	D(1)	33	C	30	C
Princes Highway/ Organs Road	6	A	15	B	19	B	20	B	12	A	11	A
Princes Highway/ Molloy Street	14	A	39	C	33	C	26	B	20	B	18	B
Princes Highway/ Hospital Road	27	B	28	B	29	C	30	C	31	C	27	B

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

Table B.5 Level of Service summary – Scenario 2 – 2026

	2026 AM				2026 PM				2026 SAT			
	7.00 am–8.00 am		8.00 am–9.00 am		4.00 pm–5.00 pm		5.00 pm–6.00 pm		11.00 am–12.00 pm		12.00 pm–1.00 pm	
Intersection	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS
Princes Highway/ Beattie Avenue	30	C	37	C	31	C	33	C	28	B	28	B
Princes Highway/ Hobart Street	9	A	16	B	12	A	12	A	10	A	8	A
Princes Highway/ Point Street	10	A	13	A	12	A	13	A	11	A	10	A
Princes Highway/ Grevillea Park Road	12	A	8	A	12	A	10	A	8	A	8	A
Princes Highway/ Park Road	5	A	8	A	7	A	8	A	7	A	7	A
Princes Highway/ Station Street	25	B	40	C	31	C	36	C	35	C	29	C
Princes Highway/ Organs Road	8	A	11	A	15	B	19	B	17	B	14	A
Princes Highway/ Molloy Street	12	A	22	B	17	B	17	B	19	B	16	B
Princes Highway/ Hospital Road	26	B	26	B	28	B	29	C	26	B	25	B

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

Table B.6 Level of Service summary – Scenario 2 – 2036

	2036 AM				2036 PM				2036 SAT			
	7.00 am–8.00 am		8.00 am–9.00 am		4.00 pm–5.00 pm		5.00 pm–6.00 pm		11.00 am–12.00 pm		12.00 pm–1.00 pm	
Intersection	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS
Princes Highway/ Beattie Avenue	25	B	41	C	30	C	35	C	29	C	27	B
Princes Highway/ Hobart Street	9	A	17	B	12	A	13	A	10	A	9	A
Princes Highway/ Point Street	10	A	13	A	14	A	14	A	12	A	11	A
Princes Highway/ Grevillea Park Road	13	A	9	A	13	A	11	A	9	A	8	A
Princes Highway/ Park Road	5	A	9	A	8	A	9	A	8	A	8	A
Princes Highway/ Station Street	23	B	49	D(1)	39	C	42	C	40	C	50	D(1)
Princes Highway/ Organs Road	8	A	12	A	15	B	21	B	18	B	15	B
Princes Highway/ Molloy Street	13	A	22	B	17	B	18	B	20	B	15	B
Princes Highway/ Hospital Road	27	B	27	B	29	C	30	C	27	B	25	B

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

Table B.7 Level of Service summary – Scenario 3 – 2026

	2026 AM				2026 PM				2026 SAT			
	7.00 am–8.00 am		8.00 am–9.00 am		4.00 pm–5.00 pm		5.00 pm–6.00 pm		11.00 am–12.00 pm		12.00 pm–1.00 pm	
Intersection	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**
Princes Highway/ Beattie Avenue	29	C	36	C	33	C	31	C	28	B	30	C
Princes Highway/ Hobart Street	9	A	16	B	12	A	12	A	9	A	8	A
Princes Highway/ Point Street	9	A	12	A	13	A	14	A	11	A	10	A
Princes Highway/ Grevillea Park Road	12	A	8	A	12	A	11	A	8	A	9	A
Princes Highway/ Park Road	5	A	9	A	7	A	8	A	7	A	7	A
Princes Highway/ Station Street	24	B	34	C	31	C	37	C	34	C	32	C
Princes Highway/ Organs Road	8	A	10	A	13	A	15	B	14	A	12	A
Princes Highway/ Molloy Street	30	C	36	C	39	C	37	C	37	C	33	C
Princes Highway/ Hospital Road	11	A	10	A	9	A	8	A	7	A	7	A

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

Table B.8 Level of Service summary – Scenario 3 – 2036

Intersection	2036 AM				2036 PM				2036 SAT			
	7.00 am–8.00 am		8.00 am–9.00 am		4.00 pm–5.00 pm		5.00 pm–6.00 pm		11.00 am–12.00 pm		12.00 pm–1.00 pm	
	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS
Princes Highway/ Beattie Avenue	25	B	42	C	33	C	34	C	29	C	28	B
Princes Highway/ Hobart Street	9	A	17	B	12	A	13	A	10	A	8	A
Princes Highway/ Point Street	10	A	13	A	14	A	15	B	12	A	11	A
Princes Highway/ Grevillea Park Road	12	A	9	A	13	A	11	A	9	A	9	A
Princes Highway/ Park Road	5	A	9	A	8	A	9	A	8	A	8	A
Princes Highway/ Station Street	21	B	36	C	34	C	38	C	40	C	31	C
Princes Highway/ Organs Road	8	A	11	A	14	A	16	B	15	B	13	A
Princes Highway/ Molloy Street	30	C	38	C	40	C	39	C	37	C	35	C
Princes Highway/ Hospital Road	11	A	10	A	9	A	8	A	8	A	8	A

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

Table B.9 Level of Service summary – Scenario 4 – 2026

	2026 AM				2026 PM				2026 SAT			
	7.00 am–8.00 am		8.00 am–9.00 am		4.00 pm–5.00 pm		5.00 pm–6.00 pm		11.00 am–12.00 pm		12.00 pm–1.00 pm	
Intersection	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**
Princes Highway/ Beattie Avenue	28	B	39	C	31	C	32	C	26	B	26	B
Princes Highway/ Hobart Street	9	A	16	B	12	A	12	A	9	A	8	A
Princes Highway/ Point Street	10	A	13	A	13	A	14	A	11	A	10	A
Princes Highway/ Grevillea Park Road	11	A	9	A	12	A	11	A	8	A	8	A
Princes Highway/ Park Road	10	A	16	B	15	B	16	B	13	A	12	A
Princes Highway/ Station Street	15	B	24	B	23	B	17	B	33	C	26	B
Princes Highway/ Organs Road	4	A	8	A	12	A	13	A	11	A	9	A
Princes Highway/ Molloy Street	12	A	26	B	26	B	21	B	17	B	16	B
Princes Highway/ Hospital Road	25	B	28	B	29	C	30	C	31	C	27	B

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

Table B.10 Level of Service summary – Scenario 4 – 2036

	2036 AM				2036 PM				2036 SAT			
	7.00 am–8.00 am		8.00 am–9.00 am		4.00 pm–5.00 pm		5.00 pm–6.00 pm		11.00 am–12.00 pm		12.00 pm–1.00 pm	
Intersection	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**
Princes Highway/ Beattie Avenue	26	B	38	C	31	C	35	C	28	B	29	C
Princes Highway/ Hobart Street	10	A	17	B	12	A	13	A	9	A	8	A
Princes Highway/ Point Street	10	A	13	A	14	A	14	A	12	A	11	A
Princes Highway/ Grevillea Park Road	11	A	10	A	13	A	11	A	9	A	9	A
Princes Highway/ Park Road	10	A	19	B	16	B	17	B	14	A	13	A
Princes Highway/ Station Street	16	B	> 100	F(1)	27	B	43	D	33	C	15	B
Princes Highway/ Organs Road	4	A	18	B	13	A	16	B	11	A	9	A
Princes Highway/ Molloy Street	14	A	39	C	29	C	24	B	20	B	19	B
Princes Highway/ Hospital Road	27	B	28	B	30	C	33	C	31	C	28	B

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

Table B.11 Level of Service summary – Scenario 5 – 2026

	2026 AM				2026 PM				2026 SAT			
	7.00 am–8.00 am		8.00 am–9.00 am		4.00 pm–5.00 pm		5.00 pm–6.00 pm		11.00 am–12.00 pm		12.00 pm–1.00 pm	
Intersection	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS
Princes Highway/ Beattie Avenue	27	B	37	C	32	C	33	C	28	B	27	B
Princes Highway/ Hobart Street	9	A	17	B	12	A	12	A	10	A	9	A
Princes Highway/ Point Street	10	A	13	A	13	A	13	A	11	A	10	A
Princes Highway/ Grevillea Park Road	11	A	6	A	12	A	11	A	8	A	8	A
Princes Highway/ Park Road	5	A	9	A	7	A	7	A	7	A	6	A
Princes Highway/ Station Street	4	A	9	A	11	A	11	A	8	A	7	A
Princes Highway/ Organs Road	6	A	13	A	15	B	17	B	12	A	10	A
Princes Highway/ Molloy Street	13	A	27	B	28	B	21	B	15	B	17	B
Princes Highway/ Hospital Road	25	B	28	B	29	C	31	C	31	C	28	B

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

Table B.12 Level of Service summary – Scenario 5 – 2036

	2036 AM				2036 PM				2036 SAT			
	7.00 am–8.00 am		8.00 am–9.00 am		4.00 pm–5.00 pm		5.00 pm–6.00 pm		11.00 am–12.00 pm		12.00 pm–1.00 pm	
Intersection	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**
Princes Highway/ Beattie Avenue	27	B	40	C	31	C	35	C	28	B	29	C
Princes Highway/ Hobart Street	10	A	18	B	12	A	13	A	10	A	9	A
Princes Highway/ Point Street	10	A	13	A	14	A	15	B	12	A	11	A
Princes Highway/ Grevillea Park Road	11	A	8	A	13	A	12	A	9	A	9	A
Princes Highway/ Park Road	5	A	12	A	7	A	10	A	7	A	7	A
Princes Highway/ Station Street	4	A	20	B	11	A	18	B	9	A	7	A
Princes Highway/ Organs Road	6	A	27	B	16	B	28	B	12	A	10	A
Princes Highway/ Molloy Street	14	A	41	C	29	C	26	B	18	B	20	B
Princes Highway/ Hospital Road	27	B	28	B	30	C	33	C	31	C	28	B

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

Table B.13 Level of Service summary – Scenario 6 – 2026

Intersection	2026 AM				2026 PM				2026 SAT			
	7.00 am–8.00 am		8.00 am–9.00 am		4.00 pm–5.00 pm		5.00 pm–6.00 pm		11.00 am–12.00 pm		12.00 pm–1.00 pm	
	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS	Delay (s)	LoS
Princes Highway/ Beattie Avenue	27	B	37	C	33	C	32	C	27	B	27	B
Princes Highway/ Hobart Street	9	A	16	B	12	A	12	A	9	A	8	A
Princes Highway/ Point Street	8	A	11	A	11	A	12	A	10	A	9	A
Princes Highway/ Grevillea Park Road	11	A	9	A	12	A	11	A	8	A	8	A
Princes Highway/ Park Road	10	A	16	B	15	B	16	B	13	A	12	A
Princes Highway/ Station Street	15	B	26	B	29	C	15	B	33	C	26	B
Princes Highway/ Organs Road	4	A	8	A	13	A	13	A	11	A	9	A
Princes Highway/ Molloy Street	13	A	26	B	28	B	20	B	17	B	16	B
Princes Highway/ Hospital Road	25	B	27	B	29	C	31	C	31	C	28	B

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

Table B.14 Level of Service summary – Scenario 6 – 2036

	2036 AM				2036 PM				2036 SAT			
	7.00 am–8.00 am		8.00 am–9.00 am		4.00 pm–5.00 pm		5.00 pm–6.00 pm		11.00 am–12.00 pm		12.00 pm–1.00 pm	
Intersection	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**	**Delay (s)**	**LoS**
Princes Highway/ Beattie Avenue	28	B	39	C	30	C	33	C	28	B	29	C
Princes Highway/ Hobart Street	9	A	16	B	12	A	12	A	9	A	8	A
Princes Highway/ Point Street	9	A	12	A	12	A	12	A	10	A	9	A
Princes Highway/ Grevillea Park Road	11	A	10	A	13	A	12	A	9	A	9	A
Princes Highway/ Park Road	10	A	19	B	16	B	17	B	14	A	13	A
Princes Highway/ Station Street	15	B	89	F(1)	32	C	42	C	32	C	13	A
Princes Highway/ Organs Road	4	A	15	B	14	A	17	B	12	A	9	A
Princes Highway/ Molloy Street	14	A	38	C	30	C	25	B	19	B	19	B
Princes Highway/ Hospital Road	27	B	28	B	30	C	32	C	30	C	28	B

(1) Demand for critical movement (right-turn from side-street) is < 20 vehicles/hour and therefore the outcome may be skewed by the delay experienced by a couple of vehicles

Appendix C

ECONOMIC APPRAISAL MEMORANDUM

MEMO

TO: s74 Scope

FROM:

SUBJECT: **HW1 Princes Highway at Bulli – Rapid Economic Appraisal**

OUR REF: 2196958A-ITP-MEM-005-RevA.docx

DATE: **13 September 2016**

1. INTRODUCTION

NSW Roads and Maritime Services (Roads and Maritime) commissioned WSP | Parsons Brinckerhoff to undertake a traffic study for the purpose of assessing the existing and future operational performances of the HW1 Princes Highway corridor in Bulli New South Wales, between Sturdee Avenue in the north and Hospital Road in the south.

This technical note details the methodology and results of a rapid economic assessment undertaken for the improvements to the Princes Highway at Bulli being considered by Roads and Maritime:

- Scenario 1 includes clearways on Princes Highway, between Park Road and Station Street, and revising lane allocation for Pacific Highway | Molloy Street roundabout.
- Scenario 2 includes clearways on Princes Highway, between Park Road and Station Street, and converting Pacific Highway | Molloy Street roundabout into traffic signalised intersection.
- Scenario 4 is based on Scenario 1 but also includes 'No right turn' from Princes Highway to Station Street, and provision of protected right-turn phase at the Princes Highway/Park Road.
- Scenario 6 is based on Scenario 4 but also includes a right-turn bay at the Princes Highway/Point Street intersection.

The details of the four scenarios were provided in *2196958A-ITP-MEM-003 HW1 Bulli Proposed Traffic Modelling Options*.

The economic assessment involved a cost benefit analysis comparing the benefits and costs of the four improvement scenarios against a 'do minimum' base case. It was carried out according to *Principles and Guidelines for Economic Appraisal on Transport Investment and Initiatives (Transport for NSW (TfNSW), March 2013 and Parameter Update March 2015)* – abbreviated in this report to TfNSW Guidelines.

2. KEY ASSUMPTIONS AND INPUTS

2.1 Economic parameters and expansion factors

Table 2.1 shows the economic parameters used in the analysis.

Table 2.1 Economic parameters

Economic parameters	Value
Discount rate	7%
Opening year	2021/22

Economic parameters	Value
Appraisal period	30 years from opening year
Base year for discounting	2015/16
Price base	2015/16

The Aimsun traffic model outputs covering two-hour AM peak and two-hour PM peak of a typical weekday was used for the rapid economic appraisal. The peak periods were converted to an annual total using cost expansion factors. The factors used are shown in Table 2.2.

Table 2.2 Modelling period to annual cost expansion factors (urban)

Modelling period	Expansion factor
From four-hour peak periods to weekday	3.15
From weekday to year	336

Source: TfNSW Guidelines

2.2 Economic costs

The estimated capital cost for each scenario was provided for the rapid economic appraisal (refer to Table 2.3). The construction period is assumed to be two years.

The additional maintenance cost incurred by each scenario was not provided. For this rapid assessment, it was assumed that annual maintenance cost would be 1% of capital cost (refer to Table 2.3). The maintenance cost is not expected to have significant impact on the economic viability of the project.

Table 2.3 Cost estimates (in 2015/16 dollar value)

Options	Capital cost	Annual maintenance cost
Scenario 1	$3,099,000	$30,990
Scenario 2	$4,110,000	$41,100
Scenario 4	$3,860,000	$38,600
Scenario 6	$4,701,000	$47,010

2.3 Traffic model results

Utilising the modelling software Aimsun traffic models were developed for 2016, 2026 and 2036. The base case and four scenarios were assessed for AM and PM peak hours in all three modelling years.

The following traffic modelling results of the base case and the four scenarios were used as inputs to the economic appraisal:

- Total vehicle hours travelled (VHT) – to inform travel time benefit assessment
- Total vehicle kilometre travelled (VKT) – to inform vehicle operating cost and emission cost assessment
- Total number of stops – to inform vehicle operating cost assessment.

The above were extracted separately for light vehicles (cars), heavy vehicles (trucks), and buses.

The traffic model used for the project is a corridor model, and does not model the effects that the increasing congestion along the corridor in the future (e.g. 2036) may divert traffic to somewhere else or a different mode i.e. the actual congestion in the future may not be as bad as what is shown by the traffic model. According to traffic modelling, the modelled corridor becomes very congested during the peak periods of 2026. To minimise the risk of overstating the project benefits, only 2016 and 2026 model results are used to inform the economic assessment assuming that benefits will initially grow until 2026 and will then stay the same over the remaining years of the appraisal period.

2.4 Crash analysis results

A crash analysis was undertaken to identify the impacts to road safety from the proposed upgrade options, as the input to the economic appraisal. The latest crash data for the project area was obtained from RMS between 2005 and 2015.

The impacts to road safety based on the proposed improvements were assessed for each option. Table 2.4 shows the estimated number of crashes per year for the base case and the proposed two options. To minimise the potential risk of overstating the crash reduction benefits, it was assumed that the potential crash reductions by the improvements would not increase in the future.

Table 2.4 Predicted crashes per year with the proposed options

Crash type	Number of crashes per year				
	Base	**Scenario 1**	**Scenario 2**	**Scenario 4**	**Scenario 6**
Fatal	0.1	0.1	0.1	0.1	0.1
Injury	5.7	5.6	5.5	5.4	5.4
Non-casualty	7.8	7.7	7.1	7.5	7.3
Overall	13.6	13.4	12.7	13.0	12.8

3. ECONOMIC APPRAISAL RESULTS

3.1 Assessment criteria

Two economic indicators were calculated as outputs of the economic appraisal to evaluate the relative attractiveness of the options against the base case:

- Net Present Value (NPV)
- Benefit Cost Ratio (BCR).

A brief description of each indicator is provided as follows:

- NPV measures the difference between benefits and costs, whilst accounting for the timing of benefits and costs. Net cash flows are discounted at the prescribed discount rate, reflecting the notion that future benefits and costs have less value compared to current benefits and costs. A project with a Net Present Value greater than zero would be considered economic.
- BCR measures the return received per dollar of costs. The Benefit Cost Ratio is calculated by dividing the present value of all benefits by the present value of all costs. A project with a Benefit Cost Ratio greater than one would be considered economic.

3.2 Value of benefits

The following standard economic benefits have been calculated:

- Road user benefits:
  - Travel time savings
  - Vehicle operating cost savings
- Non-user benefits (or externality cost savings):
  - Environmental externality savings (air pollution and greenhouse gas emission)
  - Crash cost savings.

Travel time savings for each options were calculated by taking the difference between travel time costs (i.e. value of time multiplied by total vehicle hours estimated by the Aimsun traffic model). In all options the modelled total vehicle hours decrease compared to the base case. Therefore all four scenarios would provide travel time benefits.

Vehicle operating costs comprise all resource cost of fuel, oil, depreciation, maintenance, and wear on tyres and brakes. The estimation took account of both network congestion (i.e. operating cost per stop multiplied by number of stops estimated by the Aimsun traffic model) and vehicle travel distance (i.e. operating cost per km multiplied by total vehicle travel distances estimated by the Aimsun traffic model). The savings for each of the options were calculated by taking the difference between the base case and scenario selected. In all options the modelled total number of stops decrease significantly compared to the base case. The changes to total vehicle travel distances are not significant. Overall, all four scenarios would provide vehicle operation cost savings.

Environmental externality caused by air pollution and greenhouse gas emitted from vehicles are considered in the appraisal. The latter refers to gases (e.g. carbon diode, methane) that contribute toward the greenhouse effect which represents a negative externality. They were estimated by multiplying the total travel distances with a distance based unit value (i.e. emission cost per km). The modelled changes to total vehicle travel distances are not significant. Overall, the environmental externality benefits (or disbenefits) of all four scenarios are negligible comparing to travel time benefits.

Crash reduction benefits for each option were calculated by taking the difference between crash costs (i.e. cost per crash multiplied by predicted number of crashes). In all four scenarios the predicted number of crashes per year decrease compared to the base case. Therefore, each scenarios would provide crash reduction benefits.

All four scenarios involve providing additional road capacity through reduction of on-road parking spaces. Although the associated capital cost is minimal, it will incur disbenefit to the drivers who normally use these parking spaces. A parking study for the area is outside the scope of this project. For this rapid assessment, the following assumptions were used to estimate the road user disbenefit associated with the loss of on-road parking spaces:

- Each parking space would serve one car per hour on average.
- Loss of an on-road parking space would incur 20 minutes delay to the driver’s trip, covering:
  - Additional driving time to find alternative car park
  - Additional walking time between alternative car park and destination.

The unit values adopted for the assessment of the above benefits were based on *TfNSW Guidelines* and are listed in Table 3.1. The latest update of the *TfNSW Guidelines* presents parameter values are 2013/14 prices. Travel time values were indexed from 2013/14 to 2015/16 using Average Weekly Earnings in NSW reported by Australian Bureau of Statistics (ABS) (an increase of 5.6%). Other values were indexed from 2013/14 to 2015/16 using Consumer Price Index in Sydney reported by ABS (an increase of 2.6%).

Table 3.1 Monetary values of items included for benefit assessment (urban)

Item	Value
Light vehicle travel time per hour	$28.47
Heavy vehicle travel time per hour	$56.62
Bus travel time per hour (including drive and average 20 passengers)	$354.67
Light vehicle operating cost per km	$0.27
Heavy vehicle and bus operating cost per km	$1.23
Light vehicle operating cost per stop	$0.08
Heavy vehicle and bus operating cost per stop	$0.41
Light vehicle emission cost per km	$0.06
Heavy vehicle and bus emission cost per km	$0.50[1]
Crash – fatal per occurrence	$6,854,724
Crash – injury per occurrence	$144,485
Crash – non injury per occurrence	$9,779

Source: TfNSW Guidelines

3.3 Cost benefit results

The results from cost benefit analysis for each option are summarised in Table 3.2. All options are economically viable, given that each of them has a positive NPV and a BCR larger than 1.

Table 3.2 Cost benefit results

	Scenario 1	Scenario 2	Scenario 4	Scenario 6
PV Capital Cost	$2,286,878	$3,032,936	$2,848,451	$3,469,059
PV net maintenance cost	$274,183	$363,631	$341,513	$415,920
PV TOTAL COST	**$2,561,061**	**$3,396,567**	**$3,189,964**	**$3,884,979**
PV Travel time benefit	$41,848,215	$46,365,776	$39,388,473	$40,772,401
PV Vehicle operation cost savings	$6,331,161	$6,657,144	$6,210,723	$6,673,021
PV emission savings	$6,824	$46,474	-$38,057	-$37,117
PV Crash cost savings	$136,485	$316,230	$409,454	$426,758
Clearway disbenefit	-$1,691,124	-$1,691,124	-$1,691,124	-$1,691,124
PV TOTAL BENEFIT	**$46,631,560**	**$51,694,499**	**$44,279,469**	**$46,143,938**
NPV	**$44,070,499**	**$48,297,932**	**$41,089,505**	**$42,258,959**
BCR	**18.2**	**15.2**	**13.9**	**11.9**

PV – Present value

1 The TfNSW Guidelines did not provide externality unit cost based on truck kilometre travelled. The values recommended for buses were adopted as approximation. The impact on the appraisal outcome would be negligible.

4. CONCLUSION

All scenarios assessed in this rapid economic assessment are economically viable, as evidenced by positive NPVs and BCRs larger than 1, discounted at 7 percent. The cost benefit analysis shows Scenario 2 provides the highest NPV (~$48.3 million), while Scenario 1 has the highest BCR (18.2).

Travel time savings make up the largest proportion of benefits for all scenarios, with further significant cost savings due to reduced vehicle operating costs. Emissions savings and crash savings are not as significant. Negative benefits (or disbenefits) arise from the impact of lost parking spaces under each scenario.

The capital cost estimates in this report include the construction cost of each option. Maintenance costs were not provided so were estimated at 1% of capital costs per annum, representing just over 10% of total costs after discounting.

s74 Scope

Technical Executive

ROADS AND MARITIME SERVICES

MR185 Lawrence Hargrave Drive, Thirroul – Traffic modelling

Options assessment report

MR185 Lawrence Hargrave Drive, Thirroul – Traffic modelling

Options assessment report

Roads and Maritime Services

Project no: 2196958A-ITP-RPT-003 RevA.docx
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EXECUTIVE SUMMARY

WSP | Parsons Brinckerhoff was commissioned by the New South Wales Roads and Maritime Services Southern Region (Roads and Maritime) to undertake a traffic modelling study, for the purpose of assessing the operational performance on the Lawrence Hargrave Drive corridor (MR185) in Thirroul, between Hewitts Avenue to the south and Mary Street to the north.

A base model was developed in Aimsun using traffic surveys from March 2016 in order to establish a baseline for the future year modelling. The 2016 weekday AM, weekday PM and Saturday base models were calibrated and validated to the criteria defined by the Roads and Maritime *Traffic Modelling Guidelines (2013)*. These base models (and associated documentation) were submitted to Roads and Maritime and subsequently approved as fit-for-purpose in the future year modelling of the study area.

The results of 'do-minimum' models indicate that without the provision of any upgrade to the network, the Lawrence Hargrave Drive corridor will not have sufficient capacity to accommodate the projected future traffic demands in both future years 2026 and 2036. This is particularly the case for the Saturday peak. In addition, excessive delays on side streets were predicted at almost all the priority intersections. This is particularly evident at Arthur Street and Church Street, and at the signalised Phillip Street intersection. The travel time results for the Saturday peak predict a doubling in travel time for the southbound flow in 2036 when compared with the current situation.

To reduce the congestion on Lawrence Hargrave Drive corridor identified in 'do-minimum' assessment, the improvement options were assessed in six scenarios in future years 2026 and 2036. The assessment was undertaken in two stages. The magnitude of the improvements each scenario provides to the road network, based on the microsimulation modelling results, was seen as the key factor to select the preferred scenario. The estimated construction and implementation cost of the scenarios were also considered in this process.

STAGE 1 ASSESSMENT (SCENARIO 1 AND 2) – LAWRENCE HARGRAVE DRIVE | PHILLIP STREET INTERSECTION

Two layouts were assessed at this intersection, which was identified as a critical pinch point. Both scenarios include clearways in peak directions, which provides downstream two-lane sections on Lawrence Hargrave Drive and complements the widening at this intersection.

Scenario 2, which features two through lanes and one 30 metre short right turn lane in the southbound direction, was deemed as the preferred scenario to be carried through to Stage 2 assessment. It was predicted to provide more substantial benefits in both PM and Saturday peak periods than Scenario 1

STAGE 2A ASSESSMENT WITH CLEARWAYS SCHEME (SCENARIO 4 AND 5)

Northbound short right turn lane on Lawrence Hargrave Drive to Station Street and Church Street rail over-bridge widening (Scenario 5 only) were assessed. Although Scenario 5 produced marginally better results in the AM and Saturday peak, **Scenario 4** was identified as the preferred scenario due to the much lower costs to construct and implement.

Scenario 4 would provide the following benefits compared to the do-minimum scenario in future year 2036, based upon the microsimulation modelling results:

- VHT in network statistics are reduced by 32%, 45% and 37% in the respective AM, PM and Saturday peak periods.
- Number of vehicle stops in network statistics are 32%, 45% and 37% lower in the respective AM, PM and Saturday peak periods.

- Northbound travel time is improved by 20% (approximately 40 seconds), 35% (1 minute and 30 seconds) and 35% (2 minutes) in the respective AM, PM and Saturday peak hours.
- Southbound travel time is improved by 40% (approximately 2 minutes), 45% (3 minutes) and 37% (3 minutes) in the respective AM, PM and Saturday peak hours.

Scenario 4 has a BCR of 3.3 and a positive NPV of $2.6M. It would also reduce the total crash number by four (or 0.4 crashes/year).

STAGE 2B ASSESSMENT WITHOUT CLEARWAYS SCHEME (SCENARIO 3 AND 6)

An S-lane scheme is implemented as an alternative to clearways, to streamline the through movement by providing dedicated right turn lane to side streets on Lawrence Hargrave Drive corridor. Lachlan Street, Station Street and Raymond Road are upgraded to have S-lanes in Scenario 6; Scenario 3 provides S-lanes at all the intersections except for Railway Parade and Church Street due to the existing geometric constraints.

Scenario 3 was identified as the preferred scenario as it provides more substantial benefits during the Saturday peak (e.g. additional 2 minutes southbound travel time savings compared to Scenario 6).

Scenario 3 would provide the following benefits compared to the do-minimum scenario in future year 2036, based upon the microsimulation modelling results.

- VHT in network statistics are reduced by 17%, 38% and 54% in the respective AM, PM and Saturday peak periods.
- Number of vehicle stops in network statistics are 23%, 50% and 56% lower in the respective AM, PM and Saturday peak periods.
- Northbound travel time is improved by 18% (approximately 40 seconds), 30% (1 minute and 20 seconds) and 39% (2 minutes) in the respective AM, PM and Saturday peak hours.
- Southbound travel time is improved by 30% (approximately 1 minute and 40 seconds), 52% (3 minutes) and 62% (5 minute s and 20 seconds) in the respective AM, PM and Saturday peak hours

Scenario 3 has a BCR of 5.2 and a positive NPV of $5.9M. It would also reduce the total crash number by 16 (or 1.6 crashes/year).

POTENTIAL STAGING CONSIDERATION

The provision of two through lanes on Lawrence Hargrave Drive (Layout 2) is not fully utilised in Scenario 3 (without clearways) due to the downstream single lane section for the through movement. A staging implementation approach, such as upgrading to Layout 1 prior to 2026 and then to Layout 2 in 2036, might provide higher cost-efficiency for this scenario.

1 Introduction

1.1 Background

WSP | Parsons Brinckerhoff was commissioned by the New South Wales Roads and Maritime Services Southern Region (Roads and Maritime) to undertake a traffic modelling study, for the purpose of assessing the operational performance on the Lawrence Hargrave Drive corridor (MR185) in Thirroul, between Hewitts Avenue to the south and Mary Street to the north. The study area is shown in Figure 1.1.

Figure 1.1 Study area of Lawrence Hargrave Drive in Thirroul

1.2 Modelling objectives

The microsimulation traffic model used in this study was AIMSUN (version 8.1). The main objectives of this traffic modelling study are to:

1. Replicate the existing conditions in the base model including known congestion and traffic operation, for the following periods:
   a) AM weekday peak
   b) PM weekday peak

c) Saturday midday peak.

2. Inform the design schemes of potential operational improvements by assessing travel time, traffic delay, queue length and intersection performances for the future year traffic models.
3. Support future business case development by providing the relevant traffic model outputs from the proposed options or scenarios.

1.3 Summary of base model calibration and validation results

The base model results were documented in *MR185 Lawrence Hargrave Drive – Base microsimulation model calibration and validation report* issued to Roads and Maritime on 29 April 2016. The results (summarised in Table 1.1) demonstrated that the Lawrence Hargrave Drive Aimsun base model has been calibrated and validated in all (AM, PM and Saturday) peak periods. As a consequence the base model was deemed to be fit for the purpose of testing the impact of the proposed road network upgrade in future year scenarios.

Table 1.1 Summary of base model calibration and validation results

Criteria	Performance	AM Meets criteria	PM Meets criteria	Saturday Meets criteria
Model calibration				
Intersection turning counts calibration	100% of all the 87 turning counts are below GEH 5	Yes	Yes	Yes
	100% are below GEH 10	Yes	Yes	Yes
	the R-square values are over 0.9	Yes	Yes	Yes
Model validation				
Travel time validation	Difference within 1 minute or 15%, for all of the routes	Yes	Yes	Yes
Queue length validation	Comparable for all of the key movements	Yes	Yes	Yes
Model stability				
Model variability	Reasonable level of variability	Yes	Yes	Yes
Vehicle release blocking	Vehicle released block not observed	Yes	Yes	Yes

1.4 Report structure

This report, which documents the assessment results of future year traffic scenarios, is structured as follows:

- Section 2 summarises the methodology and the results of the future year traffic estimation
- Section 3 presents the options to be tested and the results of the future do-minimum models
- Section 4 introduces the options to be assessed in future year scenario models
- Sections 5 to 7 detail the assessment results of each scenario in Stage 1 and 2
- Section 8 presents the crash reduction analysis results.
- Section 9 summarises the economic assessment results
- Section 10 presents a summary of the conclusions of the assessment and lists the recommendations.

2 Future traffic demands

The future traffic demands on the corridor were estimated for the purpose of assessing the future road network performance. The estimated future traffic demand was identified from the following data sources and references:

- Population and employment forecasts sourced from the NSW Bureau of Statistics and Analytics (BSA) website
- Forecast traffic growth from the Roads and Maritime TRACKS model for 2011, 2021 and 2036
- Historical AADT traffic growth at Roads and Maritime traffic count stations
- Bulli Pass Strategic Review (Roads and Maritime, October 2015).

Table 2.1 summarises the projected annual traffic growth rate, based on the review and analysis of the above data sources and references.

Table 2.1 Proposed future traffic annual growth by corridor

Annual growth rates	Weekday AM peak		Weekday PM peak		Saturday peak	
	Short term (before 2021)	Long term (after 2021)	Short term (before 2021)	Long term (after 2021)	Short term (before 2021)	Long term (after 2021)
Bulli Pass	1.4%	0.5%	1.4%	0.5%	1.4%	0.5%
Princes Highway	1.4%	0.7%	1.4%	0.5%	1.4%	0.5%
Memorial Drive	1.4%	0.5%	1.4%	0.5%	1.4%	0.5%
Lawrence Hargrave Drive	0.4%	0.5%	0.5%	0.5%	0.5%	0.5%
Other side streets	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%

In relation to the proposed traffic generating developments within the Thirroul and Bulli study areas, the approved trip generation rates and distributions have been applied to the following developments:

- Sandon Point residential subdivision
- Bulli Brickworks.

In combination, these developments are estimated to generate approximately 400 vehicle trips per hour during the weekday AM and PM peak periods. For the purposes of modelling, this trip generation rate has also been applied to the Saturday peak period on the basis that the *Guide to Traffic Generating Developments v2.2 (2002)* and *TDT 2013/04a* provides limited guidance for the proposed relevant land uses during this period. The traffic growth has been applied equally to both directions of the corridor by each origin zone as the TRACKS results show traffic growth is similar in both directions, particularly over the longer term.

Table 2.2 summarises the total future midblock traffic volumes for the modelling years 2026 and 2036, based on the projected traffic growth rate. It can be seen that generally traffic flows in the peak directions are expected to increase to between 1,200 and 1,500 vehicles per hour on Lawrence Hargrave Drive. This is well beyond the generally accepted capacity of 1,000 vehicles per hour for a single traffic lane in an urban environment.

Table 2.2 Estimated future traffic volumes at midblock

Lawrence Hargrave Drive (vehicles)	Year	AM peak hour	PM peak hour	Saturday peak hour
Northbound, south of Princes Street	2016	750	1,230	1,100
	2026	840	1,390	1,220
	2036	880	1,460	1,280
Southbound, south of Princes Street	2016	1,160	820	1,020
	2026	1,300	920	1,140
	2036	1,360	960	1,200

The details of the methodology used in estimating the future traffic growth was documented in memorandum *Bulli and Thirroul future traffic growth assumptions* (**Appendix A**). This memorandum was issued to Roads and Maritime in May 2016. Roads and Maritime has since approved WSP | Parsons Brinckerhoff's use of the proposed traffic growth rates in the future year traffic modelling.

3 Assessment results – Future Do-minimum

As advised by Roads and Maritime there are no current or planned future network upgrades to the Lawrence Hargrave Drive corridor. Thus, the road network modelled in the future year 'Do-minimum' scenarios is identical to the existing road network. With this in mind, the results of future do-minimum scenarios has been adopted as the reference case to estimate the impact of the proposed traffic options. The future year traffic demands and the corresponding traffic signal adjustments were applied in the do-minimum scenarios. The applied traffic signal adjustments were initially based on the results from Sidra, and then adjusted accordingly, following the analysis of the network operational performance from the microsimulation model.

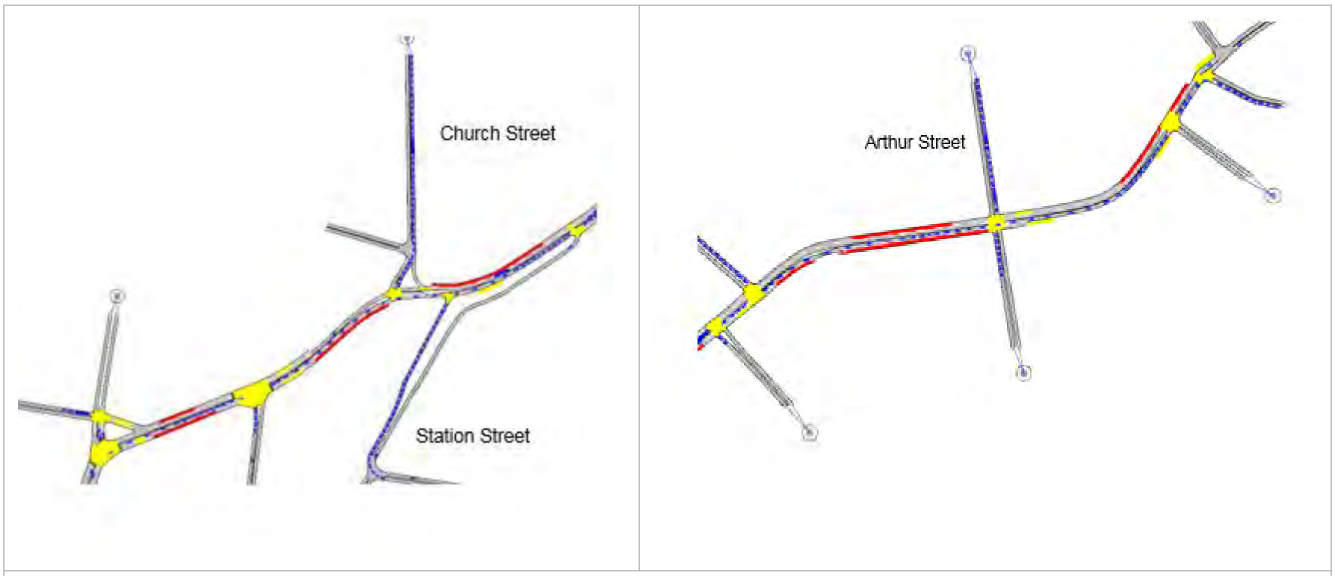
3.1 Network performance

Table 3.1 summarises the network statistics results of the do-minimum scenarios for the AM, PM and Saturday peak periods.

Table 3.1 Network statistics results – Do-minimum Scenarios

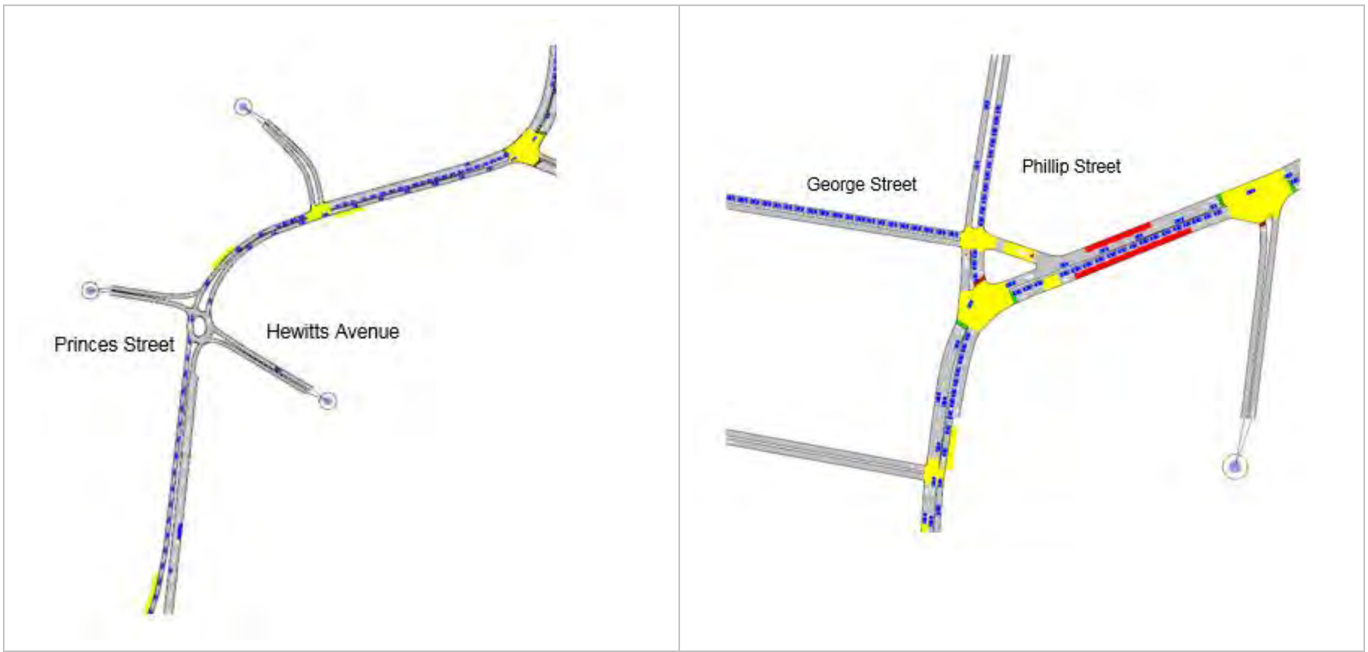
Performance indicators (all vehicles)	2026 7–9 am	2026 4–6 pm	2026 11 am–1 pm	2036 7–9 am	2036 4–6 pm	2036 11 am–1 pm
Total vehicle kilometre travelled (VKT)	7,820	8,970	9,570	8,020	9,240	9,560
Total vehicle hour travelled (VHT)	275	378	697	327	489	813
Average vehicle speed (km/h)	31	27	19	29	23	17
Average vehicle delay (seconds/km)	59	102	223	82	145	283
Completed trips	5,250	6,290	6,530	5,390	6,480	6,530

Figure 3.1 to Figure 3.3 provide the snapshots of the key network pinch points identified in the future do-minimum scenarios, for the respective AM, PM and Saturday peak hours. The results indicate that without the provision of any upgrade to the network, the Lawrence Hargrave Drive corridor will not have sufficient capacity to accommodate the projected future traffic demands. In addition, excessive delays on side streets were predicted at almost all the priority intersections. This is particularly evident at Arthur Street and Church Street, and at the signalised Phillip Street intersection.



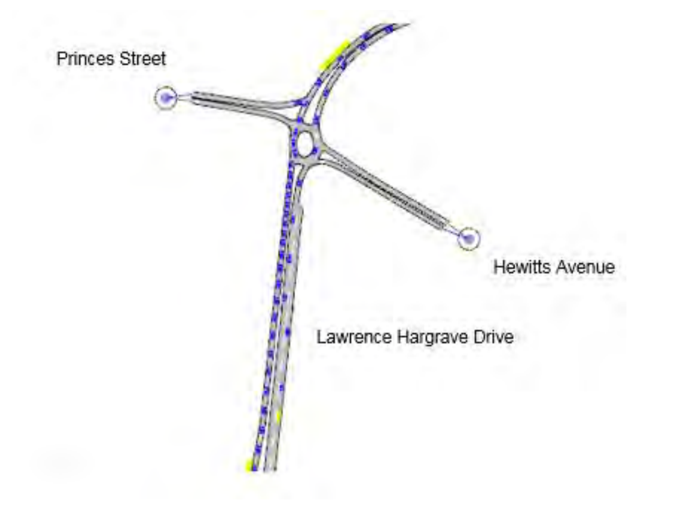
Excessive southbound queuing (over 1 km) on Lawrence Hargrave Drive and side street 'gridlock'– AM peak 2026 and 2036

Figure 3.1 Snapshots of congestion in future do-minimum scenario – AM peak



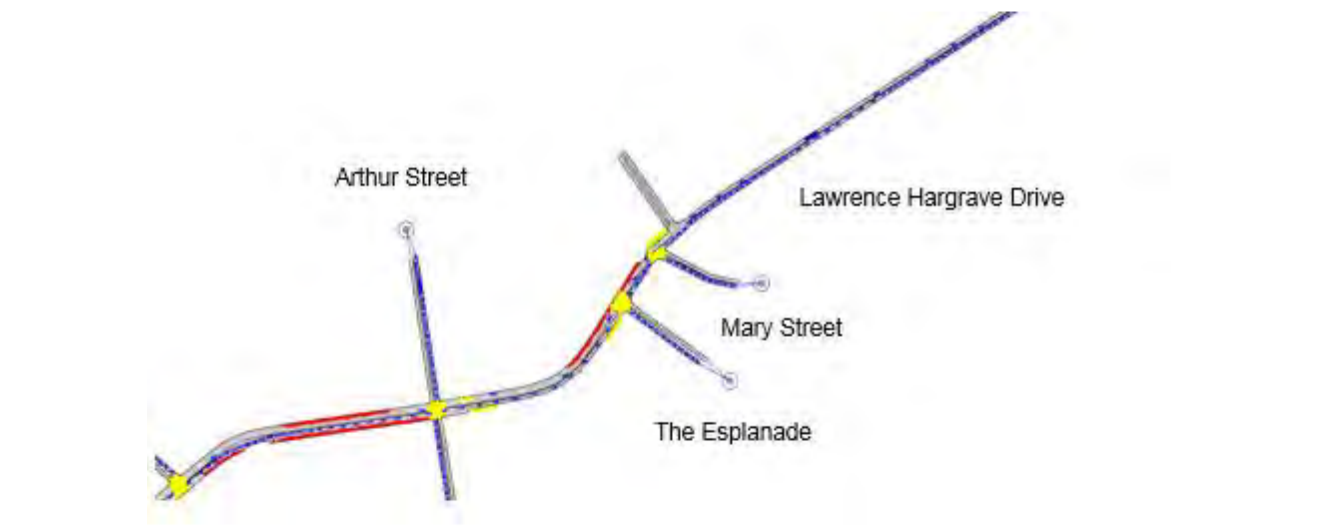
Northbound queuing on Lawrence Hargrave Drive extend back to south of Hewitts Avenue – PM peak 2026 and 2036	Southbound queuing on Lawrence Hargrave Drive, Phillip Street and George Street – PM peak 2026 and 2036

Figure 3.2 Snapshots of congestion in future do-minimum scenario – PM peak



Northbound queuing on Lawrence Hargrave Drive extend back to south of Hewitts Avenue – Saturday peak 2026

Southbound queuing on Lawrence Hargrave Drive extend back to Phillip Street – Saturday peak 2026



Excessive southbound queuing on Lawrence Hargrave Drive extend back beyond Mary Street – Saturday peak 2026 and 2036; in 2036 this was predicted to deteriorate into a network-wide ‘gridlock’

Figure 3.3 Snapshots of congestion in future do- minimum scenario – Saturday peak

3.2 Travel time difference

The travel time results were extracted from the future do-minimum scenarios for the AM, PM and Saturday peak hours. Due to the increasing model variability associated with the additional traffic demands in the network, it was deemed suitable to use additional seed values (on top of the default five seeds) in averaging the travel time result.

The results presented in Table 3.2 indicate that the percentage increase in travel time on Lawrence Hargrave Drive in 2036 (+20 years) is predicted to range between 17% and 102%. This is much higher than the magnitude of corresponding growth in traffic demand which ranges between 15% and 30%. Not surprisingly, the travel time results for the Saturday peak predict a doubling in travel time for the southbound flow in 2036 when compared with the current situation.

It should be noted that due to the increasing congestion on the corridor numerous trips were unable to be completed between 11 am and 12 pm and hence were continuing to travel on the network after 12 pm. As a consequence, the peak (or the busiest) hour was identified to be between 12 and 1 pm in the future year Saturday traffic model.

Table 3.2 Comparison of travel time results – future Do-minimum scenarios

Travel time (minutes)	Year	AM peak hour	PM peak hour	Saturday peak hour
Northbound on Lawrence Hargrave Drive, between south of Hewitts Avenue to Mary Street	2016	3.0	3.1	3.8
	2026	3.4	4.1	5.1
	2036	3.5	4.3	5.5
Difference 2036 vs 2016		+17%	+39%	+45%
Southbound on Lawrence Hargrave Drive, between Mary Street o south of Hewitts Avenue	2016	3.6	3.1	4.3
	2026	4.1	4.3	8.7
	2036	5.2	6.1	8.7
Difference 2036 vs 2016		+44%	+97%	+102%

3.3 Intersection Performance Summary

Figure 3.4, Figure 3.5 and Figure 3.6 present the intersection performance results in terms of Level of Service (LoS) for each of the AM, PM and Saturday peak hour periods. The results demonstrated that:

→ Due to the extensive traffic flows, the following priority controlled intersections would operate beyond capacity (primarily measured by traffic delay at side approaches) in all the peak hours.

- Church Street (All)
- Station Street (All)
- King Street (All)
- Arthur Street (All)
- Hewitts Avenue (PM)
- Lachlan Street (PM)
- The Esplanade (Saturday)
- Mary Street (Saturday).

It should be noted that some side approaches were predicted to have disproportionally excessive traffic delays, even though the volume of traffic flows is minimal (50 vehicles per hour). It is believed that under these conditions, motorists are likely to re-route to less severely congested side streets given the accessibility of the surrounding road network. These predicted changes to traffic patterns have not been captured in the traffic model.

→ The Lawrence Hargrave Drive and Phillip Street intersection is predicted to operate within capacity (LoS E) in both PM and Saturday peak hour. However, it is expected that with the increase in capacity at upstream sections and more traffic able to get through the road network, this intersection will exceed its operating capacity.

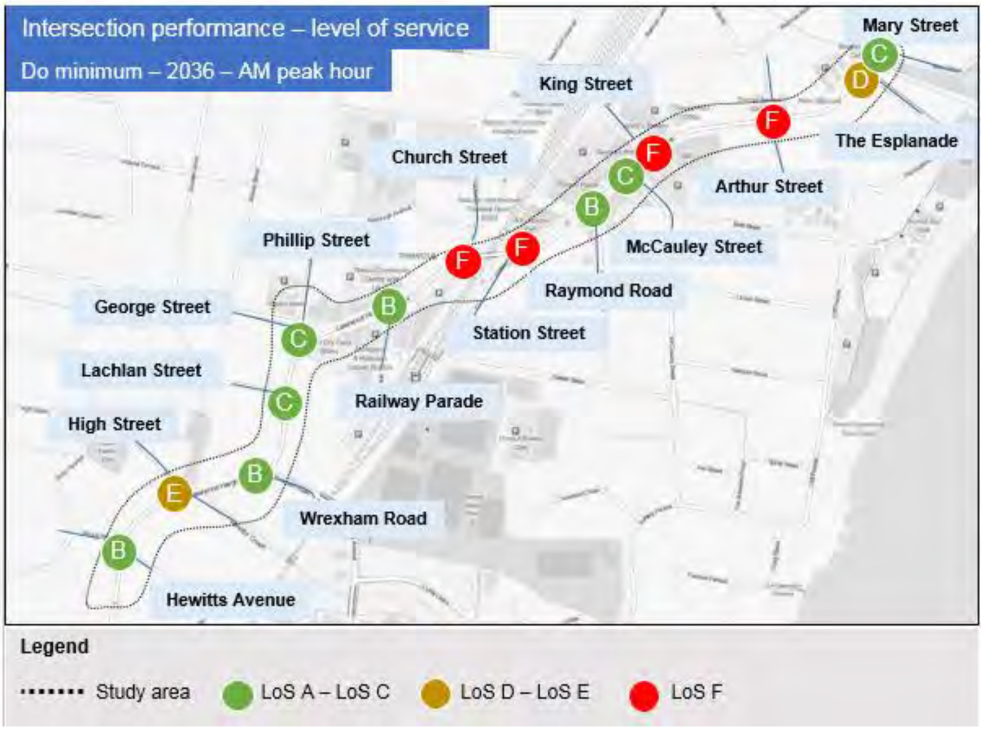


Figure 3.4 Intersection performance (LoS) Summary – Do-minimum – 2036 – AM peak

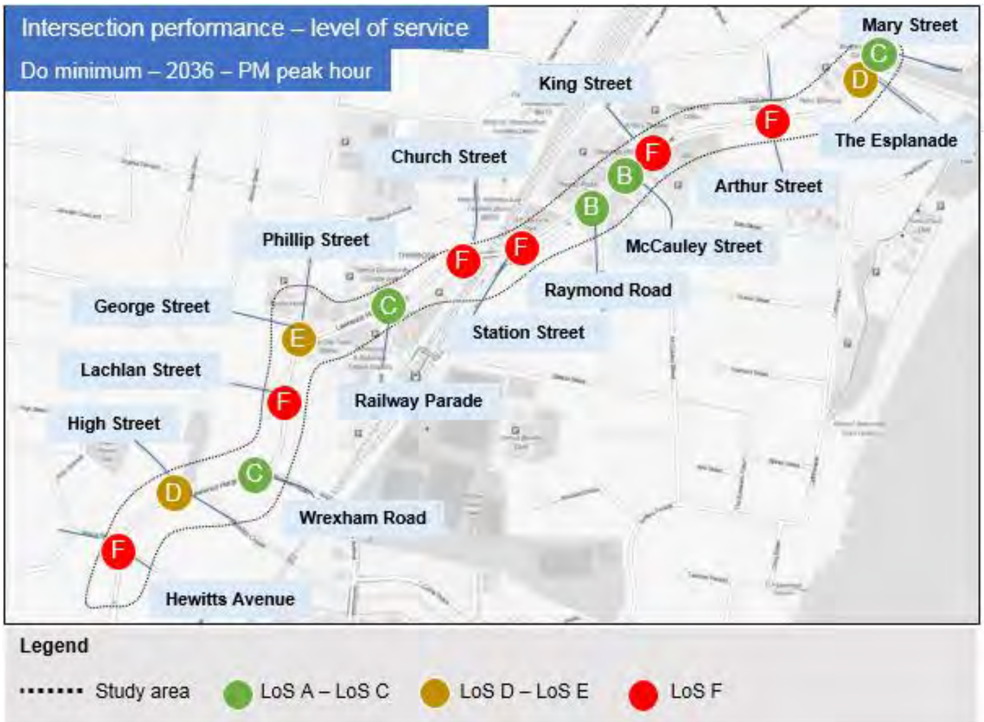


Figure 3.5 Intersection performance (LoS) Summary – Do-minimum – 2036 – PM peak

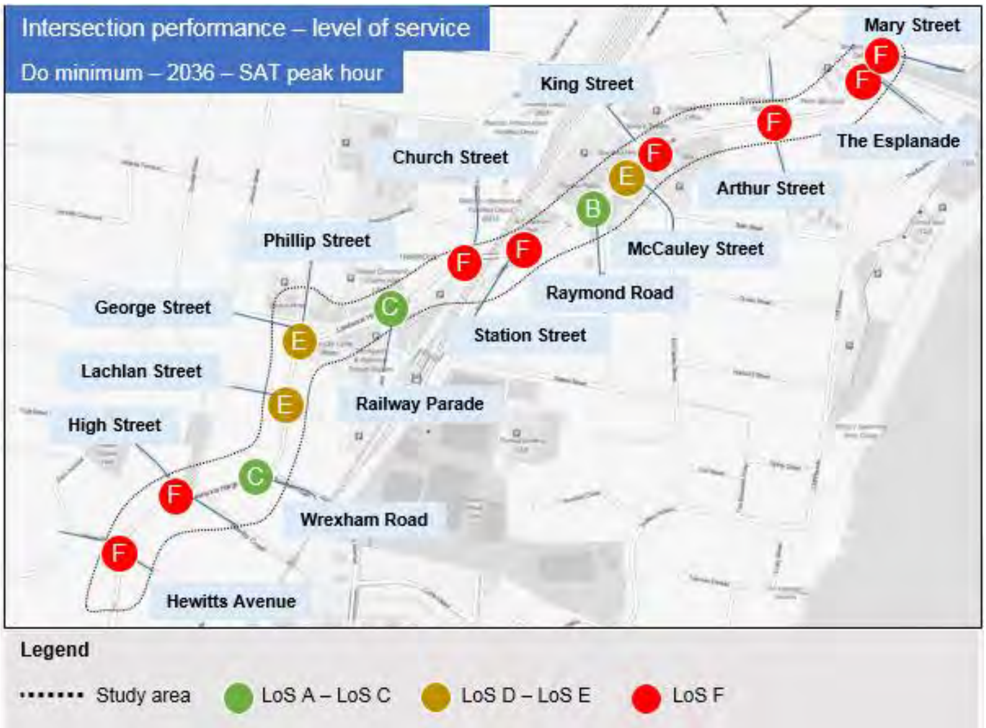


Figure 3.6 Intersection performance (LoS) Summary – Do-minimum – 2036 – Saturday peak

The results are consistent with the snapshots of network congestion in Figure 3.1, Figure 3.2 and Figure 3.3, and reflective of the travel time results on Lawrence Hargrave Drive summarised in Table 3.2.

4 Summary of preliminary traffic options

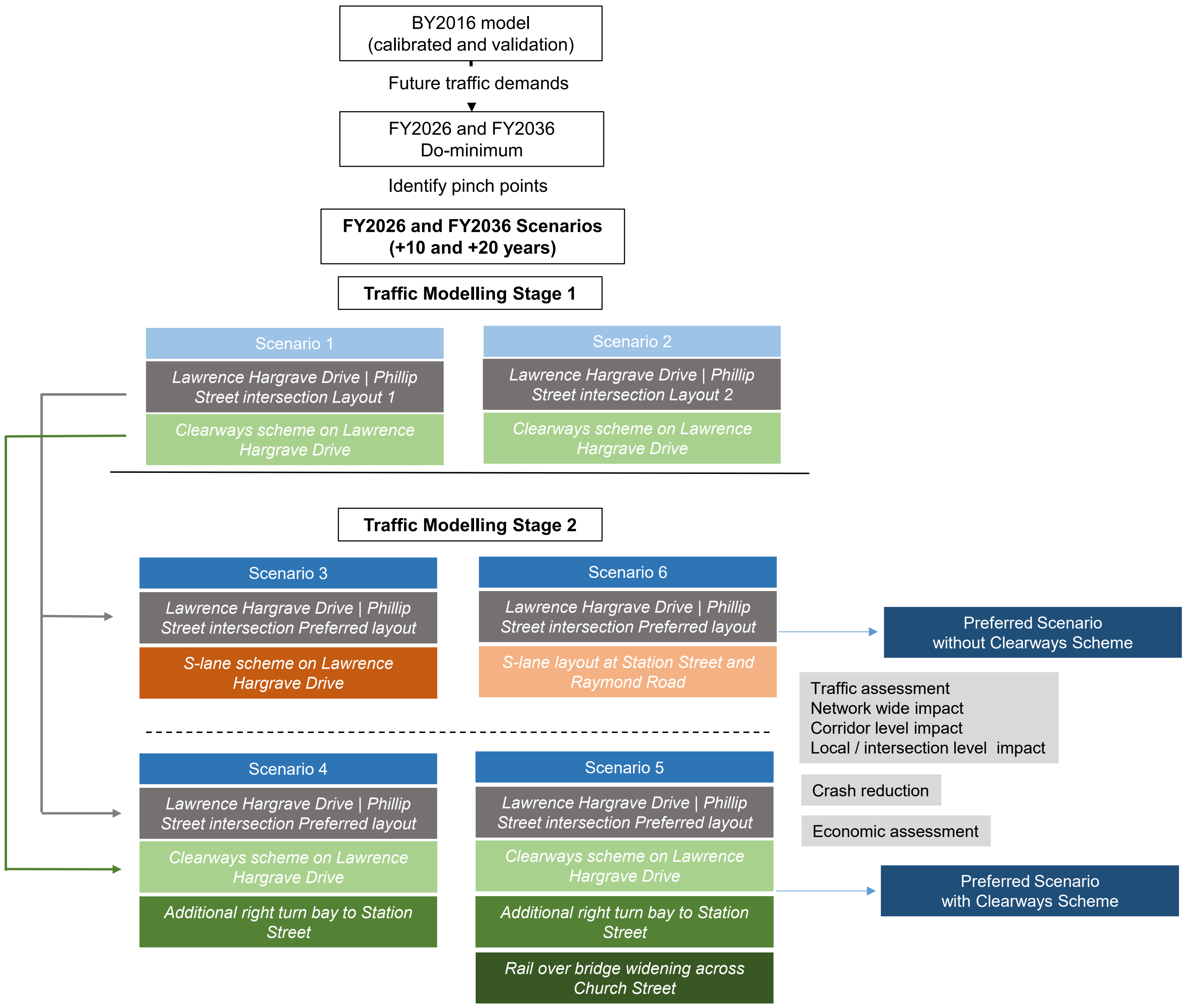
4.1 Traffic modelling methodology

The Lawrence Hargrave Drive Thirroul traffic modelling and design workshop was held on 10 May 2016. Roads and Maritime and WSP | Parsons Brinckerhoff held discussions on preliminary design options which were developed on the basis of traffic performance outputs from the 2016, 2026 and 2036 base/do-minimum traffic models.

A two-stage approach was adopted for the traffic modelling. This resulted in the identification of a number of future year scenarios (combination of traffic schemes). The methodology and scenarios are summarised in Figure 4.1. It should be noted the works outlined in the scenario schemes are conceptual and for traffic modelling purposes only to assess the relative operational benefits compared to the existing network layout. Details of each proposed traffic scheme are provided in section 4.2 and section 4.3.

The traffic modelling results from the AIMSUN microsimulation models have been captured at the following three levels of detail.

- → Network wide statistics: number of vehicle stops, vehicle delays, total vehicle travel time (VHT), vehicle travel distance (VKT), number of completed trips results of the entire Thirroul study area. This covers the study objectives of both through traffic movements on Lawrence Hargrave Drive and local area traffic (e.g. in and out of Thirroul town centre).
- → Lawrence Hargrave Drive corridor level: travel time performance along Lawrence Hargrave Drive.
- → Intersection level: traffic flows and delays at each individual intersection.



All the scenarios were tested in AM, PM and Saturday peak periods in 2026 and 2036
Scenarios required economic assessment were also assessed in 2016

Figure 4.1 Summary of future year scenarios

4.2 Modelling Stage 1 (Scenario 1 and 2)

Figure 4.2 summarises the scenarios to be assessed in Stage 1. The objective of Stage 1 is to determine the preferred layout of Lawrence Hargrave Drive | Phillip Street intersection under the scenario where the Clearway on Lawrence Hargrave Drive has been introduced.

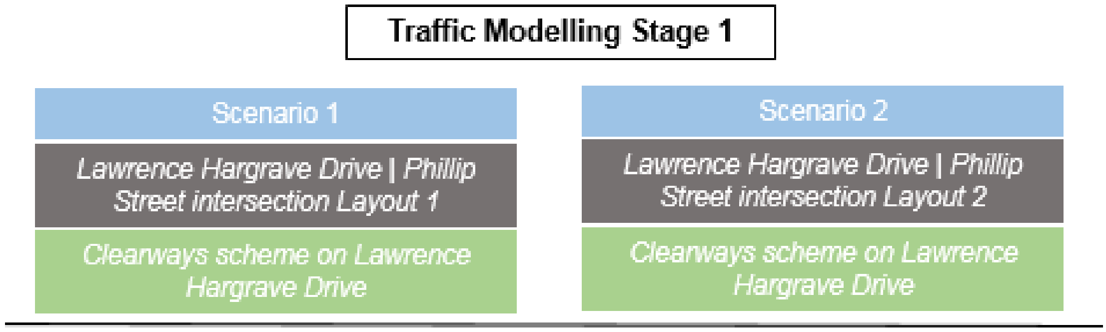


Figure 4.2 Summary of Scenario 1 and 2 (Stage 1)

The introduction of each scheme and upgrade is provided in section 4.2.1 and section 4.2.2.

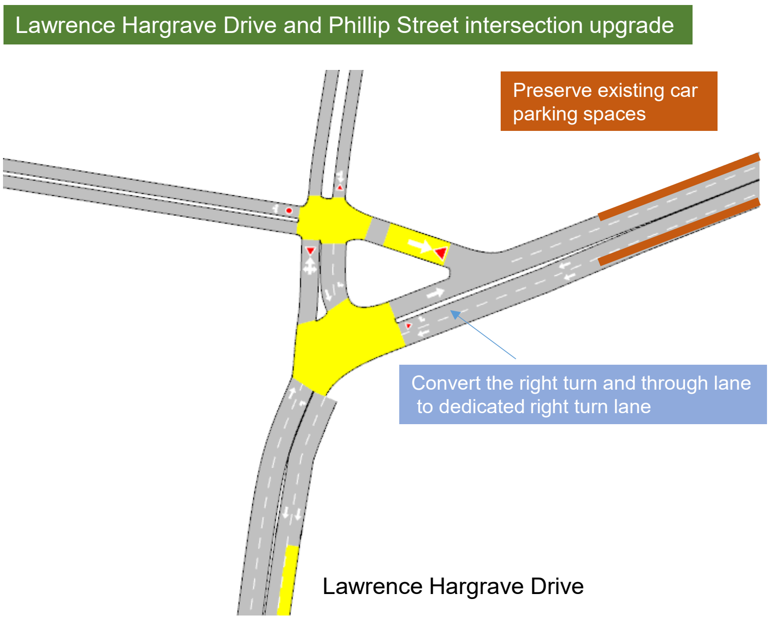
4.2.1 Lawrence Hargrave Drive | Phillip Street intersection upgrade

The results of the base and future year do-minimum models, identified the Lawrence Hargrave Drive and Phillip Street intersection as the most critical pinch point location with delays to traffic in both directions. In order for traffic congestion on Lawrence Hargrave Drive corridor to be eased, it is essential that the intersection be upgraded to provide for additional capacity. This is particularly important in the southbound direction. Figure 4.3 describes the proposed Scenario (Layout) 1 and Scenario (Layout) 2 configuration at this intersection.

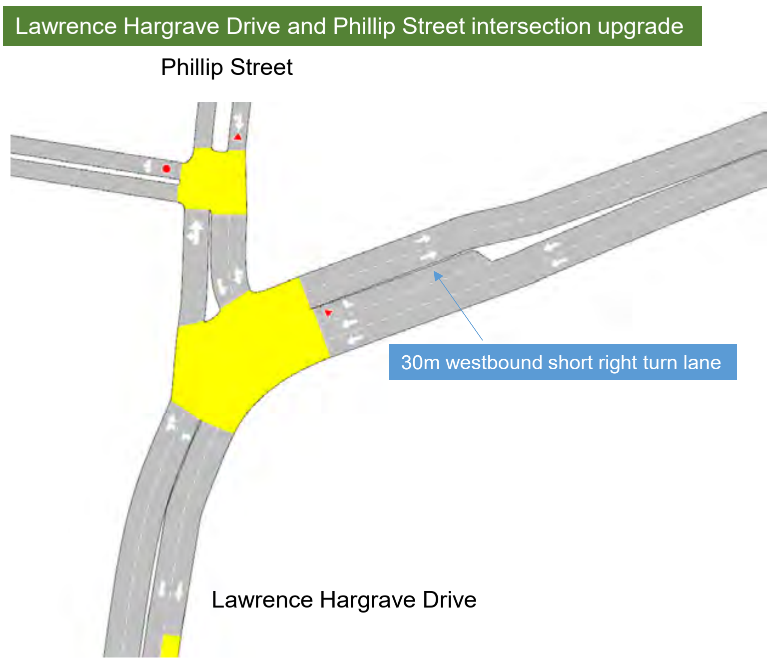
The Scenario 1 layout converts the median lane to a short right turn lane and re-aligns the through movement into the kerbside lane. This option aims to minimise the interaction between the through and right turn movements by providing the dedicated short right turn lane. This upgrade is unlikely to require the demolition of the existing triangular island.

The Scenario 2 layout includes the following upgrades and would require the demolition of the existing island.

- Provide two full through lanes and one 30 metre short right turn lane in the southbound direction
- Convert the existing left turn lane to a shared through and left turn lane in the northbound direction
- Convert the existing left turn lane on Phillip Street to a shared left and right turn lane.



Layout 1 (used in Scenario 1)



Layout 2 (used in Scenario 2)

Figure 4.3 Proposed intersection Layout 1 at Lawrence Hargrave Drive | Phillip Street

4.2.2 Clearways Scheme (Weekdays only)

The key outcome of implementing clearways on Lawrence Hargrave Drive during the weekday AM and PM peak is to provide two continuous lanes of capacity in peak directions, by utilising the existing kerbside lane. In order to achieve this some roadworks such as modifications to intersection and carriageway alignment are required. The initial scope of clearways scheme is from Princes Street to Mary Street; it would be extended with the potential rail over-bridge widening at Church Street.

With the proposed clearways, the widening on Lawrence Hargrave Drive at Hewitts Avenue and Wrexham Road in the southbound direction is required. Minor changes to other intersections (e.g. line markings) are incorporated in the traffic modelling.

4.3 Modelling Stage 2 (Scenario 3–6)

Figure 4.4 summarises the scenarios to be assessed in Stage 2. The preferred layout, established in Stage 1 for the Lawrence Hargrave Drive | Phillip Street intersection forms the base case for each of the scenarios assessed in Stage 2. The objective of Stage 2 is to identify an appropriate package of works which will expand on the improvements achieved with the upgrade of Lawrence Hargrave Dive/Phillip Street (Stage 1) over the length of the study corridor. All the scenarios have been modelled for the AM, PM and Saturday peak periods.

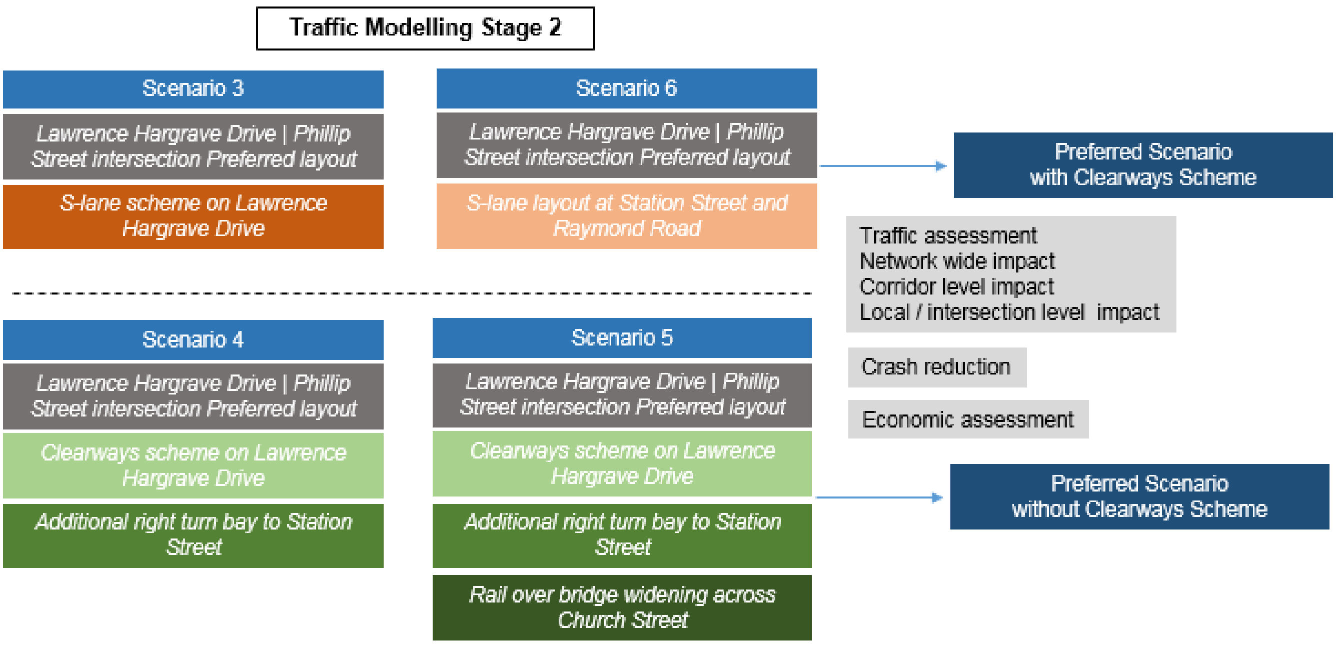


Figure 4.4 Summary of Scenario 3–6 (Stage 2)

As mentioned above, each of the scenarios in Stage 2 includes the preferred layout at Lawrence Hargrave Drive | Phillip Street intersection determined in Stage 1. In addition:

→ Scenario 3 provides S-lane schemes (lane marking changes to provided dedicated right turn lanes) in replace of clearways scheme. It also aims to address the corridor capacity constraint outside workday peak hours (e.g. on Saturday). The S-lanes would be implemented at 10 intersections on the corridor in this scenario. Both Scenario 4 and Scenario 5 have clearways scheme on Lawrence Hargrave Drive:
  - Scenario 4 also provides additional short right turn lane on Lawrence Hargrave Drive at Station Street.

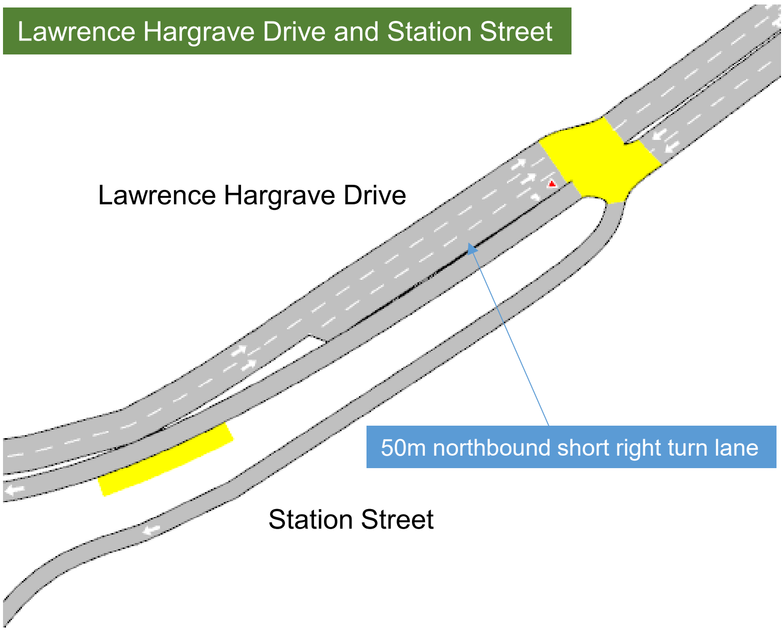
- Scenario 5 includes all measures identified in Scenario 4 and also widens the rail over-bridge at Church Street. This will facilitate the provision of a continuous two-lane section on the Lawrence Hargrave Drive corridor at Thirroul.

→ Scenario 6 is a low-cost option and provides S-lanes at three intersections at Station Street, Raymond Road and Lachlan Street.

The details of each scheme and upgrade works are provided in sections 4.3.1 to 4.3.4 inclusive.

4.3.1 Additional right turn bay on Lawrence Hargrave Drive to Station Street

The short northbound right turn lane (50 m) in Lawrence Hargrave Drive on the approach to Station Street was developed to remove the impact of in excess of 110 vehicles per hour turning right into Station Street on the efficiency of the through northbound movement. The modelled layout is shown in Figure 4.5.

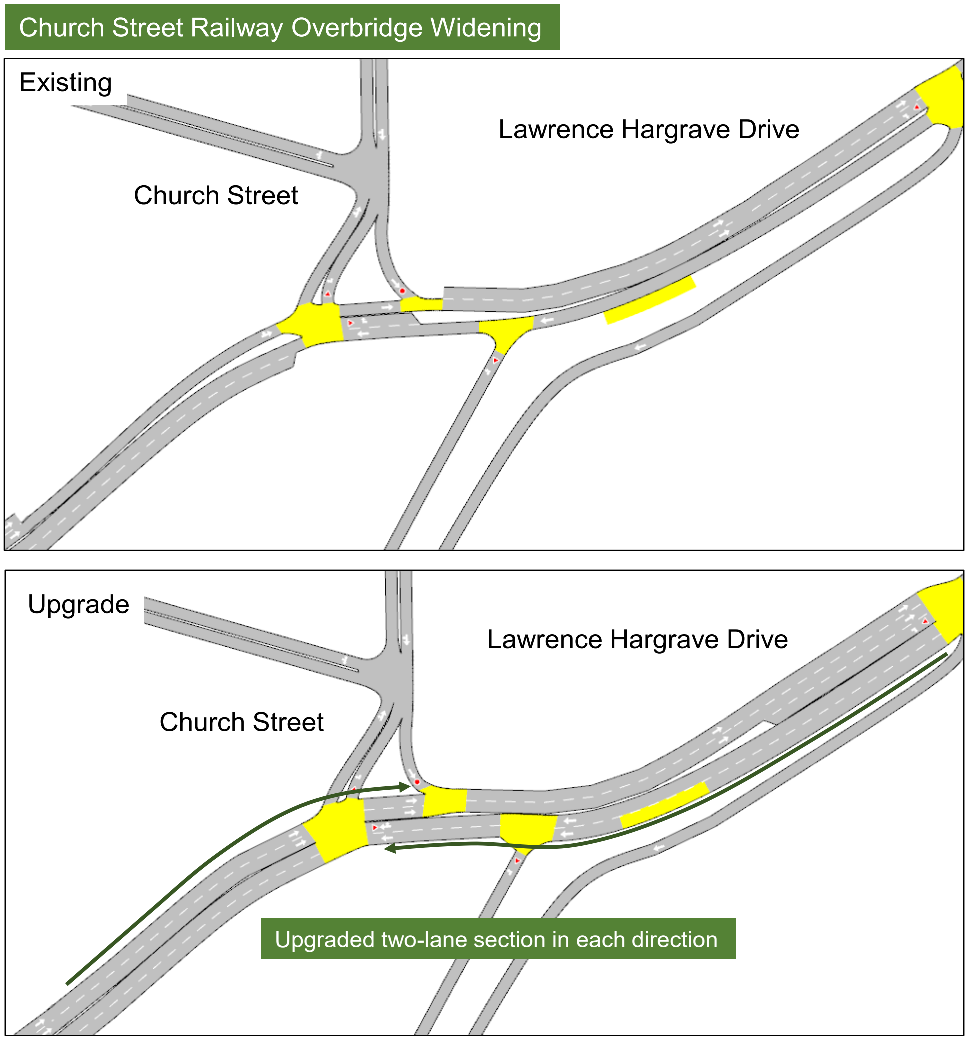


Used in Scenario 4 and Scenario 5

Figure 4.5 Additional right turn bay on Lawrence Hargrave to Station Street

4.3.2 Widening of Rail over-bridge on Lawrence Hargrave Drive

Subject to funding and agreement from relevant authorities, there is the potential opportunity to widen the existing single-lane rail over-bridge to two lanes in each direction. For the purpose of the traffic modelling assessment, the widening of the bridge is regarded as the optimum solution to reducing congestion on Lawrence Hargrave Drive. The modelled layout is shown in Figure 4.6.



Used in Scenario 5

Figure 4.6 Rail over bridge widening on Lawrence Hargrave Drive

The widening of this rail over bridge would also enable the scope of the clearways scheme to be extended from Church Street to Arthur Street in the southbound direction during the AM peak. The impact of this would be approximately 30 kerbside parking spaces.

4.3.3 S-lane Scheme on Lawrence Hargrave Drive

The objective of the S-lane scheme (providing a single continuous through lane on Lawrence Hargrave Drive) is to minimise the interaction between right turn and through movements whilst maintaining the majority of the existing kerbside parking. This is an alternative to the proposed clearway schemes on Lawrence Hargrave Drive. The provision of the S-lane treatment would also provide benefits to corridor efficiency outside the weekday peak hours, such as on Saturday. Table 4.1 summarises the preliminary intersection modification to accommodate the proposed S-lane.

Table 4.1 Summary of preliminary intersection modification (S-lane)

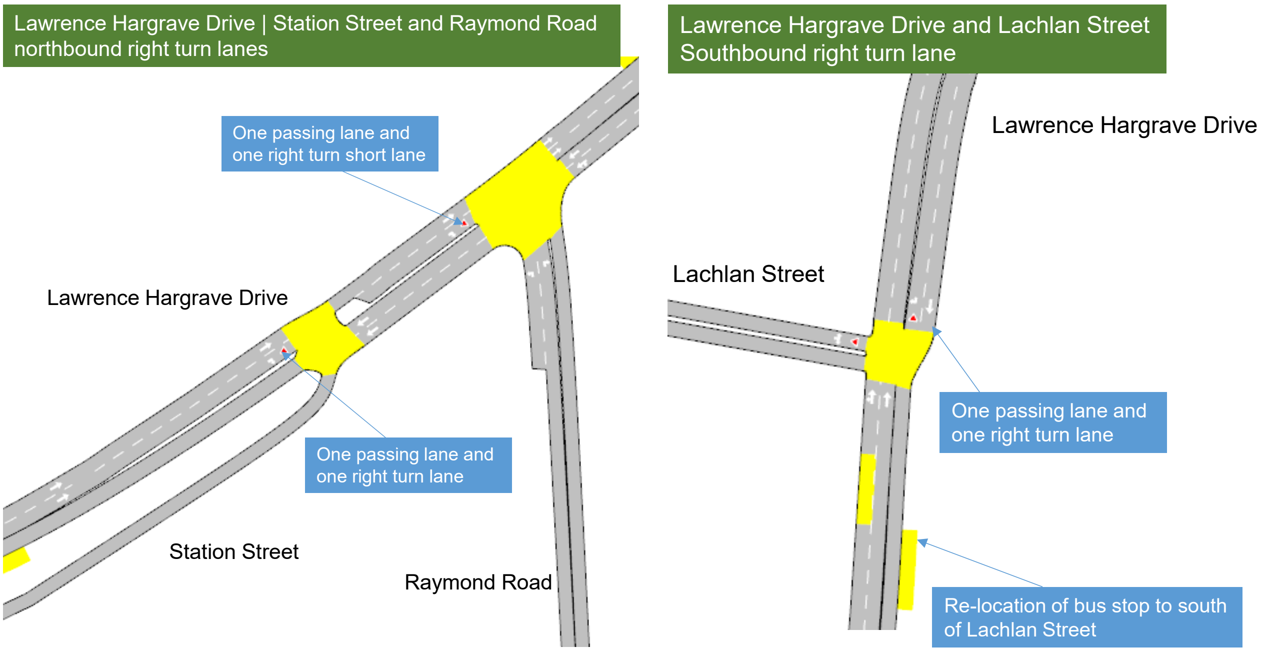
INTERSECTIONS	ACTION
Mary Street	Additional northbound 30m short right turn lane
The Esplanade	Northbound lanes convert to one through lane and one dedicated right turn lane
Arthur Street	Northbound and southbound lanes convert to one through lane and one dedicated right turn lane
King Street	Southbound lanes convert to one through lane and one dedicated right turn lane
McCauley Street	Northbound lanes convert to one through lane and one dedicated right turn lane
Raymond Road	Northbound lanes convert to one through lane and one dedicated 30 m right turn short lane
Station Street	Northbound lanes convert to one through lane and one dedicated right turn lane
Church Street	Retain existing layout
Railway Parade	Retain the existing layout due to proximity to the upgraded Lawrence Hargrave Drive | Phillip Street, this enables the northbound merge to be retained at just west of one-lane rail over-bridge
Phillip Street	Preferred layout from Stage 1 Modelling
Lachlan Street	Southbound lanes convert to one through lane and one dedicated right turn lane
Wrexham Road	Additional northbound 50m short right turn lane (signalised)
High Street	Additional southbound 30m short right turn lane
Princes Street	Retain existing roundabout layout

The space required for the majority of the proposed right turn lanes will be achieved by re-aligning the dedicated through lane to the kerbside on Lawrence Hargrave Drive; at some intersections, such as Arthur Street it would lead to a reduction in the number of kerbside parking spaces. For the traffic modelling purpose, the preliminary length of each short right turn lane was assumed to be either 30 metres or 50 metres based on a mix of the level of right turn traffic volumes and available road space. It should be noted this is the only scheme which provides for a northbound right turn bay at Wrexham Road.

Figure 4.7 Preliminary layout of proposed S-lane on Lawrence Hargrave Drive

4.3.4 S-lane scheme on Lachlan Street, Station Street and Raymond Road

The lane configuration on Lawrence Hargrave Drive is converted to one through passing lane and one right turn lane (Figure 4.8), at Lachlan Street, Station Street and Raymond Road. The layouts at all three intersections are identical to those adopted in Scenario 3.



Used in Scenario 6 (identical to Scenario 3)

Figure 4.8 Right turn lane on Lawrence Hargrave to Lachlan Street Station Street and Raymond Road

5 Stage 1 assessment results

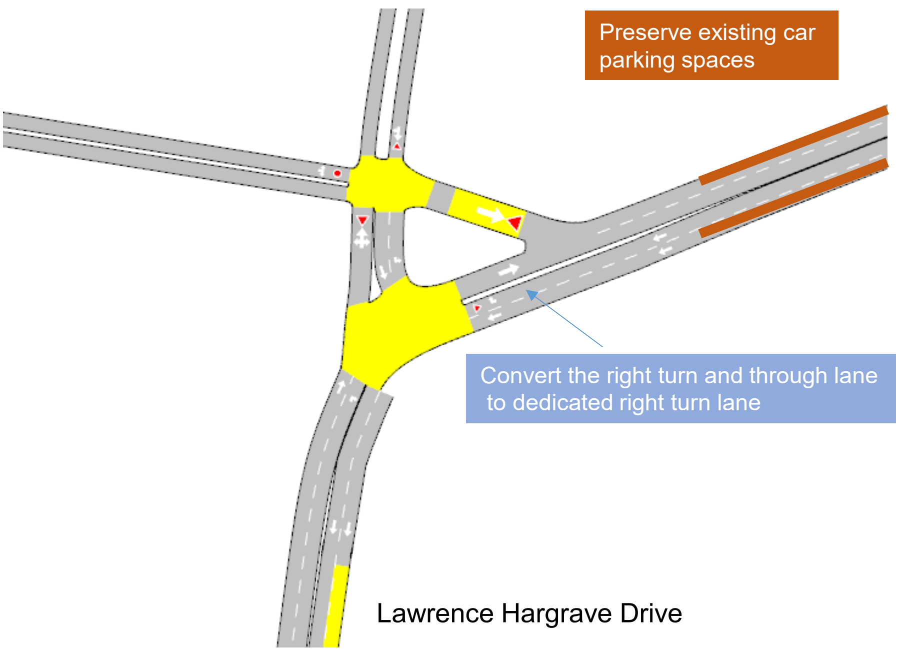
5.1 Scenario 1

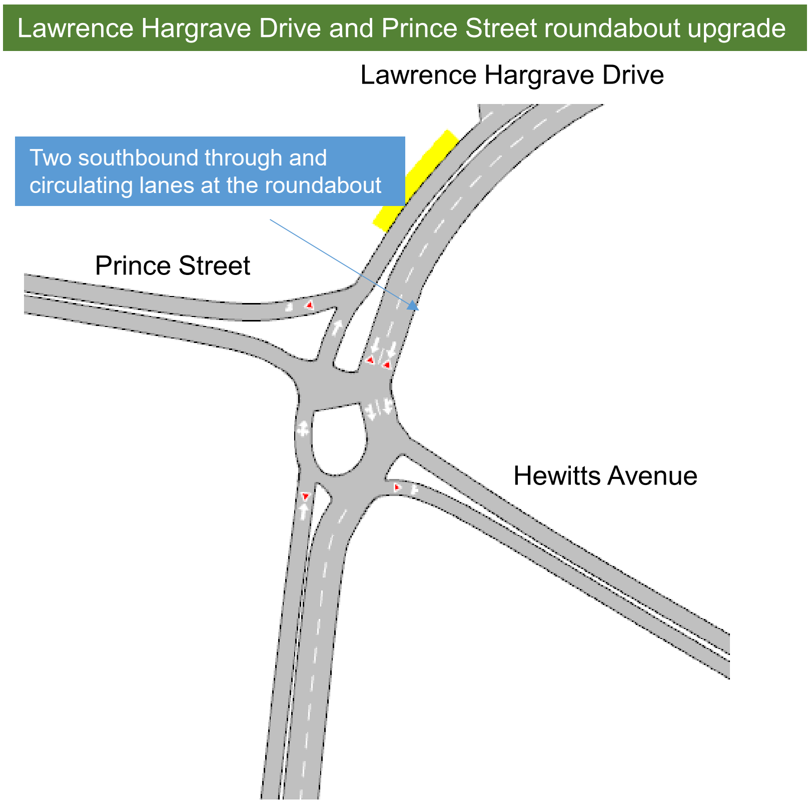
5.1.1 Introduction

Scenario 1 has been modelled for the future years 2026 and 2036 and includes the following key network upgrades as initially outlined in section 4.2.

- Revised intersection layouts as depicted in Figure 5.1 at the following intersections:
  - Lawrence Hargrave Drive | Phillip Street (Layout 1)
  - Lawrence Hargrave Drive | Wrexham Road
  - Lawrence Hargrave Drive | Prince Street roundabout
- Peak directional Clearways on Lawrence Hargrave Drive in both the AM and PM peak periods as shown in Figure 5.2.

Lawrence Hargrave Drive and Phillip Street intersection upgrade





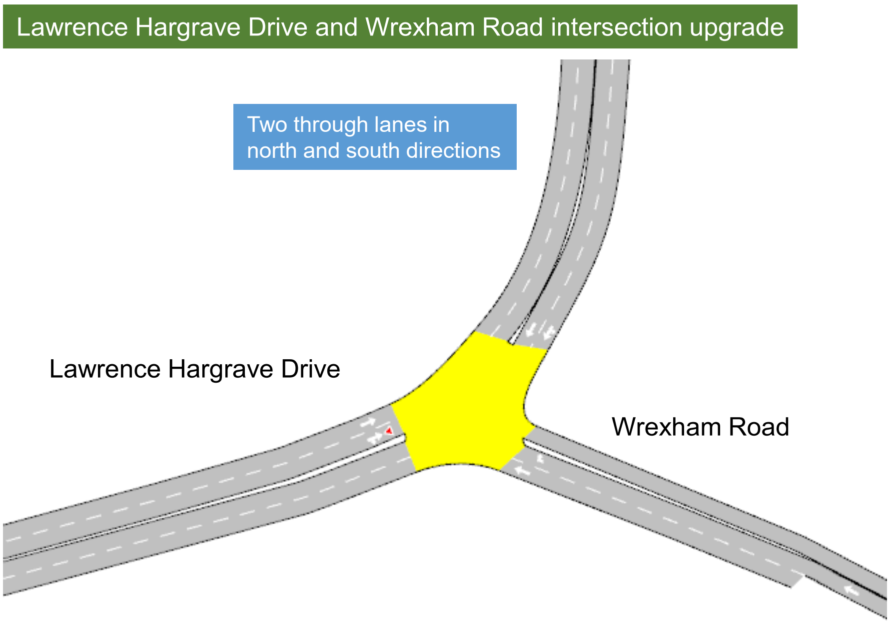
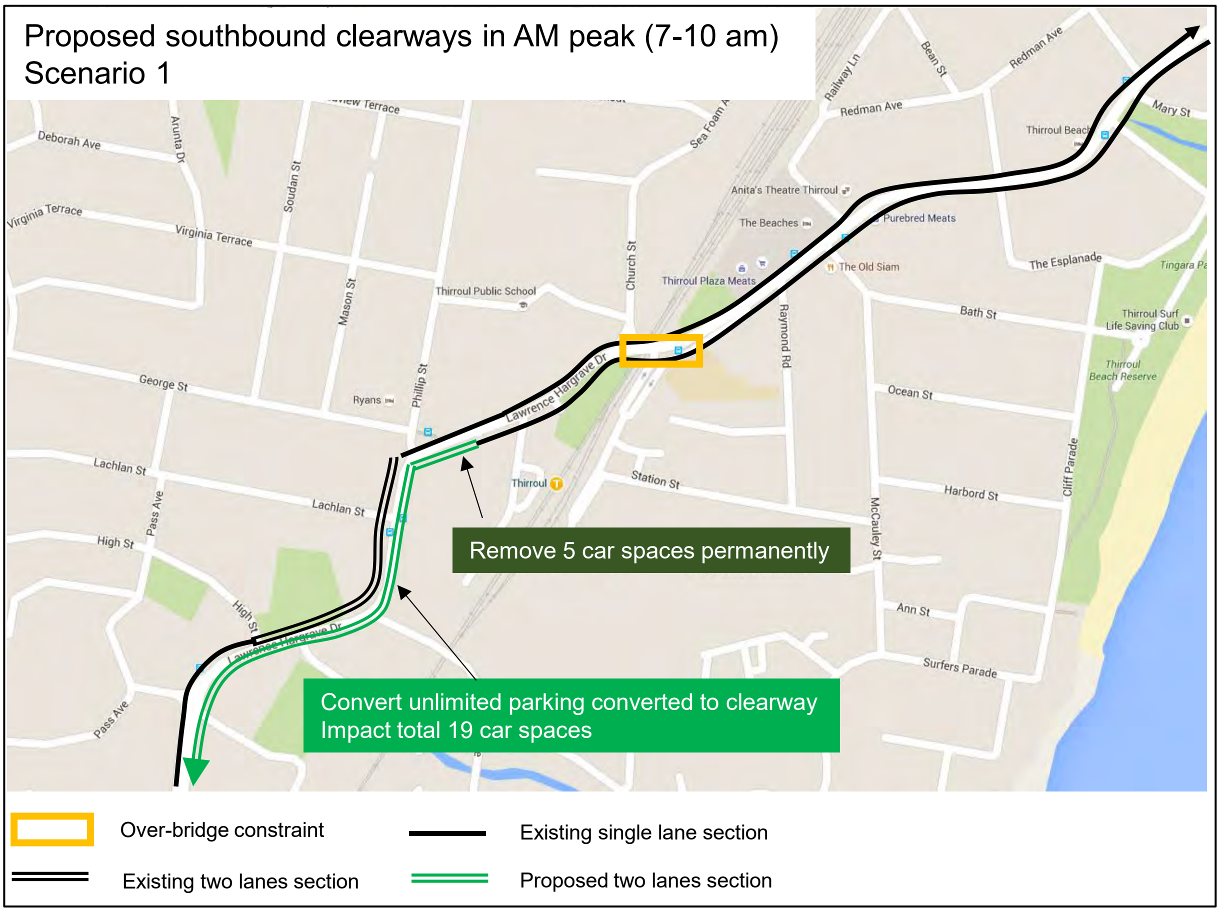
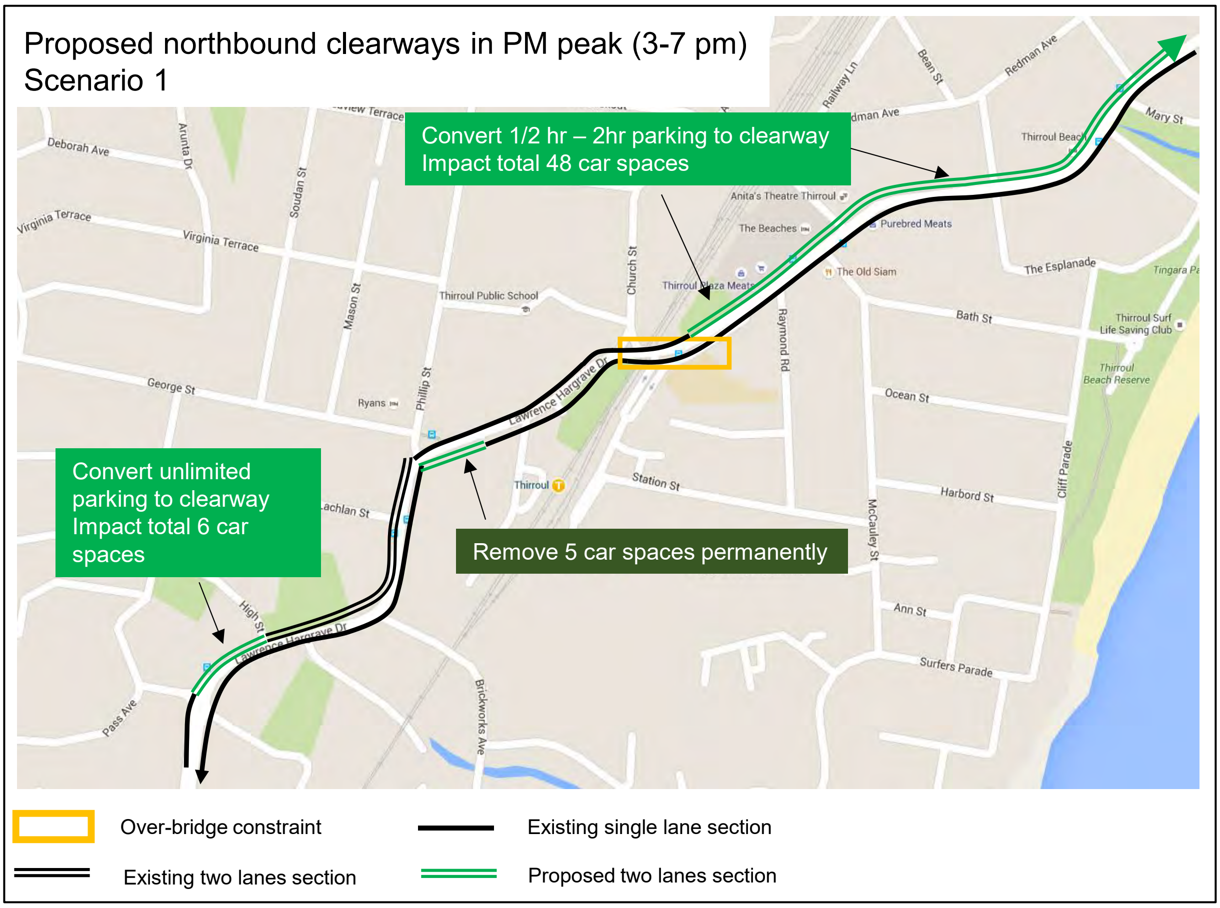


Figure 5.1 Proposed intersection upgrades on Lawrence Hargrave Drive – Scenario 1



→ In line with Layout 1 of Lawrence Hargrave Drive | Phillip Street intersection

→ Starts from Phillip Street and finish at south of Hewitts Avenue



→ In line with Layout 1 of Lawrence Hargrave Drive | Phillip Street intersection

→ Main section starts from Church Street and finish at north of Mary Street

→ Secondary section between High Street and Prince Street

Figure 5.2 Proposed clearways on Lawrence Hargrave Drive – Scenario 1

The number of car spaces identified as being removed as a result of the proposed Clearways is an estimation only and would need be confirmed as the design is progressed in more detail. As shown in Figure 5.2, a total of five car spaces are estimated to be permanently removed on Lawrence Hargrave Drive, including on weekends. The number of parking spaces partially impacted as a consequence of the Clearway is estimated to be approximately 73 spaces.

5.1.2 Network performance

The Scenario 1 scheme provides the following benefits to the road network:

- Increased corridor capacity from one lane to two in peak directions, provided by the clearways schemes, particularly at Hewitts Avenue and Wrexham Road.
- Increased intersection capacity at Lawrence Hargrave Drive | Phillip Street intersection, which provides dedicated lanes for southbound right turn and uninterrupted through movements.

A comparison between Scenario 1 and the corresponding Do-minimum scenarios for both the AM and PM peak periods is presented in Table 5.1 and Table 5.2. The comparison indicates a noticeable improvement to the network performance. In particular:

- Scenario 1 was predicted to have a higher value in VKT, by 3% in 2036, in line with the additional 3% vehicles which are able to complete the journey
- Scenario 1 would have a lower VHT, by 17% in the AM and 23% in the PM in 2036. The average vehicle delay would also reduce by up to 29 seconds in AM and 53 seconds in PM.

Table 5.1 Comparison of Network performance statistics – Scenario 1 vs Do-minimum AM peak

Performance indicators (all vehicle classes)	Diff 2026 7–9 am	Diff% 2026 7–9 am	Diff 2036 7–9 am	Diff% 2036 7–9 am
Total vehicle kilometre travelled (VKT)	+152	+2%	+252	+3%
Total vehicle hour travelled (VHT)	-27	-10%	-56	-17%
Average vehicle speed (km/h)	+3	+8%	+4	+13%
Average vehicle delay (seconds/km)	-15	-25%	-29	-36%
Completed trips	+87	+2%	+164	+3%

Table 5.2 Comparison of Network performance statistics – Scenario 1 vs Do-minimum PM peak

Performance indicators (all vehicle classes)	Diff 2026 4–6 pm	Diff% 2026 4–6 pm	Diff 2036 4–6 pm	Diff% 2036 4–6 pm
Total vehicle kilometre travelled (VKT)	+166	+2%	+277	+3%
Total vehicle hour travelled (VHT)	-48	-13%	-115	-23%
Average vehicle speed (km/h)	+4	+13%	+6	+26%
Average vehicle delay (seconds/km)	-25	-25%	-53	-36%
Completed trips	+113	+2%	+187	+3%

The comparison between the Scenario 1 and do-minimum scenarios presented in Table 5.3 for the Saturday peak periods indicates that:

- Scenario 1 was predicted to have a higher value in VKT, by 5% in both 2026 and 2036; this is in line with the additional 5% vehicles which are able to complete the journey
- VHT in Scenario 1 would reduce by 16% in both 2026 and 2036; the average vehicle delay would reduce by 64 seconds (or 23%) whilst the average speed would increase by 3 km/h in 2036.

Table 5.3 Comparison of Network performance statistics – Scenario 1 vs Do-minimum Saturday peak

Performance indicators (all vehicle classes)	Diff 2026 11 am–1 pm	Diff% 2026 11 am–1 pm	Diff 2036 11 am–1 pm	Diff% 2036 11 am–1 pm
Total vehicle kilometre travelled (VKT)	+467	+5%	+448	+5%
Total vehicle hour travelled (VHT)	-110	-16%	-129	-16%
Average vehicle speed (km/h)	+3	+15%	+3	+16%
Average vehicle delay (seconds/km)	-52	-23%	-64	-23%
Completed trips	+367	+6%	+351	+5%

5.1.3 Travel time difference

The travel time on Lawrence Hargrave Drive was assessed in the AM, PM and Saturday peak periods. Table 5.4 summarises the results of Scenario 1 and the difference to those achieved in the Do-minimum scenarios.

Table 5.4 Comparison of travel time results – Scenario 1 vs Do-minimum

Travel time results and difference (minutes)			AM peak hour	PM peak hour	Saturday peak hour
Northbound on Lawrence Hargrave Drive, between Hewitts Avenue to Mary Street	2026	Do-minimum	3.4	4.1	5.1
		Scenario 1	3.1	3.4	5.5
		Difference	-0.3	-0.7	+0.4
		Difference %	-8%	-16%	+8%
	2036	Do-minimum	3.5	4.3	5.5
		Scenario 1	3.5	3.8	6.9
		Difference	-0.1	-0.5	+1.4
		Difference %	-2%	-12%	+26%
Southbound on Lawrence Hargrave Drive, between Mary Street south of Hewitts Avenue	2026	Do-minimum	4.1	4.3	8.7
		Scenario 1	3.2	3.5	6.7
		Difference	-0.9	-0.9	-2.0
		Difference %	-22%	-20%	-23%
	2036	Do-minimum	5.2	6.1	8.7
		Scenario 1	3.3	4.1	6.6
		Difference	-1.9	-2.1	-2.1
		Difference %	-36%	-34%	-24%

The results in the above tables demonstrated that during the weekday AM and PM peak periods:

- The northbound travel time on Lawrence Hargrave Drive was predicted to reduce by over 30 seconds in PM peak in both 2026 and 2036, primarily due to the impact of the northbound clearway.
- The southbound travel time on Lawrence Hargrave Drive was predicted to reduce by almost 1 minute in 2026 and 2 minutes in 2036. This is due to the increased corridor capacity provided by the southbound clearway, and the dedicated right turn lane to Phillip Street.

For the Saturday peak the results indicate:

- The southbound travel time would reduce by 2 minutes in both 2026 and 2036. This was due to the reduction of lane changing movements by the dedicated right turn lane to Phillip Street
- The northbound travel time was predicted to increase by up to 1.4 minutes in 2036. This is primarily due to the filter right turn movements at several intersections (e.g. Railway Parade) opposed by increasing southbound flows.

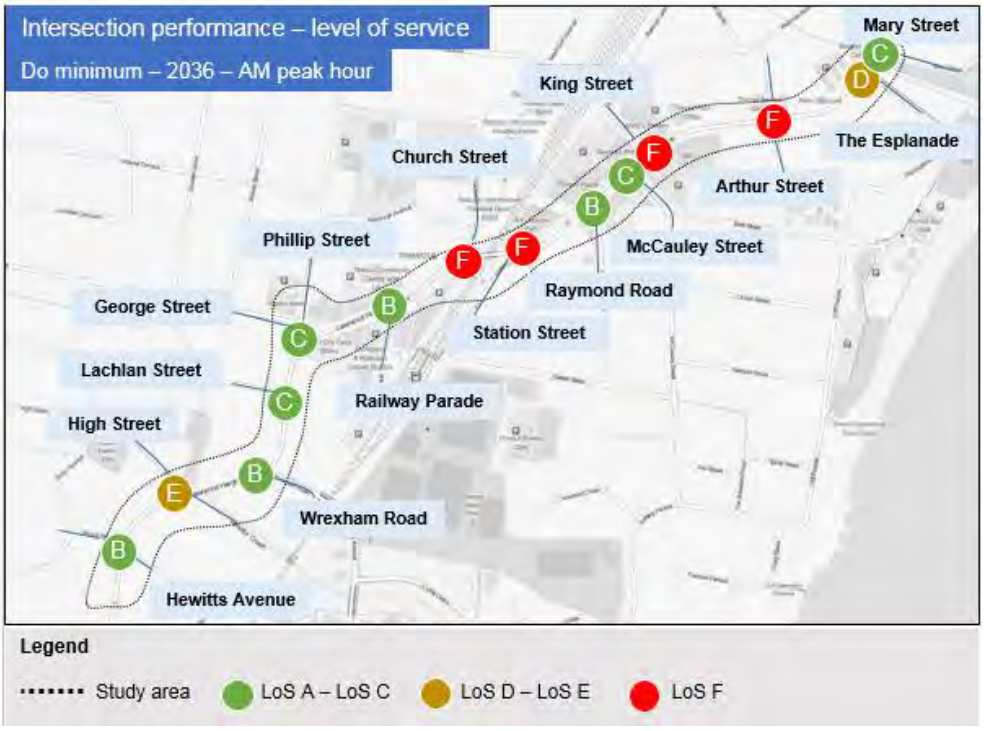
The full results of the travel time associated with Scenario 1 are presented in Appendix B1.

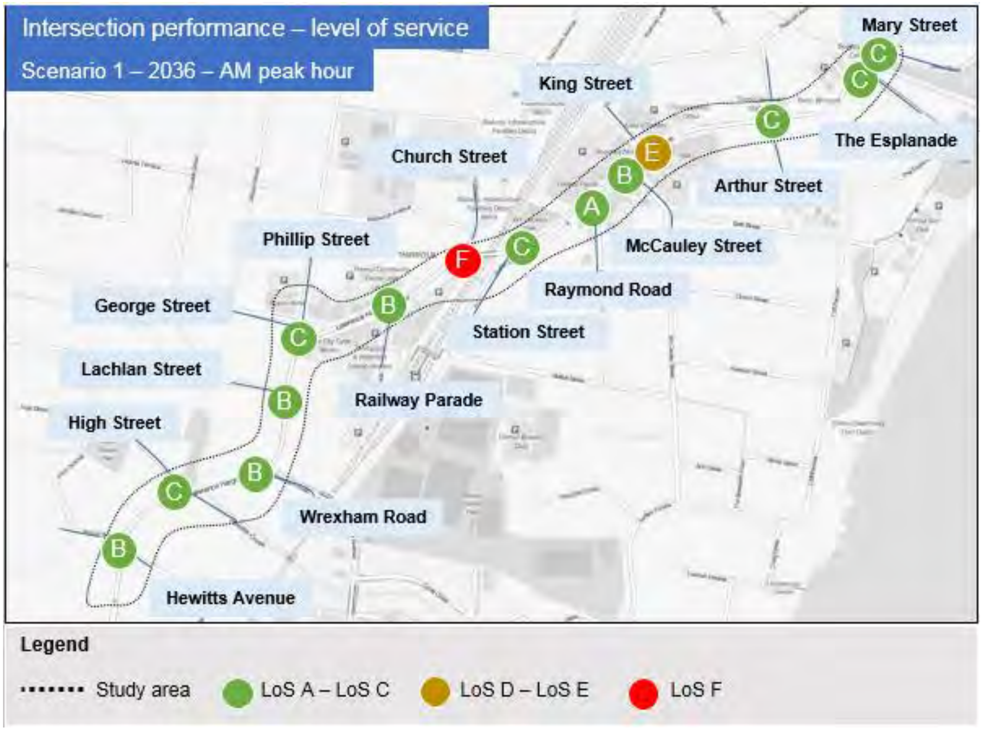
5.1.4 Intersection Performance Summary

Figure 5.3–Figure 5.5 inclusive, compare the intersection performances between Scenario 1 and the corresponding do-minimum scenarios in the AM, PM and Saturday peak hours. The results also identified the locations of those intersections (side approaches at priority controlled intersection) in Scenario 1 where the level of service (LoS) is improved from the LoS F achieved in the do-minimum scenarios.

The alleviation of congestion in both directions on Lawrence Hargrave Drive in the weekday AM and PM peak, leads to a reduction in the traffic delay on the side streets (e.g. Station Street) and removes the extent of stationary queuing observed in do-minimum scenarios.

Although Scenario 1 would alleviate the queuing in the southbound direction during the Saturday peak hour, the intersection north of King Street would still operate beyond capacity. Adversely, the higher traffic throughput in the southbound direction was predicted to impact on the opposing northbound right turn movement which in turn would lead to increased delays to the through northbound movement.

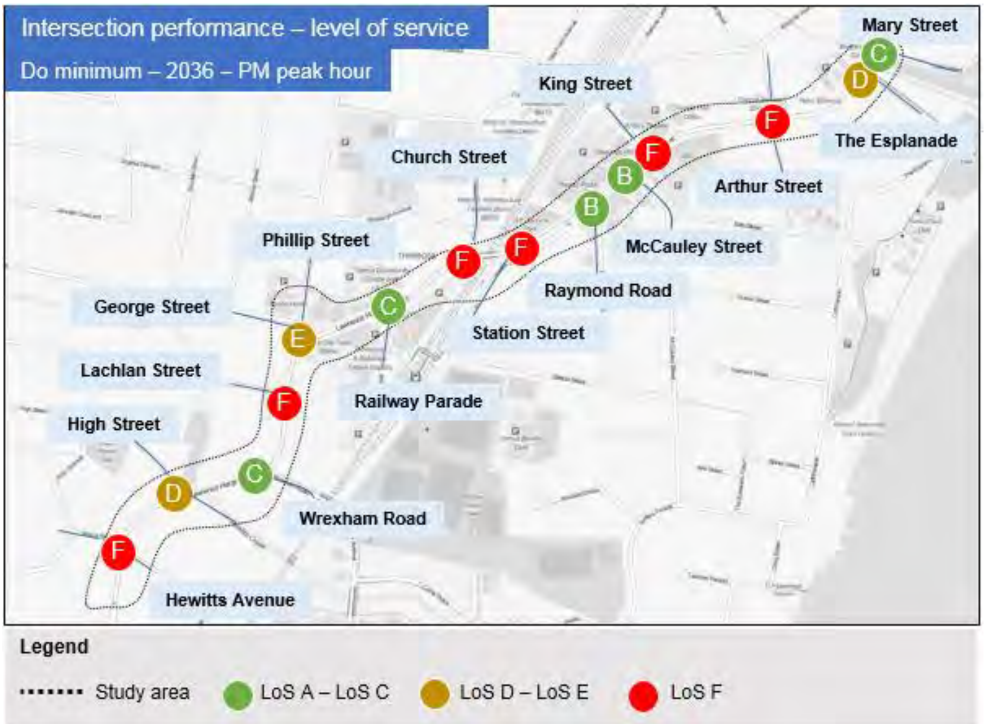


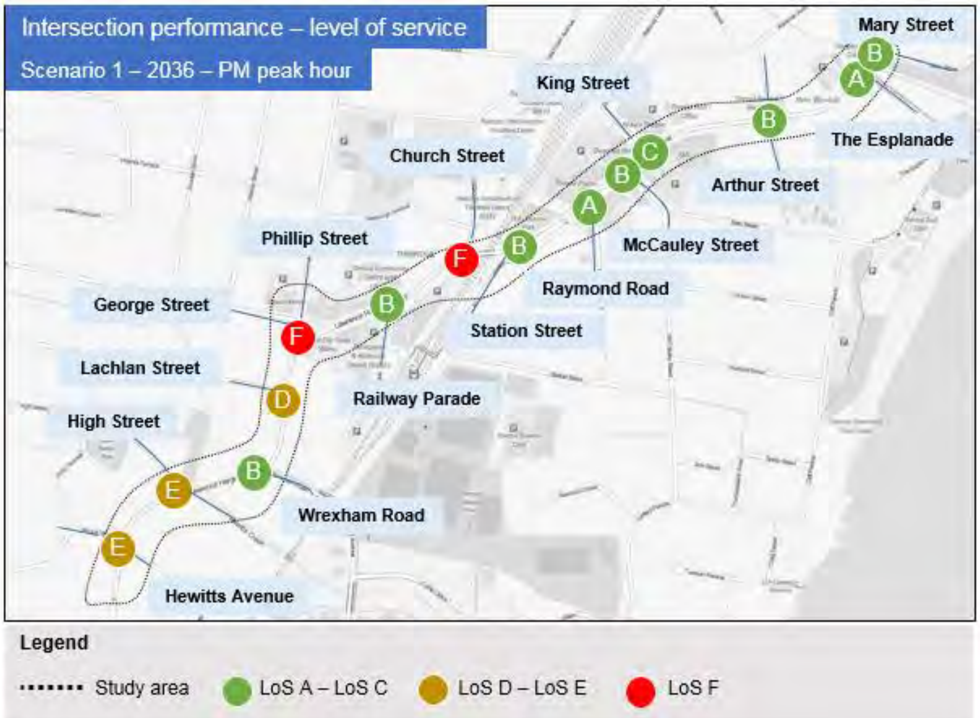


List of intersections improved from LoS F in do-minimum scenarios:

- Arthur Street (to LoS C)
- King Street (to LoS E)
- Station Street (to LoS C).

Figure 5.3 Intersection performance summary Scenario 1 vs Do-minimum – 2036 – AM peak

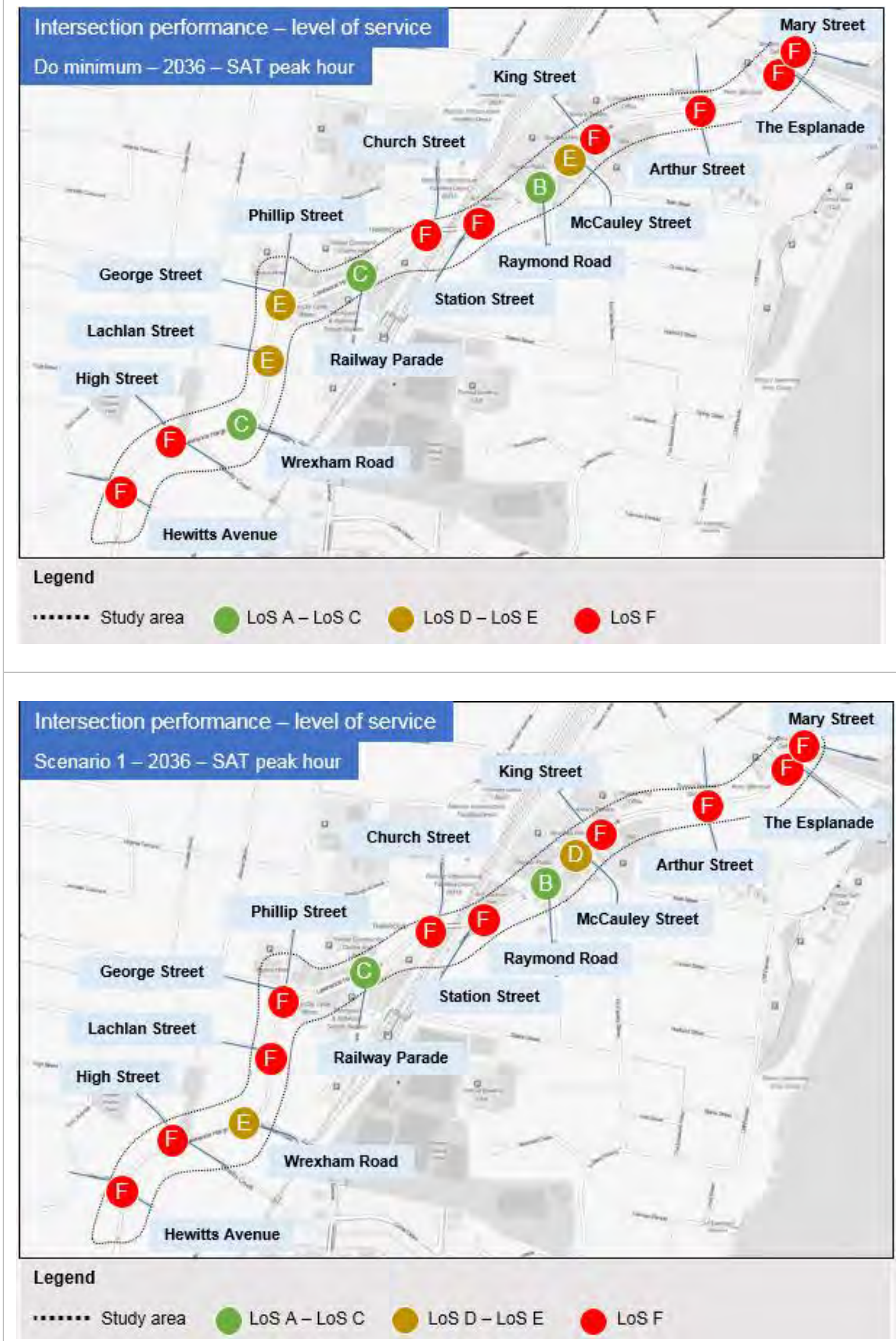




List of intersections improved from LoS F in do-minimum scenarios:

- Arthur Street (to LoS B)
- King Street (to LoS C)
- Station Street (to LoS B)
- Lachlan Street (to LoS D)
- Hewitts Avenue (to LoS E).

Figure 5.4 Intersection performance summary Scenario 1 vs Do-minimum – 2036 – PM peak



Following intersections havng worsened performance due to higher southbound opposing throuput:

- Laclan Street
- Phillip Street
- Wrexham Road.

Figure 5.5 Intersection performance summary Scenario 1 vs Do-minimum – 2036 – Saturday peak

5.1.4.1 LAWRENCE HARGRAVE DRIVE | PHILLIP STREET INTERSECTION

The southbound throughput on Lawrence Hargrave Drive at Phillip Street intersection was predicted to increase by between 50 and 140 veh/hr in all the peak periods. This increase in throughput is primarily a consequence of providing a dedicated right turn lane which reduces the lane changing movements approaching the stop line. Where the corridor is highly congested, such as Lawrence Hargrave Drive corridor, this type of measure can contribute to significant travel time performance on a corridor. In the case of Lawrence Hargrave Drive a two minute travel time reduction is achieved over the length of the entire corridor (refer to Table 5.4).

Figure 5.6 compares the traffic delay at Lawrence Hargrave Drive | Phillip Street intersection, with the existing and the revised southbound lanes layout in Scenario 1.

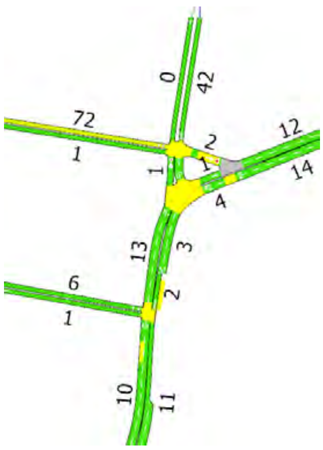
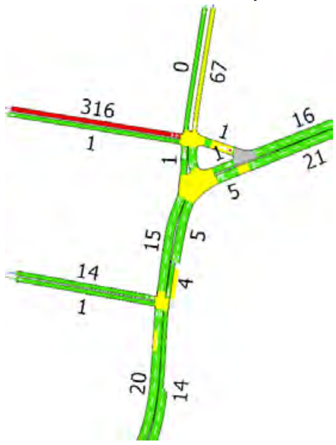
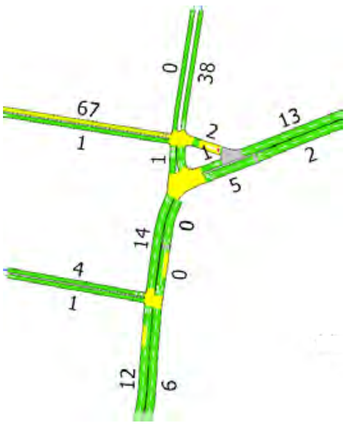
Do-minimum AM Traffic delay - 2036 	Do-minimum PM Traffic delay - 2036 	Do-minimum SAT Traffic delay - 2036 
Scenario 1 AM Traffic delay - 2036 	Scenario 1 PM Traffic delay - 2036 	Scenario 1 SAT Traffic delay - 2036 
AM peak: Stop line delay reduction in soutbhound direction due to the revised lane configuraiton.	PM peak: Stop line delay reduction in southbound direction due to the revised lane configuraiton.	Saturday peak: Increased southbound throughput would be capped by the downstream one-lane section, and in turn propagate back and reduce the throughput/discharge rate of traffic from Phillip Street and George Street.

Figure 5.6 Delays at Lawrence Hargrave Drive | Phillip Street intersection (2036) – Scenario 1 vs Do-minimum

In summary, the revised southbound lane configuration would reduce the traffic delay at the upstream sections, by minimising the lane changing movement at this critical intersection. The benefit at an intersection level is most evident in the AM peak, with the compound impact provided by the downstream southbound clearway. However, in Saturday peak, the increased throughput would lead to the propagated queueing from downstream sections and in turn reduce the effective green time at Phillip Street and George Street.

5.1.5 Summary

Table 5.5 summarises the network performance benefits, travel time savings and impact on Lawrence Hargrave Drive | Phillip Street provided by Scenario 1 in future year 2036.

Table 5.5 Summary of Scenario 1 impact in 2036

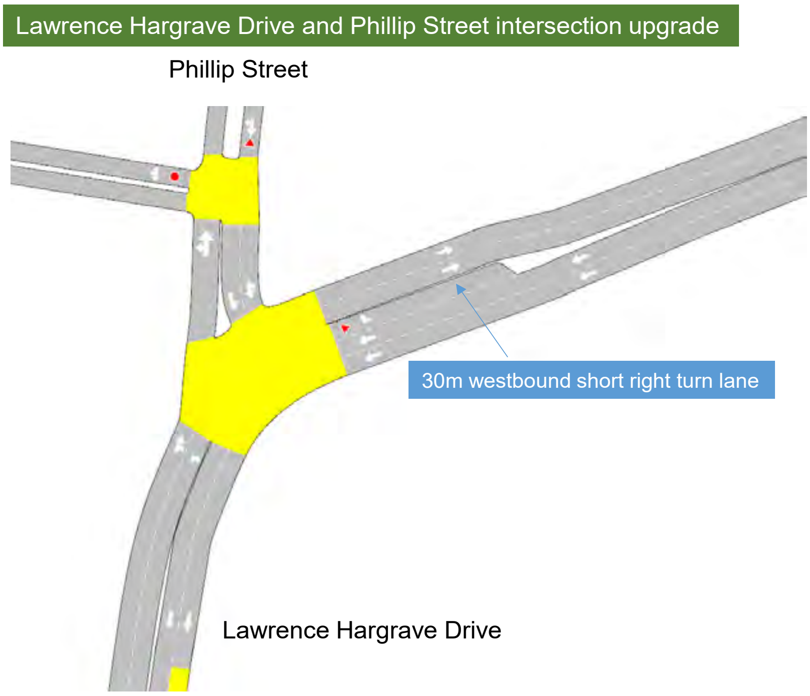
Scenario 1	Network results	Travel time savings	Intersection performance
AM	→ +3% vehicle distance travelled. → -17% vehicle hours travelled. → +13% average vehicle speed.	→ 2 minutes saving in southbound direction on Lawrence Hargrave Drive.	→ Church Street operate outside capacity. → Additional 50 veh/hr throughput in southbound direction at Phillip Street intersection.
PM	→ +3% vehicle distance travelled. → -23% vehicle hours travelled. → +26% average vehicle speed.	→ 30 seconds saving in northbound direction on Lawrence Hargrave Drive. → 2 minutes saving in southbound direction on Lawrence Hargrave Drive.	→ Additional 140 veh/hr throughput in northbound direction at Phillip Street intersection. → Church Street and Phillip Street operate outside capacity.
Saturday	→ +5% vehicle distance travelled. → -16% vehicle hours travelled. → +16% average vehicle speed.	→ 1.4 minutes increase in northbound direction on Lawrence Hargrave Drive. → 2 minutes saving in southbound direction on Lawrence Hargrave Drive.	→ Additional 130 veh/hr throughput in southbound direction at Phillip Street intersection. → Increased delay at Phillip Street and George Street due to the downstream queuing on Lawrence Hargrave Drive. → Worsened intersection performance south of Phillip Street due to higher opposing southbound flows.

5.2 Scenario 2

5.2.1 Introduction

Scenario 2 has been modelled for the future years 2026 and 2036 and includes the following key network upgrades as initially outlined in section 4.2.

- Revised intersection layout as depicted in Figure 5.7 at the following intersections:
  - Lawrence Hargrave Drive | Phillip Street (Layout 2)
  - Lawrence Hargrave Drive | Wrexham Road
  - Lawrence Hargrave Drive | Prince Street roundabout
- Peak directional Clearways on Lawrence Hargrave Drive in both the weekday AM and PM peak periods as shown in Figure 5.8.



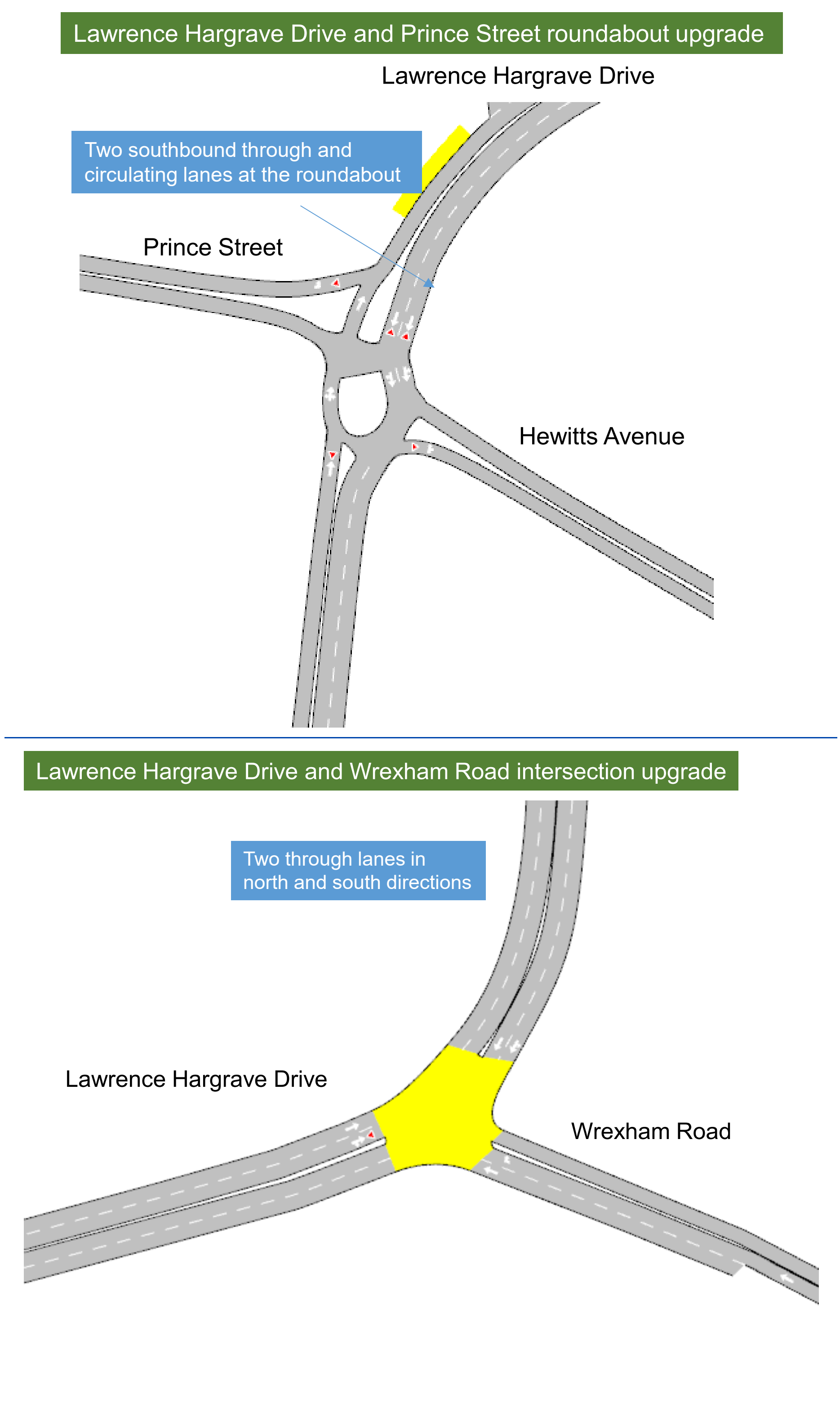
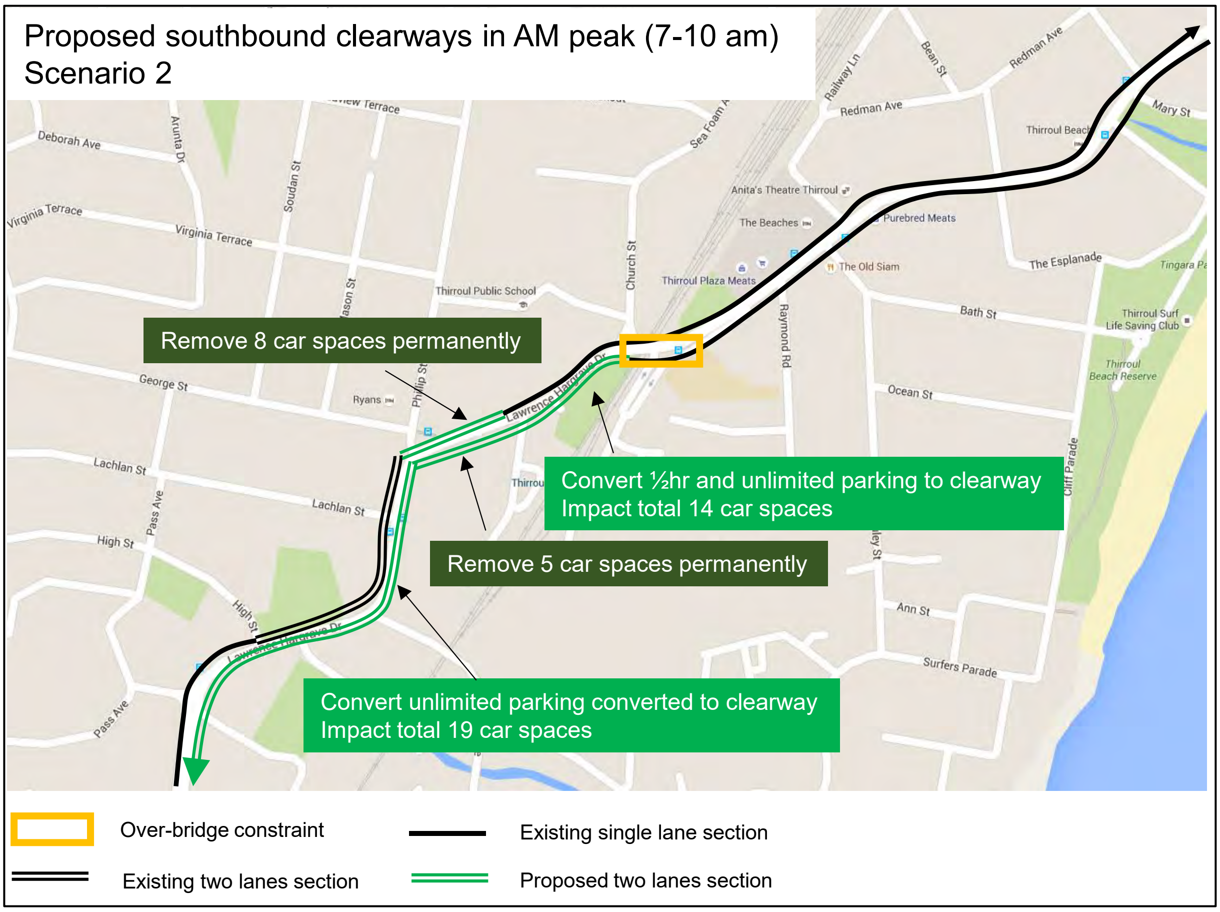
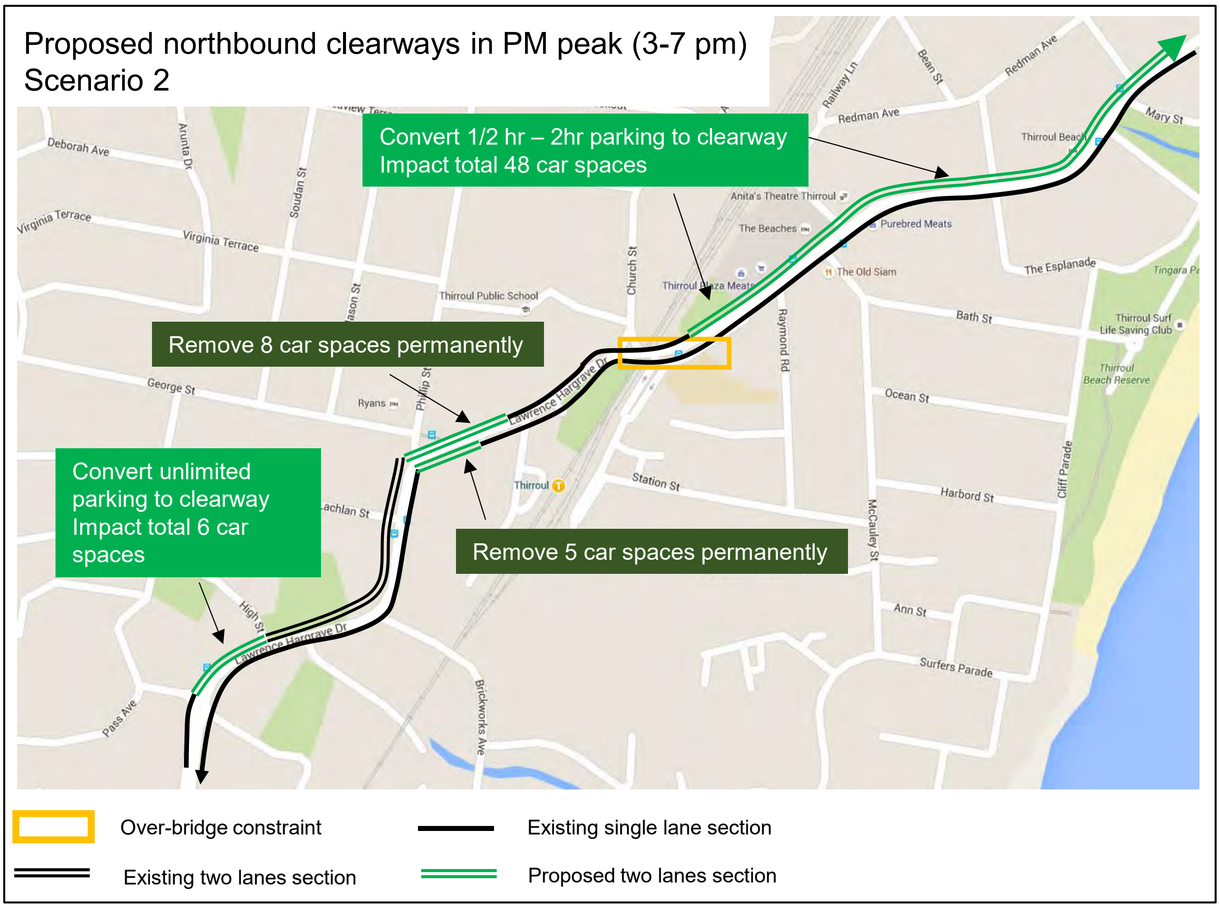


Figure 5.7 Proposed intersection upgrades on Lawrence Hargrave Drive – Scenario 2



- In line with the Layout 2 of Lawrence Hargrave Drive | Phillip Street intersection
- Starts from Church Street and finish at south of Hewitts Avenue



- In line with Layout 2 of Lawrence Hargrave Drive | Phillip Street intersection
- Main section starts from Church Street and finish at north of Mary Street
- Secondary section between High Street and Prince Street

Figure 5.8 Proposed clearways on Lawrence Hargrave Drive – Scenario 2

The number of car spaces identified as being removed as a result of the proposed Clearways is an estimation only and would need be confirmed as the design is progressed in more detail. As shown in Figure 5.2, a total of 13 car spaces are estimated to be permanently removed on Lawrence Hargrave Drive, including on weekends. The number of parking spaces partially impacted as a consequence of the Clearways is estimated to be approximately 87 spaces.

5.2.2 Network performance

The following benefits to the road network were expected from Scenario 2:

- Increased corridor capacity provided by the AM and PM peak clearways schemes, particularly at Hewitts Avenue and Wrexham Road.
- Increased intersection capacity at the intersection of Lawrence Hargrave Drive | Phillip Street, which provides two lanes for through and one short lane for right turn movements.

A comparison between Scenario 2 and the corresponding Do-minimum scenarios for the AM peak period is presented in Table 5.6. The comparison indicates:

- Scenario 2 was predicted to have a higher VKT, by 4% in both the 2026 and 2036; this is in line with the additional 4% vehicles which are able to complete the journey
- Scenario 2 would have a lower VHT, by 12% in 2026 and 23% in 2036; the average vehicle delay would reduce by 38 seconds (or 47%) whilst the average speed would increase by 5 km/h in 2036.

Table 5.6 Comparison of Network performance statistics – Scenario 2 vs Do-minimum AM peak

Performance indicators (all vehicle classes)	Diff 2026 7–9 am	Diff% 2026 7–9 am	Diff 2036 7–9 am	Diff% 2036 7–9 am
Total vehicle kilometre travelled (VKT)	+335	+4%	+325	+4%
Total vehicle hour travelled (VHT)	-32	-12%	-74	-23%
Average vehicle speed (km/h)	+4	+12%	+5	+19%
Average vehicle delay (seconds/km)	-19	-31%	-38	-47%
Completed trips	+246	+5%	+216	+4%

The comparison in Table 5.7 between the Scenario 2 and do-minimum scenarios in the PM peak periods indicates that:

- Scenario 2 would have a higher VKT by 3% in 2036, in line with the additional 3% vehicles which are able to complete the journey
- Scenario 2 would have a lower VHT by 25% in 2026 and 38% in 2036; the average vehicle delay would reduce by 92 seconds whilst the average speed would increase by 10 km/h in 2036.

Table 5.7 Comparison of Network performance statistics – Scenario 2 vs Do-minimum PM peak

Performance indicators (all vehicle classes)	Diff 2026 4–6 pm	Diff% 2026 4–6 pm	Diff 2036 4–6 pm	Diff% 2036 4–6 pm
Total vehicle kilometre travelled (VKT)	+191	+2%	+312	+3%
Total vehicle hour travelled (VHT)	-93	-25%	-186	-38%
Average vehicle speed (km/h)	+7	+24%	+10	+42%
Average vehicle delay (seconds/km)	-51	-50%	-92	-64%
Completed trips	+132	+2%	+218	+3%

The comparison in Table 5.8 between the Scenario 2 and do-minimum scenarios in the Saturday peak periods revealed that:

- Scenario 2 was predicted to have a higher VKT, by up to 13% in 2036, in line with the additional 13% vehicles which are able to complete the journey
- VHT in Scenario 2 would reduce by 45% in 2026 and 38% in 2036; the average vehicle delay would reduce by almost 3 minutes (or 60%) whilst the average speed would increase by 10 km/h in 2036.

Table 5.8 Comparison of Network performance statistics – Scenario 2 vs Do-minimum Saturday peak

Performance indicators (all vehicle classes)	Diff 2026 11 am–1 pm	Diff% 2026 11 am–1 pm	Diff 2036 11 am–1 pm	Diff% 2036 11 am–1 pm
Total vehicle kilometre travelled (VKT)	+842	+9%	+1,235	+13%
Total vehicle hour travelled (VHT)	-312	-45%	-312	-38%
Average vehicle speed (km/h)	+11	+57%	+10	+58%
Average vehicle delay (seconds/km)	-152	-68%	-169	-60%
Completed trips	+621	+10%	+864	+13%

5.2.3 Travel time difference

The travel time was assessed for Scenario 2 for the AM, PM and Saturday peak periods. Table 5.9 summarises the results of Scenario 2 and the difference to those achieved in the do-minimum scenarios.

Table 5.9 Comparison of travel time results – Scenario 2 vs Do-minimum

Travel time results and difference (minutes)			AM peak hour	PM peak hour	Saturday peak hour
Northbound on Lawrence Hargrave Drive, between south of Hewitts Avenue to Mary Street	2026	Do-minimum	3.4	4.1	5.1
		Scenario 2	2.8	2.8	3.0
		Difference	-0.6	-1.4	-2.1
		Difference %	-17%	-33%	-40%
	2036	Do-minimum	3.5	4.3	5.5
		Scenario 2	2.9	2.8	3.5
		Difference	-0.6	-1.5	-2.0
		Difference %	-17%	-35%	-37%
Southbound on Lawrence Hargrave Drive, between Mary Street south of Hewitts Avenue	2026	Do-minimum	4.1	4.3	8.7
		Scenario 2	3.1	3.2	4.2
		Difference	-1.0	-1.1	-4.4
		Difference %	-25%	-26%	-51%
	2036	Do-minimum	5.2	6.1	8.7
		Scenario 2	3.2	3.4	5.7
		Difference	-2.1	-2.8	-2.9
		Difference %	-40%	-45%	-34%

The results in the above tables demonstrated that in the AM peak:

- The southbound travel time on Lawrence Hargrave Drive was predicted to reduce by 1 minute in 2026 and 2 minutes in 2036. This is due to the impact of the southbound clearway and the widening on Lawrence Hargrave Drive at Phillip Street intersection.
- The widening on Lawrence Hargrave Drive at Phillip Street resulted to a travel time reduction of approximately 40 seconds in northbound direction.

For the PM peak the results indicate:

- The northbound travel time on Lawrence Hargrave Drive was predicted to reduce by approximately 1.5 minutes in both 2026 and 2036, primarily due to the widening at Phillip Street intersection and the northbound clearway up to Mary Street (except for on the rail over-bridge).
- The widening on Lawrence Hargrave Drive at Phillip Street resulted to a travel time reduction of 2.8 minutes in northbound direction.

For the Saturday peak, the results indicate:

- The southbound travel time would reduce by over 4 minutes in 2026 and 3 minutes in 2036. This was resulted by the widening on Lawrence Hargrave Drive at Phillip Street intersection.
- The northbound travel time was predicted to reduce by 2 minutes in both 2026 and 2036. This is primarily due to the widening on Lawrence Hargrave Drive at Phillip Street and the downstream continuous two-lane section up to Railway Parade (by removing approximately six existing car spaces).

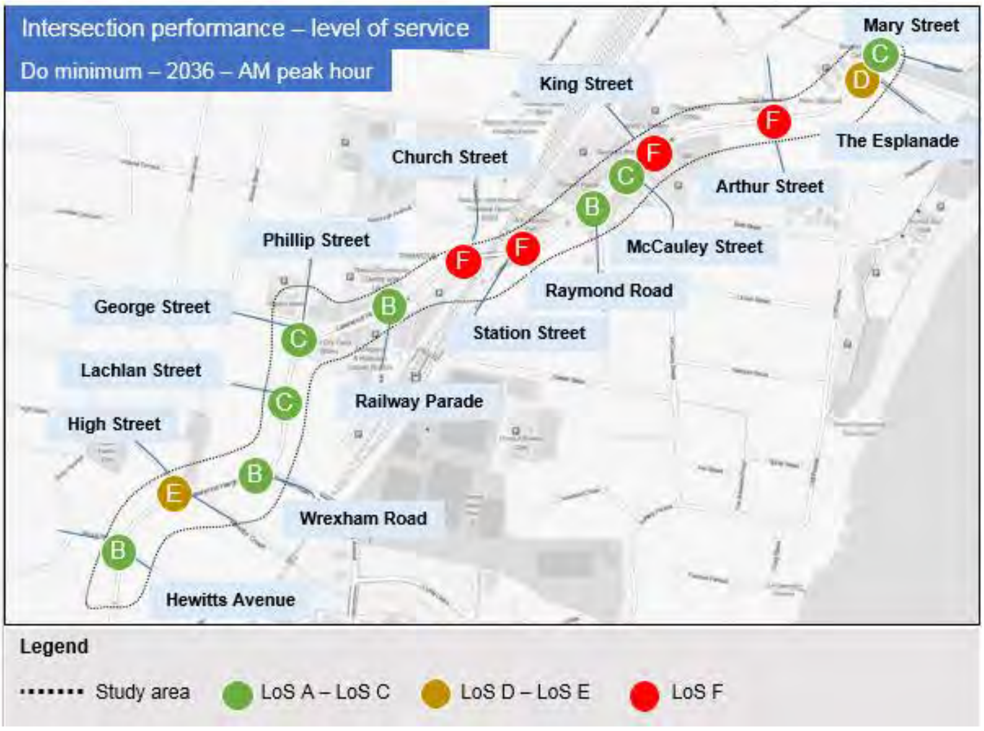
In summary, Scenario 2 is predicted to provide substantial travel time savings on Lawrence Hargrave Drive corridor, with over a 40% improvement in total travel time during the AM, PM and Saturday peak periods in modelled future years of 2026 and 2036.

The full results of the travel time for Scenario 2 are presented in Appendix B2.

5.2.4 Intersection Performance Summary

Figure 5.9–Figure 5.11 inclusive, compare the intersection performances between Scenario 2 and the corresponding do-minimum scenarios for the AM, PM and Saturday peak hours. The results also identified the locations of those intersections (side approaches at priority controlled intersection) where under Scenario 2 the level of service (LoS) is improved from the LoS F achieved in the do-minimum scenarios.

Similar to Scenario 1, the alleviation of congestion in both directions on Lawrence Hargrave Drive in the weekday AM and PM peak, leads to a reduction in the traffic delay on the side streets (e.g. Station Street) and removes the extent of stationary queuing observed in do-minimum scenarios.

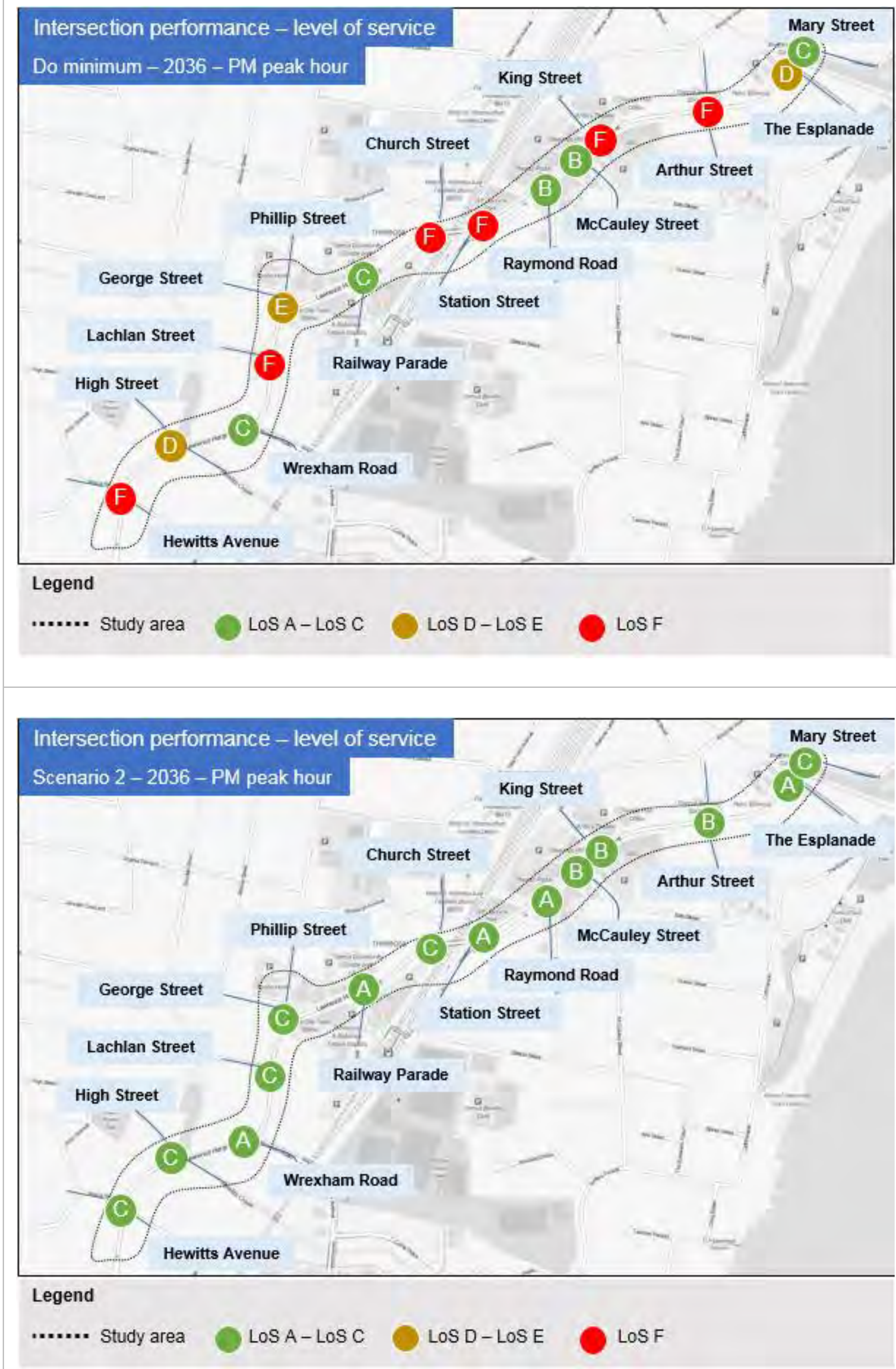


List of intersections improved from LoS F in do-minimum scenarios:

- → Arthur Street (to LoS D)
- → King Street (to LoS D)
- → Station Street (to LoS B)
- → Church Street (to LoS D)

Lawrence Hargrave Drive | Philip Street (from LoS C to LoS B)

Figure 5.9 Intersection performance summary Scenario 2 vs Do-minimum – 2036 – AM peak

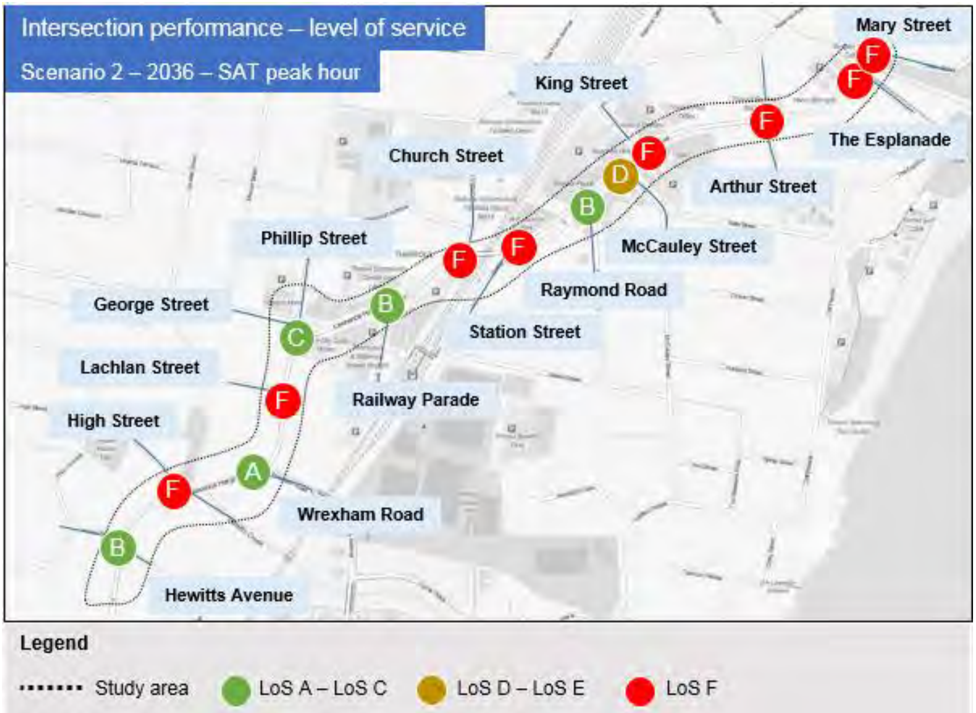


List of intersections improved from LoS F in do-minimum scenarios:

- Arthur Street (to LoS B)
- King Street (to LoS B)
- Station Street (to LoS A)
- Church Street (to LoS C)
- Lachlan Street (to LoS C)
- Hewitts Avenue (to LoS A).

Lawrence Hargrave Drive | Philip Street (from LoS E to LoS C)

Figure 5.10 Intersection performance summary Scenario 2 vs Do-minimum – 2036 – PM peak



List of intersections improved from LoS F in do-minimum scenarios:

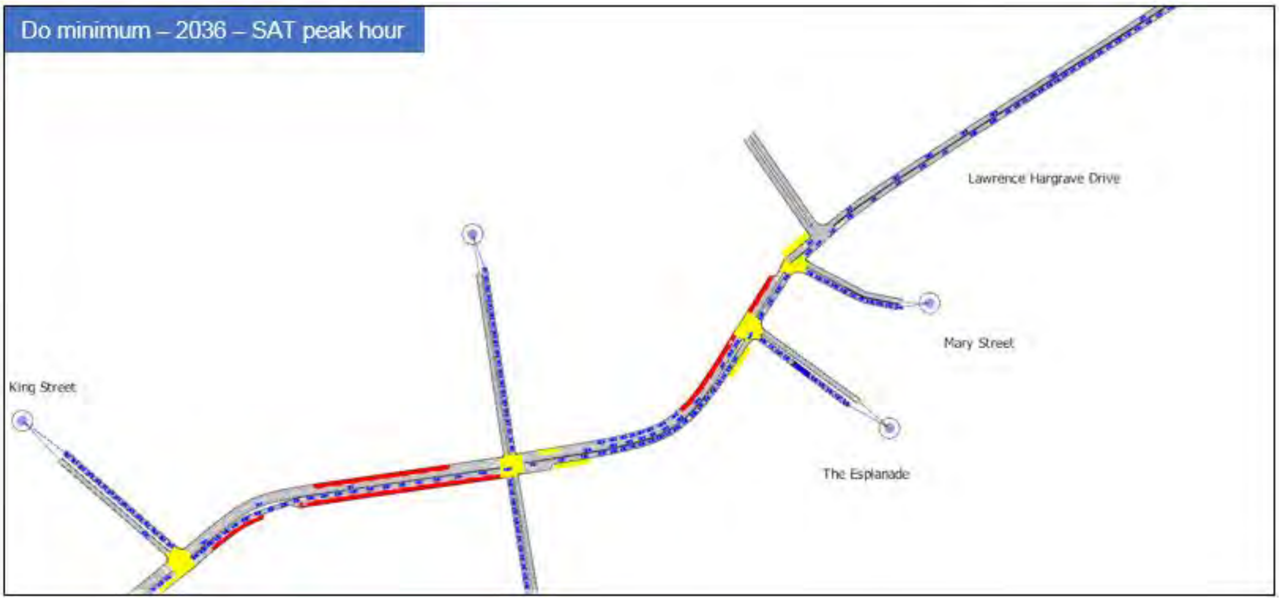
→ Hewitts Avenue (to LoS B).

Lawrence Hargrave Drive | Philip Street (from LoS E to LoS C)

Figure 5.11 Intersection performance summary Scenario 2 vs Do-minimum – 2036 – Saturday peak

Whilst most of the intersections north of Phillip Street still operate beyond capacity, the widening on Lawrence Hargrave Drive at Phillip Street provides a noticeable reduction in overall delay in both directions during the Saturday peak hour and significantly alleviates the gridlock and slow moving traffic on the corridor network. The improvement in the network congestion is described in Figure 5.12 and Figure 5.13.

Figure 5.12 Comparison of network congestion Scenario 2 vs Do-minimum (1) – 2036 – Saturday peak



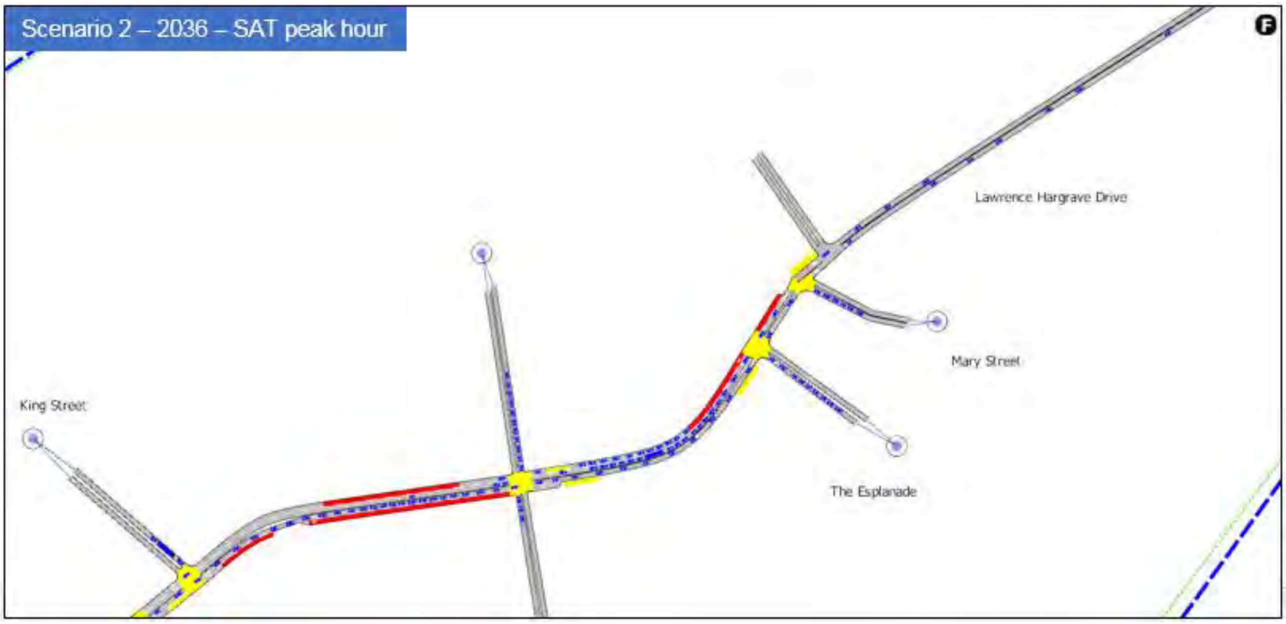
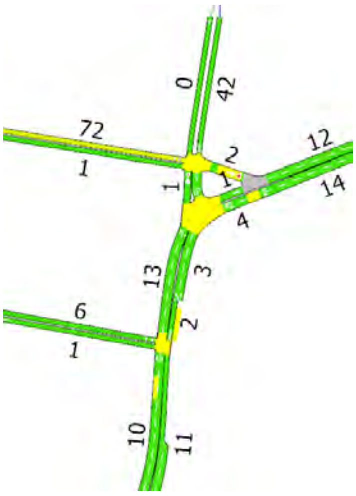


Figure 5.13 Comparison of network congestion Scenario 2 vs Do-minimum (2) – 2036 – Saturday peak

5.2.4.1 LAWRENCE HARGRAVE DRIVE | PHILLIP STREET INTERSECTION

The southbound throughput on Lawrence Hargrave Drive at Phillip Street is predicted to increase by between 50 and 170 veh/hr in all the peak periods. The northbound throughput was predicted to increase by 140 veh/hr in PM peak. Both are due to the widening on Lawrence Hargrave Drive to two through lanes, and the downstream clearways. Figure 5.14 compares the traffic delay at the Lawrence Hargrave Drive | Phillip Street intersection, with the existing (Do-Minimum) and upgraded layout in Scenario 2. The benefit from this work is predicted to lead to a general reduction in travel time over the entire length of the corridor (refer to Table 5.9.

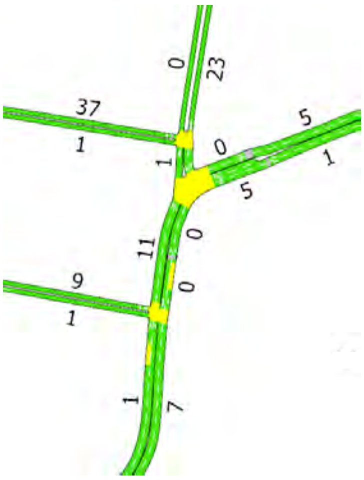
Do-minimum AM Traffic delay - 2036



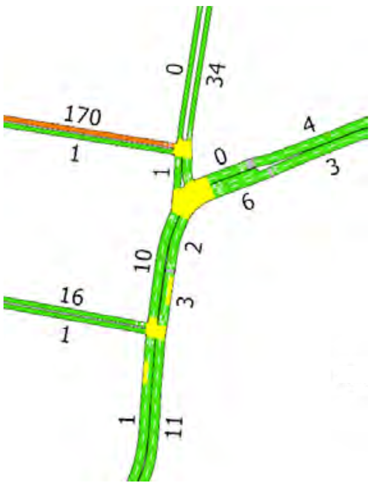
Do-minimum PM Traffic delay - 2036

Do-minimum SAT Traffic delay - 2036

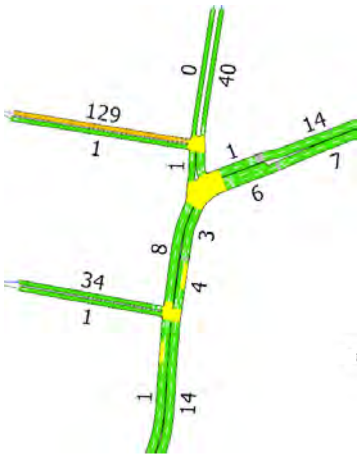
Scenario 2 AM Traffic delay - 2036



Scenario 2 PM Traffic delay - 2036



Scenario 2 SAT Traffic delay - 2036



AM peak	PM peak:	Saturday peak:
Stopline delay reduction in both direcitons.	Stopline delay reduction in both direcitons.	Stopline delay reduction in both direcitons.
	Substantial delay reduction on Phillip Street and George Street, by up to 9 minutes.	Substantial delay reduction on Phillip Street and George Street, by up to 3 minutes.

Figure 5.14 Delays at Lawrence Hargrave Drive | Phillip Street intersection (2036) – Scenario 2 vs Do-minimum

In summary, the widening on Lawrence Hargrave Drive at Phillip Street would reduce the traffic delay of upstream sections, by substantially increasing the throughput at this critical intersection. The benefit at intersection level is evident in all the three peak periods. The traffic delay at Phillip Street and George Street would also reduce due to the provision of two right turn lanes (one is shared with left turn) on Phillip Street. This will increase the discharge rate within a similar amount of green time currently provided to this approach.

5.2.5 Summary

Table 5.10 summarises network statistic benefits, travel time savings and impact on Lawrence Hargrave Drive | Phillip Street provided by the Scenario 2 configuration in future year 2036.

Table 5.10 Summary of Scenario 2 impact in 2036

Scenario 2	Network results	Travel time savings	Intersection performance
AM	→ +4% vehicle distance travelled. → -23% vehicle hours travelled. → +19% average vehicle speed.	→ 0.6 minute saving in northbound direction on Lawrence Hargrave Drive. → 2 minutes saving in southbound direction on Lawrence Hargrave Drive.	→ No intersection operate outside capacity. → Additional 70 veh/hr throughput in southbound direction.
PM	→ +3% vehicle distance travelled. → -38% vehicle hours travelled. → +42% average vehicle speed.	→ 1.5 minutes saving in northbound direction on Lawrence Hargrave Drive. → 3 minutes saving in southbound direction on Lawrence Hargrave Drive.	→ No intersection operate outside capacity. → 9 minutes delay reduction on Phillip Street and George Street; additional 140 veh/hr throughput in northbound direction.
Saturday	→ +13% vehicle distance travelled. → -39% vehicle hours travelled. → +58% average vehicle speed.	→ 2 minutes increase in northbound direction on Lawrence Hargrave Drive. → 3 minutes saving in southbound direction on Lawrence Hargrave Drive.	→ 3.5 minutes delay reduction on Phillip Street and George Street; additional 70 and 170 veh/hr throughput in northbound and southbound directions.

5.3 Conclusion: Scenario 1 vs Scenario 2

Table 5.11 summarises the additional benefits provided by Scenario 1 and Scenario 2, as a comparison of the do-minimum scenario.

Table 5.11 Comparison of results Scenario 1 and 2 vs Do-minimum

Scenario 1 and 2 vs Do-minimum in 2036	AM		PM		Saturday	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Total vehicle kilometre travelled (VKT)	+3%	+4%	+3%	+3%	+5%	+13%
Total vehicle hour travelled (VHT)	-17%	-23%	-23%	-38%	-16%	-38%
Average vehicle speed (km/h)	+13%	+19%	+26%	+42%	+16%	+58%
Travel time – northbound (minutes)	-0.1	-0.6	-0.5	-1.5	+1.4	-2.0
Travel time – southbound (minutes)	-1.9	-2.1	-2.1	-2.8	-2.1	-2.9

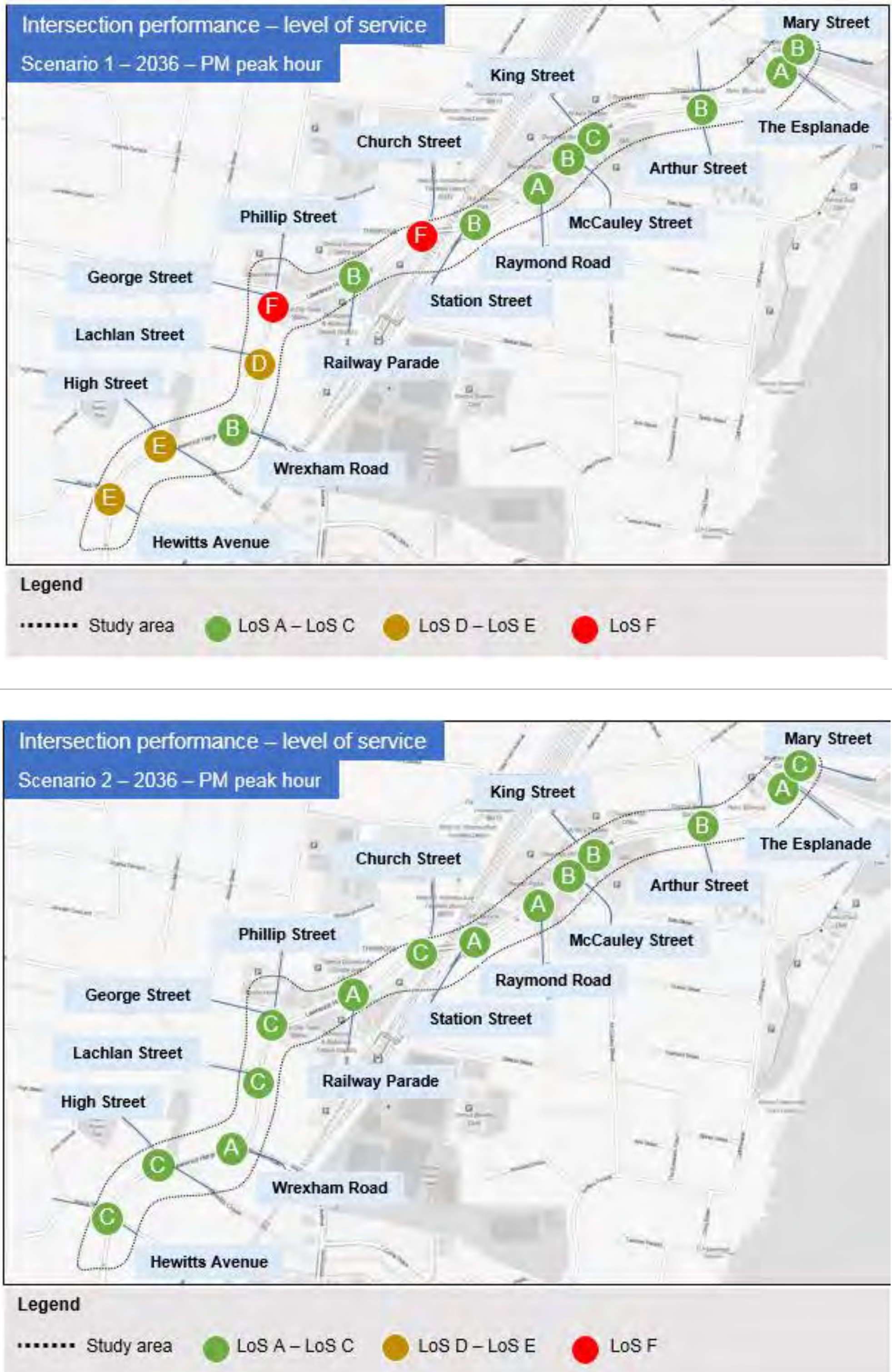
The salient points from the results presented in Table 5.11 are:

- Scenario 2 provides an additional 6%–22% reduction in VHT in all the peak periods over Scenario 1
- Scenario 2 produces an additional 8% increase in VKT and 8% increase in the total number of completed trips in Saturday peak
- Scenario 2 provides an additional 6%–42% increase in average vehicle speed. During the Saturday peak the average vehicle speed increases 19km/h in Scenario 1 to 26 km/h in Scenario 2
- Scenario 2 offers a 2 minute travel time saving in the northbound direction during the Saturday peak, and almost 1 additional minute in both directions during the weekday AM and PM peak periods.

The most noticeable improvement in intersection performance is provided by Scenario 2 for the weekday PM peak as shown in Figure 5.15. In addition, the stationary queuing at George Street and Phillip Street would be significantly reduced during the Saturday peak.

It was agreed by Roads and Maritime Service that Scenario 2 (or Layout 2 of Lawrence Hargrave Drive | Phillip Street intersection), is the preferred option to be carried forward to the next stage of traffic modelling.

The crash reduction results of both Scenario 1 and Scenario 2 is provided in Section 8, whilst the economic assessment results of both Scenarios is in Section 9 of this report.



List of intersections improved in Scenario 2:

- King Street (from LoS C to LoS B)
- Station Street (from LoS B to LoS A)
- Church Street (from LoS F to LoS C)
- Railway Parade (from LoS B to LoS A)
- Philip Street (from LoS F to LoS C)
- Lachlan Street (from LoS D to LoS C)
- Wrexham Road (from LoS B to LoS A)
- High Street (from LoS E to LoS C)
- Hewitts Avenue (from LoS E to LoS C).

Figure 5.15 Intersection performance summary Scenario 2 vs Scenario 1 – 2036 – PM peak

6 Stage 2a (with clearway scheme) assessment results

6.1 Scenario 4

6.1.1 Introduction

Scenario 4 is a modified version of Scenario 2, by having a short right turn lane on Lawrence Hargrave Drive on the approach to Station Street.

The following network upgrade features are identical to those in Scenario 2, namely:

- Revised intersection layout at the following intersections:
  - Lawrence Hargrave Drive | Phillip Street (Layout 2)
  - Lawrence Hargrave Drive | Wrexham Road
  - Lawrence Hargrave Drive | Prince Street roundabout
- Clearway scheme on Lawrence Hargrave Drive in both AM and PM peak periods.

The northbound short right turn lane (50 m) to access Station Street was proposed to improve the northbound throughput efficiency by removing blockages caused vehicles queuing to turn right into Station Street (over 110 vehicles per hour in AM peak). The modelled layout is shown in Figure 6.1.

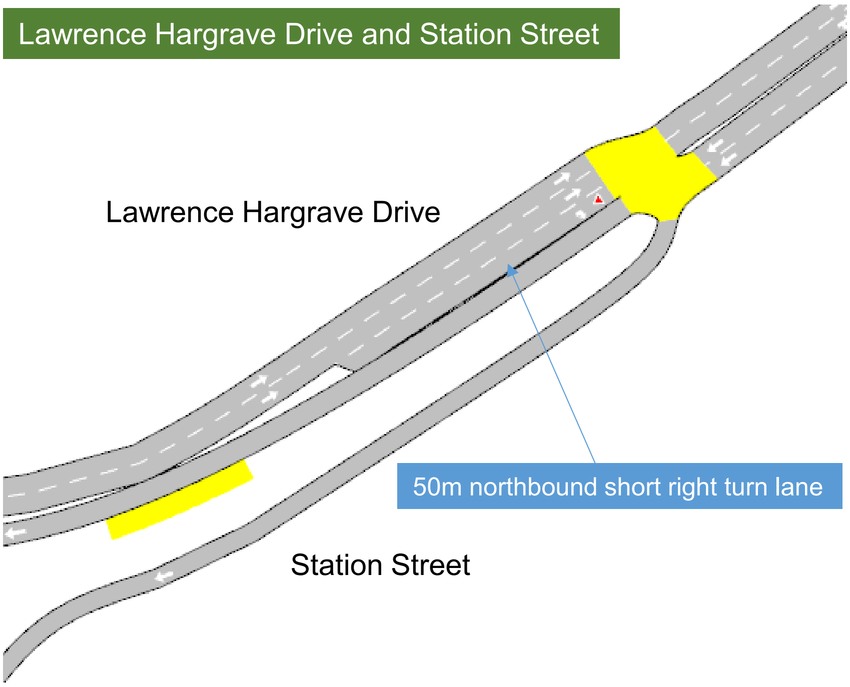


Figure 6.1 Proposed additional short right turn lane to Station Street

6.1.2 Network performance

The Scenario 2 results (section 5.2) have been adopted as a base case for a comparative assessment of Scenario 4.

The modelling results indicate that due to the localised nature of providing a single additional right turn lane, the network performs almost identically in the weekday AM and PM peak for Scenario 2 and Scenario 4. In the Saturday peak, Scenario 4 provides marginal improvements to the road network as shown in Table 6.1.

Table 6.1 Comparison of Network performance statistics – Scenario 4 vs Scenario 2 Saturday peak

Performance indicators (all vehicle classes)	Diff 2026 11 am–1 pm	Diff% 2026 11 am–1 pm	Diff 2036 11 am–1 pm	Diff% 2036 11 am–1 pm
Total vehicle kilometre travelled (VKT)	Less than 1%		35	0
Total vehicle hour travelled (VHT)			-21	-3%
Average vehicle speed (km/h)			1	4%
Average vehicle delay (seconds/km)			-9	-3%
Completed trips			28	1%

Benefits (against do-minimum) of Scenario 4 were compared to those of Scenario 2; thus, the percentage difference is different to those when comparing Scenario 4 statistics directly to Scenario 2 statistics.

The full results of the network performance results for Scenario 4 are presented in Appendix B3.

6.1.3 Travel time difference

The travel time was assessed for Scenario 4 for the AM, PM and Saturday peak periods. The difference between the travel times achieved for Scenario 4 and those achieved for Scenario 2 are negligible, being within 10 seconds in all the peak periods. This outcome is not unexpected as the localised benefit of this short right turn lane is limited to the Lawrence Hargrave Drive | Station Street intersection.

The full results of the travel time assessment for Scenario 4 are presented in Appendix B3.

6.1.4 Intersection Performance Summary

The intersection performances were assessed for all the intersections on Lawrence Hargrave Drive in Scenario 4. The results are almost identical to those of Scenario 2 in all the peak periods. A reduction in delay was identified for the northbound movement on Lawrence Hargrave Drive at Station Street intersection (refer to Table 6.2).

Table 6.2 Northbound delay reduction on Lawrence Hargrave Drive at Station Street (vs Scenario 2)

Lawrence Hargrave Drive	Flows	Delay (Scenario 2)	Delay (Scenario 4)
Lane configuration	Northbound direction	1 through lane and 1 through and right turn shared lane	2 through lanes and 1 short right turn lane
Through movement	AM: 740 veh/h PM: 1150 veh/h SAT: 1,200 veh/h	AM: 5s PM: <1s SAT: 5s	AM: <1s PM: <1s SAT: 3s
Right turn movement	AM: 130 veh/h PM: 80 veh/h SAT: 50veh/h	AM: 22s PM: 10s SAT:26s	AM: 20s PM: 8s SAT: 20s

The analysis estimates a reduced delay of between 2 and 6 seconds for the right turn movement in all the peak periods.

6.1.5 Summary

Table 6.3 summarises the network performance benefits and travel time savings provided by Scenario 4 in the 2036 future year scenario as a comparison of Scenario 2 and Do-Minimum scenario.

Table 6.3 Summary of Scenario 4 impact in 2036

Scenario 4	Network results	Travel time savings
All	Negligible difference in all the peak periods, compared to Scenario 2.	
Results below are those compared to do-minimum scenarios		
AM	→ +4% vehicle distance travelled. → -23% vehicle hours travelled. → +19% average vehicle speed.	→ 0.7 minute saving in northbound direction on Lawrence Hargrave Drive. → 2 minutes saving in southbound direction on Lawrence Hargrave Drive.
PM	→ +3% vehicle distance travelled. → -38% vehicle hours travelled. → +42% average vehicle speed.	→ 1.5 minutes saving in northbound direction on Lawrence Hargrave Drive. → 3 minutes saving in southbound direction on Lawrence Hargrave Drive.
Saturday	→ +13% vehicle distance travelled. → -41% vehicle hours travelled. → +62% average vehicle speed.	→ 2 minutes increase in northbound direction on Lawrence Hargrave Drive. → 3 minutes saving in southbound direction on Lawrence Hargrave Drive.

6.2 Scenario 5

6.2.1 Introduction

Scenario 5 is similar to Scenario 4 with the exception that it also provides two lanes in each direction on the rail overbridge at Church Street. The following network upgrade features are identical to those in Scenario 4, namely:

- Revised intersection layout at the following intersections:
  - Lawrence Hargrave Drive | Phillip Street (Layout 2)
  - Lawrence Hargrave Drive | Wrexham Road
  - Lawrence Hargrave Drive | Prince Street roundabout
- Peak directional clearway scheme on Lawrence Hargrave Drive in both AM and PM peak periods
- Northbound short right turn lane in Lawrence Hargrave Drive on approach to Station Street.

The widening of the rail overbridge on Lawrence Hargrave Drive was introduced in section 4.3.2, and the modelled layout in Scenario 5 is described in Figure 6.2.

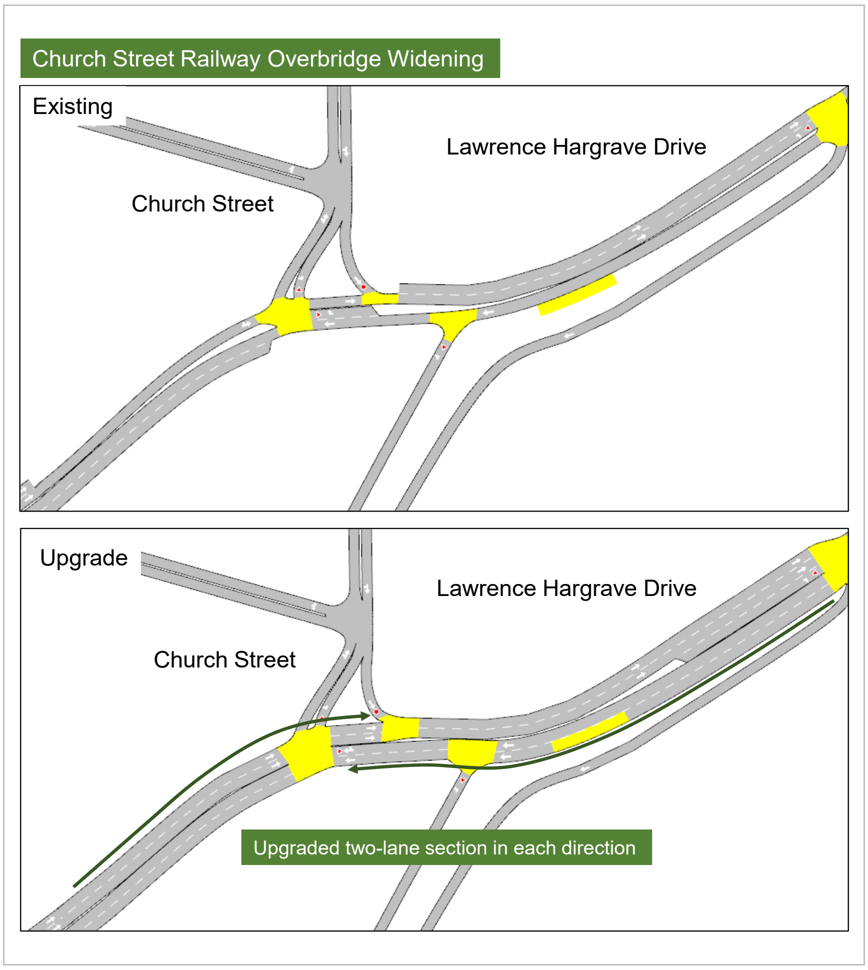
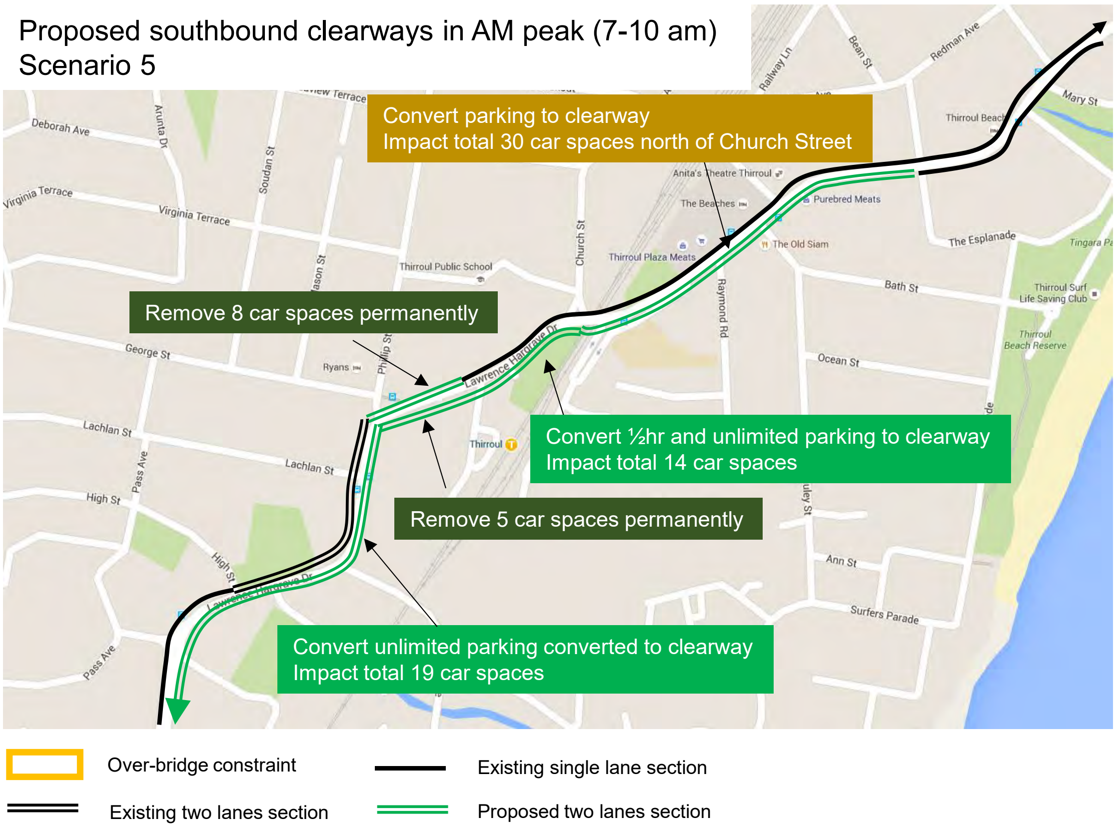


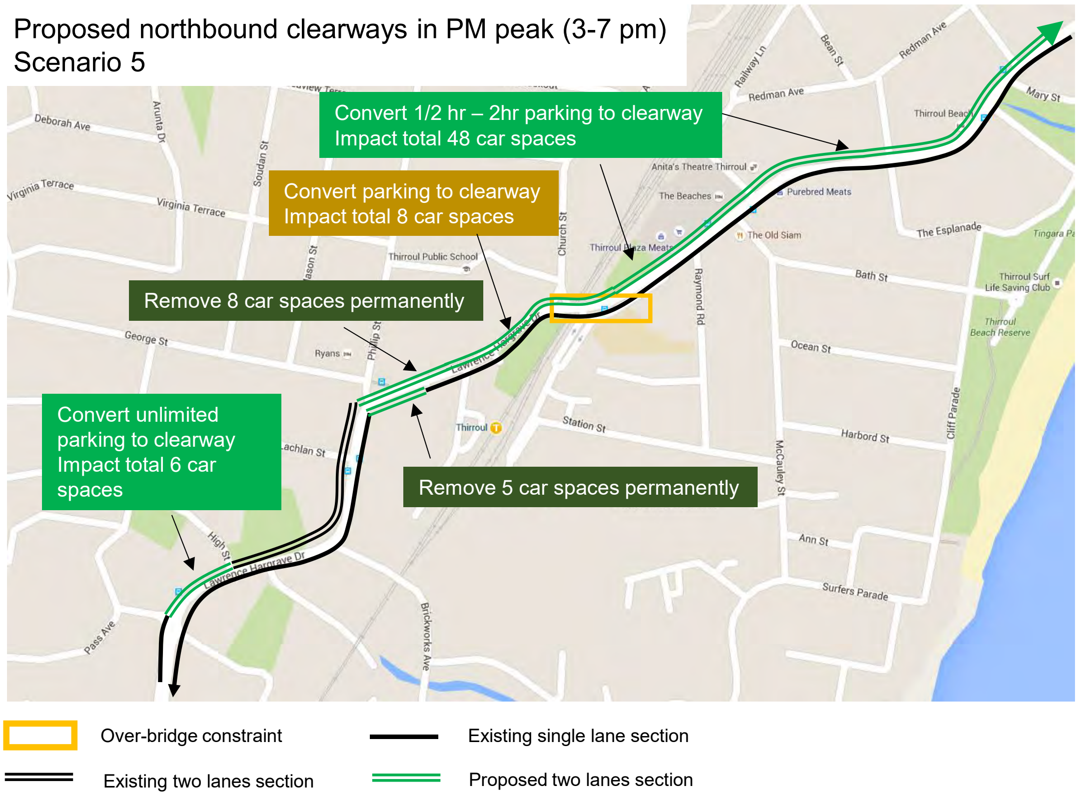
Figure 6.2 Modelled layout of rail over-bridge widening on Lawrence Hargrave Drive – Scenario 5

The main purpose of the widening is to provide two continuous peak directional lanes (with the implementation of clearways scheme) between Hewitts Avenue and Arthur Street/Mary Street during the weekday peak hours. The extended scope of clearways scheme in Scenario 5 is shown in Figure 6.3.



→ In line with Layout 2 of Lawrence Hargrave Drive | Phillip Street intersection

→ Starts from Arthur Street and finish at south of Hewitts Avenue, two southbound lanes over railway bridge



- In line with Layout 2 of Lawrence Hargrave Drive | Phillip Street intersection
- Main section starts from Phillip Street and finishes, north of Mary Street, two northbound lanes at rail overbridge
- Secondary section between High Street and Prince Street

Figure 6.3 Proposed clearways on Lawrence Hargrave Drive – Scenario 5

6.2.2 Network performance

The Scenario 2 results (section 5.2) have been adopted as a base case for a comparative assessment of Scenario 5.

The results in Table 6.4 indicate that Scenario 5 would have a lower VHT, by 2% in both 2026 and 2036 in the AM peak. The average vehicle delay would reduce by 5 seconds in 2036.

Table 6.4 Comparison of Network performance statistics – Scenario 5 vs Scenario 2 AM peak

Performance indicators (all vehicle classes)	Diff 2026 7–9 am	Diff% 2026 7–9 am	Diff 2036 7–9 am	Diff% 2036 7–9 am
Total vehicle kilometre travelled (VKT)	+33	-	+68	-
Total vehicle hour travelled (VHT)	-6	-2%	-9	-2%
Average vehicle speed (km/h)	+1	3%	+2	+4%
Average vehicle delay (seconds/km)	-3	-6%	-5	-5%
Completed trips	+19	-	+38	-

The network performance results of Scenario 5 In the PM peak are almost identical to those achieved in Scenario 2.

The results in Table 6.5 reveal that the VHT in Scenario 5 would reduce by 3% in 2026 and 6% in 2036 in Saturday peak. Further the average vehicle delay would reduce by over 22 seconds whilst the average speed would increase by 1 km/h in 2036.

Table 6.5 Comparison of Network performance statistics – Scenario 5 vs Scenario 2 Saturday peak

Performance indicators (all vehicle classes)	Diff 2026 11 am–1 pm	Diff% 2026 11 am–1 pm	Diff 2036 11 am–1 pm	Diff% 2036 11 am–1 pm
Total vehicle kilometre travelled (VKT)	-10	-	+71	-
Total vehicle hour travelled (VHT)	-10	-3%	-46	-6%
Average vehicle speed (km/h)	1	+5%	+1	+11%
Average vehicle delay (seconds/km)	-9	-4%	-22	-8%
Completed trips	-7	-	+66	-

The full results of the network performance results of Scenario 5 are presented in Appendix B4.

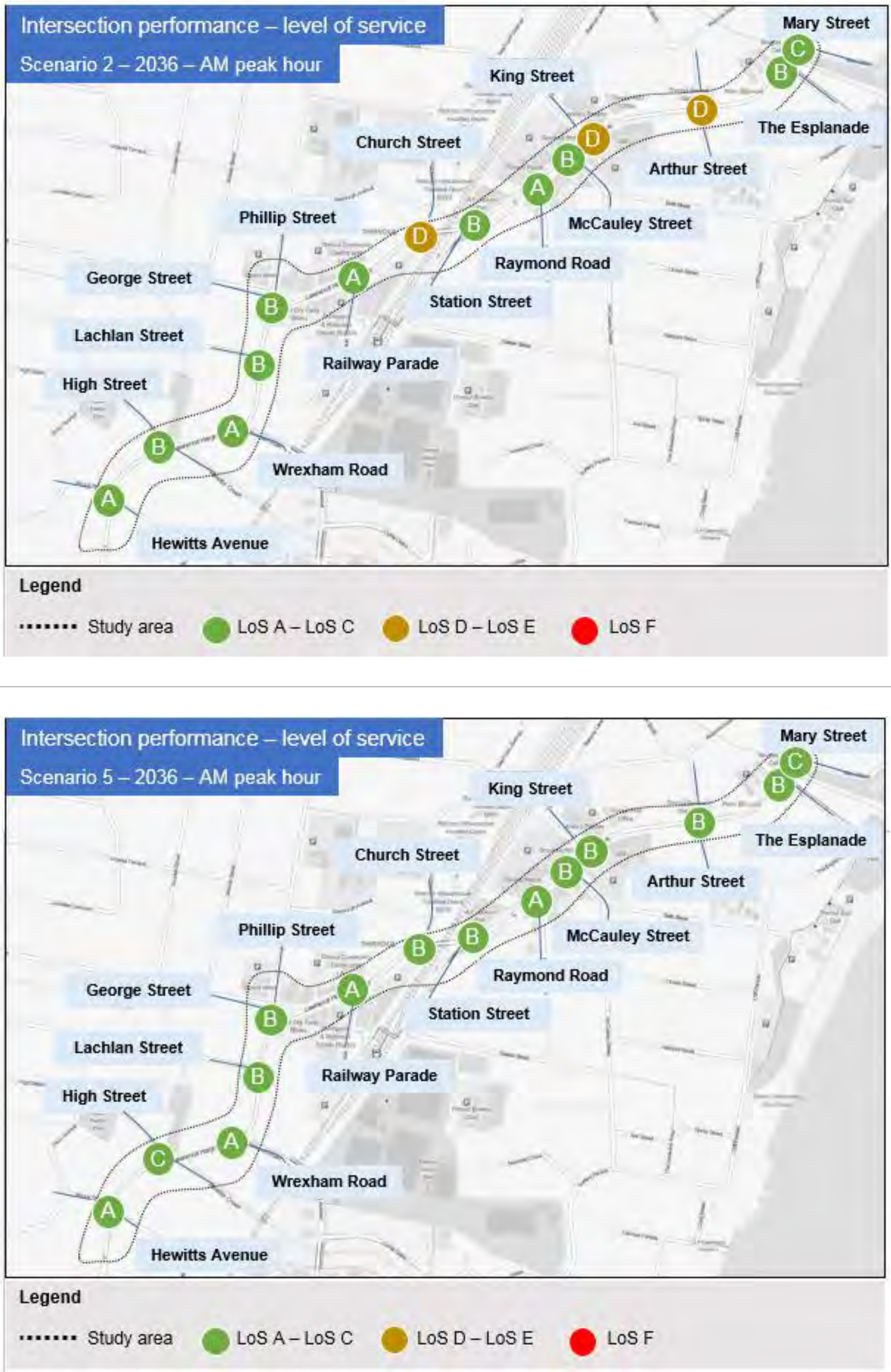
6.2.3 Travel time difference

The travel time was assessed for Scenario 5 in the AM, PM and Saturday peak periods. Compared to Scenario 2, Scenario 5 provides negligible travel time savings during the PM peak. The eventual merging at the downstream single lane section offsets any travel time saving from the widening of rail overbridge (more discussion on this is provided in section 6.2.4).

The benefit provided by the rail overbridge widening was only noticeable in the AM and Saturday peak in 2036. The travel time saving in AM peak was estimated to be just under 20 seconds for the southbound movement and also for northbound in the Saturday peak. The full results of the travel time of Scenario 5 are presented in Appendix B4.

6.2.4 Intersection Performance Summary

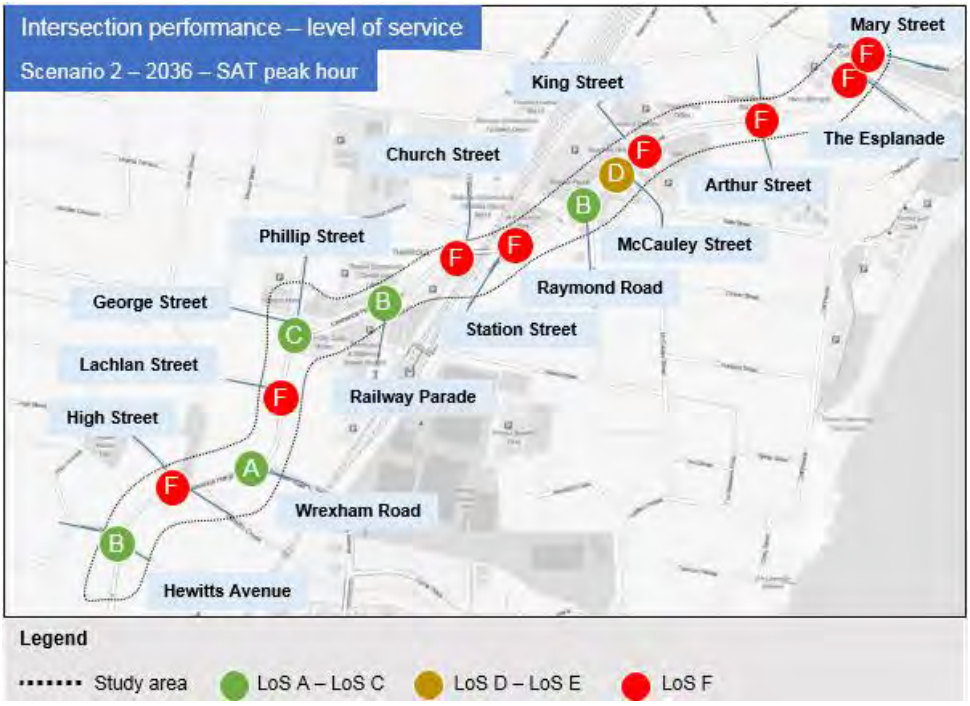
The intersection performances were assessed for all the intersections on Lawrence Hargrave Drive under the Scenario 5 arrangement. Figure 6.4 and Figure 6.5 compare the results to those achieved for Scenario 2 in the AM and Saturday peak hours. The results demonstrated that Scenario 5 provided noticeable improvement at the intersections north of Church Street, with the most notable reduction in congestion on the southbound traffic flow. There is virtually no difference in the PM peak period.

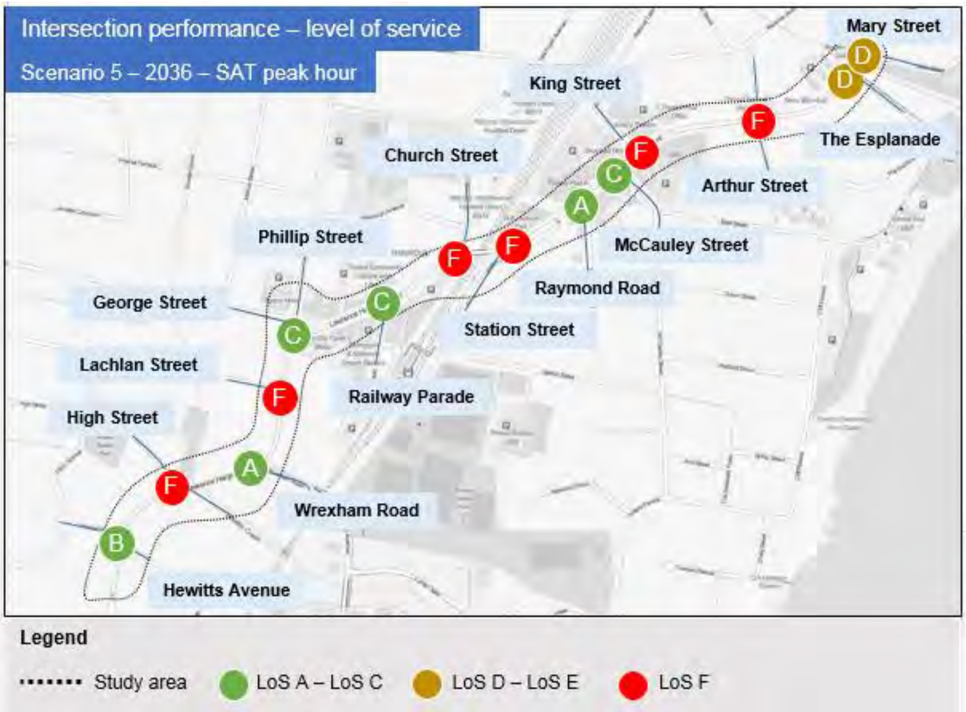


List of intersections improved in Scenario 5:

- Arthur Street (from LoS D to LoS B)
- King Street (from LoS D to LoS B)
- Church Street (from LoS D to LoS B)

Figure 6.4 Intersection performance summary Scenario 5 vs Scenario 2 – 2036 – AM peak





List of intersections improved in Scenario 5:

- → Mary Street (from LoS F to LoS D)
- → The Esplanade (from LoS F to LoS D)
- → McCauley Street (from LoS D to LoS C)
- → Raymond Road (from LoS B to LoS A).

Figure 6.5 Intersection performance summary Scenario 5 vs Scenario 2 – 2036 – Saturday peak

6.2.5 Summary

Table 6.6 summarises network performance benefits and travel time savings provided by Scenario 5 in future year 2036.

Table 6.6 Summary of Scenario 5 impact in 2036

Scenario 5	Network results	Travel time savings
Results below are those compared to Scenario 2		
AM	→ -2% vehicle hours travelled. → +4% average vehicle speed.	16 seconds saving in southbound direction on Lawrence Hargrave Drive.
PM	Negligible difference	Negligible difference.
Saturday	→ -6% vehicle hours travelled. → +11% average vehicle speed.	Negligible difference.
Results below are those compared to Do-minimum		
AM	→ +4% vehicle distance travelled. → -23% vehicle hours travelled. → +19% average vehicle speed.	→ 1 minutes saving in northbound direction on Lawrence Hargrave Drive. → 2 minutes saving in southbound direction on Lawrence Hargrave Drive.
PM	→ +3% vehicle distance travelled. → -38% vehicle hours travelled. → +42% average vehicle speed.	→ 1.5 minutes saving in northbound direction on Lawrence Hargrave Drive. → 3 minutes saving in southbound direction on Lawrence Hargrave Drive.
Saturday	→ +13% vehicle distance travelled. → -41% vehicle hours travelled. → +62% average vehicle speed.	→ 2 minutes increase in northbound direction on Lawrence Hargrave Drive. → 3 minutes saving in southbound direction on Lawrence Hargrave Drive.

Benefits (against do-minimum) of Scenario 5 were compared to those of Scenario 2; thus, the percentage difference is different to those comparing Scenario 5 statistics directly to Scenario 2 statistics.

6.3 Conclusion: Scenario 4 vs Scenario 5

Both Scenario 4 and Scenario 5 were developed with the arrangements for Scenario 2 being the base case design (this was established as the preferred scenario during the Stage 1 analysis). Table 6.7 summarises the additional network performance improvement and travel time savings achieved under Scenario 4 and Scenario 5, as a comparison of the 2036 Scenario 2 results.

Table 6.7 Comparison of results Scenario 4 and 5 vs Scenario 2

Scenario 4 and 5 vs Scenario 2 in 2036	AM		PM		Saturday	
	Scenario 4	Scenario 5	Scenario 4	Scenario 5	Scenario 4	Scenario 5
Total vehicle kilometre travelled (VKT)		-			-	-
Total vehicle hour travelled (VHT)	-	-2%	-	-	-3%	-6%
Average vehicle speed (km/h)		+4%			+5%	+11%
Travel time – northbound (minutes)	-	-12s	-	-	-	-18s
Travel time – southbound (minutes)		-18s			-12s	-

The difference below 1% or 10s in travel time is not provided.

Following the comparison:

- Scenario 5 provides additional 2% reduction in VHT and 18s travel time savings in AM peak
- Scenario 4 provides additional 3% reduction in VHT and 12s travel time savings in Saturday peak
- Scenario 5 provides additional 6% reduction in VHT and 18s travel time savings in Saturday peak.

The individual intersection performances of Scenario 4 was predicted to be almost identical to those in Scenario 2. With the widening of rail overbridge, Scenario 5 would improve the intersection performance of those intersections north of Church Street during the AM and Saturday peak periods.

Although Scenario 5 produced marginally better results particularly in AM and Saturday peak, Scenario 4 was identified by Roads and Maritime as the preferred scenario to be carried forward for economic assessment due to its relatively cheaper costs to construct and implement.

The crash reduction results of Scenario 4 are provided in Section 8 whilst the economics assessment results of Scenario 4 are presented in Section 9 of this report.

7 Stage 2b (without clearway scheme) assessment results

7.1 Scenario 3

7.1.1 Introduction

Scenario 3 is based on the preferred Layout 2 of Lawrence Hargrave Drive, with the addition of S-lane treatments at numerous intersections on the corridor as indicated in Table 7.1.

Table 7.1 Summary of preliminary intersection modification (S-lane)

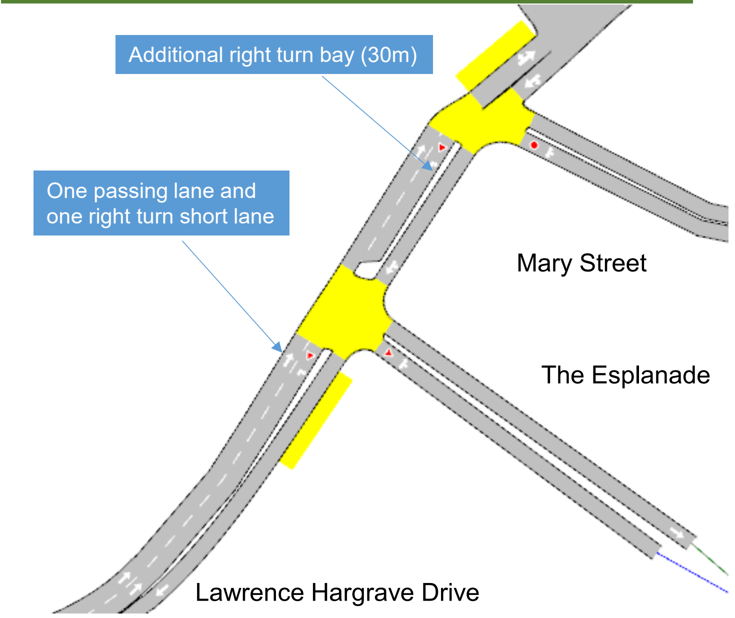
Intersections	Action
Mary Street	Additional northbound 30 m short right turn lane.
The Esplanade	Northbound lanes convert to one through lane and one dedicated right turn lane.
Arthur Street	Northbound and southbound lanes convert to one through lane and one dedicated right turn lane.
King Street	Southbound lanes convert to one through lane and one dedicated right turn lane.
McCauley Street	Northbound lanes convert to one through lane and one dedicated right turn lane.
Raymond Road	Northbound lanes convert to one through lane and one dedicated 30 m right turn short lane.
Station Street	Northbound lanes convert to one through lane and one dedicated right turn lane.
Church Street	Retain existing layout.
Railway Parade	Retain the existing layout due to proximity to the upgraded Lawrence Hargrave Drive | Phillip Street, this enables the northbound merge to be retained at just west of one-lane rail over-bridge.
Phillip Street	Layout 2.
Lachlan Street	Southbound lanes convert to one through lane and one dedicated right turn lane.
Wrexham Road	Additional northbound 50 m short right turn lane (signalised).
High Street	Additional southbound 30 m short right turn lane.
Princes Street	Retain existing roundabout layout.

As previously indicated, the objective of the S-lane scheme (providing a single continuous through lane and dedicated right turn lane on Lawrence Hargrave Drive) is to facilitate uninterrupted through movement, by minimising the weaving movement and at the same time retaining the majority of the existing kerbside parking.

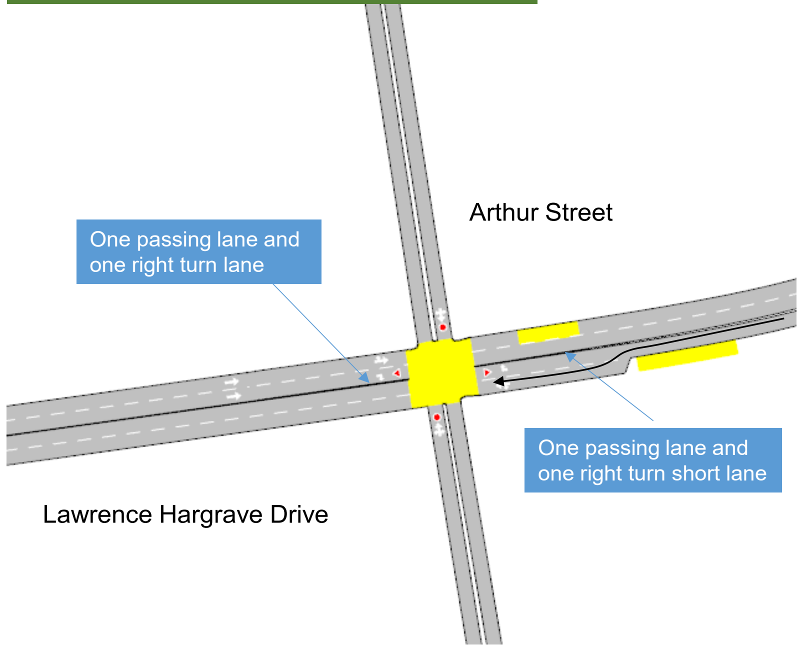
This is an alternative to the proposed clearway schemes adopted in Scenario 4 and 5. The additional benefit of the S-lane scheme is that it provides a full time positive impact on the road network, rather than the temporal impact associated with the clearways scheme (which provides positive network benefits during only the clearway hours).

Figure 7.1 summarises the modified intersection layouts to accommodate the proposed S-lane arrangement.

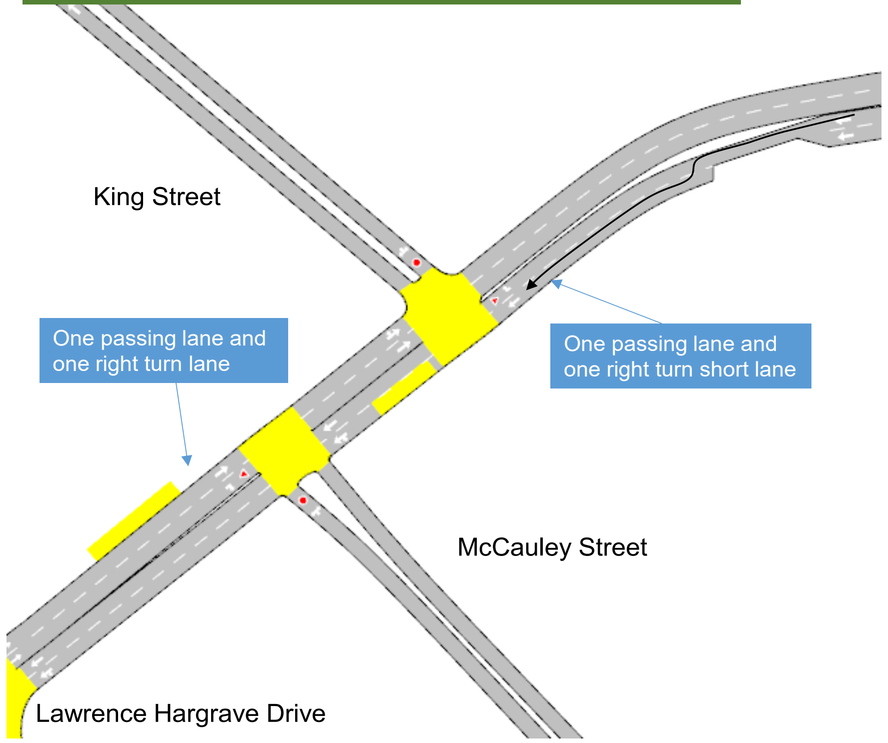
Lawrence Hargrave Drive | Mary Street and The Esplanade northbound right turn lanes



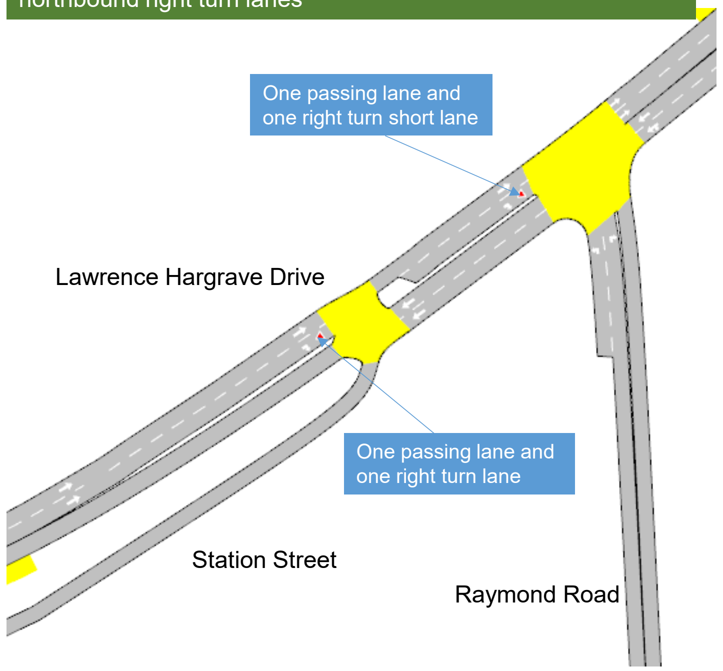
Lawrence Hargrave Drive | Arthur Street northbound and southbound right turn lanes



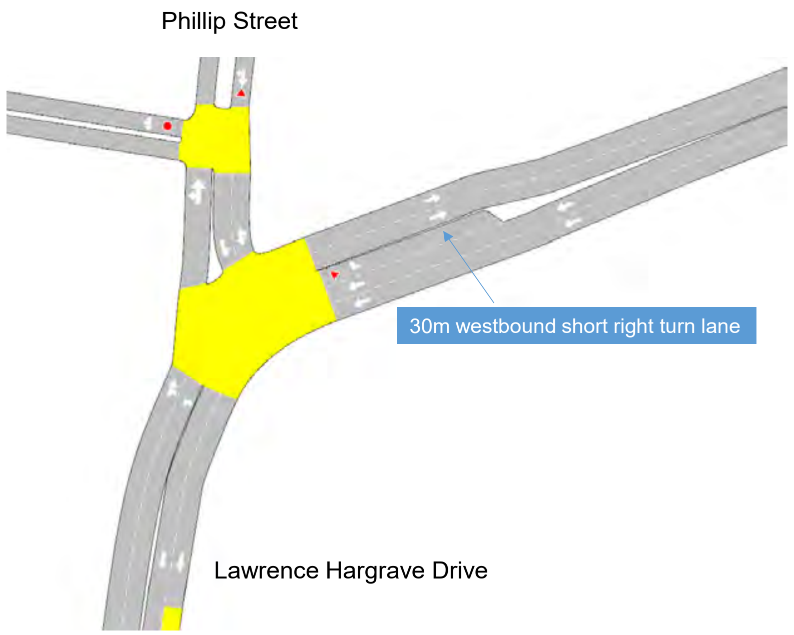
Lawrence Hargrave Drive | King Street and McCauley Street northbound and southbound right turn lanes



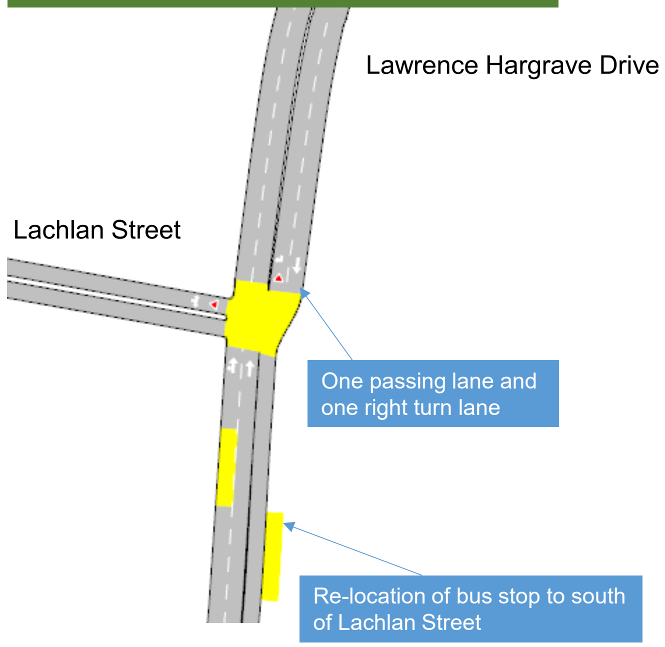
Lawrence Hargrave Drive | Station Street and Raymond Road northbound right turn lanes



Lawrence Hargrave Drive and Phillip Street intersection upgrade



Lawrence Hargrave Drive and Lachlan Street Southbound right turn lane



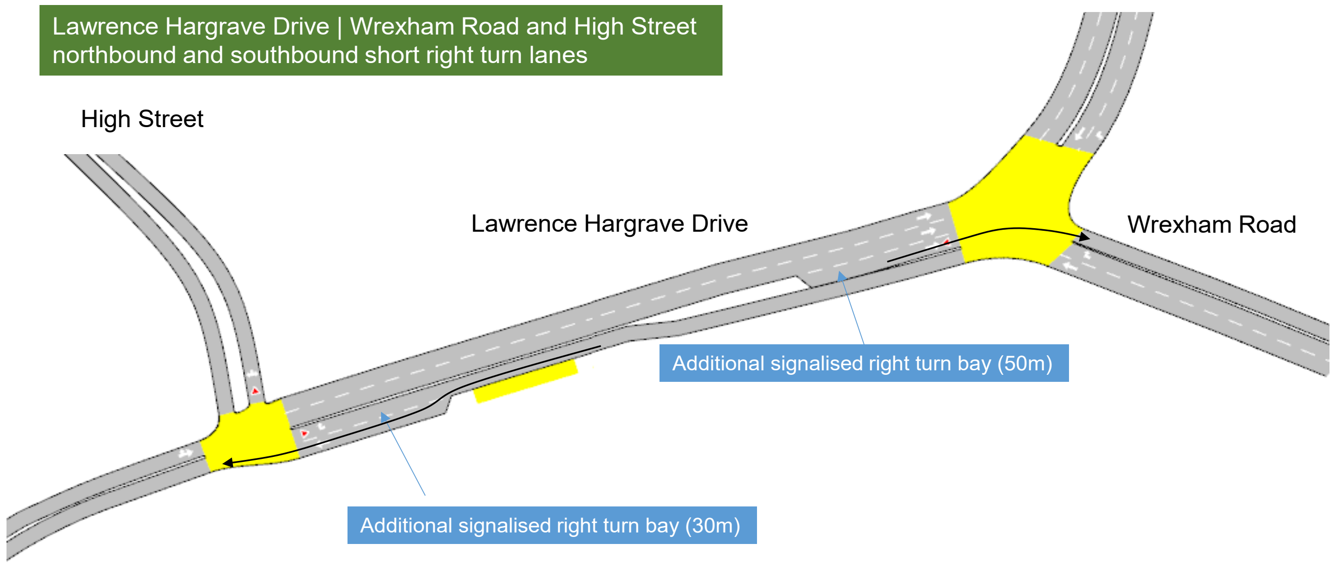


Figure 7.1 Modelled intersection layouts – S-lane Scheme in Scenario 3

Note: the preliminary length of each short right turn lane was assumed as either 30 or 50 m based on the level of right turn traffic volumes and available road space, for the traffic modelling purpose. It should be noted this is the only scenario/scheme which provides northbound right turn bay at Wrexham Road.

7.1.2 Network performance

The following benefits to the road network were expected from Scenario 3:

- Increased intersection capacity at Lawrence Hargrave Drive | Phillip Street intersection (Layout 2)
- Improved efficiency at the following 10 intersections, particularly for the through movements:
  - Southbound approach at Lawrence Hargrave Drive | Lachlan Street intersection
  - Northbound approach at Lawrence Hargrave Drive | Raymond Road intersection
  - Northbound approach at Lawrence Hargrave Drive | Station Street intersection
  - Northbound approach at Lawrence Hargrave Drive | Mary Street intersection
  - Northbound approach at Lawrence Hargrave Drive | the Esplanade intersection
  - Northbound and southbound approaches at Lawrence Hargrave Drive | Arthur Street intersection
  - Northbound approach at Lawrence Hargrave Drive | McCauley Street intersection
  - Southbound approach at Lawrence Hargrave Drive | King Street intersection
  - Northbound approach at Lawrence Hargrave Drive | Wrexham Road intersection
  - Southbound approach at Lawrence Hargrave Drive | High Street intersection.

The comparison presented in Table 7.2 between Scenario 3 and the corresponding Do-minimum scenario for the AM peak period indicates that:

- Scenario 3 is predicted to have a higher VKT, by 3% in 2036; this is in line with the additional 3% vehicles which are able to complete the journey
- Scenario 3 would have a lower VHT, by 7% in 2026 and 17% in 2036; the average vehicle delay would reduce by 27 seconds (or 34%) whilst the average speed would increase by 3 km/h in 2036.

Table 7.2 Comparison of Network performance statistics – Scenario 3 vs Do-minimum AM peak

Performance indicators (all vehicle classes)	Diff 2026 7–9 am	Diff% 2026 7–9 am	Diff 2036 7–9 am	Diff% 2036 7–9 am
Total vehicle kilometre travelled (VKT)	+286	+4%	+228	+3%
Total vehicle hour travelled (VHT)	-20	-7%	-55	-17%
Average vehicle speed (km/h)	+2	+7%	+3	+12%
Average vehicle delay (seconds/km)	-12	-20%	-27	-34%
Completed trips	+217	+4%	+155	+3%

The comparison presented in Table 7.3 between the Scenario 3 and do-minimum scenario for the PM peak period indicates that:

- Scenario 3 would have a higher VKT by 3% in 2036, in line with the additional 3% vehicles which are able to complete the journey
- Scenario 3 would have a lower VHT by 24% in 2026 and 38% in 2036; the average vehicle delay would reduce by 90 seconds whilst the average speed would increase by 9 km/h in 2036.

Table 7.3 Comparison of Network performance statistics – Scenario 3 vs do-minimum PM peak

Performance indicators (all vehicle classes)	Diff 2026 4–6 pm	Diff% 2026 4–6 pm	Diff 2036 4–6 pm	Diff% 2036 4–6 pm
Total vehicle kilometre travelled (VKT)	+200	+2%	+307	+3%
Total vehicle hour travelled (VHT)	-92	-24%	-184	-38%
Average vehicle speed (km/h)	+6	+23%	+9	+41%
Average vehicle delay (seconds/km)	-51	-50%	-90	-62%
Completed trips	+140	+2%	+217	+3%

The comparison in Table 7.4 between the Scenario 3 and do-minimum scenarios for the Saturday peak period indicates that:

- Scenario 3 is predicted to have a higher VKT, by 14% in 2036, in line with the additional 15% vehicles which are able to complete the journey
- Scenario 3 would have a lower VHT by 52% in 2026 and 54% in 2036; the average vehicle delay would reduce by over 3.5 minutes (or 77%) whilst the average speed would increase by 15 km/h in 2036.

Table 7.4 Comparison of Network performance statistics – Scenario 3 vs do-minimum Saturday peak

Performance indicators (all vehicle classes)	Diff 2026 11 am–1pm Sat	Diff% 2026 11 am–1pm Sat	Diff 2036 11 am–1pm Sat	Diff% 2036 11 am–1pm Sat
Total vehicle kilometre travelled (VKT)	+829	+9%	+1,368	+14%
Total vehicle hour travelled (VHT)	-362	-52%	-436	-54%
Average vehicle speed (km/h)	+13	+71%	+15	+87%
Average vehicle delay (seconds/km)	-170	-76%	-219	-77%
Completed trips	+614	+9%	+973	+15%

The full results of the network performance of Scenario 3 are presented in Appendix B5.

7.1.3 Travel time difference

The travel time was assessed for Scenario 3 in the AM, PM and Saturday peak periods. Table 7.5 summarises the results of Scenario 3 and the difference to those from the do-minimum scenarios.

Table 7.5 Comparison of travel time results – Scenario 3 vs Do-minimum

Travel time results and difference (minutes)			AM peak hour	PM peak hour	Saturday peak hour
Northbound on Lawrence Hargrave Drive, between south of Hewitts Avenue to Mary Street	2026	Do-minimum	3.4	4.1	5.1
		Scenario 2	2.8	2.9	3.0
		Difference	-0.6	-1.2	-2.1
		Difference %	-17%	-29%	-42%

Travel time results and difference (minutes)			AM peak hour	PM peak hour	Saturday peak hour
	2036	Do-minimum	3.5	4.3	5.5
		Scenario 2	2.9	3.0	3.3
		Difference	-0.6	-1.3	-2.2
		Difference %	-18%	-30%	-39%
Southbound on Lawrence Hargrave Drive, between Mary Street south of Hewitts Avenue	2026	Do-minimum	4.1	4.3	8.7
		Scenario 2	3.5	2.9	3.2
		Difference	-0.7	-1.4	-5.5
		Difference %	-16%	-33%	-63%
	2036	Do-minimum	5.2	6.1	8.7
		Scenario 2	3.7	3.0	3.3
		Difference	-1.6	-3.2	-5.3
		Difference %	-30%	-52%	-62%

The results in the above tables indicate that

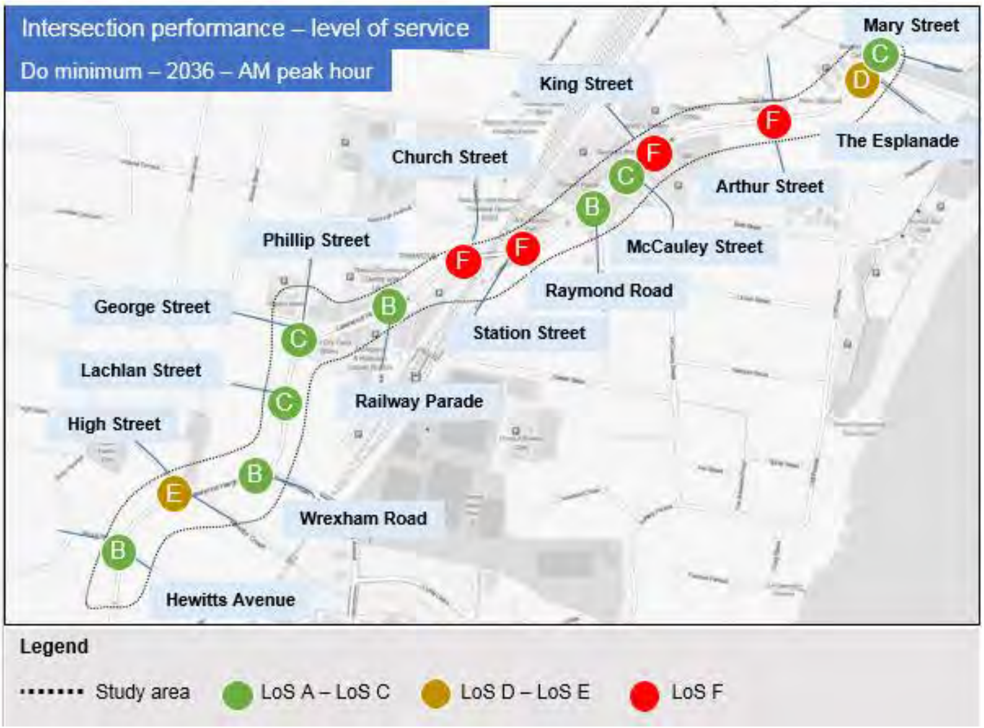
- The northbound travel time on Lawrence Hargrave Drive is predicted to reduce by 0.6, 1.3 and 2.2 minutes in respective AM, PM and Saturday peak. This is due to the impact of the upgrade at Lawrence Hargrave Drive | Phillip Street intersection, and S-lanes at various locations on the northbound approaches to intersections.
- The southbound travel time on Lawrence Hargrave Drive was predicted to reduce by 1.6, 3.2 and 5.3 minutes in respective AM, PM and Saturday peak. This is due to the impact of the upgrade at Lawrence Hargrave Drive | Phillip Street intersection, and S-lanes at various locations on the southbound approaches to intersections.

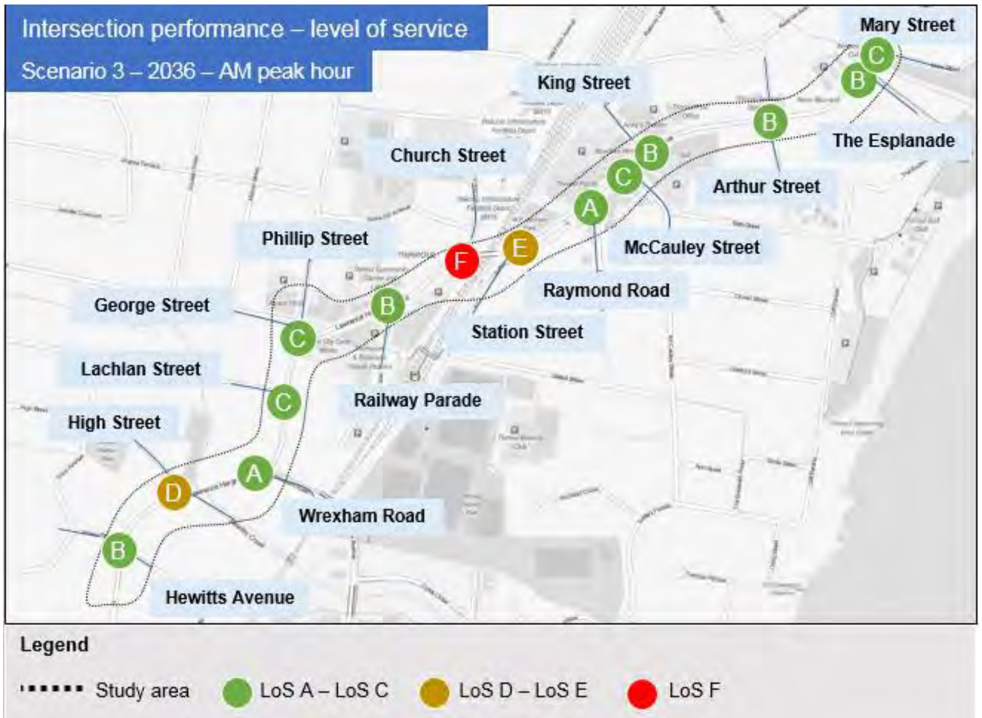
In summary, Scenario 3 is expected to provide substantial travel time savings on Lawrence Hargrave Drive corridor, with up to 42% (northbound) and 63% (southbound) savings in the AM, PM and Saturday peak periods.

The full results of the travel time of Scenario 3 are presented in Appendix B5.

7.1.4 Intersection Performance Summary

Figure 7.2–Figure 7.4 inclusive, compare the intersection performances between Scenario 3 and the corresponding do-minimum scenarios for the AM, PM and Saturday peak hours. The results also identified the locations of those intersections (side approaches at priority controlled intersection) where under Scenario 3 the level of service (LoS) is improved from the LoS F achieved in the do-minimum scenarios.



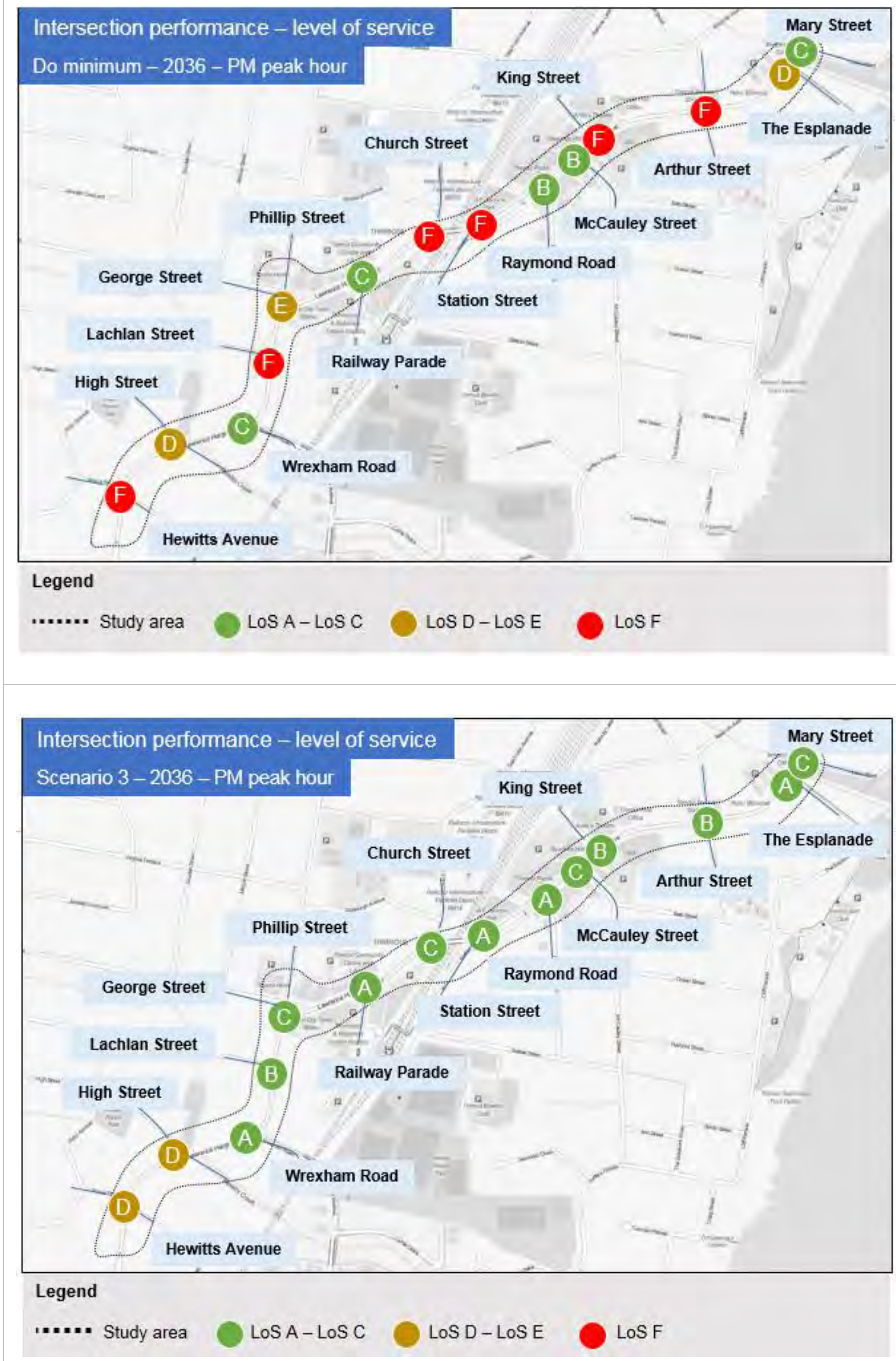


List of intersections improved from LoS F in do-minimum scenarios:

- Arthur Street (to LoS B)
- King Street (to LoS B)
- Station Street (to LoS E).

It is noted that with the downstream single lane section, the median through lane on Lawrence Hargrave Drive is noticeably under-utilised at Phillip Street.

Figure 7.2 Intersection performance summary Scenario 3 vs Do-minimum – 2036 – AM peak



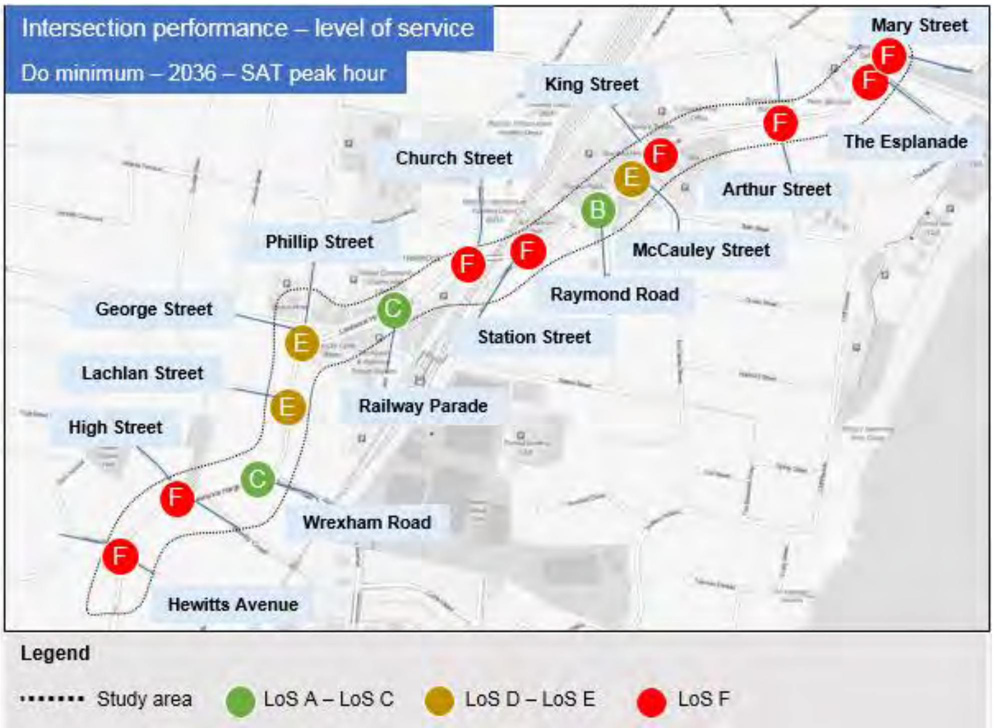
List of intersections improved from LoS F in do-minimum scenarios:

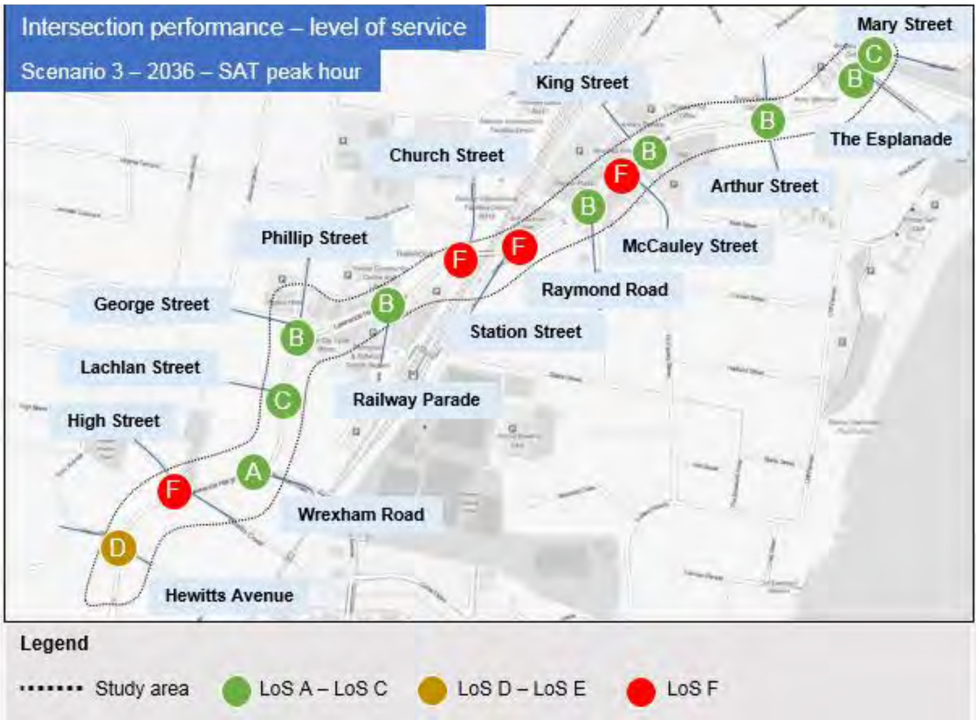
- Arthur Street (to LoS B)
- King Street (to LoS B)
- Station Street (to LoS A)
- Church Street (to LoS C)
- Lachlan Street (to Los B)
- Hewitts Avenue (to LoS D).

Lawrence Hargrave Drive | Philip Street (from LoS E to LoS C).

It is noted that with the downstream single lane section, the median through lane on Lawrence Hargrave Drive is noticeably under-utilised at Phillip Street.

Figure 7.3 Intersection performance summary Scenario 3 vs Do-minimum – 2036 – PM peak





List of intersections improved from LoS F in do-minimum scenarios:

- Mary Street (to LoS C)
- The Esplanade (to LoS B)
- Arthur Street (to LoS B)
- King Street (to LoS B)
- Station Street (to LoS B)
- Hewitts Avenue (to LoS D).

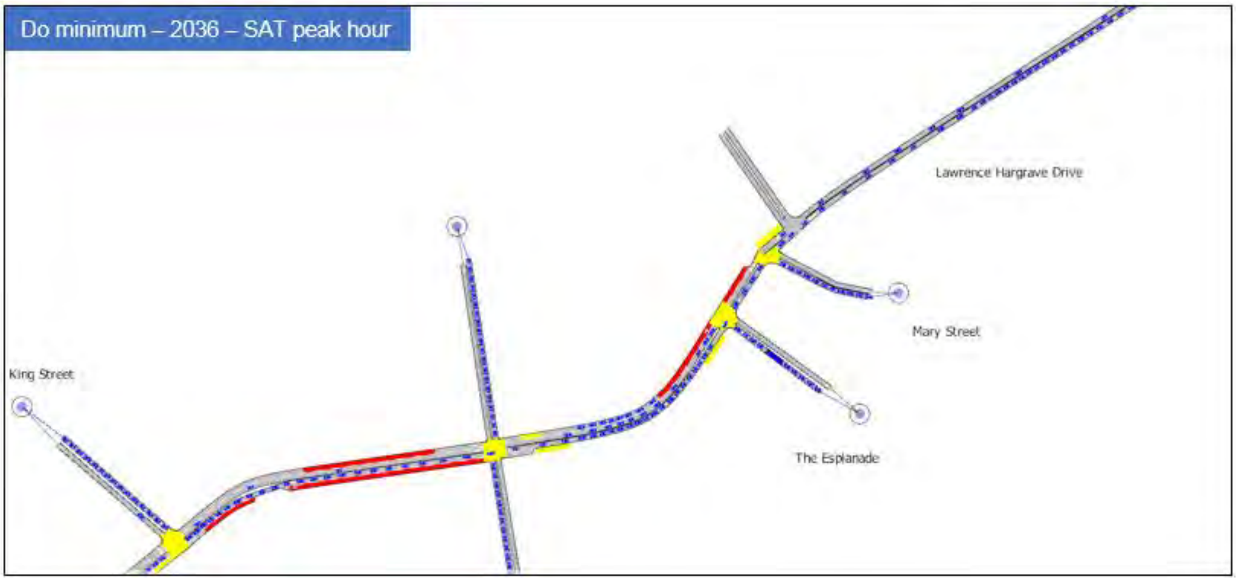
Lawrence Hargrave Drive | Philip Street (from LoS E to LoS B).

It is noted that with the downstream single lane section, the median through lane on Lawrence Hargrave Drive is noticeably under-utilised at Phillip Street.

Figure 7.4 Intersection performance summary Scenario 3 vs Do-minimum – 2036 – Saturday peak

As evident in the above figures, the provision of S-lane treatments at ten intersections would significantly alleviate the congestion on Lawrence Hargrave Drive, and consequently reduce traffic delay at the respective intersections. The differences in the congestion and queuing between Scenario 3 and do-minimum scenarios in the Saturday peak are graphically described in Figure 7.5 and Figure 7.6.

Figure 7.5 Comparison of network congestion Scenario 3 vs Do-minimum (1) – 2036 – Saturday peak



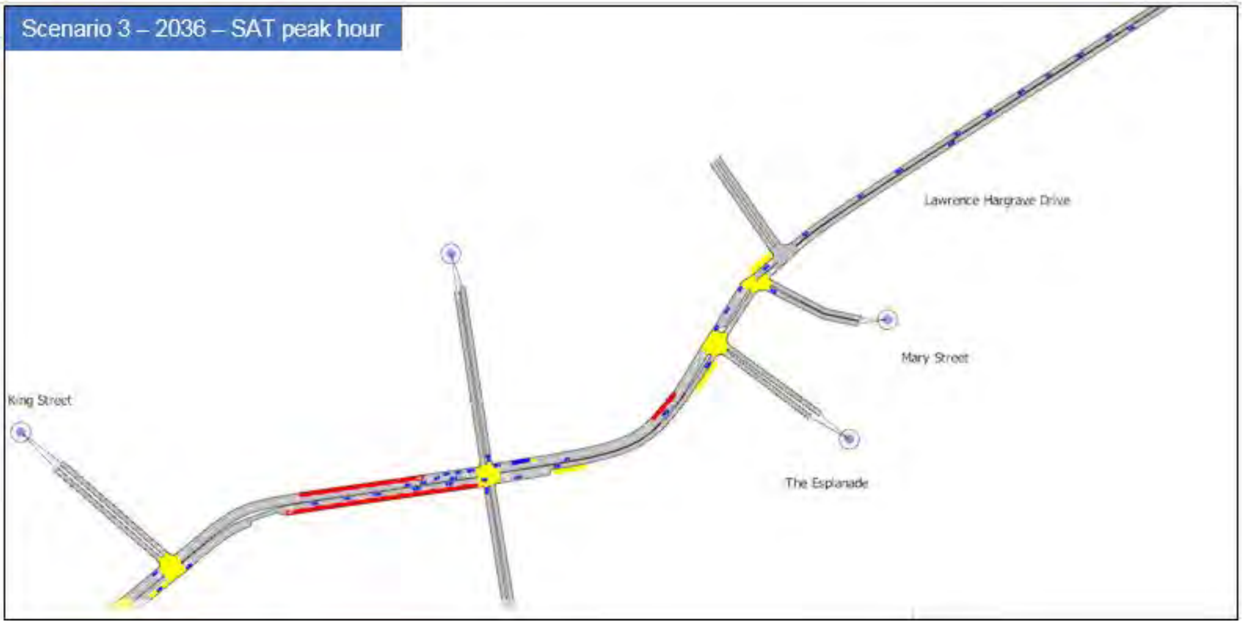


Figure 7.6 Comparison of network congestion Scenario 3 vs Do-minimum (2) – 2036 – Saturday peak

7.2 Scenario 6

7.2.1 Introduction

Scenario 6 is based on the preferred Layout 2 of Lawrence Hargrave Drive, with the addition of S-lane treatments at Lachlan Street, Station Street and Raymond Road intersections (shown in Figure 7.7). It should be noted that the proposed layouts at all three intersections are identical to those in Scenario 3.

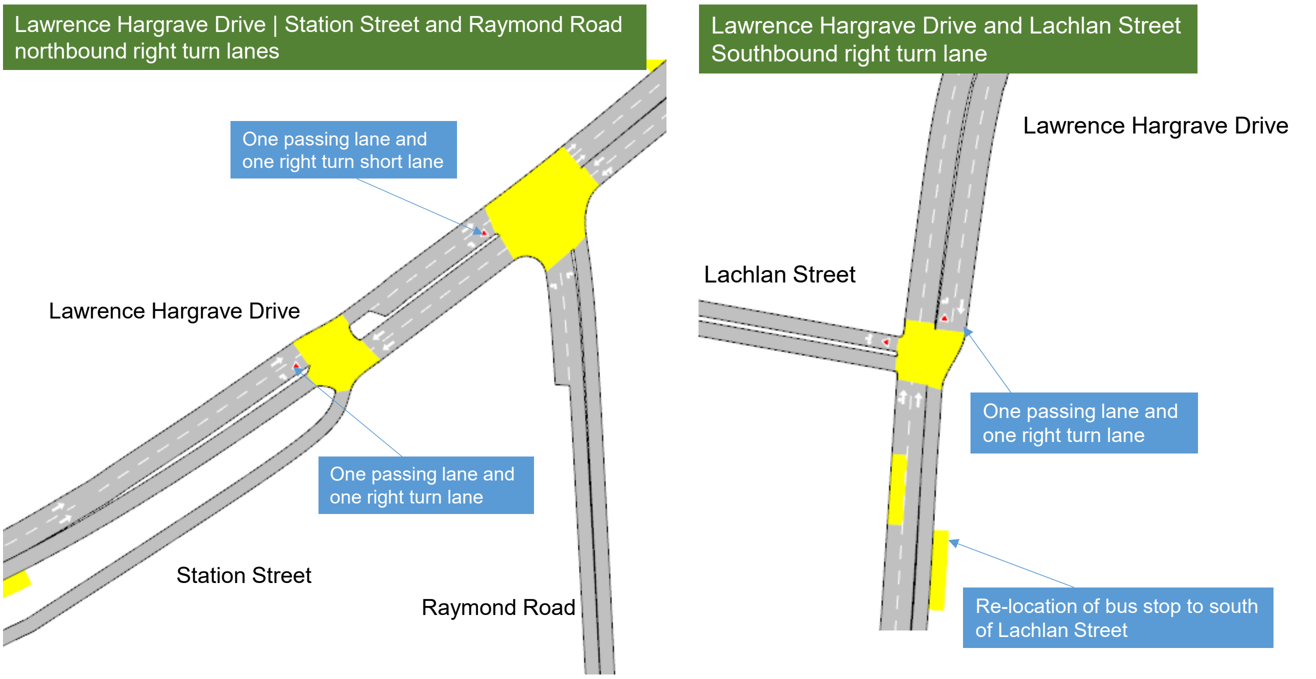


Figure 7.7 S-lanes at Lachlan Street, Station Street and Raymond Road intersection

7.2.2 Network performance

As a consequence of the measures proposed under Scenario 6, the following improvements to the road network are anticipated:

- Increased intersection capacity at Lawrence Hargrave Drive | Phillip Street intersection (Layout 2)
- Improved efficiency at the following intersection approaches, particularly for the through and right turn movements:
  - Southbound approach at Lawrence Hargrave Drive | Lachlan Street intersection
  - Northbound approach at Lawrence Hargrave Drive | Raymond Road intersection
  - Northbound approach at Lawrence Hargrave Drive | Station Street intersection.

The comparison presented in Table 7.6 between Scenario 6 and the corresponding Do-minimum scenarios in the AM peak periods indicate that:

- Scenario 6 is predicted to have a higher VKT, by 3% in 2036; this is in line with the additional 3% vehicles which are able to complete the journey
- Scenario 6 will have a lower VHT, by 7% in 2026 and 17% in 2036. In addition the average vehicle delay reduces by 27 seconds (or 33%) whilst the average speed increases by 3 km/h in 2036.

Table 7.6 Comparison of Network performance statistics – Scenario 6 vs Do-minimum AM peak

Performance indicators (all vehicle classes)	Diff 2026 7–9 am	Diff% 2026 7–9 am	Diff 2036 7–9 am	Diff% 2036 7–9 am
Total vehicle kilometre travelled (VKT)	+267	+3%	+206	+3%
Total vehicle hour travelled (VHT)	-19	-7%	-54	-17%
Average vehicle speed (km/h)	+2	+7%	+3	+11%
Average vehicle delay (seconds/km)	-11	-18%	-27	-33%
Completed trips	+205	+4%	+135	+3%

The comparison in Table 7.7 between the Scenario 6 and do-minimum scenarios in the PM peak periods indicates that:

→ Scenario 6 will have a higher VKT by 3% in 2036, in line with the additional 3% vehicles which are able to complete the journey

→ Scenario 6 will have a 24% lower VHT in 2026 and 37% in 2036. In addition the average vehicle delay will reduce by 87 seconds whilst the average speed is expected to increase by 9 km/h in 2036.

Table 7.7 Comparison of Network performance statistics – Scenario 6 vs Do-minimum PM peak

Performance indicators (all vehicle classes)	Diff 2026 4–6 pm	Diff% 2026 4–6 pm	Diff 2036 4–6 pm	Diff% 2036 4–6 pm
Total vehicle kilometre travelled (VKT)	+187	+2%	+295	+3%
Total vehicle hour travelled (VHT)	-89	-24%	-179	-37%
Average vehicle speed (km/h)	+6	+21%	+9	+38%
Average vehicle delay (seconds/km)	-49	-48%	-87	-60%
Completed trips	+133	+2%	+215	+3%

The comparison in Table 7.8 between the Scenario 6 and do-minimum scenarios in the Saturday peak periods indicates that:

- Scenario 6 is predicted to have a 13% higher VKT in 2036, in line with the additional 13% vehicles which are able to complete the journey
- Scenario 6 will have a 44% lower VHT in 2026 and 41% in 2036. In addition, the average vehicle delay will reduce by almost 3 minutes (or 61%) whilst the average speed is expected to increase by 10 km/h in 2036.

Table 7.8 Comparison of Network performance statistics – Scenario 6 vs Do-minimum Saturday peak

Performance indicators (all vehicle classes)	Diff 2026 4–6 sat	Diff% 2026 4–6 sat	Diff 2036 4–6 sat	Diff% 2036 4–6 sat
Total vehicle kilometre travelled (VKT)	+807	+8%	+1,235	+13%
Total vehicle hour travelled (VHT)	-307	-44%	-332	-41%
Average vehicle speed (km/h)	+11	+56%	+10	+60%

Performance indicators (all vehicle classes)	Diff 2026 4–6 sat	Diff% 2026 4–6 sat	Diff 2036 4–6 sat	Diff% 2036 4–6 sat
Average vehicle delay (seconds/km)	-144	-65%	-171	-61%
Completed trips	+606	+9%	+878	+13%

7.2.3 Travel time difference

The travel time was assessed for Scenario 6 in the AM, PM and Saturday peak periods. Table 7.9 summarises the results of Scenario 6 and the difference of those results with those achieved from the do-minimum scenario modelling.

Table 7.9 Comparison of travel time results – Scenario 6 vs Do-minimum

Travel time results and difference (minutes)			AM peak hour	PM peak hour	Saturday peak hour
Northbound on Lawrence Hargrave Drive, between south of Hewitts Avenue to Mary Street	2026	Do-minimum	3.4	4.1	5.1
		Scenario 2	2.9	2.9	3.1
		Difference	-0.6	-1.2	-2.0
		Difference %	-16%	-29%	-39%
	2036	Do-minimum	3.5	4.3	5.5
		Scenario 2	2.9	3.0	3.7
		Difference	-0.6	-1.3	-1.8
		Difference %	-17%	-30%	-33%
Southbound on Lawrence Hargrave Drive, between Mary Street south of Hewitts Avenue	2026	Do-minimum	4.1	4.3	8.7
		Scenario 2	3.5	3.1	4.2
		Difference	-0.6	-1.3	-4.5
		Difference %	-15%	-30%	-52%
	2036	Do-minimum	5.2	6.1	8.7
		Scenario 2	3.8	3.1	5.3
		Difference	-1.5	-3.0	-3.3
		Difference %	-28%	-49%	-39%

The results in the above tables indicate that:

- The northbound travel time on Lawrence Hargrave Drive is predicted to reduce by 0.6, 1.3 and 1.8 minutes in the respective AM, PM and Saturday peak periods. This is due to the impact of the upgrade at Lawrence Hargrave Drive | Phillip Street intersection, and S-lanes at the northbound approach to Station Street and Raymond Road intersections.

- The southbound travel time on Lawrence Hargrave Drive is predicted to reduce by 1.5, 3.0 and 3.3 minutes in respective the AM, PM and Saturday peak. This is due to the impact of the upgrade at Lawrence Hargrave Drive | Phillip Street intersection, and S-lanes at southbound approach to Lachlan Street.

In summary, Scenario 6 was predicted to provide substantial travel time savings on the Lawrence Hargrave Drive corridor, with reductions of up to 33% (northbound) and 39% (southbound) in the AM, PM and Saturday peak periods.

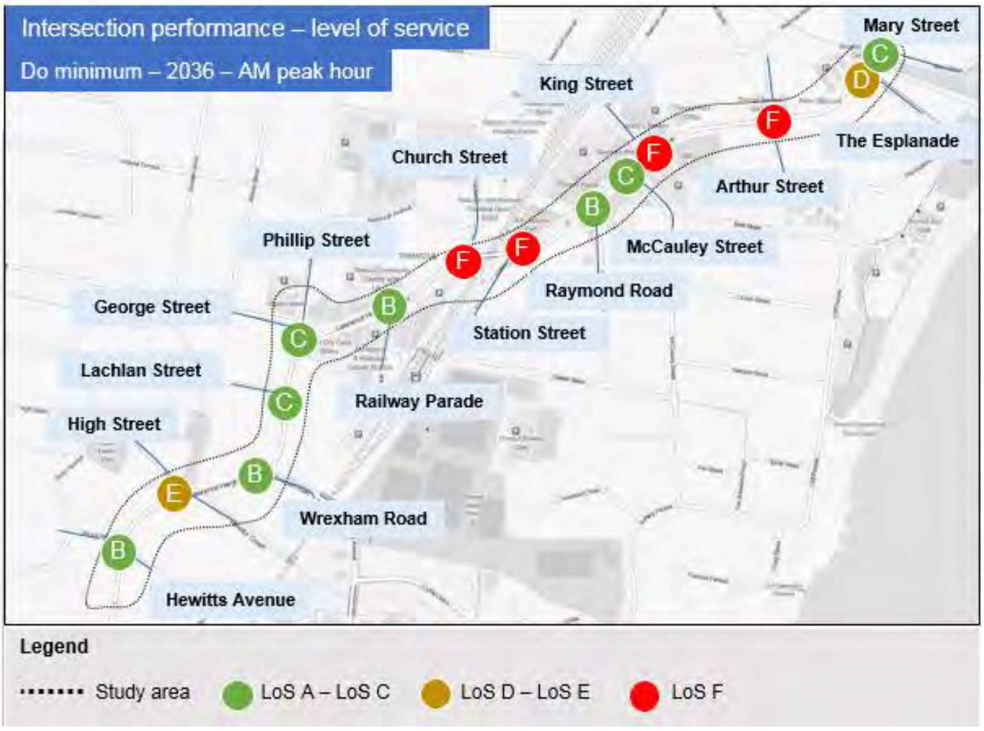
The full results of the travel time of Scenario 6 are presented in Appendix B6.

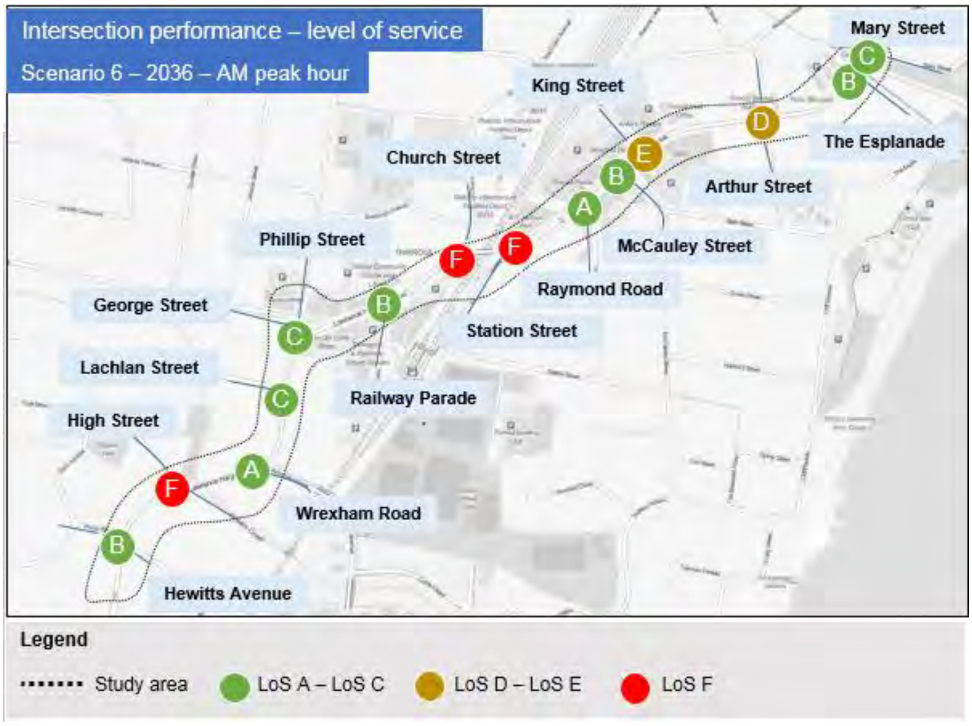
7.2.4 Intersection Performance Summary

Figure 7.8 and Figure 7.9 compare the intersection performances between Scenario 6 and the corresponding do-minimum scenarios in AM and PM peak hours. The results also identified the locations of the intersections in Scenario 6 which would be improved from LoS F in do-minimum scenarios.

The results demonstrated that the provision of S-lane schemes at the three intersections, coupled with the widening on Lawrence Hargrave Drive at Phillip Street (Layout 2), would significantly alleviate the congestion on Lawrence Hargrave Drive, and correspondingly reduce the traffic delays, most evident in the PM peak period.

Scenario 6 would fail to provide a noticeable improvement with regards to the intersection level of service performance during the Saturday peak period.



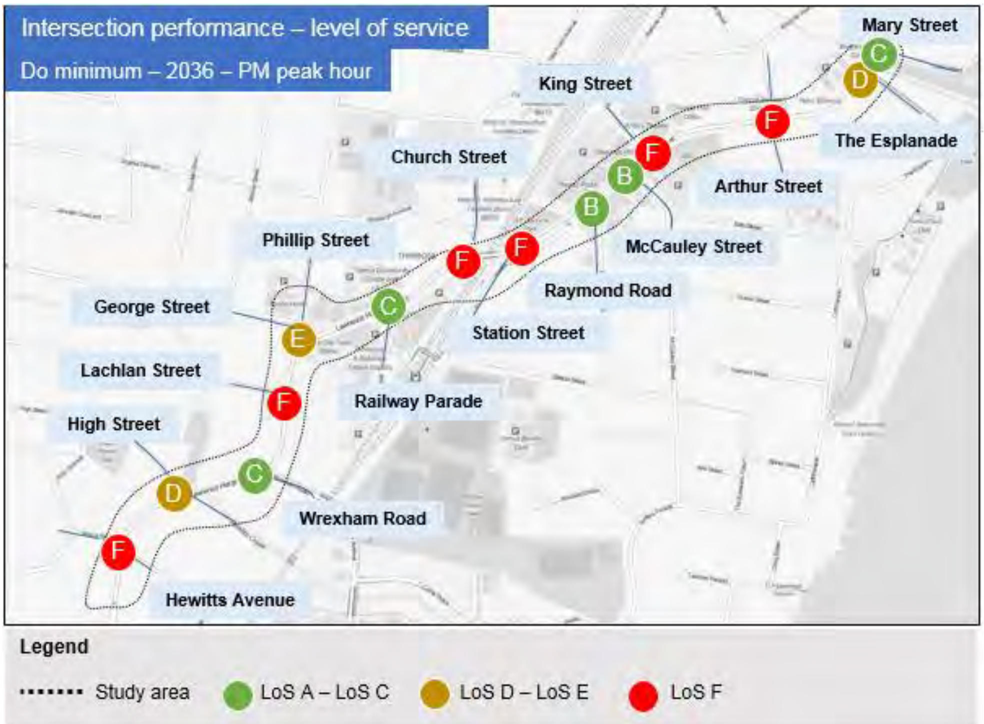


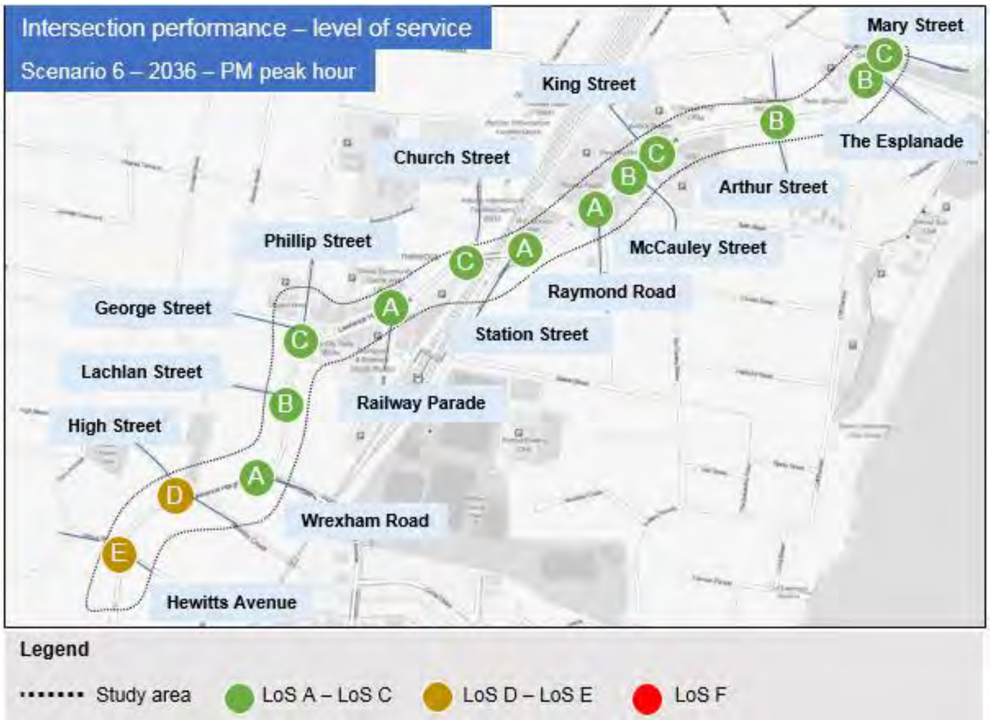
List of intersections improved from LoS F in do-minimum scenarios:

- Arthur Street (to LoS D)
- King Street (to LoS E).

It is noted that with the downstream single lane section, the median through lane on Lawrence Hargrave Drive is noticeably under-utilised at Phillip Street.

Figure 7.8 Intersection performance summary Scenario 6 vs Do-minimum – 2036 – AM peak





List of intersections improved from LoS F in do-minimum scenarios

- Arthur Street (to LoS B)
- King Street (to LoS C)
- Station Street (to LoS A)
- Church Street (to LoS C)
- Lachlan Street (to Los B)
- Hewitts Avenue (to LoS E).

Lawrence Hargrave Drive | Philip Street (from LoS E to LoS C).

It is noted that with the downstream single lane section, the median through lane on Lawrence Hargrave Drive is noticeably under-utilised at Phillip Street.

Figure 7.9 Intersection performance summary Scenario 6 vs Do-minimum – 2036 – PM peak

7.3 Conclusion: Scenario 3 vs Scenario 6

Both Scenario 3 and Scenario 6 were developed with the arrangements for Scenario 2 being the base case design. This was established as the preferred scenario during the Stage 1 analysis. Table 6.7 summarises the additional network performance improvement and travel time savings achieved under Scenario 4 and Scenario 5, as a comparison of the 2036 Scenario 2 results.

Both Scenario 3 and Scenario 6 were developed on the basis of the Layout 2 design for the Lawrence Hargrave Drive | Phillip Street intersection. In addition, Scenario 3 provides a continuous through lane at 10 intersections by means of S Lane treatments, whilst Scenario 6 incorporates similar traffic management measures at three intersections.

Table 7.10 compares the network performance improvement and travel time savings provided by Scenario 3 and Scenario 6, as a comparison to the do-minimum scenario in 2036.

Table 7.10 Comparison of results Scenario 3 and 6 vs Do-minimum

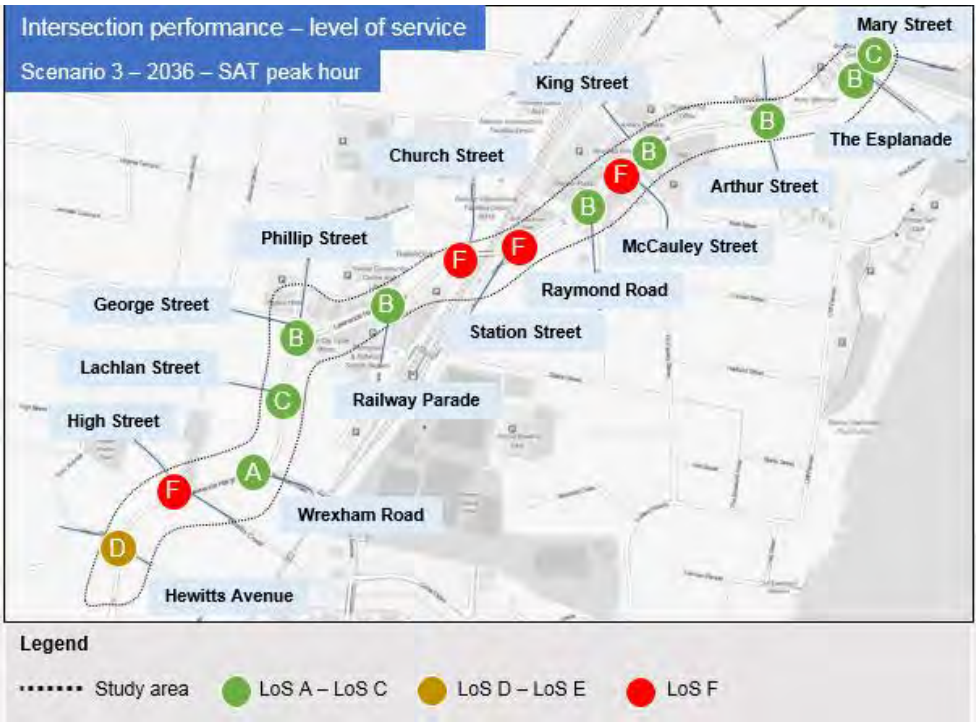
Scenario 3 and 6 vs Do-minimum in 2036	AM		PM		Saturday	
	Scenario 3	Scenario 6	Scenario 3	Scenario 6	Scenario 3	Scenario 6
Total vehicle kilometre travelled (VKT)	+3%	+3%	+3%	+3%	+14%	+13%
Total vehicle hour travelled (VHT)	-17%	-17%	-38%	-37%	-54%	-41%
Average vehicle speed (km/h)	+12%	+11%	+41%	+38%	+87%	+60%
Travel time – northbound (minutes)	-0.6	-0.6	-1.3	-1.3	-2.2	-1.8
Travel time – southbound (minutes)	-1.6	-1.5	-3.2	-3.0	-5.3	-3.3

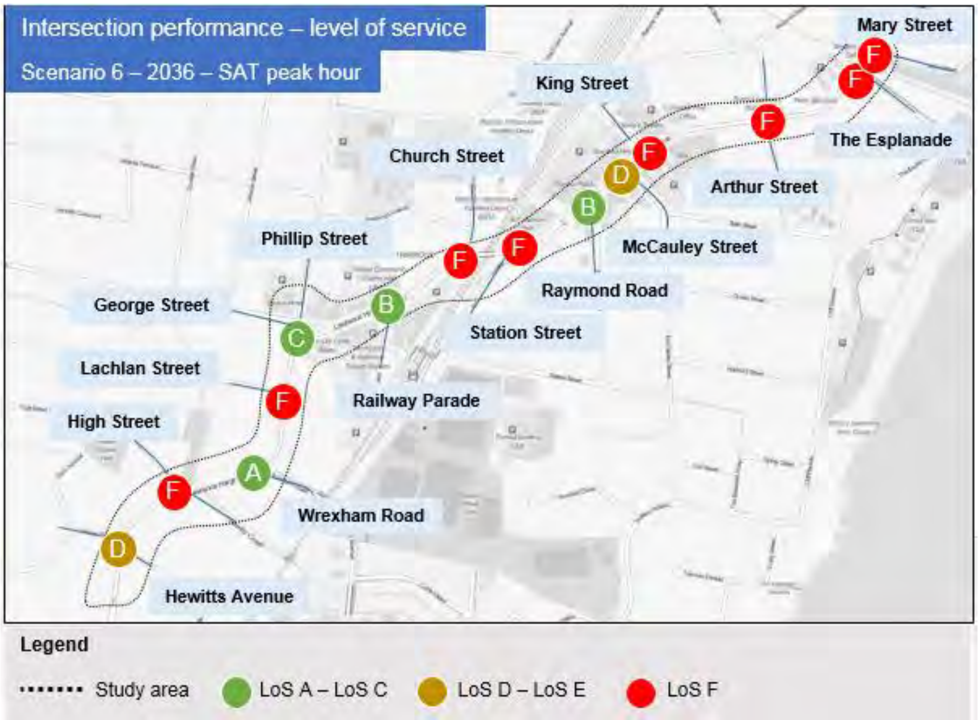
The salient points with respect to the comparative analysis are as follows:

- Scenario 3 and Scenario 6 provided very similar results in the AM and PM peaks
- Scenario 3 provides additional 13% reduction in VHT in the Saturday peak
- Scenario 3 provides an additional 27% increase in average vehicle speed in the Saturday peak period
- Scenario 3 offers an additional 2 minutes travel time saving for the southbound direction during the Saturday peak.

The most significant improvement to intersection performance occurs in the Saturday peak under Scenario 3 as shown in Figure 7.10.

It was agreed by Roads and Maritime Service that Scenario 3 be carried forward for economic assessment as it provides more substantial benefits during the Saturday peak. The crash reduction results of Scenario 3 are provided in Section 8 whilst the economic assessment results of Scenario 3 are detailed in Section 9 of this report.





List of intersections improved in Scenario 3:

- → Mary Street (from LoS F to LoS C)
- → The Esplanade (from LoS F to LoS B)
- → Arthur Street from LoS F to LoS B)
- → King Street (from LoS F to LoS B)
- → Philip Street (from LoS C to LoS B)
- → Lachlan Street (from LoS F to LoS C).

Figure 7.10 Intersection performance summary Scenario 3 vs Do-minimum – 2036 – Saturday peak

8 Crash reduction analysis

8.1 Existing crash trends

In order to estimate the accident patterns in the study area, crash data was obtained from Roads and Maritime Service for the 10-year period from 1 January 2005 to 31 December 2014. The data was collected for Lawrence Hargrave Drive between the Princes Highway and Cochrane Road and includes intersection crashes on intersecting streets up to 50 metres from Lawrence Hargrave Drive.

A detailed breakdown of the existing crash data was provided in *MR185 Lawrence Hargrave Drive – Base microsimulation model calibration and validation report,* and is summarised in Table 8.1. These trends represent the baseline for analysing the forecast crash rates for the preferred options.

Table 8.1 Summary of crash data (January 2005–December 2014)

Crashes		Counts (%)		Casualties		Counts (%)	
Fatal		0	0%	Killed		0	0%
Injury	Serious	18	15%	Injured	Seriously	25	31%
	Moderate	18	15%		Moderately	20	25%
	Minor/other	18	15%		Minor/other	27	34%
	Uncategorised	5	4%		Uncategorised	8	10%
Non-casualty		62	51%	**Total number of casualties**		**80**	
Total number of crashes		**121**					

8.2 Methodology

For the purposes of the crash reduction analysis, it has been assumed that the future year crash trends (including frequency and crash type) will remain relatively unchanged without any proposed treatments in place. The impacts to road safety would therefore be assumed to occur as a direct result of the upgrade of the Lawrence Hargrave Drive.

The Roads and Maritime *Accident Reduction Guide Part 1: Accident Investigation and Prevention (2004)* was used as a guide for the forecasting the changes in crash frequency as a result of the proposed treatments.

Table 8.2 Impact upon road safety of treatments

Location	Treatment	Crashes in location by DCA	Percentage reduction	Impact upon road safety
Clearways Scheme on Lawrence Hargrave Drive	Clearway (peak periods) (treatment ID: 103)	→ DCA 104 (right-through from right) ▪ 2x injury crash → DCA 301 (rear end collisions) ▪ 3x injury crash ▪ 2x non-casualty crash → DCA 202 (right through collisions) ▪ 1x injury crash → DCA 804 (left bend into object) ▪ 1x non-casualty crash → DCA 805 (out of control) ▪ 1x injury crash → DCA 309 (left turn side swipe) ▪ 1x injury crash → DCA 101 (cross traffic) ▪ 1x injury crash → DCA 303 (rear right collision) ▪ 1x non-casualty crash → DCA 406 (emerging from driveway) ▪ 1x non-casualty crash	→ U-turns (DCA 207–304): –20% → Rear ends (DCA 301–303): –20% → Manoeuvring (DCA 401–409): –20% → Hit parked vehicles (DCA 601): –50% → Hit pedestrians (DCA 001–008 and 901–902): –30%	This would reduce the potential for hitting parked vehicles by removing these vehicles from the corridor. This also reduces rear-ends by reducing the need for vehicles to slow-down to avoid parking areas.
Lawrence Hargrave Drive | Phillip Street intersection upgrade Layout 1 and 2	Protected right turn lane Channelization (treatment ID: 28)	→ DCA 301 (rear end collisions) ▪ 1x injury crash ▪ 1x non-casualty crash → DCA 202 (right through collisions) ▪ 1x non-casualty crash → DCA 804 (left bend into object) ▪ 1x non-casualty crash → DCA 201 (head on collisions) ▪ 1x non-casualty crash → DCA 403 (parking-parked vehicle collisions) ▪ 1x non-casualty crash	→ Adjacent approaches of intersections (DCA 101–109): –15% → Opposing vehicles turning (DCA 202–206): –40% → Rear ends (DCA 301–303): –60% → Lane change (DCA 305–307): –40% → Parallel lanes turning manoeuvres (DCA 308–309): –40% → Overtake in same direction (DCA 503–506): –70%	This would reduce crashes related to intersections, rear ends and lane changing by providing right-turn vehicles with a separate lane from the through lanes.

Location	Treatment	Crashes in location by DCA	Percentage reduction	Impact upon road safety
S-lane on Lawrence Hargrave Drive (Scenario 3)	Protected right turn lane S-lane (treatment ID: 29)	→ DCA 301 (rear end collisions) ▪ 2x injury crash ▪ 5x non-casualty crash → DCA 202 (right through collisions) ▪ 1x injury crash ▪ 4x non-casualty crash → DCA 804 (left bend into object) ▪ 1x non-casualty crash → DCA 303 (rear right collision) ▪ 5x injury crash ▪ 7x non-casualty crash → DCA 1 (near side collision with pedestrians) ▪ 2x injury crash → DCA 305 (lane side swipe) ▪ 1x injury crash → DCA 307 (lane change) ▪ 1x injury crash → DCA 703 (left off carriageway into object) ▪ 1x non-casualty crash → DCA 704 (right off carriageway into object) ▪ 1x injury crash	→ Adjacent approaches of intersections (DCA 101–109): –15% → Opposing vehicles turning (DCA 202–206): –40% → Rear ends (DCA 301–303): –60% → Lane change (DCA 305–307): –40% → Parallel lanes turning manoeuvres (DCA 308–309): –40% → Overtake in same direction (DCA 503–506): –70%	This would reduce crashes related to intersections, rear ends and lane changing by providing right-turn vehicles with a separate lane from the through lanes.
Additional right turn lane to Station Street	Protected right turn lane Channelization (treatment ID: 28)	→ DCA 301 (rear end collisions) ▪ 1x non-casualty crash → DCA 303 (rear right collision) ▪ 1x injury crash	→ Adjacent approaches of intersections (DCA 101–109): –15% → Opposing vehicles turning (DCA 202–206): –40% → Rear ends (DCA 301–303): –60% → Lane change (DCA 305–307): –40% → Parallel lanes turning manoeuvres (DCA 308–309): –40% → Overtake in same direction (DCA 503–506): –70%	This would reduce crashes related to intersections, rear ends and lane changing by providing right-turn vehicles with a separate lane from the through lanes.

8.3 Predicted crash rate

Table 8.3 summarises the estimated number of crashes under each proposed scenario to the do-minimum base case.

Table 8.3 Predicted annual crash rate with proposed improvements

		Stage 1		Stage 2	Stage 2
Crash type	**Do-minimum**	**Scenario 1**	**Scenario 2**	**Scenario 4**	**Scenario 3**
Fatal	6.2	6.0	6.0	6.0	5.2
Injury	5.9	5.8	5.8	5.7	5.3
Non-casualty	0.0	0	0	0	0
Overall	12.1	11.8	11.8	11.7	10.5

The results demonstrated that, compared to the do-minimum scenarios:

- Both Scenario 1 and Scenario 2 would reduce the total crash number by three (or 0.3 crashes/year)
- Scenario 4 would reduce the total crash number by four (or 0.4 crashes/year)
- Scenario 3 would reduce the total crash number by 16 (or 1.6 crashes/year).

Based upon this assessment it is evident that Scenario 3 provides for the highest crash reduction rate and that this reduction is a direct result of the S-lane measures being over much of the length of the Lawrence Hargrave Drive corridor in Thirroul.

These crash reduction results have been applied as an input to the economic assessment in section 9.

9 Economic assessment results

The economic assessment involved a cost benefit analysis comparing the benefits and costs of the proposed scenarios against the do-minimum (base case). It was carried out according to the document *Principles and Guidelines for Economic Appraisal on Transport Investment and Initiatives (Transport for NSW, March 2013 and Parameter Update March 2015,* hereafter referred to be TfNSW Guidelines).

The following traffic modelling results of the base case (do-minimum) and the scenarios were used as inputs to the economic appraisal:

- Total vehicle hours travelled (VHT) – to inform travel time benefit assessment
- Total vehicle kilometre travelled (VKT) – to inform vehicle operating cost and emission cost assessment
- Total number of stops – to inform vehicle operating cost assessment.

The traffic model used for the project is a corridor model, and does not model the effects that the increasing congestion along the corridor in the future (e.g. 2026 and 2036) may divert traffic to somewhere else or a different mode i.e. the actual congestion in the future may not be as bad as what is shown by the traffic model. To minimise the risk of overstating the project benefits, only 2016 model results are used to inform the economic assessment assuming that benefits stay the same over the 30-year appraisal period.

The crash reduction analysis and strategic cost estimate results of each scenario are also used as the inputs to this assessment. Two economic indicators were calculated as outputs of the economic appraisal to evaluate the relative attractiveness of the scenarios against the base case:

- Net Present Value (NPV)
- Benefit Cost Ratio (BCR).

A brief description of each indicator is provided as follows:

- NPV measures the difference between benefits and costs, whilst accounting for the timing of benefits and costs. Net cash flows are discounted at the prescribed discount rate, reflecting the notion that future benefits and costs have less value compared to current benefits and costs. A project with a Net Present Value greater than zero would be considered economic.
- BCR measures the return received per dollar of costs. The Benefit Cost Ratio is calculated by dividing the present value of all benefits by the present value of all costs. A project with a Benefit Cost Ratio greater than one would be considered economic.

Table 9.1 summarises the economic assessment results of each nominated scenario.

Table 9.1 Cost benefit results

Monetary values (,000)	Scenario 1	Scenario 2	Scenario 3	Scenario 4
PV Capital Cost	$177	$602	$1,268	$990
PV net maintenance cost	$21	$72	$152	$119
PV TOTAL COST	**$198**	**$674**	**$1,419**	**$1,108**
PV Travel time benefit	$9,876	$12,617	$9,148	$12,742
PV Vehicle operation cost savings	$1,845	$2,623	$2,811	$2,736
PV emission savings	$15	$18	$18	$17
PV Crash cost savings	$145	$145	$854	$273
Clearway disbenefit	-$7,985	-$12,103	-$5,511	-$12,103
PV TOTAL BENEFIT	**$3,865**	**$3,299**	**$7,319**	**$3,664**
NPV	**$3,667**	**$2,625**	**$5,899**	**$2,556**
BCR	**19.5**	**4.9**	**5.2**	**3.3**

PV – Present value

The detailed documentation of economic assessment is provided in Appendix C Memorandum *MR185 Lawrence Hargrave Drive at Thirroul – Rapid Economic Appraisal.*

10 Conclusions and recommendation

10.1 Options initiation and discussion

WSP | Parsons Brinckerhoff was commissioned by the Roads and Maritime Service to undertake a traffic study, including microsimulation traffic modelling for the purpose of assessing traffic operational performance on the Lawrence Hargrave Drive corridor (MR185) in Thirroul, between Hewitts Avenue to the south and Mary Street to the north.

Based on the calibrated and validated traffic model in 2016, Do-minimum scenarios were assessed in future year 2026 and 2036 for the AM, PM and Saturday (midday) peak periods. The results revealed that without providing any network upgrades, the Lawrence Hargrave Drive corridor would not have sufficient road capacity to accommodate the projected future traffic demands, particularly at the signalised Lawrence Hargrave Drive | Phillip Street intersection. In addition, excessive delays at side streets were predicted at almost all the priority controlled intersections, such as Arthur Street and Church Street. The detailed results are provided in section 3 of this report.

A traffic modelling and design workshop was held on 10 May 2016. Roads and Maritime and WSP | Parsons Brinckerhoff held discussions and prepared preliminary traffic options based on the traffic performance from the do-minimum traffic models. Following the discussion, the assessment of a total of *six model scenarios* (model scenario is combination of a variety of traffic option schemes) was agreed to be undertaken in *two stages* (hold point for Roads and Maritime review between each stage). The introduction of each traffic option scheme is provided in section 4 of this report.

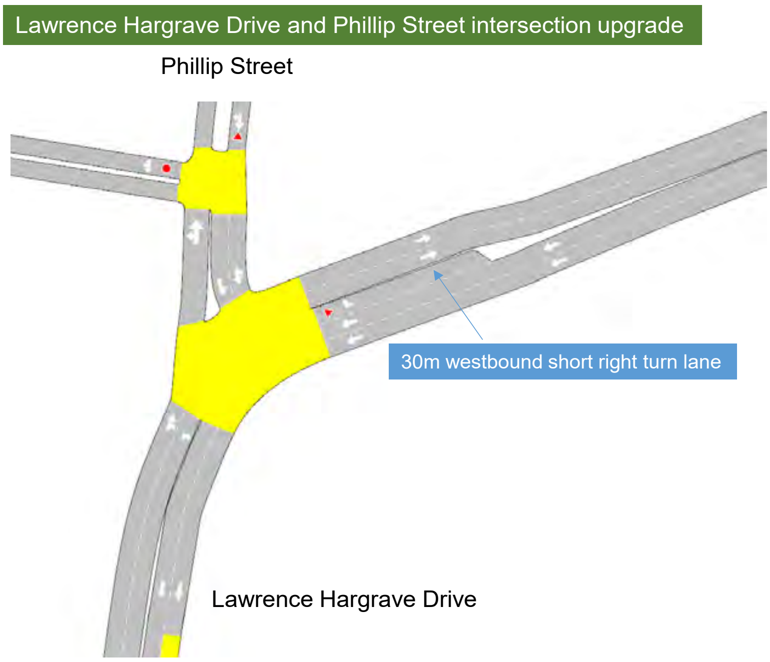
10.2 Stage 1 traffic modelling

Stage 1, being Scenario 1 and Scenario 2, determined the preferred layout of Lawrence Hargrave Drive | Phillip Street intersection, with peak directional clearways during weekday peak periods. The traffic assessment compares the network performance statistics, travel time and intersection performances on Lawrence Hargrave Drive corridor, between each scenario and the do-minimum base case (as shown in Table 10.1). It established that Scenario 2 would provide the most substantial improvement in traffic performance, particularly in the Saturday peak period.

Table 10.1 Comparison of results Scenario 1 and 2 vs Do-minimum

Scenario 1 and 2 vs Do-minimum in 2036	AM		PM		Saturday	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Total vehicle kilometre travelled (VKT)	+3%	+4%	+3%	+3%	+5%	+13%
Total vehicle hour travelled (VHT)	-17%	-23%	-23%	-38%	-16%	-38%
Average vehicle speed (km/h)	13%	+19%	26%	+42%	+16%	+58%
Travel time – northbound (minutes)	-0.1	-0.6	-0.5	-1.5	+1.4	-2.0
Travel time – southbound (minutes)	-1.9	-2.1	-2.1	-2.8	-2.1	-2.9

As a consequence of these results, Layout 2 of the Lawrence Hargrave Drive | Phillip Street intersection (shown in Figure 10.1) was recommended and endorsed by Roads and Maritime as the preferred arrangement to be carried forward to Stage 2 of the traffic modelling assessment. Crash reduction and economic assessment was undertaken for both Scenario 1 and Scenario 2.



Layout 2 (used in Scenario 2)

Figure 10.1 Preferred Layout 2 at Lawrence Hargrave Drive | Phillip Street

The detailed results and discussion relating to this layout are provided in section 5 of this report.

10.3 Stage 2 traffic modelling

10.3.1 With clearways scheme

Both Scenario 4 and Scenario 5 were developed based on Scenario 2, and incorporate peak directional clearways on Lawrence Hargrave Drive:

- Scenario 4 also provides additional short right turn lane on Lawrence Hargrave Drive to Station Street
- Scenario 5 also widens the rail overbridge across Church Street, on top of all the measures included in Scenario 4. This scenario provides a continuous two-lane section on Lawrence Hargrave Drive corridor in Thirroul.

The result of each scenario was compared to those of Scenario 2 (used as the base case). Scenario 4 provided a marginal delay reduction to the northbound right turn and through movement on Lawrence Hargrave Drive at Station Street. The individual intersection performances of Scenario 4 was predicted to be almost identical to those in Scenario 2. With the widening of the rail overbridge, Scenario 5 improves the intersection performance of those intersections north of Church Street in the AM and Saturday peak periods. Table 10.2 presents the results of network performance and travel time savings, highlighting the additional benefits provided by Scenario 5 in the AM and Saturday peak periods.

Table 10.2 Comparison of results Scenario 4 and 5 vs Scenario 2

Scenario 4 and 5 vs Scenario 2 in 2036	AM		Saturday	
	Scenario 4	Scenario 5	Scenario 4	Scenario 5
Total vehicle kilometre travelled (VKT)	-	-	-	-
Total vehicle hour travelled (VHT)		-2%	-3%	-6%
Average vehicle speed (km/h)		+4%	+5%	+11%
Travel time – northbound (minutes)	-	-12s	-	-18s
Travel time – southbound (minutes)		-18s	-12s	-

The difference below 1% or 10s in travel time is not provided.

Scenario 4 was agreed by Roads and Maritime to be carried forward for economic assessment due to its relatively cheaper costs to construct and implement. The detailed results and discussion relating to this Scenario is provided in section 6 of this report.

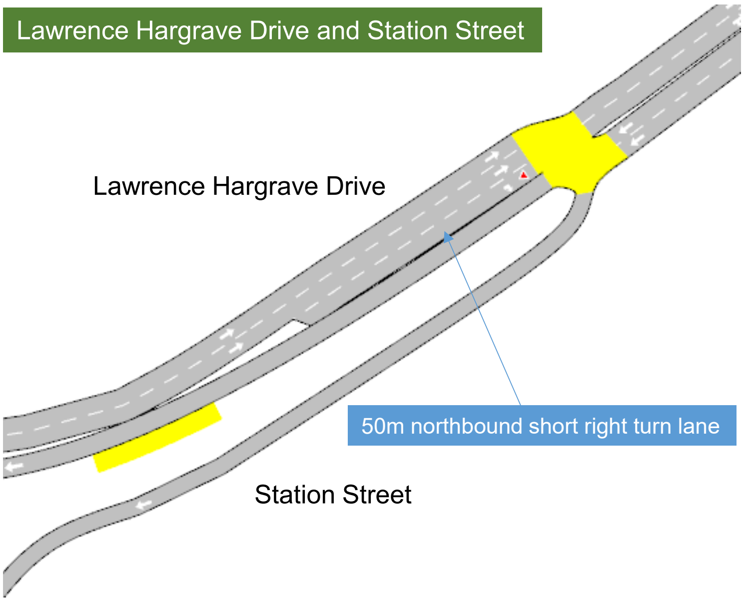


Figure 10.2 Proposed additional short right turn lane to Station Street in Scenario 4

The detailed results and associated discussion is provided in section 6.1 of this report.

10.3.2 Without clearways scheme

Both Scenario 3 and Scenario 6 were developed using Layout 2 of the Lawrence Hargrave Drive | Phillip Street intersection:

- Scenario 3 provides S-lane treatments (mainly lane marking changes to provide dedicated right turn lanes) in lieu of the clearway provision. It also aims to address the corridor capacity constraint on Saturday. The S-lanes would be implemented at 10 intersections on the corridor in this scenario.
- Scenario 6 is a low-cost option and provides S-lanes at Station Street, Raymond Road and Lachlan Street only.

The assessment results demonstrated that both scenarios provide benefits in terms of the network and intersection performances in all the peak periods. Scenario 3, with S-lane schemes implemented at 10 intersections on the corridor, was predicted to be more effective in addressing the congestion in Saturday peak as shown in Table 10.3.

Table 10.3 Comparison of results Scenario 3 and 6 vs Do-minimum

Scenario 3 and 6 vs Do-minimum in 2036	Saturday	
	Scenario 3	Scenario 6
Total vehicle kilometre travelled (VKT)	+14%	+13%
Total vehicle hour travelled (VHT)	-54%	-41%
Average vehicle speed (km/h)	+87%	+60%
Travel time – northbound (minutes)	-2.2	-1.8
Travel time – southbound (minutes)	-5.3	-3.3

It was agreed by Roads and Maritime Service that **Scenario 3** be carried forward for economic assessment as it provides more substantial benefits in Saturday peak. The details of the S-lane schemes proposed in Scenario 3 are provided in Figure 7.1

The detailed results and associated discussion is provided in Section 6.2 of this report.

10.4 Crash reduction and economic assessment

The Roads and Maritime *Accident Reduction Guide Part 1: Accident Investigation and Prevention (2004)* was used as a guide for the forecasting the changes in crash frequency as a result of the proposed treatments. The crash reduction results of the proposed Scenario 1, 2, 3 and 4 were assessed.

The results demonstrated that, compared to the do-minimum scenarios:

- Both Scenario 1 and Scenario 2 would reduce the total crash number by 3 (or 0.3 crashes/year)
- Scenario 4 would reduce the total crash number by 4 (or 0.4 crashes/year)
- Scenario 3 would reduce the total crash number by 16 (or 1.6 crashes/year); Scenario 3 has the highest crash reduction rate, resulted by the S-lane scheme on the entire Lawrence Hargrave Drive corridor in Thirroul.

All scenarios assessed in this rapid economic assessment are economically viable, as evidenced by positive NPVs and BCRs larger than 1, discounted at 7 percent. The cost benefit analysis shows Scenario 3 provides the highest NPV ($5.9M) whilst all the scenarios provide positive NPV and BCR greater than 1.0.

Travel time savings make up the largest proportion of benefits for all scenarios, with further significant cost savings due to reduced vehicle operating costs. Emissions savings and crash savings are not as significant. Negative benefits (or disbenefit) arise from the impact of lost parking spaces under each scenario.

10.5 Conclusion

Figure 10.3 provides a summary of the preferred scenario selection, with and without the clearways scheme. All the scenarios provide benefits to the network performance and corridor travel time in both future years 2026 and 2036. The following key factors were considered to select the preferred scenarios:

- The magnitude of the improvements each scenario provides to the road network, particularly in the Saturday peak, based on the microsimulation modelling results.
- The construction and implementation cost of the scenarios, based on the strategic estimation.

With the clearways scheme, **Scenario 4** was deemed as the preferred scenario (Section 10.3.1), due to its relatively lower costs (compared to Scenario 5 which will incur significant costs for rail over-bridge). In summary, it would provide the following benefits compared to the do-minimum scenario in future year 2036, based upon the microsimulation modelling results.

- VHT in network statistics are reduced by 32%, 45% and 37% in the respective AM, PM and Saturday peak periods.
- Number of vehicle stops in network statistics are 32%, 45% and 37% lower in the respective AM, PM and Saturday peak periods.
- Northbound travel time is improved by 20% (approximately 40 seconds), 35% (1 minute and 30 seconds) and 35% (2 minutes) in the respective AM, PM and Saturday peak hours.
- Southbound travel time is improved by 40% (approximately 2 minutes), 45% (3 minutes) and 37% (3 minutes) in the respective AM, PM and Saturday peak hours

Scenario 4 has a BCR of 3.3 and a positive NPV of $2.6M. It would also reduce the total crash number by four (or 0.4 crashes/year).

It was deemed that the implementation of clearways scheme should be complemented by the widening of Lawrence Hargrave Drive at Phillip Street intersection (Layout 2) in both 2026 and 2036.

Without the clearways scheme, **Scenario 3** was deemed as the preferred scenario (Section 10.3.2), due to the substantial benefits it would provide in Saturday peak (compared to Scenario 6). In summary, it would provide the following benefits compared to the do-minimum scenario in future year 2036, based upon the microsimulation modelling results.

- VHT in network statistics are reduced by 17%, 38% and 54% in the respective AM, PM and Saturday peak periods.
- Number of vehicle stops in network statistics are 23%, 50% and 56% lower in the respective AM, PM and Saturday peak periods.
- Northbound travel time is improved by 18% (approximately 40 seconds), 30% (1 minute and 20 seconds) and 39% (2 minutes) in the respective AM, PM and Saturday peak hours.
- Southbound travel time is improved by 30% (approximately 1 minute and 40 seconds), 52% (3 minutes) and 62% (5 minute s and 20 seconds) in the respective AM, PM and Saturday peak hours.

Scenario 3 has a BCR of 5.2 and a positive NPV of $5.9M. It would also reduce the total crash number by 16 (or 1.6 crashes/year).

The provision of two through lanes on Lawrence Hargrave Drive (Layout 2) is not fully utilised in Scenario 3 (without clearways) due to the downstream single lane section for the through movement. A staging implementation approach, such as upgrading to Layout 1 prior to 2026 and then to Layout 2 in 2036, might provide higher cost-efficiency for this scenario.

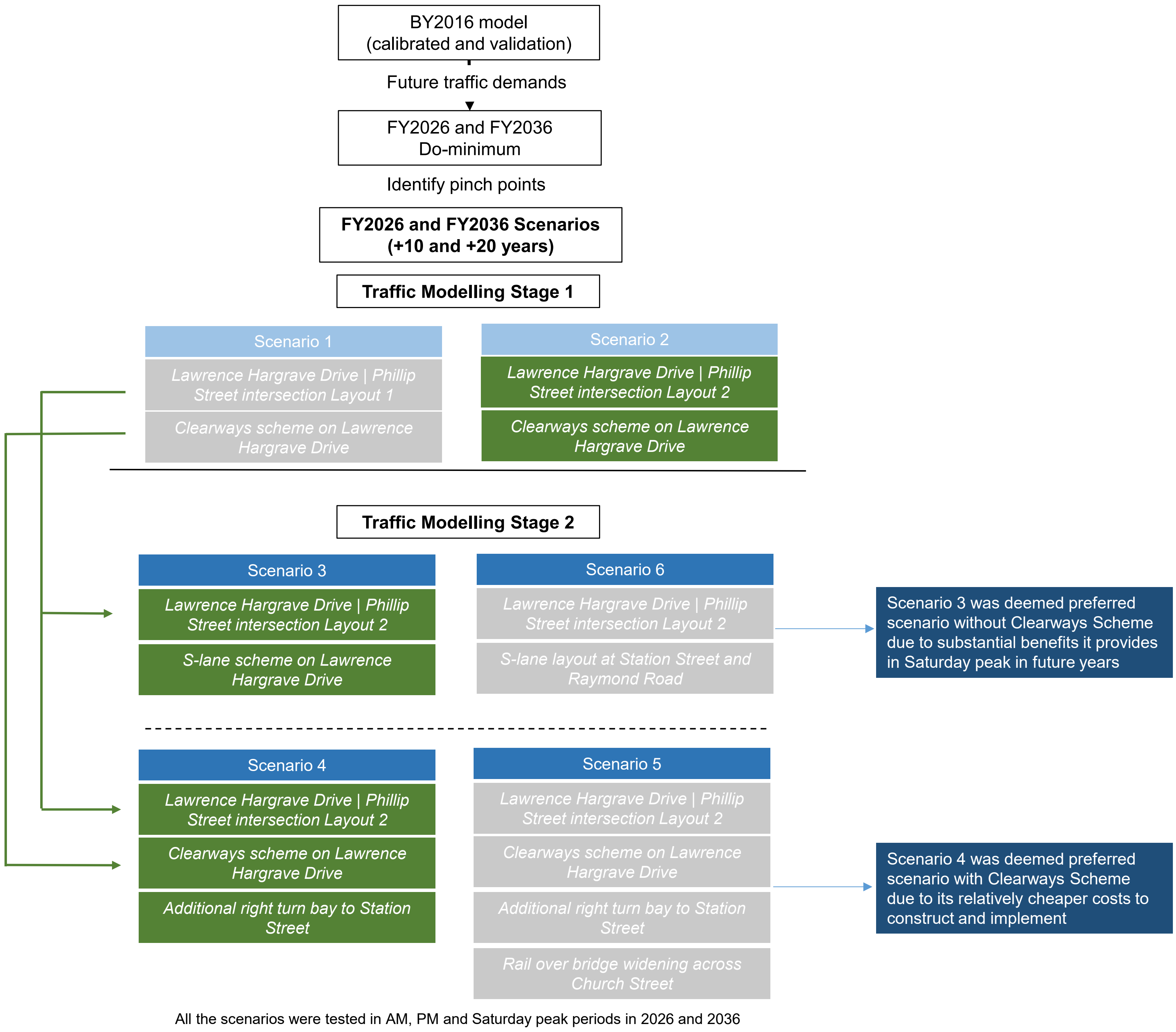


Figure 10.3 Preferred Scenario selection

Appendix A

MEMORANDUM: *BULLI AND THIRROUL FUTURE TRAFFIC GROWTH ASSUMPTIONS*

MEMO

TO: s74 Scope

FROM:

SUBJECT: **Bulli & Thirroul future traffic growth assumptions**

OUR REF: 2196958A-ITP-MEM-002-RevA.docx

DATE: **4 May 2016**

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1. INTRODUCTION

WSP | Parsons Brinckerhoff was commissioned by New South Wales Roads and Maritime Services (Roads and Maritime) to undertake traffic modelling of the following corridors:

- Princes Highway, Bulli
- Lawrence Hargrave Drive, Thirroul.

This modelling project was commissioned to assess the existing and future operational performance and identify future improvement options for the above two corridors in the future years 2026 and 2036.

This technical memorandum has been prepared to document the following assumptions:

- Future year background traffic growth
- Future year development traffic.

As part of preparing this memorandum, the following data sources and references have been reviewed:

- Population and employment forecasts sourced from the NSW Bureau of Statistics and Analytics (BSA) website
- Forecast traffic growth from the Roads and Maritime TRACKS model for 2011, 2021 and 2036
- Historical AADT traffic growth at Roads and Maritime traffic count stations
- Bulli Pass Strategic Review (Roads and Maritime, October 2015).

2. BACKBROUND TRAFFIC GROWTH ANALYSIS

2.1 Population and employment

The population and employment forecasts from the NSW Bureau of Transport Statistics for the following suburbs have been analysed for the period 2011–2036:

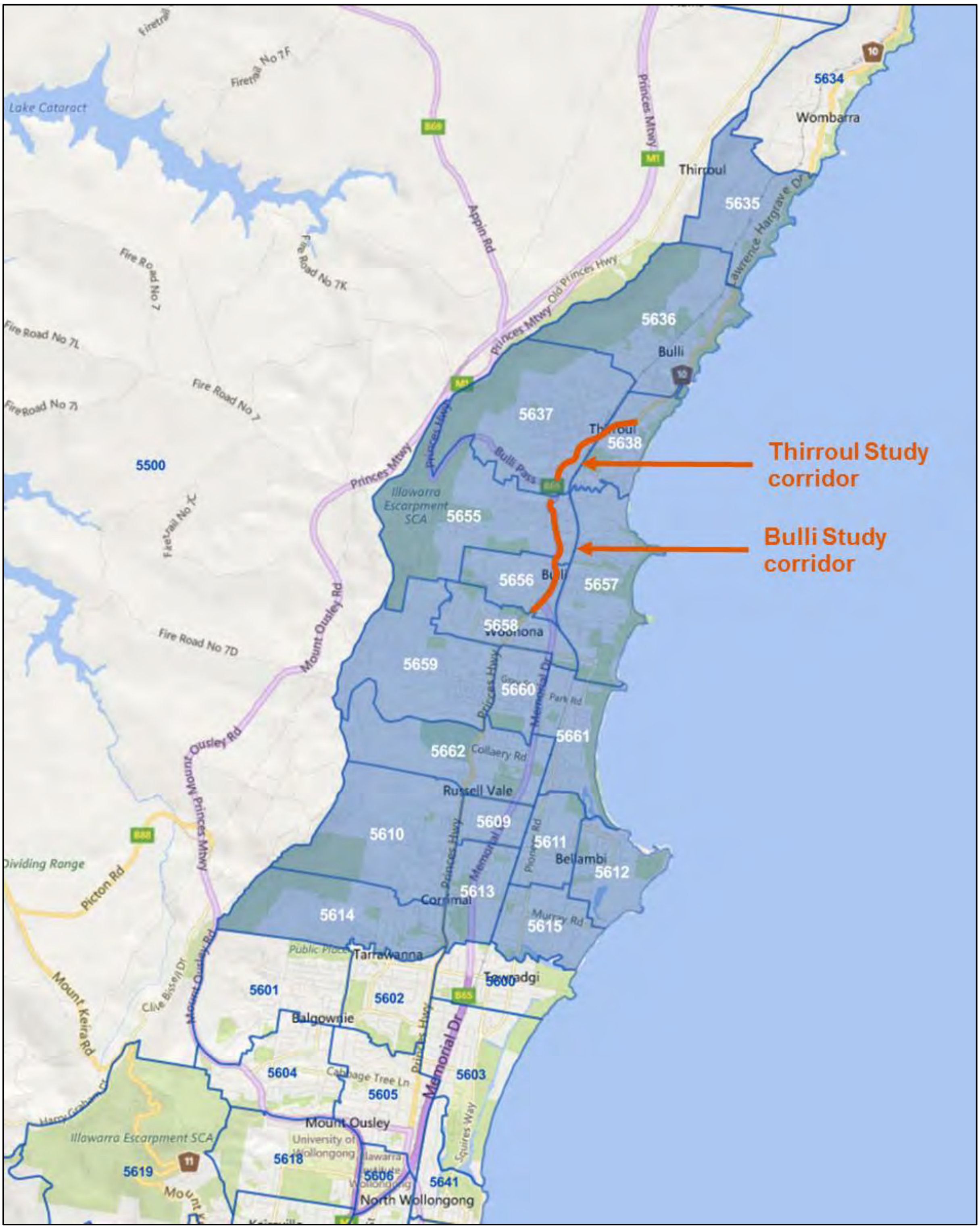
- **Austinmer**
- **Thirroul**
- **Bulli**
- **Russell Vale**
- **Bellambi**
- **Corrimal**
- **Towradgi.**

These suburbs comprise a total of 16 travel zones (based on 2011 Travel Zone Geography) which are shown in Figure 2.1. These specific suburbs have been chosen based upon the expected catchment for the Lawrence Hargrave Drive, Princes Highway and Memorial Drive corridors which are most likely to impact traffic demand within and travelling through the Bulli and Thirroul area. The wide network connectivity to the Princes Motorway means that the area selected covers between the southern-most suburb, Towradgi and the northern-most suburb, Austinmer.

The population and employment forecasts are summarised in Table 2.1, with the selected travel zones shown in Figure 2.1. The population, employment and workforce forecasts show a steady rate of growth over the five year intervals between 2011 and 2036. Overall, the data indicates that the short and long term growth rates in population and employment within the study corridor are approximately 0.5% p.a. It is noted that the growth rate for the local workforce is expected to be slower, at approximately 0.2% p.a. which indicates that the population is gaining an increasing percentage of retirees.

Table 2.1 Population & employment forecast growth (per annum)

FROM	2011	2016	2021	2026	2031	2011	2021
TO	**2016**	**2021**	**2026**	**2031**	**2036**	**2021**	**2036**
Population	0.3%	0.7%	0.4%	0.4%	0.3%	0.5%	0.4%
Employment	0.4%	0.6%	0.5%	0.6%	0.6%	0.5%	0.6%
Workforce	0.0%	0.6%	0.2%	0.1%	0.2%	0.4%	0.1%



Source: *NSW Bureau of Statistics and Analytics (BSA) & Bing Maps*

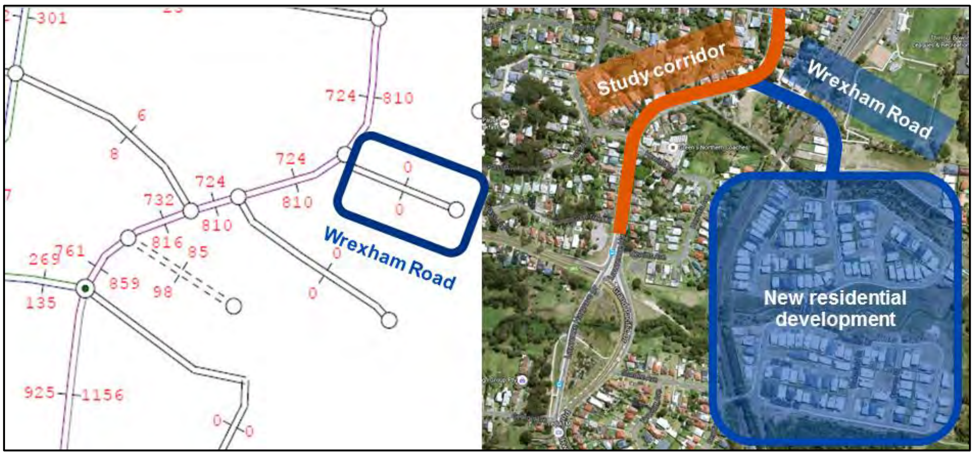
Figure 2.1 2011 Travel zones selected

2.2 TRACKS model forecasts

2.2.1 Overview

The Roads and Maritime WOLSH06 TRACKS model is a strategic model of the traffic flows within the wider Wollongong and Illawarra region. As part of this project, Roads and Maritime provided the relevant link flow diagrams for the Princes Highway corridor in Bulli and the surrounding areas. An example of the link flow diagram is presented in Figure 2.2. It is noted that the link flow diagrams do not distinguish between light vehicles and heavy vehicles. The TRACKS model outputs were provided for 2011, 2021 and 2036 for one hour AM and PM peak periods. As part of the analysis, future year modelling horizons 2026 and 2036 were agreed with Roads and Maritime.

It is noted that TRACKS link flow plots indicate that within the Thirroul study area, there is no zone connector defined for Wrexham Road in any modelling scenarios. However the aerial images from Google Earth indicate that there has been recent residential development work in this area, as indicated on Figure 2.2.



Source: *TRACKS WM36NL link plot & Google Maps*

Figure 2.2 TRACKS model link flows (2036 AM), Wrexham Road development

Similar issues exist in the Bulli study area. TRACKS does not include the proposed residential development site west of Grevillea Park Road, as shown in the Figure 2.3.

Figure 2.3 TRACKS model link flows (2036 AM), Grevillea Park Road development

2.2.2 Link flow traffic growth

Princes Highway and Memorial Drive – Bulli

It was noted that the 2011 TRACKS link flows were significantly higher than 2016 traffic counts on Princes Highway and Memorial Drive, as shown in Table 2.5.

Table 2.2 TRACKS 2011 link flows vs 2016 traffic counts – Bulli

SECTION	AM PEAK		PM PEAK	
	TRACKS 2011	Traffic counts 2016	TRACKS 2011	Traffic counts 2016
Princes Highway, North of Memorial Drive	3,200	2,100	3,300	2,500
Princes Highway, North of Park Road	3,200	2,200	3,300	2,600
Princes Highway, North of Hobart Street	2,900	2,300	3,000	2,600
Princes Highway, South of Hospital Road	1,100	700	1,200	1,000
Memorial Drive, East of Princes Highway	2,200	1,600	2,300	1,900

It is noted that over the longer term (2021–2036), the TRACKS model growth rates on both corridors are comparable to the BSA population and employment growth forecasts of 0.5% p.a.

Table 2.3 TRACKS model link flow growth (per annum) – Bulli

SECTION	2011–2021			2021–2036		
	NB	SB	TOTAL	NB	SB	TOTAL
Princes Highway – AM	0.6%	1.2%	0.9%	0.8%	0.5%	0.7%
Princes Highway – PM	1.0%	0.7%	0.8%	0.5%	0.5%	0.5%
Memorial Drive – AM	0.7%	1.4%	1.1%	0.6%	0.3%	0.5%
Memorial Drive – PM	1.1%	0.6%	0.8%	0.4%	0.4%	0.4%

Lawrence Hargrave Drive – Thirroul

Not surprisingly, 2016 traffic counts on Lawrence Hargrave Drive are higher than those from the 2011 TRACKS model, as shown in Table 2.4.

Table 2.4 TRACKS 2011 link flows vs 2016 traffic counts – Thirroul

SECTION	AM PEAK		PM PEAK	
	TRACKS 2011	Traffic counts 2016	TRACKS 2011	Traffic counts 2016
Lawrence Hargrave Drive, north of Raymond Road	1,300	1,300	1,400	1,500
Lawrence Hargrave Drive, south of Railway Parade	1,400	1,500	1,500	1,700
Lawrence Hargrave Drive, south of Wrexham Road	1,500	1,900	1,500	2,000

Based upon the TRACKS link flow plots, the model suggests that the traffic growth rate will be comparable in both directions with a slight decline in growth rate over the longer term, as shown in Table 2.5. It is noted that over both short and long term, the TRACKS model growth rate on Lawrence Hargrave Drive is similar to the BSA population and employment forecast growth 0.5% p.a.

Table 2.5 TRACKS model link flow growth (per annum)

SECTION	2011–2021			2021–2036		
	NB	SB	TOTAL	NB	SB	TOTAL
Lawrence Hargrave Drive – AM	0.5%	0.4%	0.4%	0.3%	0.2%	0.3%
Lawrence Hargrave Drive – PM	0.6%	0.3%	0.5%	0.5%	0.3%	0.4%

2.3 Historical traffic growth

2.3.1 Overview

The AADT midblock traffic counts at the locations in Table 2.6 have been reviewed as part of estimating the historical traffic growth within the study area.

Table 2.6 Permanent count station locations

STATION ID	ROAD	COUNT TYPE	YEARS COVERED
07747	Bulli Pass	Vehicles	2012–2015 (ADT)
07766	Princes Highway, north of Bellambi Lane, Russell Vale (south of project area)	Vehicles	1990, 1992–2009 2010–2015 (ADT)
07801	Memorial Drive, south of Towradgi Road, Towradgi	Vehicles	1990, 1992–2006 2007–2011, 2015 (ADT)
07749	Princes Highway, north of Hobart Street, Bulli	Vehicles	1990, 1992, 1994, 1997, 1998, 2000, 2003, 2005

It is noted that the Memorial Drive (formerly the Northern Distributor) connection to Bulli was opened in 2009. In addition, the analysis of the historical AADT volumes indicated individual years where there were significant fluctuations in traffic volumes. This would most likely be related to the opening of new links or road upgrades and the redistribution of traffic between the Princes Highway and Memorial Drive connection at Bulli roundabout.

The only available historical traffic counts are at Lawrence Hargrave Drive, Clifton, which is significantly north of the Thirroul study area. As a consequence the counts at this location were not used.

2.3.2 Growth analysis

This historical traffic growth analysis summarised in Table 2.7 indicates that prior to 2005, the traffic growth on the Princes Highway and Memorial Drive ranged between 0.5–1.7% p.a.

Over the recent 10-year period, there was a significant amount of traffic growth on the Princes Highway (1.8% p.a.) and Memorial Drive (1.4% p.a.). The traffic growth on the Bulli Pass was calculated as being between 0.8% and 1.4% p.a. A historical growth of 1.4% p.a. on Bulli Pass was used in the *Bulli Pass Strategic Review* (Roads and Maritime, October 2015).

Table 2.7 AADT/ADT annual growth at Roads and Maritime count stations

STATION ID	ROAD	10-YEAR GROWTH UP TO 2005	RECENT 10-YEAR GROWTH
Bulli study area or surrounding			
07749	Princes Highway, north of Hobart Street	1.4%	-
07766	Princes Highway, north of Bellambi Lane, Russell Vale (1)	0.5%	1.8%
07801	Memorial Drive, south of Towradgi Road, Towradgi (1)	1.7%	1.4%
07.747	Bulli Pass	3.3%	0.8%–1.4%(2)
No count station is located within Thirroul study area			

(1) south of Bulli study area
(2) 1.4% was used in the *Bulli Pass Strategic Review*

The peak period traffic growth rates for 2010–2015 were also calculated and are shown in Table 2.8. The historical peak hour traffic growth trend, following the completion of the Memorial Drive extension to Bulli, indicates that whilst the growth for Princes Highway is negligible, the traffic growth on Memorial Drive and Bulli Pass are higher, at around 2–3% p.a. The traffic growth on the Saturday peak period is mostly consistent with the weekday trends for the Princes Highway, Memorial Drive and Bulli Pass.

It was recommended that the available recent 10-year traffic growth rate be adopted to forecast the future traffic demands for the modelling exercise, whilst the peak hour growth rate (with limited data range) be used as a sensitivity test if required.

Table 2.8 Recent peak hour traffic growth – Weekday/weekend (per anum)

STATION ID	ROAD	AFTER 2010		
		Weekday AM peak	Weekday PM peak	Saturday peak
Bulli study area				
07747	Bulli Pass (1)	3.2%	2.8%	2.4%
07766	Princes Highway, north of Bellambi Lane, Russell Vale (2)	-0.4%	0.1%	-0.4%
07801	Memorial Drive, south of Towradgi Road, Towradgi (3)	2.1%	2.1%	2.7%
No count station is located within Thirroul study area				

(1) Traffic growth for these sites are 2012–2015 due to no data being available for 2010 and 2011
(2) Traffic growth for these sites are 2010–2014 as the 2015 dataset is limited to five days
(3) 2015 data is incomplete with only southbound traffic, use ADT growth instead

2.4 Conclusion and recommendation of background traffic growth

The comparison of the forecast and historical traffic growth results from the various sources is summarised in Table 2.9.

Table 2.9 Comparison of traffic forecast and historical trends

AVERAGE ANNUAL GROWTH RATE		WEEKDAY AM PEAK	WEEKDAY PM PEAK	SATURDAY PEAK
BSA Population and Employment forecasts	Bulli and Thirroul catchment area	Short term: 0.5% Long term: 0.5%		
TRACK models **Short term: 2011–2021** **Long term: 2021–2036**	Princes Highway	Long term: 0.7%	Long term: 0.5%	n/a
	Memorial Drive	Long term: 0.5%	Long term: 0.4%	
	Lawrence Hargrave Drive	Short term: 0.4% Long term: 0.3%	Short term: 0.5% Long term: 0.4%	
Historical traffic growth (10-year growth)	Bulli Pass	1.4%	1.4%	1.4%
	Princes Highway north of Hobart Street	1.4%	1.4%	1.4%
	Memorial Drive, Towradgi	1.4%	1.4%	1.4%

Based upon an assessment of the available information the recommendations for the future year traffic growth rates are summarised in Table 2.10. Overall, it is proposed that:

- The TRACKS model results, historical growth rate and the BSA population and employment forecast, which is greater, will be applied for short term growth (up to 2021)
- The TRACKS model results and the BSA population and employment forecast, which is greater, will be applied for long term growth
- For any locations where the annual growth was indicated as being negative, the BSA population and employment growth is used as a conservative assessment for the future year scenario.

Table 2.10 Recommended future background traffic growth rates (per annum)

ANNUAL GROWTH RATES	WEEKDAY AM PEAK		WEEKDAY PM PEAK		SATURDAY PEAK	
	Short term (before 2021)	Long term (after 2021)	Short term (before 2021)	Long term (after 2021)	Short term (before 2021)	Long term (after 2021)
Bulli Pass	1.4%	0.5%	1.4%	0.5%	1.4%	0.5%
Princes Highway	1.4%	0.7%	1.4%	0.5%	1.4%	0.5%
Memorial Drive	1.4%	0.5%	1.4%	0.5%	1.4%	0.5%
Lawrence Hargrave Drive	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Other side streets	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%

BSA – highlighted in 'yellow'; TRACKS results – highlighted in 'blue'; Historical AADT/ADT – highlighted in 'green

3. DEVELOPMENT TRAFFIC

The traffic impact assessments for the approved and committed developments within the Bulli and Thirroul study areas have been provided by Roads and Maritime. As part of this, the following reports have been provided:

- Thirroul study area:
  - Sandon Point residential subdivision (2007, 2008 and 2009)
- Bulli study area:
  - Sturdee Avenue seniors housing and residential care facility (2006)
  - Bulli Brickworks residential development (2012).

As discussed in section 2.2, the proposed developments at Bulli Brickworks (accessing via Grevillea Park Road) and Sandon Point (accessing via Wrexham Road) have not been included in the TRACKS models. In addition, these developments are of sufficient scale that the application of background traffic growth rates on the existing flows for these roads would not be sufficient to reflect the expected traffic demand generated by these developments.

As a result of the split between the model coverage areas, the additional trips applied to one study area (e.g. Thirroul) is proposed to be applied to the second study area (e.g. Bulli) as additional through trips. These trips will be distributed according to the origin-destination survey commissioned as part of these studies.

For the purposes of modelling the Saturday peak period, it is proposed to utilise the same trip generation and distribution as the weekday peak period. Where trip generation rates differ between the AM and PM peak periods, an average of the two will be utilised. This is in the absence of guidance in the *Guide to Traffic Generating Developments v2.2 (2002)* and *TDT 2013/04a* regarding weekend trip generation for low density residential areas and wellness/recreation centres.

Overall, it is considered that the application of the weekday peak period trip generation rates during the Saturday peak will be sufficient to provide a fit for purpose model of the future year scenarios and the impact of the proposed developments.

3.1 Sandon Point residential subdivision

The proposed Sandon Point residential subdivision consists of the following development yield:

- 167 low-density dwellings
- 14 medium density townhouses
- 80 medium density apartment units
- 232 seniors living retirement dwellings
- 102 assisted care dwellings.

Based upon this development yield, the following peak period trip generation would result:

- AM peak: 270 vehicle trips/hour
- PM peak: 332 vehicle trips/hour.

The majority of the trips generated by the development are expected to access and egress the site via Wrexham Road according to the distribution in Table 3.1. However, the abovementioned reports also identify a connection to Point Street, and that trips to/from Wollongong would utilise this link. As a result, the number of trips entering/exiting via Wrexham Road would reduce to:

- AM peak: 211 vehicle trips/hour
- PM peak: 279 vehicle trips/hour.

The difference in trips to the estimated site trip generation is assumed to travel via Point Street. As no entry/exit splits have been defined in the traffic assessment for the Point Street movements, the following splits are proposed:

- AM peak: 20% entry/80% exit
- PM peak: 80% entry/20% exit.

These splits are consistent with those applied for the Wrexham Road trip distribution and are generally consistent with the industry standard applied to residential developments as part of traffic impact assessments.

The reporting does not identify a more detailed trip distribution other than vehicles travelling north or south on Lawrence Hargrave Drive. The forecast traffic volumes of some movements are lower than the corresponding existing traffic volumes.

As a result, it is proposed to distribute these additional trips to match the forecast traffic volumes, whilst maintaining the existing traffic level in other directions. The modelled traffic volumes related to this development are summarised in Table 3.2.

Table 3.1 Forecast trip distribution in RMS report – Sandon Point

ORIGIN-DESTINATION (TRIPS)	AM – IN	AM – OUT	PM – IN	PM – OUT
Lawrence Hargrave Drive (north)	95	80	98	140
Lawrence Hargrave Drive (south)	11	25	26	15
Point Street (Bulli)	14	55	42	11

Source: *Traffic access to Sandon Point – Intersection of Lawrence Hargrave Drive & Wrexham Road, Thirroul, Christopher Hallam & Associates (2009)*

Table 3.2 Modelled trip distribution – Sandon Point

ORIGIN-DESTINATION (TRIPS)	AM – IN	AM – OUT	PM – IN	PM – OUT	SAT-IN	SAT-OUT
Lawrence Hargrave Drive (north)	95	80	98	140	97	110
Lawrence Hargrave Drive (south)	17	63	72	28	45	46
Point Street (Bulli)	14	55	42	11	28	33

Source: *Traffic access to Sandon Point – Intersection of Lawrence Hargrave Drive & Wrexham Road, Thirroul, Christopher Hallam & Associates (2009) & Austraffic 2016 traffic survey*

3.2 Bulli Brickworks

The proposed Bulli Brickworks consists of the following development yield:

- 250 low-density dwellings
- 4,000 m^2 GFA wellness and recreation centre.

This proposed development would generate approximately 230 vehicle trips/hour during the AM and PM peak periods. The trip distribution utilised as part of the traffic assessment is summarised in Table 3.3.

Table 3.3 Modelled trip distribution – Bulli Brickworks development

ORIGIN-DESTINATION (TRIPS)	AM – IN	AM – OUT	PM – IN	PM – OUT	SAT-IN	SAT-OUT
Princes Highway (north)	30	70	70	30	50	50
Princes Highway (south)	30	70	70	30	50	50
Point Street	5	10	10	5	8	8
Park Road	5	10	10	5	8	8

Source: Transport report for proposed residential/mixed use development, Bulli, Colston Budd Hunt & Kafes (2012)

This trip distribution indicates that the majority of trips are expected to travel on the Princes Highway to/from the site, via Grevillea Park Road. However, the trip distribution only covers the section of the Princes Highway between Point Street and Park Road. As a result, it does not identify whether drivers will be travelling to the specific destinations. Thus, the 2016 OD survey results were used as the key indicator for the following destination split:

- Lawrence Hargrave Drive or Bulli Pass (to the north)
- Princes Highway or Memorial Drive (to the south).

Other than the reported distribution to Point Street and Park Road, it is proposed to apply the existing trip distributions to the aforementioned roads (i.e. based upon the origin-destination surveys commissioned as part of this study).

3.3 Sturdee Avenue residential care facility

It is noted that the traffic study undertaken for the Sturdee Avenue residential care facility identified that the additional trip generation of the site (compared to the existing land use) is approximately 15 additional trips during the peak periods. As a result, the impact of this development is expected to be incorporated within the background traffic growth assumptions and as such no additional traffic is proposed to be assigned to the Sturdee Avenue or Beattie Avenue travel zones.

4. CONCLUSION AND RECOMMENDATION

Table 4.1 summarises the total future background traffic growth for the future modelling year 2026 and 2036, based on the annual growth rate recommended in Table 2.10. The traffic growth will be applied to both directions of each corridor by each origin zone on the basis that both TRACKS results show similar traffic growth in both directions, particularly over the long term.

Table 4.1 Proposed cumulative future traffic growth (by modelling years)

2016 CUMULATIVE TRAFFIC GROWTH DEMANDS	WEEKDAY AM PEAK		WEEKDAY PM PEAK		SATURDAY PEAK	
	2026	2036	2026	2036	2026	2036
Bulli Pass	10%	16%	10%	16%	10%	16%
Princes Highway	11%	19%	10%	16%	10%	16%
Memorial Drive	10%	16%	10%	16%	10%	16%
Lawrence Hargrave Drive	5%	10%	5%	10%	5%	10%
Other side streets	5%	10%	5%	10%	5%	10%

In relation to the proposed traffic generating developments within the Thirroul and Bulli study areas, it is proposed that the approved trip generation rates and distributions be applied for the Sandon Point residential subdivision and Bulli Brickworks developments.

These developments, combined, are estimated to generate approximately 400 vehicle trips during the weekday AM and PM peak periods. For the purposes of modelling, this trip generation rate will also be applied during the Saturday peak period due to limited guidance from the *Guide to Traffic Generating Developments v2.2 (2002)* and *TDT 2013/04a* for the relevant land uses.

The predicted future traffic volumes at the midblock locations along Princes Highway and Memorial Drive were summarised in Table 4.2 and Table 4.3. The future traffic volumes considered both background traffic growth and the development traffic from Sandon Point and Bulli Brickworks.

Table 4.2 Predicted future year midblock volumes – Bulli 2026

Section – Future year 2026		AM peak hour			PM peak hour			SAT peak hour		
		NB	SB	Total	NB	SB	Total	NB	SB	Total
Princes Highway	North of Memorial Drive	1,240	1,740	2,980	1,520	1,670	3,180	1,370	1,550	2,920
Princes Highway	North of Park Road	1,340	1,750	3,080	1,580	1,750	3,330	1,490	1,480	2,970
Princes Highway	North of Hobart Street	1,420	1,600	3,020	1,420	1,810	3,240	1,460	1,460	2,920
Princes Highway	South of Hospital Road	600	610	1,210	540	760	1,300	630	600	1,220
Memorial Drive	East of Princes Highway	910	1,360	2,280	1,260	1,040	2,300	980	1,040	2,020

Table 4.3 Predicted future year midblock volumes – Bulli 2036

Section – Future year 2036		AM peak hour			PM peak hour			SAT peak hour		
		NB	SB	Total	NB	SB	Total	NB	SB	Total
Princes Highway	North of Memorial Drive	1,310	1,840	3,150	1,590	1,750	3,340	1,440	1,620	3,060
Princes Highway	North of Park Road	1,410	1,840	3,250	1,650	1,840	3,490	1,560	1,550	3,110
Princes Highway	North of Hobart Street	1,500	1,680	3,180	1,500	1,900	3,400	1,530	1,530	3,060
Princes Highway	South of Hospital Road	650	650	1,290	570	800	1,370	660	620	1,280
Memorial Drive	East of Princes Highway	960	1,430	2,390	1,320	1,090	2,410	1,020	1,090	2,120

The predicted future traffic volumes at the midblock locations along Lawrence Hargrave Drive were summarised in Table 4.4 and Table 4.5. The future traffic volumes considered both background traffic growth and the development traffic from Sandon Point and Bulli Brickworks.

Table 4.4 Predicted future year midblock volumes – Thirroul 2026

Section – future year 2026		AM peak hour			PM peak hour			SAT peak hour		
		NB	SB	Total	NB	SB	Total	NB	SB	Total
Lawrence Hargrave Drive	South of Princes Street	840	1,300	2,140	1,390	920	2,310	1,220	1,140	2,360
Lawrence Hargrave Drive	South of Phillip Street	960	1,260	2,220	1,360	1,020	2,380	1,250	1,180	2,430
Lawrence Hargrave Drive	South of Raymond Road	710	980	1,690	1,100	800	1,900	1,130	1,000	2,130
Lawrence Hargrave Drive	South of Mary Street	510	850	1,360	860	630	1,490	890	890	1,780

Table 4.5 Predicted future year midblock volumes – Thirroul 2036

Section – future year 2036		AM peak hour			PM peak hour			SAT peak hour		
		NB	SB	Total	NB	SB	Total	NB	SB	Total
Lawrence Hargrave Drive	South of Princes Street	880	1,360	2,240	1,460	960	2,420	1,280	1,200	2,480
Lawrence Hargrave Drive	South of Phillip Street	1,000	1,320	2,320	1,420	1,070	2,490	1,310	1,230	2,540
Lawrence Hargrave Drive	South of Raymond Road	740	1,030	1,770	1,140	840	1,980	1,180	1,040	2,220
Lawrence Hargrave Drive	South of Mary Street	530	890	1,420	890	660	1,550	930	930	1,860

Following review and agreement with Roads and Maritime, WSP | Parsons Brinckerhoff will input the proposed future year traffic growth rates in the future year traffic modelling.

s74 Scope

Transport Modeller Principal Transport Engineer

Appendix B

SCENARIO RESULTS

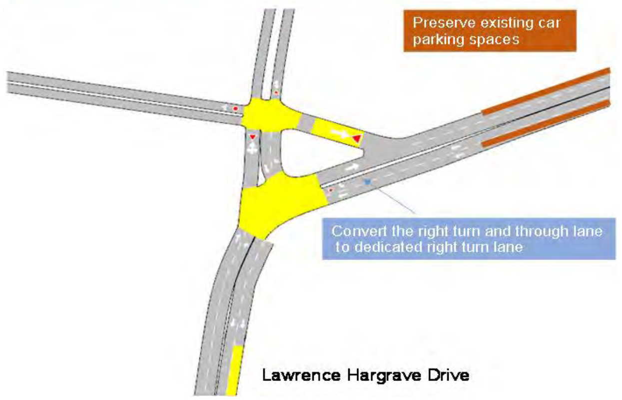
B1. SCENARIO 1 RESULTS

Scenario 1

Weekday Peak direction clearway on Lawrence Hargrave Drive
Lawrence Hargrave Drive | Phillip Street (Layout 1)

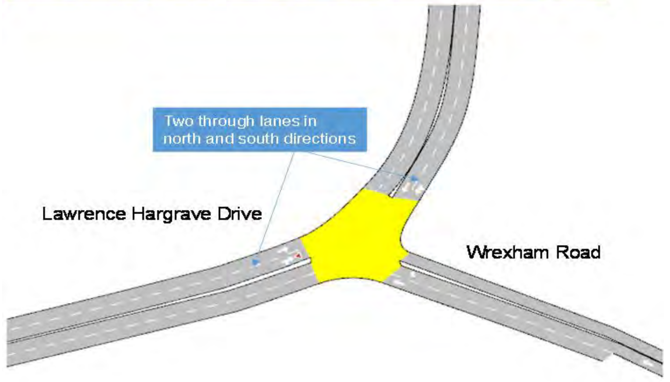
Main upgraded intersection layouts

Lawrence Hargrave Drive and Phillip Street intersection upgrade



Lawrence Hargrave Drive and Prince Street roundabout upgrade

Lawrence Hargrave Drive and Wrexham Road intersection upgrade



Network statistics comparison

	2026	2026	2026	2026	2036	2036	2036	2036
AM peak	Do-minimum	Scenario 1	Diff	Diff %	Do-minimum	Scenario 1	Diff	Diff %
Performance indicators (all veh classes)	Average	Average	Average	Average	Average	Average	Average	Average
	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.
Total vehicle kilometre travelled (VKT)	7,815	7,966	152	2%	8,020	8,272	252	3%
Total vehicle hour travelled (VHT)	275	247	-27	-10%	327	271	-56	-17%
Average vehicle speed (km/h)	31	33	3	8%	29	32	4	13%
Average vehicle delay (seconds/km)	59	45	-15	-25%	82	52	-29	-36%
Completed trips	5,252	5,339	87	2%	5,385	5,549	164	3%
Incomplete trips	460	370	-90	-20%	595	428	-167	-28%
Unreleased trips	1	0	-1	-81%	46	5	-41	-89%
Number of stops	8,396	6,830	-1,565	-19%	9,923	7,553	-2,370	-24%

	2026	2026	2026	2026	2036	2036	2036	2036
PM peak	Do-minimum	Scenario 1	Diff	Diff %	Do-minimum	Scenario 1	Diff	Diff %
Performance indicators (all veh classes)	Average	Average	Average	Average	Average	Average	Average	Average
	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.
Total vehicle kilometre travelled (VKT)	8,967	9,133	166	2%	9,244	9,521	277	3%
Total vehicle hour travelled (VHT)	378	330	-48	-13%	489	374	-115	-23%
Average vehicle speed (km/h)	27	31	4	13%	23	29	6	26%
Average vehicle delay (seconds/km)	102	77	-25	-25%	145	92	-53	-36%
Completed trips	6,285	6,398	113	2%	6,478	6,665	187	3%
Incomplete trips	401	320	-81	-20%	498	375	-123	-25%
Unreleased trips	103	8	-95	-93%	255	45	-210	-82%
Number of stops	12,664	10,041	-2,623	-21%	16,252	11,576	-4,677	-29%

	2026	2026	2026	2026	2036	2036	2036	2036
Saturday peak	Do-minimum	Scenario 1	Diff	Diff %	Do-minimum	Scenario 1	Diff	Diff %
Performance indicators (all veh classes)	Average	Average	Average	Average	Average	Average	Average	Average
	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	7 - 9 a.m.	11 a.m. - 1 p.m.
Total vehicle kilometre travelled (VKT)	9,575	10,023	449	5%	9,557	10,005	448	5%
Total vehicle hour travelled (VHT)	697	571	-127	-18%	813	683	-129	-16%
Average vehicle speed (km/h)	19	22	3	17%	17	19	3	16%
Average vehicle delay (seconds/km)	223	164	-59	-27%	283	219	-64	-23%
Completed trips	6,528	6,886	359	5%	6,533	6,884	351	5%
Incomplete trips	912	659	-252	-28%	964	782	-182	-19%
Unreleased trips	495	166	-328	-66%	1,093	649	-444	-41%
Number of stops	22,045	19,454	-2,591	-12%	24,488	22,682	-1,805	-7%

Travel time resutls and difference (minutes)

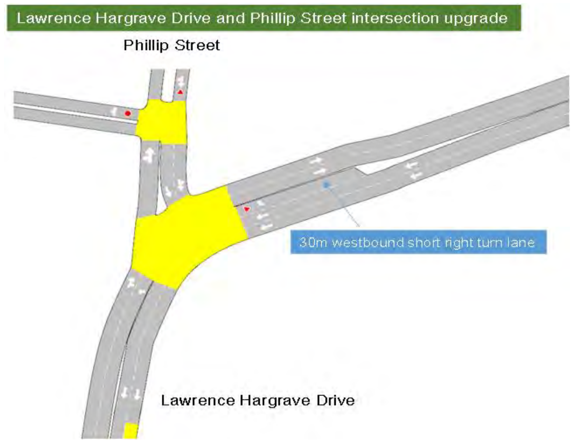
			AM peak hour	PM peak hour	Saturday peak hour
Northbound on Lawrence Hargrave Drive, between south of Hewitts Avenue to Mary Street	2026	Do-minimum	3.4	4.1	5.1
		Scenario 1	3.1	3.4	5.5
		Diff	-0.3	-0.7	0.4
		Diff%	-8%	-16%	8%
	2036	Do-minimum	3.5	4.3	5.5
		Scenario 1	3.5	3.8	6.9
		Diff	-0.1	-0.5	1.4
		Diff%	-2%	-12%	26%
Southbound on Lawrence Hargrave Drive, between Mary Street o south of Hewitts Avenue	2026	Do-minimum	4.1	4.3	8.7
		Scenario 1	3.2	3.5	6.7
		Diff	-0.9	-0.9	-2.0
		Diff%	-22%	-20%	-23%
	2036	Do-minimum	5.2	6.1	8.7
		Scenario 1	3.3	4.1	6.6
		Diff	-1.9	-2.1	-2.1
		Diff%	-36%	-34%	-24%

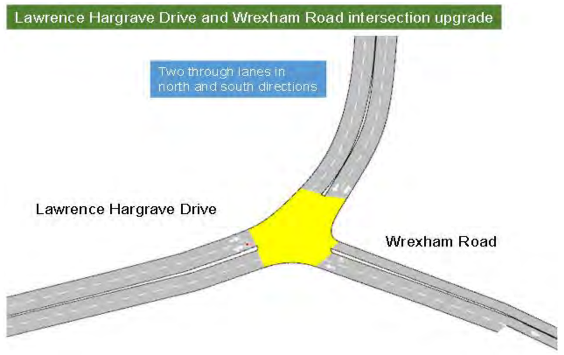
B2. SCENARIO 2 RESULTS

Scenario 2

Weekday Peak direction clearway on Lawrence Hargrave Drive
Lawrence Hargrave Drive | Phillip Street (Layout 2)

Main upgraded intersection layouts





Other changes: remove 6 car parking spaces between Phillip Street and Railway Parade

Network statistics comparison

AM peak	2026 Do-minimum	2026 Scenario 2	2026 Diff	2026 Diff %	2036 Do-minimum	2036 Scenario 2	2036 Diff	2036 Diff %
Performance indicators (all veh classes)	Average	Average	Average	Average	Average	Average	Average	Average
	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.
Total vehicle kilometre travelled (VKT)	7,815	8,150	335	4%	8,020	8,345	325	4%
Total vehicle hour travelled (VHT)	275	242	-32	-12%	327	253	-74	-23%
Average vehicle speed (km/h)	31	35	4	12%	29	34	5	19%
Average vehicle delay (seconds/km)	59	41	-19	-31%	82	43	-38	-47%
Completed trips	5,252	5,498	246	5%	5,385	5,601	216	4%
Incomplete trips	460	316	-144	-31%	595	357	-238	-40%
Unreleased trips	1	0	-1	-81%	46	1	-45	-99%
Number of stops	8,396	6,632	-1,764	-21%	9,923	6,789	-3,134	-32%

PM peak	2026 Do-minimum	2026 Scenario 2	2026 Diff	2026 Diff %	2036 Do-minimum	2036 Scenario 2	2036 Diff	2036 Diff %
Performance indicators (all veh classes)	Average	Average	Average	Average	Average	Average	Average	Average
	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.
Total vehicle kilometre travelled (VKT)	8,967	9,158	191	2%	9,244	9,556	312	3%
Total vehicle hour travelled (VHT)	378	285	-93	-25%	489	304	-186	-38%
Average vehicle speed (km/h)	27	34	7	24%	23	33	10	42%
Average vehicle delay (seconds/km)	102	51	-51	-50%	145	53	-92	-64%
Completed trips	6,285	6,417	132	2%	6,478	6,697	218	3%
Incomplete trips	401	285	-117	-29%	498	301	-197	-40%
Unreleased trips	103	3	-99	-97%	255	4	-250	-98%
Number of stops	12,664	8,301	-4,364	-34%	16,252	8,972	-7,281	-45%

Saturday peak	2026 Do-minimum	2026 Scenario 2	2026 Diff	2026 Diff %	2036 Do-minimum	2036 Scenario 2	2036 Diff	2036 Diff %
Performance indicators (all veh classes)	Average	Average	Average	Average	Average	Average	Average	Average
	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.
Total vehicle kilometre travelled (VKT)	9,575	10,416	842	9%	9,557	10,792	1,235	13%
Total vehicle hour travelled (VHT)	697	385	-312	-45%	813	500	-312	-38%
Average vehicle speed (km/h)	19	30	11	57%	17	26	10	58%
Average vehicle delay (seconds/km)	223	71	-152	-68%	283	114	-169	-60%
Completed trips	6,528	7,148	621	10%	6,533	7,397	864	13%
Incomplete trips	912	379	-533	-58%	964	552	-412	-43%
Unreleased trips	495	4	-491	-99%	1,093	52	-1,041	-95%
Number of stops	22,045	12,592	-9,453	-43%	24,488	16,375	-8,113	-33%

Travel time resutls comparison (minutes)

Route	Year		AM peak hour	PM peak hour	Saturday peak hour
Northbound on Lawrence Hargrave Drive, between south of Hewitts Avenue to Mary Street	2026	Do-minimum	3.4	4.1	5.1
		Scenario 2	2.8	2.8	3.0
		Difference	-0.6	-1.4	-2.1
		Difference %	-17%	-33%	-40%
	2036	Do-minimum	3.5	4.3	5.5
		Scenario 2	2.9	2.8	3.5
		Difference	-0.6	-1.5	-2.0
		Difference %	-17%	-35%	-37%
Southbound on Lawrence Hargrave Drive, between Mary Street o south of Hewitts Avenue	2026	Do-minimum	4.1	4.3	8.7
		Scenario 2	3.1	3.2	4.2
		Difference	-1.0	-1.1	-4.4
		Difference %	-25%	-26%	-51%
	2036	Do-minimum	5.2	6.1	8.7
		Scenario 2	3.2	3.4	5.7
		Difference	-2.1	-2.8	-2.9
		Difference %	-40%	-45%	-34%

B3. SCENARIO 4 RESULTS

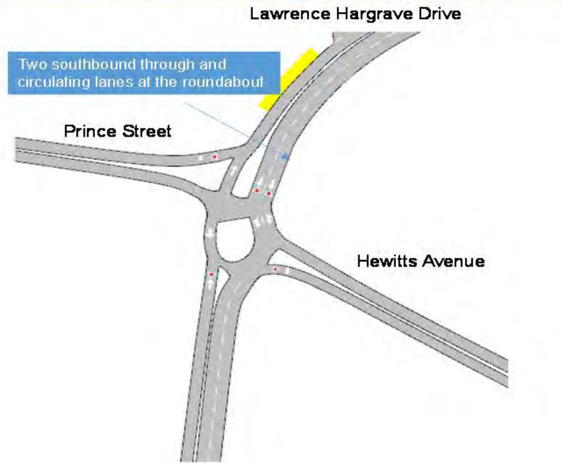
Scenario 4

Weekday Peak direction clearway on Lawrence Hargrave Drive - identical to Scenario 2
Lawrence Hargrave Drive | Phillip Street (Layout 2) - identical to Scenario 2
Lawrence Hargrave Drive | Station Street: additional Northbound right turn bay 50m

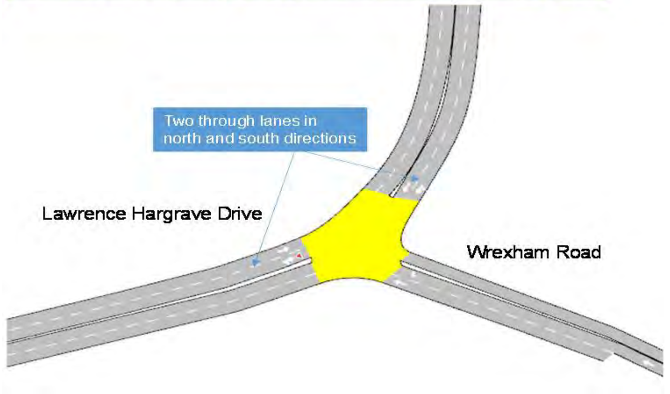
Main upgraded intersection layouts

Lawrence Hargrave Drive and Phillip Street intersection upgrade

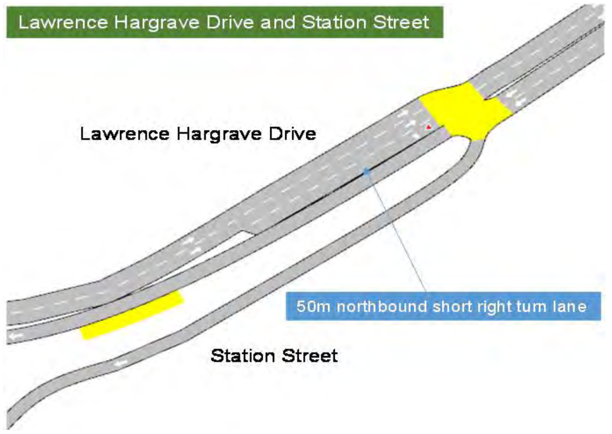
Lawrence Hargrave Drive and Prince Street roundabout upgrade



Lawrence Hargrave Drive and Wrexham Road intersection upgrade



Lawrence Hargrave Drive and Station Street



Network statistics comparison

	2026	2026	2026	2026	2036	2036	2036	2036
AM peak	Do-minimum	Scenario 4	Diff	Diff %	Do-minimum	Scenario 4	Diff	Diff %
Performance indicators (all veh classes)	Average	Average	Average	Average	Average	Average	Average	Average
	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.
Total vehicle kilometre travelled (VKT)	7,815	8,157	343	4%	8,020	8,356	336	4%
Total vehicle hour travelled (VHT)	275	242	-33	-12%	327	252	-75	-23%
Average vehicle speed (km/h)	31	35	4	12%	29	34	5	19%
Average vehicle delay (seconds/km)	59	40	-19	-32%	82	43	-39	-48%
Completed trips	5,252	5,502	251	5%	5,385	5,608	222	4%
Incomplete trips	460	310	-149	-32%	595	349	-246	-41%
Unreleased trips	1	0	-1	-81%	46	1	-45	-99%
Number of stops	8,396	6,574	-1,821	-22%	9,923	6,701	-3,222	-32%

	2026	2026	2026	2026	2036	2036	2036	2036
PM peak	Do-minimum	Scenario 4	Diff	Diff %	Do-minimum	Scenario 4	Diff	Diff %
Performance indicators (all veh classes)	Average	Average	Average	Average	Average	Average	Average	Average
	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.
Total vehicle kilometre travelled (VKT)	8,967	9,158	191	2%	9,244	9,552	308	3%
Total vehicle hour travelled (VHT)	378	284	-93	-25%	489	304	-185	-38%
Average vehicle speed (km/h)	27	34	7	24%	23	33	10	42%
Average vehicle delay (seconds/km)	102	50	-52	-51%	145	53	-92	-63%
Completed trips	6,285	6,417	132	2%	6,478	6,694	216	3%
Incomplete trips	401	284	-118	-29%	498	302	-197	-39%
Unreleased trips	103	3	-99	-97%	255	5	-250	-98%
Number of stops	12,664	8,255	-4,409	-35%	16,252	8,977	-7,276	-45%

	2026	2026	2026	2026	2036	2036	2036	2036
Saturday peak	Do-minimum	Scenario 4	Diff	Diff %	Do-minimum	Scenario 4	Diff	Diff %
Performance indicators (all veh classes)	Average	Average	Average	Average	Average	Average	Average	Average
	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	7 - 9 a.m.	11 a.m. - 1 p.m.
Total vehicle kilometre travelled (VKT)	9,575	10,393	818	9%	9,557	10,826	1,270	13%
Total vehicle hour travelled (VHT)	697	383	-315	-45%	813	479	-333	-41%
Average vehicle speed (km/h)	19	30	11	58%	17	27	10	62%
Average vehicle delay (seconds/km)	223	72	-151	-68%	283	105	-178	-63%
Completed trips	6,528	7,131	604	9%	6,533	7,425	892	14%
Incomplete trips	912	390	-521	-57%	964	513	-451	-47%
Unreleased trips	495	13	-481	-97%	1,093	30	-1,062	-97%
Number of stops	22,045	12,250	-9,795	-44%	24,488	15,520	-8,967	-37%

Travel time resutls and difference (minutes)			AM peak hour	PM peak hour	Saturday peak hour
Northbound on Lawrence Hargrave Drive, between south of Hewitts Avenue to Mary Street	2026	Do-minimum	3.4	4.1	5.1
		Scenario 4	2.8	2.7	3.0
		Diff	-0.6	-1.4	-2.1
		Diff%	-19%	-33%	-42%
	2036	Do-minimum	3.5	4.3	5.5
		Scenario 4	2.8	2.8	3.5
		Diff	-0.7	-1.5	-1.9
		Diff%	-20%	-35%	-35%
Southbound on Lawrence Hargrave Drive, between Mary Street o south of Hewitts Avenue	2026	Do-minimum	4.1	4.3	8.7
		Scenario 4	3.1	3.2	4.4
		Diff	-1.0	-1.1	-4.2
		Diff%	-25%	-26%	-49%
	2036	Do-minimum	5.2	6.1	8.7
		Scenario 4	3.1	3.4	5.5
		Diff	-2.1	-2.8	-3.2
		Diff%	-40%	-45%	-37%

B4. SCENARIO 5 RESULTS

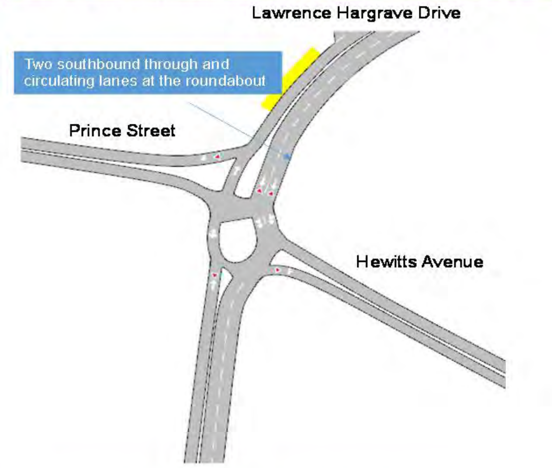
Scenario 5

Weekday Peak direction clearway on Lawrence Hargrave Drive - identical to Scenario 2
Lawrence Hargrave Drive | Phillip Street (Layout 2) - identical to Scenario 2
Lawrence Hargrave Drive | Station Street: additional Northbound right turn bay 50m - identical to Scenario 4
Church Street railway bridge widening

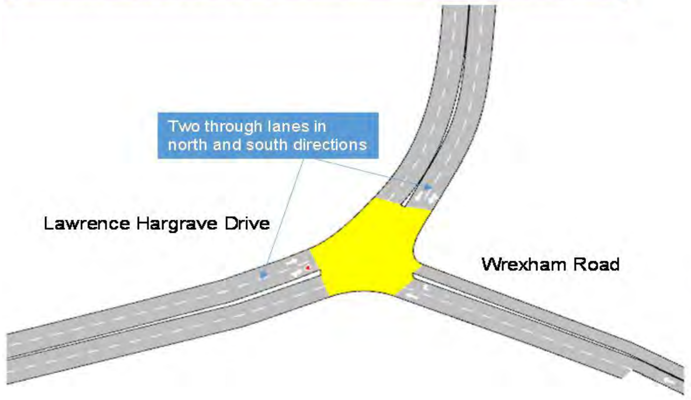
Main upgraded intersection layouts

Lawrence Hargrave Drive and Phillip Street intersection upgrade

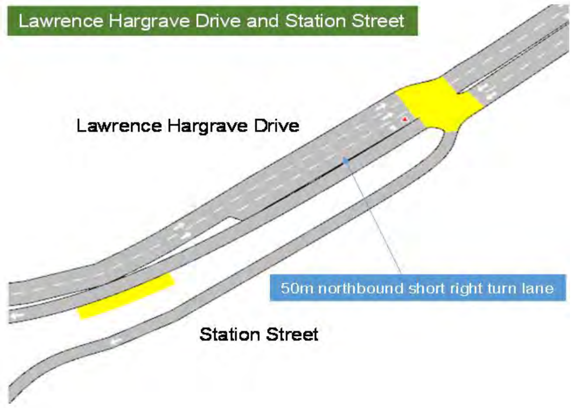
Lawrence Hargrave Drive and Prince Street roundabout upgrade



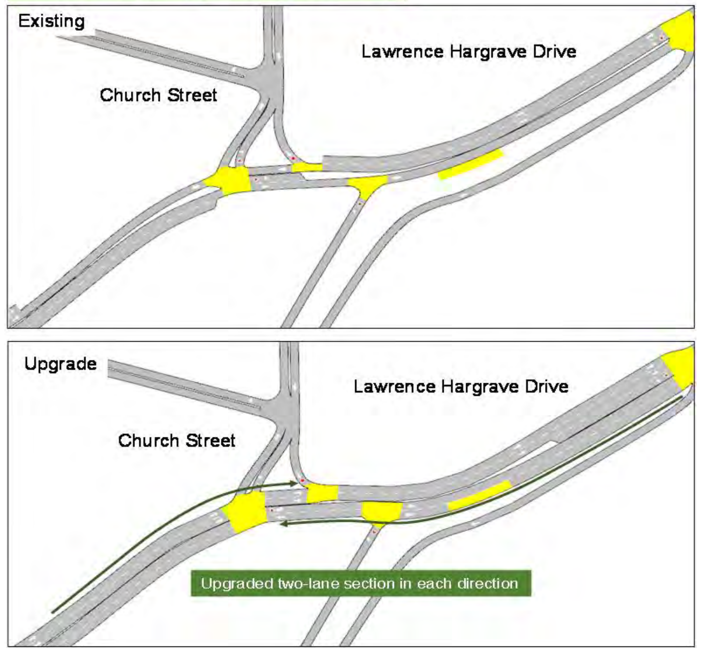
Lawrence Hargrave Drive and Wrexham Road intersection upgrade



Lawrence Hargrave Drive and Station Street



Church Street Railway Overbridge Widening



Network statistics comparison

	2026	2026	2026	2026	2036	2036	2036	2036
AM peak	Do-minimum	Scenario 5	Diff	Diff %	Do-minimum	Scenario 5	Diff	Diff %
Performance indicators (all veh classes)	Average	Average	Average	Average	Average	Average	Average	Average
	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.
Total vehicle kilometre travelled (VKT)	7,815	8,182	368	5%	8,020	8,413	393	5%
Total vehicle hour travelled (VHT)	275	235	-39	-14%	327	244	-83	-25%
Average vehicle speed (km/h)	31	36	5	15%	29	35	7	23%
Average vehicle delay (seconds/km)	59	37	-22	-37%	82	39	-43	-52%
Completed trips	5,252	5,517	265	5%	5,385	5,639	254	5%
Incomplete trips	460	294	-166	-36%	595	310	-285	-48%
Unreleased trips	1	0	-1	-81%	46	1	-45	-99%
Number of stops	8,396	6,217	-2,179	-26%	9,923	6,278	-3,645	-37%

	2026	2026	2026	2026	2036	2036	2036	2036
PM peak	Do-minimum	Scenario 5	Diff	Diff %	Do-minimum	Scenario 5	Diff	Diff %
Performance indicators (all veh classes)	Average	Average	Average	Average	Average	Average	Average	Average
	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.
Total vehicle kilometre travelled (VKT)	8,967	9,147	180	2%	9,244	9,553	308	3%
Total vehicle hour travelled (VHT)	378	281	-97	-26%	489	301	-189	-39%
Average vehicle speed (km/h)	27	34	7	26%	23	34	10	44%
Average vehicle delay (seconds/km)	102	50	-52	-51%	145	53	-93	-64%
Completed trips	6,285	6,413	128	2%	6,478	6,696	218	3%
Incomplete trips	401	282	-119	-30%	498	297	-202	-40%
Unreleased trips	103	3	-100	-97%	255	3	-252	-99%
Number of stops	12,664	7,991	-4,673	-37%	16,252	8,737	-7,515	-46%

	2026	2026	2026	2026	2036	2036	2036	2036
Saturday peak	Do-minimum	Scenario 5	Diff	Diff %	Do-minimum	Scenario 5	Diff	Diff %
Performance indicators (all veh classes)	Average	Average	Average	Average	Average	Average	Average	Average
	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	7 - 9 a.m.	11 a.m. - 1 p.m.
Total vehicle kilometre travelled (VKT)	9,575	10,406	832	9%	9,557	10,863	1,306	14%
Total vehicle hour travelled (VHT)	697	365	-332	-48%	813	455	-358	-44%
Average vehicle speed (km/h)	19	31	12	62%	17	28	11	69%
Average vehicle delay (seconds/km)	223	62	-161	-72%	283	91	-191	-68%
Completed trips	6,528	7,143	615	9%	6,533	7,463	930	14%
Incomplete trips	912	364	-548	-60%	964	496	-469	-49%
Unreleased trips	495	2	-492	-100%	1,093	3	-1,090	-100%
Number of stops	22,045	11,733	-10,312	-47%	24,488	15,066	-9,421	-38%

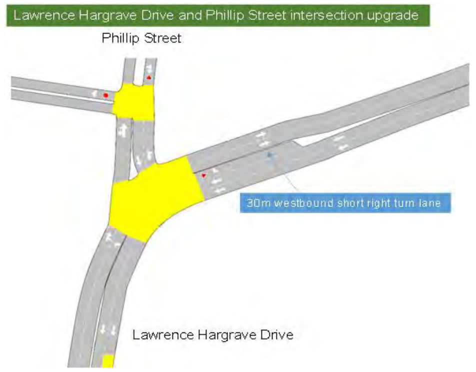
Travel time resutls and difference (minutes)			AM peak hour	PM peak hour	Saturday peak hour
Northbound on Lawrence Hargrave Drive, between south of Hewitts Avenue to Mary Street	2026	Do-minimum	3.4	4.1	5.1
		Scenario 5	2.7	2.7	2.9
		Diff	-0.7	-1.5	-2.2
		Diff%	-20%	-35%	-43%
	2036	Do-minimum	3.5	4.3	5.5
		Scenario 5	2.8	2.7	3.2
		Diff	-0.8	-1.6	-2.3
		Diff%	-22%	-37%	-42%
Southbound on Lawrence Hargrave Drive, between Mary Street o south of Hewitts Avenue	2026	Do-minimum	4.1	4.3	8.7
		Scenario 5	2.9	3.2	4.2
		Diff	-1.3	-1.2	-4.5
		Diff%	-31%	-27%	-52%
	2036	Do-minimum	5.2	6.1	8.7
		Scenario 5	2.9	3.4	5.7
		Diff	-2.3	-2.7	-2.9
		Diff%	-45%	-45%	-34%

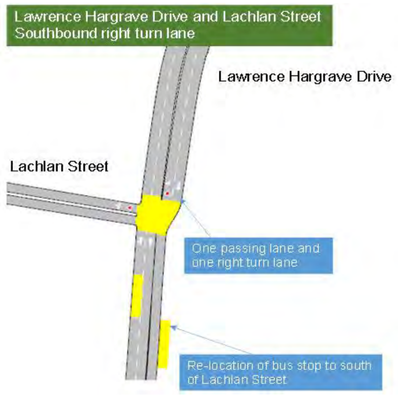
B5. SCENARIO 3 RESULTS

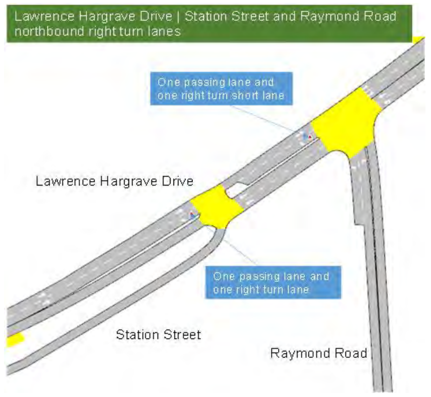
Scenario 3

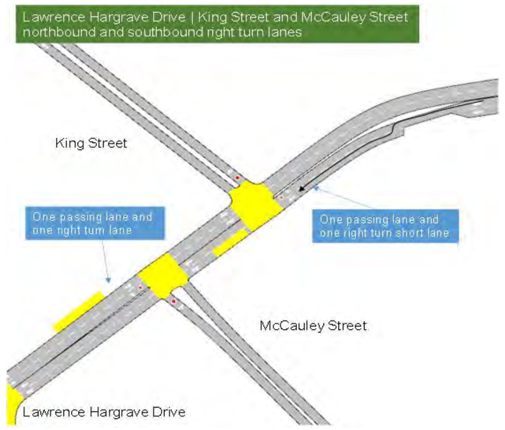
Lawrence Hargrave Drive | Phillip Street (Layout 2)
Lawrence Hargrave Drive | Station Street: Northbound right turn bay
Lawrence Hargrave Drive | Raymond Road: Northbound lanes converted to one thorugh and one right turn lane
Lawrence Hargrave Drive | Lachlan Street: southbound lanes converted to one thorugh and one right turn lane
Lawrence Hargrave Drive | Mary Street: Additional northbound short right turn bay – 30 m
Lawrence Hargrave Drive | The Esplanade: Northbound lanes convert to one through lane and one dedicated right turn lane
Lawrence Hargrave Drive | Arthur Street: Northbound and southbound lanes convert to one through lane and one dedicated right turn lane
Lawrence Hargrave Drive | King Street: Southbound lanes convert to one through lane and one dedicated right turn lane
Lawrence Hargrave Drive | McCauley Street: Northbound lanes convert to one through lane and one dedicated right turn lane
Lawrence Hargrave Drive | Church Street: Retain existing layout
Lawrence Hargrave Drive | Railway Parade: Retain existing layout
Lawrence Hargrave Drive | Wrexham Road: Additional northbound short right turn bay (signalised) – 50 m
Lawrence Hargrave Drive | High Street: Additional southbound short right turn bay – 30 m
Lawrence Hargrave Drive | Princes Street: Retain existing layout

Main upgraded intersection layouts









Network statistics comparison

	2026	2026	2026	2026	2036	2036	2036	2036
AM peak	Do-minimum	Scenario 3	Diff	Diff %	Do-minimum	Scenario 3	Diff	Diff %
Performance indicators (all veh classes)	Average	Average	Average	Average	Average	Average	Average	Average
	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.
Total vehicle kilometre travelled (VKT)	7,815	8,101	286	4%	8,020	8,248	228	3%
Total vehicle hour travelled (VHT)	275	255	-20	-7%	327	272	-55	-17%
Average vehicle speed (km/h)	31	33	2	7%	29	32	3	12%
Average vehicle delay (seconds/km)	59	48	-12	-20%	82	54	-27	-34%
Completed trips	5,252	5,469	217	4%	5,385	5,540	155	3%
Incomplete trips	460	363	-97	-21%	595	439	-155	-26%
Unreleased trips	1	1	-1	-44%	46	6	-40	-88%
Number of stops	8,396	7,033	-1,363	-16%	9,923	7,595	-2,329	-23%

	2026	2026	2026	2026	2036	2036	2036	2036
PM peak	Do-minimum	Scenario 3	Diff	Diff %	Do-minimum	Scenario 3	Diff	Diff %
Performance indicators (all veh classes)	Average	Average	Average	Average	Average	Average	Average	Average
	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.
Total vehicle kilometre travelled (VKT)	8,967	9,167	200	2%	9,244	9,551	307	3%
Total vehicle hour travelled (VHT)	378	286	-92	-24%	489	305	-184	-38%
Average vehicle speed (km/h)	27	34	6	23%	23	33	9	41%
Average vehicle delay (seconds/km)	102	51	-51	-50%	145	56	-90	-62%
Completed trips	6,285	6,425	140	2%	6,478	6,695	217	3%
Incomplete trips	401	278	-123	-31%	498	304	-194	-39%
Unreleased trips	103	1	-102	-99%	255	6	-249	-98%
Number of stops	12,664	7,598	-5,067	-40%	16,252	8,111	-8,141	-50%

	2026	2026	2026	2026	2036	2036	2036	2036
Saturday peak	Do-minimum	Scenario 3	Diff	Diff %	Do-minimum	Scenario 3	Diff	Diff %
Performance indicators (all veh classes)	Average	Average	Average	Average	Average	Average	Average	Average
	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	7 - 9 a.m.	11 a.m. - 1 p.m.
Total vehicle kilometre travelled (VKT)	9,575	10,404	829	9%	9,557	10,924	1,368	14%
Total vehicle hour travelled (VHT)	697	335	-362	-52%	813	377	-436	-54%
Average vehicle speed (km/h)	19	33	13	71%	17	31	15	87%
Average vehicle delay (seconds/km)	223	53	-170	-76%	283	64	-219	-77%
Completed trips	6,528	7,142	614	9%	6,533	7,506	973	15%
Incomplete trips	912	328	-584	-64%	964	370	-594	-62%
Unreleased trips	495	2	-493	-100%	1,093	1	-1,092	-100%
Number of stops	22,045	9,393	-12,652	-57%	24,488	10,896	-13,592	-56%

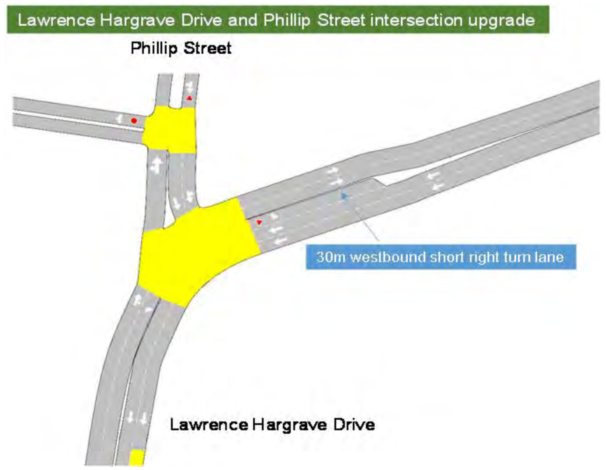
Travel time resutls and difference (minutes)			AM peak hour	PM peak hour	Saturday peak hour
Northbound on Lawrence Hargrave Drive, between south of Hewitts Avenue to Mary Street	2026	Do-minimum	3.4	4.1	5.1
		Scenario 3	2.8	2.9	3.0
		Diff	-0.6	-1.2	-2.1
		Diff%	-17%	-29%	-42%
	2036	Do-minimum	3.5	4.3	5.5
		Scenario 3	2.9	3.0	3.3
		Diff	-0.6	-1.3	-2.2
		Diff%	-18%	-30%	-39%
Southbound on Lawrence Hargrave Drive, between Mary Street o south of Hewitts Avenue	2026	Do-minimum	4.1	4.3	8.7
		Scenario 3	3.5	2.9	3.2
		Diff	-0.7	-1.4	-5.5
		Diff%	-16%	-33%	-63%
	2036	Do-minimum	5.2	6.1	8.7
		Scenario 5	3.7	3.0	3.3
		Diff	-1.6	-3.2	-5.3
		Diff%	-30%	-52%	-62%

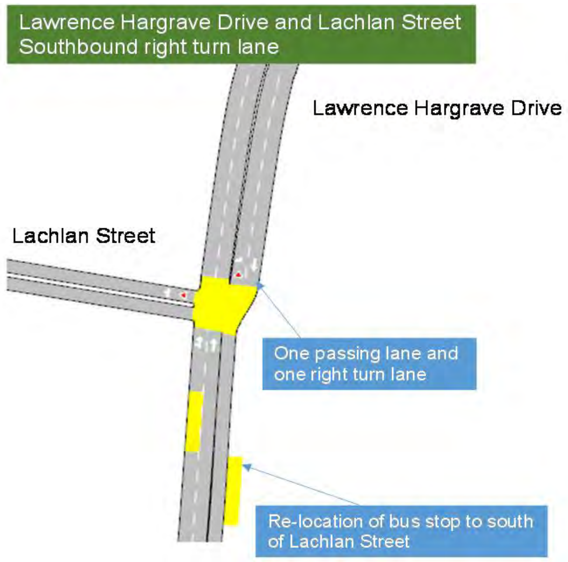
B6. SCENARIO 6 RESULTS

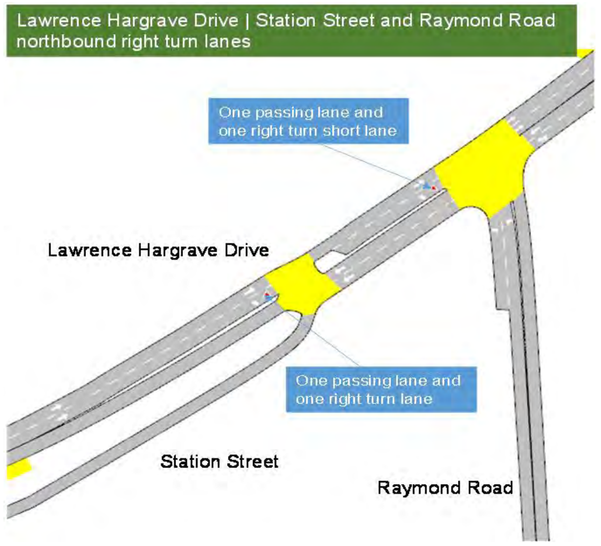
Scenario 6

Lawrence Hargrave Drive | Phillip Street (Layout 2)
Lawrence Hargrave Drive | Station Street: Northbound right turn bay
Lawrence Hargrave Drive | Raymond Road: Northbound lanes converted to one thorugh and one right turn lane
Lawrence Hargrave Drive | Lachlan Street: Southbound lanes converted to one thorugh and one right turn lane

Main upgraded intersection layouts







Network statistics comparison

	2026	2026	2026	2026	2036	2036	2036	2036
AM peak	Do-minimum	Scenario 6	Diff	Diff %	Do-minimum	Scenario 6	Diff	Diff %
Performance indicators (all veh classes)	Average	Average	Average	Average	Average	Average	Average	Average
	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.	7 - 9 a.m.
Total vehicle kilometre travelled (VKT)	7,815	8,082	267	3%	8,020	8,226	206	3%
Total vehicle hour travelled (VHT)	275	255	-19	-7%	327	273	-54	-17%
Average vehicle speed (km/h)	31	33	2	7%	29	32	3	11%
Average vehicle delay (seconds/km)	59	49	-11	-18%	82	55	-27	-33%
Completed trips	5,252	5,457	205	4%	5,385	5,521	135	3%
Incomplete trips	460	373	-87	-19%	595	461	-134	-23%
Unreleased trips	1	1	0	-34%	46	9	-37	-81%
Number of stops	8,396	7,169	-1,226	-15%	9,923	7,759	-2,164	-22%

	2026	2026	2026	2026	2036	2036	2036	2036
PM peak	Do-minimum	Scenario 6	Diff	Diff %	Do-minimum	Scenario 6	Diff	Diff %
Performance indicators (all veh classes)	Average	Average	Average	Average	Average	Average	Average	Average
	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.	4 - 6 p.m.
Total vehicle kilometre travelled (VKT)	8,967	9,154	187	2%	9,244	9,539	295	3%
Total vehicle hour travelled (VHT)	378	289	-89	-24%	489	310	-179	-37%
Average vehicle speed (km/h)	27	33	6	21%	23	32	9	38%
Average vehicle delay (seconds/km)	102	53	-49	-48%	145	58	-87	-60%
Completed trips	6,285	6,418	133	2%	6,478	6,693	215	3%
Incomplete trips	401	287	-115	-29%	498	313	-185	-37%
Unreleased trips	103	1	-102	-99%	255	5	-249	-98%
Number of stops	12,664	8,075	-4,589	-36%	16,252	8,675	-7,577	-47%

	2026	2026	2026	2026	2036	2036	2036	2036
Saturday peak	Do-minimum	Scenario 6	Diff	Diff %	Do-minimum	Scenario 6	Diff	Diff %
Performance indicators (all veh classes)	Average	Average	Average	Average	Average	Average	Average	Average
	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	11 a.m. - 1 p.m.	7 - 9 a.m.	11 a.m. - 1 p.m.
Total vehicle kilometre travelled (VKT)	9,575	10,381	807	8%	9,557	10,791	1,235	13%
Total vehicle hour travelled (VHT)	697	390	-307	-44%	813	481	-332	-41%
Average vehicle speed (km/h)	19	30	11	56%	17	27	10	60%
Average vehicle delay (seconds/km)	223	79	-144	-65%	283	112	-171	-61%
Completed trips	6,528	7,134	606	9%	6,533	7,411	878	13%
Incomplete trips	912	404	-507	-56%	964	534	-430	-45%
Unreleased trips	495	15	-479	-97%	1,093	46	-1,046	-96%
Number of stops	22,045	12,226	-9,819	-45%	24,488	15,391	-9,096	-37%

Travel time resutls and difference (minutes)			AM peak hour	PM peak hour	Saturday peak hour
Northbound on Lawrence Hargrave Drive, between south of Hewitts Avenue to Mary Street	2026	Do-minimum	3.4	4.1	5.1
		Scenario 6	2.9	2.9	3.1
		Diff	-0.6	-1.2	-2.0
		Diff%	-16%	-29%	-39%
	2036	Do-minimum	3.5	4.3	5.5
		Scenario 6	2.9	3.0	3.7
		Diff	-0.6	-1.3	-1.8
		Diff%	-17%	-30%	-33%
Southbound on Lawrence Hargrave Drive, between Mary Street o south of Hewitts Avenue	2026	Do-minimum	4.1	4.3	8.7
		Scenario 6	3.5	3.1	4.2
		Diff	-0.6	-1.3	-4.5
		Diff%	-15%	-30%	-52%
	2036	Do-minimum	5.2	6.1	8.7
		Scenario 5	3.8	3.1	5.3
		Diff	-1.5	-3.0	-3.3
		Diff%	-28%	-49%	-39%

Appendix C

MEMORANDUM: ECONOMIC ASSESSMENT

MEMO

s74 Scope

TO:

FROM:

SUBJECT: **MR185 Lawrence Hargrave Drive at Thirroul – Rapid Economic Appraisal**

OUR REF: 2196958A-ITP-MEM-006-RevA.docx

DATE: **13 September 2016**

1. INTRODUCTION

NSW Roads and Maritime Services (Roads and Maritime) commissioned WSP | Parsons Brinckerhoff to undertake a traffic study for the purpose of assessing the existing and future operational performances of the Lawrence Hargrave Drive corridor (MR185) in Thirroul New South Wales, between Hewitts Avenue and Mary Street to the north.

This technical note details the methodology and results of a rapid economic assessment undertaken for the improvements being considered by Roads and Maritime:

- Scenario 1 includes clearways on Lawrence Hargrave Drive in peak direction and proposed Layout 1 for Lawrence Hargrave Drive | Phillip Street.
- Scenario 2 includes clearways on Lawrence Hargrave Drive in peak direction and proposed Layout 2 for Lawrence Hargrave Drive | Phillip Street.
- Scenario 3 includes an S-lane scheme on Lawrence Hargrave Drive and proposed Layout 2 for Lawrence Hargrave Drive | Phillip Street.
- Scenario 4 includes clearways on Lawrence Hargrave Drive in peak direction, an additional right turn bay to Station Street and proposed Layout 2 for Lawrence Hargrave Drive | Phillip Street.

The details of the four scenarios were provided in *2196958A-ITP-MEM-004 Lawrence Hargrave Drive Thirroul Proposed Traffic Modelling Options*.

The economic assessment involved a cost benefit analysis comparing the benefits and costs of the four improvement scenarios against a 'do minimum' base case. It was carried out according to *Principles and Guidelines for Economic Appraisal on Transport Investment and Initiatives (Transport for NSW (TfNSW), March 2013 and Parameter Update March 2015)* – abbreviated in this report to TfNSW Guidelines.

2. KEY ASSUMPTIONS AND INPUTS

2.1 Economic parameters and expansion factors

Table 2.1 shows the economic parameters used in the analysis.

Table 2.1 Economic parameters

Economic parameters	Value
Discount rate	7%
Opening year	2021/22

Economic parameters	Value
Appraisal period	30 years from opening year
Base year for discounting	2015/16
Price base	2015/16

The Aimsun traffic model outputs covering two-hour AM peak and two-hour PM peak of a typical weekday, and two-hour peak of a typical Saturday were used for the rapid economic appraisal. The peak periods were converted to an annual total using cost expansion factors. The factors used are shown in Table 2.2.

Table 2.2 Modelling period to annual cost expansion factors (urban)

Modelling period	Expansion factor
From four-hour peak periods to weekday	3.15
From one weekday to all weekdays	251
From Saturday two-hour peak to Saturday all day	4
From one Saturday to all weekends and public holidays	78

Source: TfNSW Guidelines and assumptions by WSP | Parsons Brinckerhoff

The annual cost expansion factors recommended by the TfNSW guidelines were based on typical traffic conditions that road network during the peak period of weekday is more congested than during the peak period of weekend. However, for this project the study area is more congested during the peak period of Saturday. Therefore traffic modelling results for Saturday peak period are used to inform this economic appraisal in addition to the regular weekday peak periods traffic modelling results. Because the TfNSW guidelines do not provide recommended expansion factors for weekend based traffic modelling results, conservative assumptions have been adopted for the corresponding factors listed in Table 2.2.

2.2 Economic costs

The estimated capital cost for each scenario was provided for the rapid economic appraisal (refer to Table 2.3). The construction period is assumed to be two years.

The additional maintenance cost incurred by each scenario was not provided. For this rapid assessment, it was assumed that annual maintenance cost would be 1% of capital cost (refer to Table 2.3). The maintenance cost is not expected to have significant impact on the economic viability of the project.

Table 2.3 Cost estimates (in 2015/16 dollar value)

Options	Capital cost	Net annual maintenance cost
Scenario 1	$240,000	$2,400
Scenario 2	$816,000	$8,160
Scenario 3	$1,718,000	$17,180
Scenario 4	$1,341,000	$13,410

WSP | PARSONS BRINCKERHOFF

2.3 Traffic model results

Utilising the modelling software Aimsun traffic models were developed for 2016, 2026 and 2036. The base case and four scenarios were assessed for AM and PM peak hours in all three modelling years.

The following traffic modelling results of the base case and the four scenarios were used as inputs to the economic appraisal:

- Total vehicle hours travelled (VHT) – to inform travel time benefit assessment
- Total vehicle kilometre travelled (VKT) – to inform vehicle operating cost and emission cost assessment
- Total number of stops – to inform vehicle operating cost assessment.

The above were extracted separately for light vehicles (cars), heavy vehicles (trucks), and buses.

The traffic model used for the project is a corridor model, and does not model the effects that the increasing congestion along the corridor in the future (e.g. 2026 and 2036) may divert traffic to somewhere else or a different mode i.e. the actual congestion in the future may not be as bad as what is shown by the traffic model. In the 2016 model traffic is already highly congested during the peak periods. To minimise the risk of overstating the project benefits, only 2016 model results are used to inform the economic assessment assuming that benefits stay the same over the 30-year appraisal period.

2.4 Crash analysis results

A crash analysis was undertaken to identify the impacts to road safety from the proposed upgrade options, as the input to the economic appraisal. The latest crash data for the project area was obtained from Roads and Maritime between 2005 and 2015.

The impacts to road safety based on the proposed improvements were assessed for each scenario. Table 2.4 shows the estimated number of crashes per year for the base case and the proposed two scenarios. To minimise the potential risk of overstating the crash reduction benefits, it was assumed that the potential crash reductions by the improvements would not increase in the future.

Table 2.4 Predicted crashes per year with the proposed options

Crash type	Number of crashes per year				
	Base	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Fatal	0	0	0	0	0
Injury	5.9	5.8	5.8	5.3	5.7
Non-casualty	6.2	6.0	6.0	5.2	6.0
Overall	12.1	11.8	11.8	10.5	11.7

3. ECONOMIC APPRAISAL RESULTS

3.1 Assessment criteria

Two economic indicators were calculated as outputs of the economic appraisal to evaluate the relative attractiveness of the scenarios against the base case:

- Net Present Value (NPV)
- Benefit Cost Ratio (BCR).

A brief description of each indicator is provided as follows:

- NPV measures the difference between benefits and costs, whilst accounting for the timing of benefits and costs. Net cash flows are discounted at the prescribed discount rate, reflecting the notion that future benefits and costs have less value compared to current benefits and costs. A project with a Net Present Value greater than zero would be considered economic.
- BCR measures the return received per dollar of costs. The Benefit Cost Ratio is calculated by dividing the present value of all benefits by the present value of all costs. A project with a Benefit Cost Ratio greater than one would be considered economic.

3.2 Value of benefits

The following standard economic benefits have been calculated:

- Road user benefits:
  - Travel time savings
  - Vehicle operating cost savings
- Non-user benefits (or externality cost savings):
  - Environmental externality savings (air pollution and greenhouse gas emission)
  - Crash cost savings.

Travel time savings for each scenario were calculated by taking the difference between travel time costs (i.e. value of time multiplied by total vehicle hours estimated by the Aimsun traffic model). In every scenarios the modelled total vehicle hours decrease compared to the base case. Therefore all four scenarios would provide travel time benefits.

Vehicle operating costs comprise all resource cost of fuel, oil, depreciation, maintenance, and wear on tyres and brakes. The estimation took account of both network congestion (i.e. operating cost per stop multiplied by number of stops estimated by the Aimsun traffic model) and vehicle travel distance (i.e. operating cost per km multiplied by total vehicle travel distances estimated by the Aimsun traffic model). The savings for each of the options were calculated by taking the difference between the base case and scenario selected. In each scenario the modelled total number of stops decrease significantly compared to the base case. The changes to total vehicle travel distances are not significant. Overall, all four scenarios would provide vehicle operation cost savings.

Environmental externality caused by air pollution and greenhouse gas emitted from vehicles are considered in the appraisal. The latter refers to gases (e.g. carbon diode, methane) that contribute toward the greenhouse effect which represents a negative externality. They were estimated by multiplying the total travel distances with a distance based unit value (i.e. emission cost per km). The modelled changes to total vehicle travel distances are not significant. Overall the environmental externality benefits (or disbenefits) of all four scenarios are negligible comparing to travel time benefits.

Crash reduction benefits for each scenario were calculated by taking the difference between crash costs (i.e. cost per crash multiplied by predicted number of crashes). In all four scenarios the predicted number of crashes per year decrease compared to the base case. Therefore, each scenarios would provide crash reduction benefits.

All four scenarios involve providing additional road capacity through reduction of on-road parking spaces. Although the associated capital cost is minimal, it will incur disbenefit to the drivers who normally use these parking spaces. A parking study for the area is outside the scope of this project. For this rapid assessment, the following assumptions were used to estimate the road user disbenefit associated with the loss of on-road parking spaces:

- Each parking space would serve one car per hour on average.
- Loss of an on-road parking space would incur 20 minutes delay to the driver's trip, covering:
  - Additional driving time to find alternative car park
  - Additional walking time between alternative car park and destination.

The unit values adopted for the assessment of the above benefits were based on *TfNSW Guidelines* and are listed in Table 3.1. The latest update of the *TfNSW Guidelines* presents parameter values are 2013/14 prices. Travel time values were indexed from 2013/14 to 2015/16 using Average Weekly Earnings in NSW reported by Australian Bureau of Statistics (ABS) (an increase of 5.6%). Other values were indexed from 2013/14 to 2015/16 using Consumer Price Index in Sydney reported by ABS (an increase of 2.6%).

Table 3.1 Monetary values of items included for benefit assessment (urban)

Item	Value
Light vehicle travel time per hour	$28.47
Heavy vehicle travel time per hour	$56.62
Bus travel time per hour (including drive and average 20 passengers)	$354.67
Light vehicle operating cost per km	$0.27
Heavy vehicle and bus operating cost per km	$1.23
Light vehicle operating cost per stop	$0.08
Heavy vehicle and bus operating cost per stop	$0.41
Light vehicle emission cost per km	$0.06
Heavy vehicle and bus emission cost per km	$0.50[1]
Crash – fatal per occurrence	$6,854,724
Crash – injury per occurrence	$144,485
Crash – non injury per occurrence	$9,779

Source: TfNSW Guidelines

[1] The TfNSW Guidelines did not provide externality unit cost based on truck kilometre travelled. The values recommended for buses were adopted as approximation. The impact on the appraisal outcome would be negligible.

3.3 Cost benefit results

The results from cost benefit analysis for each scenario are summarised in Table 3.2. All scenarios are economically viable, given that each of them has a positive NPV and a BCR larger than 1.

Table 3.2 Cost benefit results

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
PV Capital Cost	$177,110	$602,160	$1,267,782	$989,578
PV net maintenance cost	$21,230	$72,200	$152,000	$118,645
PV TOTAL COST	**$198,340**	**$674,360**	**$1,419,782**	**$1,108,223**
PV Travel time benefit	$9,875,820	$12,617,040	$9,147,793	$12,741,557
PV Vehicle operation cost savings	$1,844,710	$2,622,870	$2,810,730	$2,735,502
PV emission savings	$15,020	$18,370	$18,311	$17,407
PV Crash cost savings	$145,140	$145,140	$853,516	$272,969
Clearway disbenefit	-$7,985,190	-$12,103,620	-$5,511,254	-$12,103,619
PV TOTAL BENEFIT	**$3,865,460**	**$3,299,800**	**$7,319,096**	**$3,663,816**
NPV	**$3,667,120**	**$2,625,450**	**$5,899,314**	**$2,555,592**
BCR	**19.5**	**4.9**	**5.2**	**3.3**

PV – Present value

4. CONCLUSION

All scenarios assessed in this rapid economic assessment are economically viable, as evidenced by positive NPVs and BCRs larger than 1, discounted at 7 percent. The cost benefit analysis shows Scenario 3 provides the highest NPV (~$5.9 million), while Scenario 1 has the highest BCR (19.5).

Travel time savings make up the largest proportion of benefits for all scenarios, with further significant cost savings due to reduced vehicle operating costs. Emissions savings and crash savings are not as significant. Negative benefits (or disbenefits) arise from the impact of lost parking spaces under each scenario.

The capital cost estimates in this report include the construction cost of each option. Maintenance costs were not provided so were estimated at 1% of capital costs per annum, representing just over 10% of total costs after discounting.

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Technical Executive