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Transport Roads & Maitime Services NSW

Newcastle Inner City Bypass
Rankin Park to Jesmond

Refined Strategic Design
Microsimulation Traffic Modelling Report

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Newcastle Inner City Bypass Rankin Park to Jesmond Refined Strategic Design

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1 Introduction

1.1 Project overview

The Newcastle Inner City Bypass is part of Roads and Maritime Services' long-term strategy to provide an orbital road within Newcastle's road network to connect the Pacific Highway at Bennetts Green and the Pacific Highway at Sandgate. The bypass was first planned in the 1950's and sections have been opened progressively since the early 1980's as outlined in the Figure 1 below.

Figure 1: Overall Newcastle Inner City Bypass

The proposal would be the fifth section of the Newcastle Inner City Bypass, which provides improved traffic flows across the western suburbs of Newcastle and connects key regional destinations such as Bennetts Green, Charlestown and Jesmond shopping centres, John Hunter Hospital, Newcastle University and the Pacific Highway.

The road network surrounding the proposal currently suffers from traffic congestion and delays at key intersections. The construction of the Rankin Park to Jesmond section would provide free flow north-south travel conditions and eliminate 11 sets of traffic control signals along the existing route.

The proposal would involve the construction of a new 3.4 kilometre (km) four lane dual carriageway highway between the intersection of McCaffrey Drive and Lookout Road, New Lambton Heights and the intersection with Main Road and Newcastle Road, Jesmond.

Key features of the project would include:

Roadway – the new roadway would consist of two lanes in each direction, separated by a median along the length of the project. The roadway would be constructed on large cut and fill embankments, which would be required due to the steeply undulating terrain

Interchanges – a northern and a southern interchange would be constructed at either end of the project, to enable connections with the existing sections of the Newcastle Inner City Bypass and key arterial roads such as Newcastle Road and Lookout Road

Aurecon was appointed by Roads and Maritime Services (Roads and Maritime), in a letter of acceptance dated 27 November 2014, as the Professional Services Contractor (PSC) to provide the project development services for the concept design and environmental assessment (EIS) for the Newcastle Inner City Bypass – Rankin Park to Jesmond (RP2J).

1.2 Microsimulation traffic model background

An integral element of the project's traffic assessment relates to the development of a base traffic model representing existing traffic conditions in the 2 hour morning (7.00am to 9.00am) and 2 hour evening (4.00pm to 6.00pm) peak periods.

The model was developed using the Quadstone Paramics (Paramics) software platform and is calibrated and validated to 2014 traffic survey data. The development of this base model is detailed in the Aurecon report "*Traffic Microsimulation Model Calibration and Validation Report, October 2015".*

The base traffic model was then used to develop future year scenarios for the assessment of project options against retention of the existing road network configuration. Aurecon has developed a staged approach to track progress and develop each element of the traffic modelling study. The overall study methodology is shown in Figure 2.

The purpose of this Refined Strategic Design Microsimulation Traffic Modelling Report is to document model development and application through elements of Stages 6 to 9 of this methodology. These stages will be further refined during the concept design and environmental assessment phase.

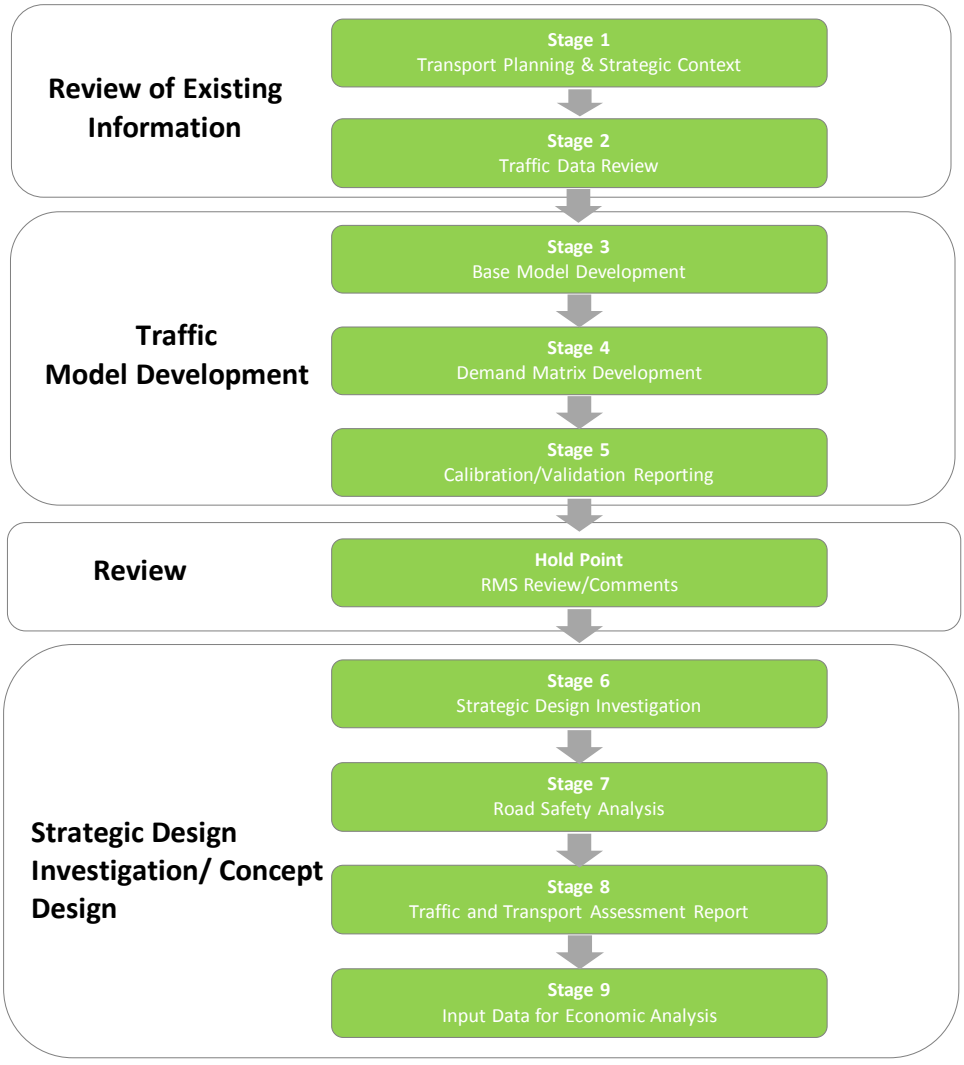

Figure 2: Study Methodology

2 Options modelling

2.1 Objectives

Microsimulation traffic modelling has been conducted with the intent of meeting the following objectives:

- Understand operational performance and identify constraints or issues with the design options
- Support other project disciplines in options development and refinement
- Provide quantitative metrics for comparison and evaluation of options
- Provide outputs for economic analysis

2.2 Overarching methodology

Traffic modelling to support the project has been conducted following commonly adopted industry practice. As illustrated in Figure 3 the methodology follows a two-tier structure where a regional strategic model, in this case the Lower Hunter Traffic Model (LHTM), is used to provide forecast trip demand information for use in a microsimulation model for operational assessment.

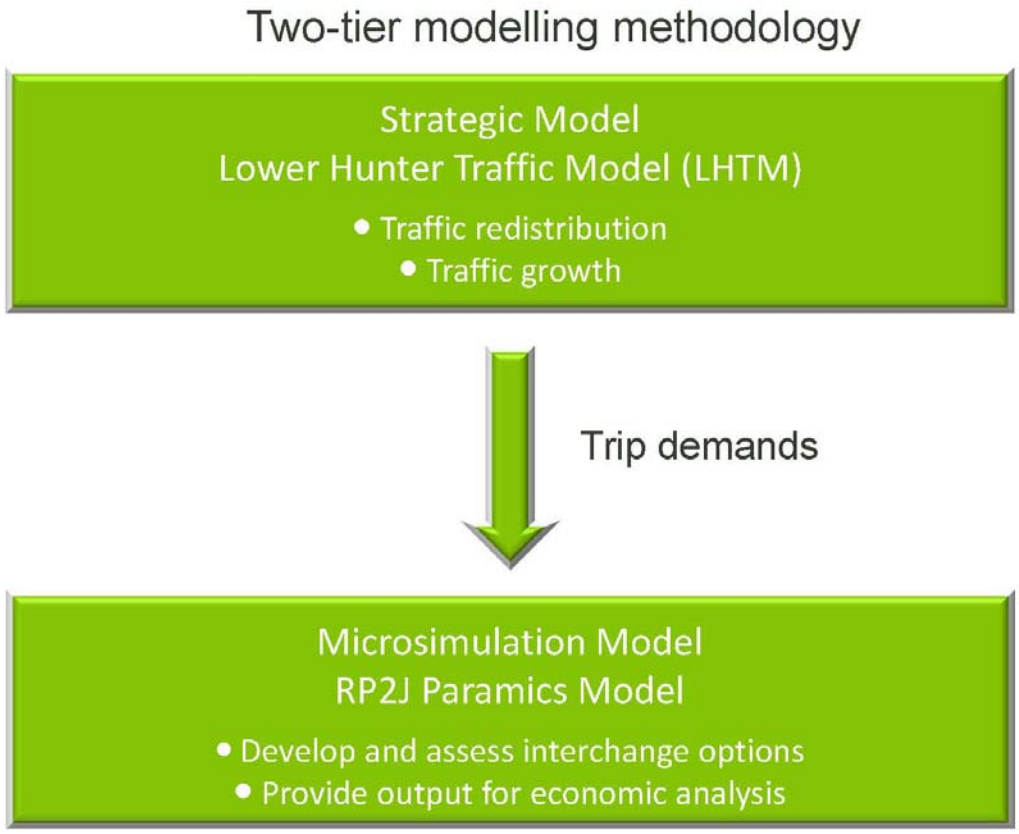

Figure 3: Two-tier traffic modelling structure

2.2.1 Strategic model – Lower Hunter Traffic Model (LHTM)

Strategic traffic models cover large areas at the regional level and are used to predict travel demand for future years based on forecast population and employment growth. The LTHM model covers the entire Lower Hunter region and is owned by Roads and Maritime. The model operates in the Transcad traffic modelling software platform and has been updated and further refined specifically for the Rankin Park to Jesmond study area by Arcadis Australia Pacific Pty Ltd (formerly Hyder Consulting Pty Ltd) using the latest traffic and origin-destination surveys undertaken in 2014 and 2015. The process and methodology of this update is detailed in the Arcadis (report *"Newcastle Inner City Bypass Rankin Park to Jesmond, Traffic Modelling Report – Lower Hunter Traffic Model (Arcadis 2016)"*.

The Lower Hunter Traffic Model has been used to assess the forecast traffic redistribution through the study area with the project and to provide the forecast traffic volume demands for future years for scenarios both with and without the project in place.

2.2.2 Microsimulation model (RP2J Paramics Model)

As outlined in Section 1.2, a microsimulation model has been developed to assess the operational performance of the proposed project including the associated interchanges. Relative to strategic models microsimulation models provide a greater level of geometric and operational detail. The model is focussed on a much smaller area, covering the project extents and immediate road network only. Individual vehicles and the interactions between them are modelled allowing for detailed replication of traffic conditions.

With the two-tier modelling methodology the Paramics model utilises trip demand forecasts from the LHTM model for modelling of future year scenarios with and without the project. Statistical outputs of network performance from the option models are then used as part of the economic analysis of the project options. Figure 4 illustrates the primary components of the microsimulation model methodology:

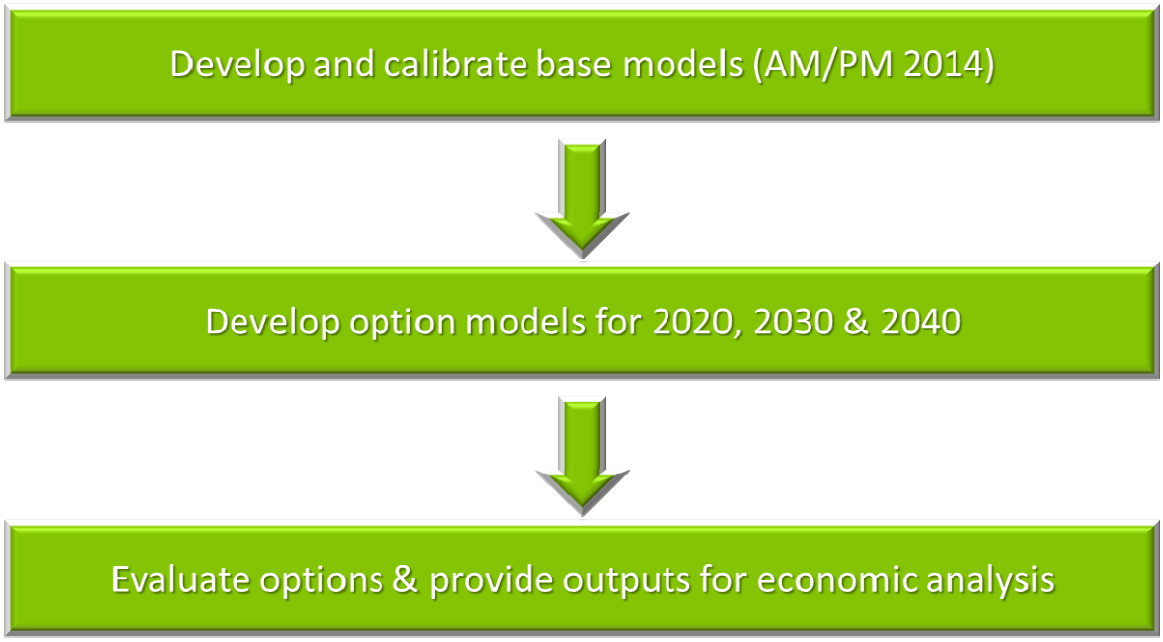

Figure 4: Outline of microsimulation model methodology

2.3 Option model development

To develop models for testing of options the base model is adapted to include:

- Network changes proposed by the design, including the new bypass, interchange upgrades, intersection control improvements etc.
- Changes to trip demands, through the redistribution of existing trips to alternative routes within the modelled
- Changes to trip demands, through the redistribution of trips from outside the existing model network attracted by improved travel conditions.

As illustrated in Figure 5, option model development is part of an iterative process in parallel with option design based on model observation, optimisation, issue identification and feedback into refinement of the design.

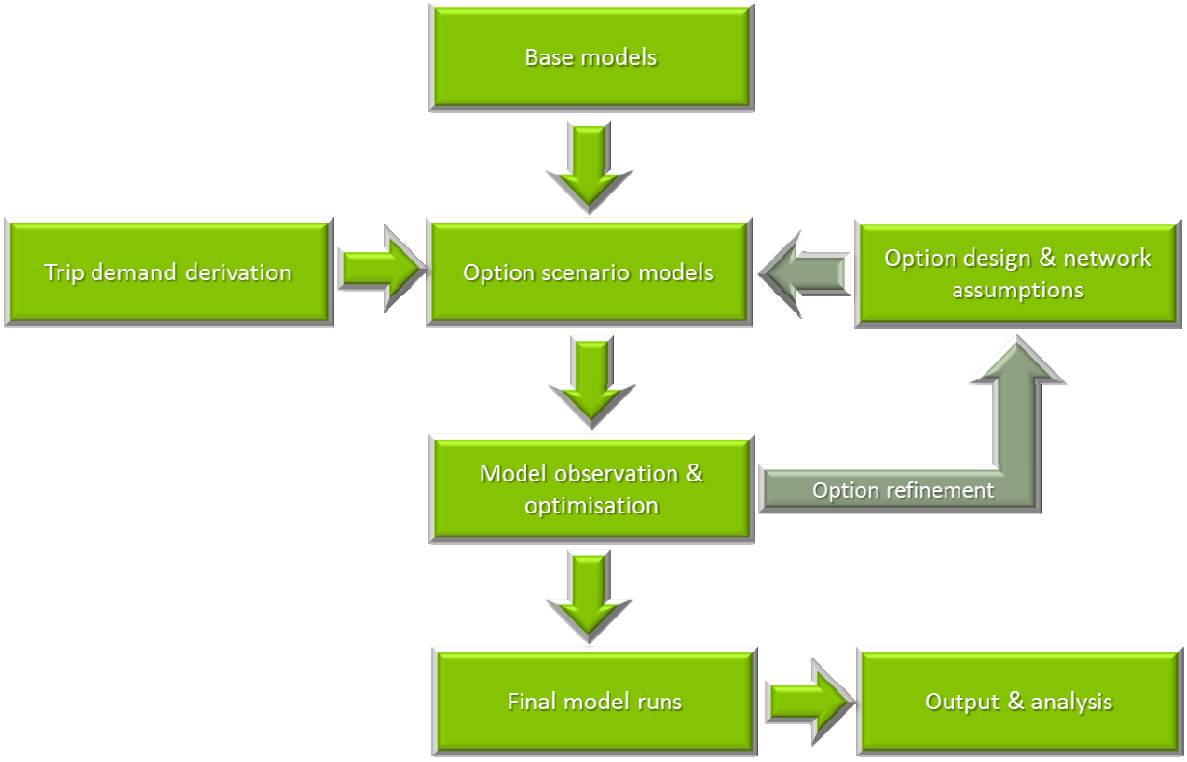

Figure 5: Option model development methodology

Once a design option has been finalised following this iterative process, model runs are undertaken to produce outputs for use in further assessment of options, such as economic and traffic performance analysis.

2.3.1 Trip demand derivation

A critical component of the option modelling process is the derivation of trip demands for forecast future years. Demands sets have been derived for morning and evening periods for the modelling of three future years at 2020, 2030 and 2040.

Trip demands for these years have been developed for two scenarios; without the project (Do Minimum) and with the project (Options).

Without project – Do Minimum

The Do Minimum scenario assumes there are no substantial changes to the modelled road network in future years. This forms the basis for performance comparison of the project options. The trip demands for the Do Minimum scenario are therefore based on predicted growth to background traffic. Forecast traffic demands are from the LHTM model. These traffic growth predictions have then been applied to the base model demands to derive a set of demand for each of the future model years.

Section 4.2 of the Arcadis (formerly Hyder Consulting Pty Ltd) report *"Newcastle Inner City Bypass Rankin Park to Jesmond, Traffic Modelling Report – Lower Hunter Traffic Model, (Arcadis (formerly Hyder Consulting Pty Ltd) 2015)"*, outlines the predicted traffic growth for future years and is summarised in Table 1 below.

Table 1: Forecast Daily Volumes from LHTM (Source: Arcadis (formerly Hyder Consulting Pty Ltd))

ID	Road/Location	Forecast Daily Traffic Volumes without the Project (two-way in vehicles)				Annual Growth Rate (%)
		2014	2020	2030	2040	2014-2040
						26 years
1	Charlestown Road, south of Cardiff Road	55,100	55,500	56,300	57,100	0.1%
2	Carnley Avenue, east of Charlestown Road	21,000	21,100	21,400	21,700	0.1%
3	Cardiff Road, west of Lookout Road	14,700	15,100	15,800	16,600	0.5%
4	Grandview Road, west of Lookout Road	2,700	2,800	3,000	3,100	0.5%
5	McCaffrey Drive, west of Lookout Road	18,600	19,100	20,000	20,900	0.4%
6	Croudace Road, west of Grandview Road	19,900	20,100	20,600	21,000	0.2%
7	Lookout Road, north of McCaffrey Drive	49,400	52,500	57,700	63,100	0.9%
8	Kookaburra Circuit (John Hunter Hospital access)	15,300	16,200	17,900	19,800	1.0%
9	Russell Road, east of Lookout Road	16,200	17,600	20,100	22,600	1.3%
10	Newcastle Road, east of Croudace Street	46,500	51,600	60,100	68,500	1.5%
11	Newcastle Inner City Bypass, north of Newcastle Road	36,100	41,700	51,000	60,300	2.0%
12	Newcastle Road, west of Newcastle Inner City Bypass	44,300	48,200	54,700	61,200	1.3%
13	Dent Street, north of Newcastle Road	4,900	5,400	6,300	7,200	1.5%
14	Jacaranda Drive (John Hunter Hospital access)	2,700	2,700	2,800	2,900	0.3%
15	Howe Street, east of Croudace Street	8,500	9,600	11,400	13,300	1.7%
16	Newcastle Road, east of Newcastle Inner City Bypass	60,200	66,200	76,200	86,200	1.4%
17	Croudace Street, north of Elder Street	41,800	43,900	47,300	50,800	0.8%
18	Lookout Road, south of Russell Road	48,700	51,500	56,400	61,300	0.9%
19	Lookout Road, south of McCaffrey Drive	47,200	48,300	50,200	52,200	0.4%
	Total study area					1%

Analysis of historic traffic counts at key locations along the existing road corridor have been used for further comparison to confirm the annual growth rates of around 1.0% predicted by the model are within an appropriate range, as illustrated in Figure 6.

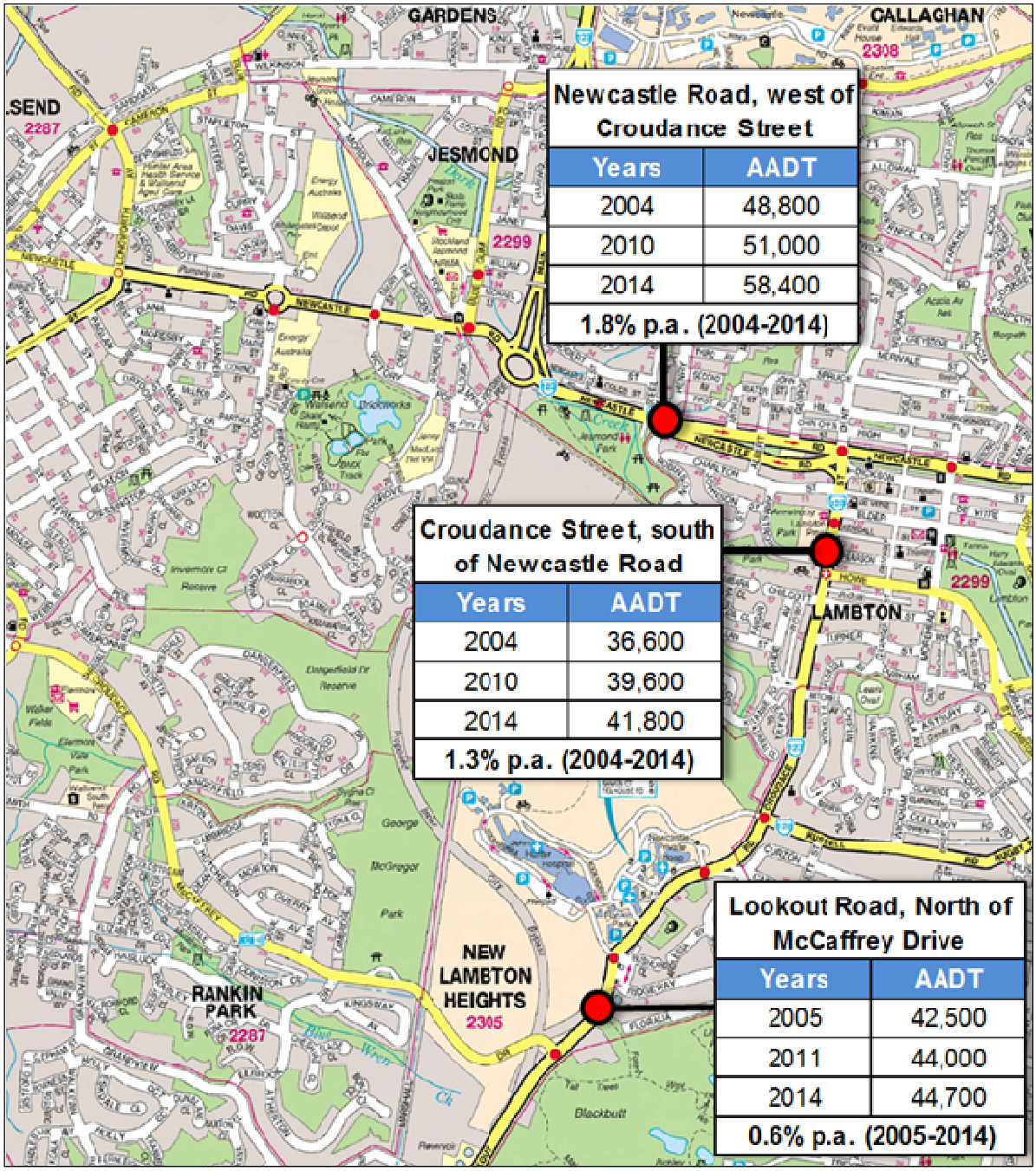

Figure 6: Historical traffic volumes in the study area

With project – RP2J project scenarios

With the project in place, in addition to background traffic growth it is expected there would be changes to the pattern of traffic demand within the network due to the improvements provided by the project. As outlined above there are two main mechanisms of change in trip demand as a result of capacity and travel time improvements provided by the project:

- Redistribution of existing trips within the modelled network from use of a one particular route to use of another route within the network
- Redistribution of existing trips from other parts of the Newcastle network, attracted to travel through the modelled area due to improved travel conditions.

The LHTM model has been used as the primary source for establishing the scale and nature of these changes. As outlined in Section 5.2 of the Arcadis report, *"Newcastle Inner City Bypass Rankin Park to Jesmond, Traffic Modelling Report – Lower Hunter Traffic Model (Arcadis 2016)",* there are changes expected on a number of roads. Further assessment of these changes has been undertaken through select link analysis outputs from the LHTM model.

Existing daily traffic volumes (2014/15) have been used to compare and examine predicted changes on the road network with the project based on current traffic conditions.

The key changes predicted with the project are:

- The project is predicted to carry between about 21,600 and 29,400 vehicles per day. The northern section between Newcastle Road and the new hospital access is expected to carry higher traffic volumes
- The new hospital access road is predicted to carry about 7,300 vehicles per day
- The project is predicted to increase traffic on Lookout Road south of McCaffrey Drive by about 10 per cent
- The project is expected to increase traffic on the Newcastle Inner City Bypass north of Newcastle Road by about 10 to 15 per cent
- The project is expected to reduce traffic from the existing route (Lookout Road, Croudace Street and Newcastle Road) by about 25 to 45 per cent depending on the location. This would substantially improve traffic flow and reduce travel times along the existing route
- The project is expected to reduce traffic on McCaffrey Drive by about 15 to 20 per cent
- The project is expected to marginally increase traffic on Grandview Road and Carnley Avenue by about 200 vehicles per day
- The new western hospital access is expected to substantially reduce traffic on the existing eastern access via Kookaburra Circuit by about 50 per cent
- The project would primarily redistribute traffic in the study area and surrounding road network for north-south and south-west movements.

In future years 2020, 2030 and 2040, similar traffic redistribution from the project on the surrounding road network are expected.

2.3.2 Review

The resulting future trip demand sets were reviewed in detail to ensure there were no anomalies and that the results were logical and considered sound. This included a detailed review of predicted trip demand flows and growth rates for individual turning movements at major intersections and midblock link flows for sensibility and consistency with LHTM predictions.

Appendix A provides summary tables of the predicted trip demand flows that were the output of this review and input for the options assessment.

3 Option scenarios

Five scenarios have been considered with the modelling and are as follows:

- **Scenario 1 - Do Minimum:**
  - Represents the existing network without improvements.
- **Scenario 2 – 2007 Strategic Design (with hospital left in/left out):**
  - Alignment Option 1 for the bypass
  - Southern Interchange: Southern Option 1 being an interchange at McCaffrey Drive with south-facing ramps and a single lane southbound connection from Lookout Road merging with a single southbound lane from the bypass
  - Hospital Option 1: Left-in/left-out intersection for the hospital access.
  - Northern Interchange: Northern Option 1 being the existing roundabout with an additional leg to the south allowing for on-ramp and off-ramp connections to the bypass. A bridge over the roundabout for north-south movements.
- **Scenario 3 - Refined strategic design with hospital left in/left out:**
  - Alignment Option 2 for the bypass
  - Southern Interchange: Southern Option 3 consisting of a northbound off-ramp connecting to existing intersection at McCaffrey Drive. Two southbound lanes from Lookout Road (southbound on-ramp) would tie-in with two lanes of bypass under control of traffic lights to form two southbound lanes downstream on Lookout Road
  - Hospital Option 1: Left-in/left-out intersection for the hospital access
  - Northern Interchange: Northern Option 5 being a full-interchange allowing for all movements to and from ramps under control of traffic lights. A bridge over the intersection for north-south movements.
- **Scenario 4 - Refined strategic design with half interchange for hospital access:**
  - Alignment Option 2 for the bypass.
  - Southern Interchange: Southern Option 3 consisting of a northbound off-ramp connecting to the existing intersection at McCaffrey Drive. Two southbound lanes from Lookout Road (southbound on-ramp) would tie-in with two lanes of bypass under control of traffic lights to form two southbound lanes downstream on Lookout Road
  - Hospital Option 4: Half-interchange for the hospital access, with a southbound off-ramp to the hospital and a northbound on-ramp from the hospital (i.e north facing ramps only)
  - Northern Interchange: Northern Option 5 being a full interchange allowing for all movements to and from ramps under control of traffic lights. A bridge over the intersection for north-south movements.
- **Scenario 5 - Refined strategic design with full interchange for hospital access:**
  - Alignment Option 2 for the bypass.
  - Southern Interchange: Southern Option 3 consisting of northbound off-ramp connecting to existing intersection at McCaffrey Drive. Two southbound lanes from Lookout Road (southbound on-ramp) tie-in with two lanes of bypass under control of traffic lights to form two southbound lanes downstream on Lookout Road/Newcastle Inner City Bypass.
  - Hospital Option 3: Full-interchange for the hospital access.

- Northern Interchange: Northern Option 5 being a full interchange allowing for all movements to and from Newcastle road and the bypass under control of traffic lights. A bridge over the intersection for north-south movements.

- **Scenario 6 - Refined strategic design with half interchange for hospital access and McCaffrey Drive ramps**
  - As per Scenario 4 however this option has the addition of two north facing ramps at the southern interchange to provide connections between the bypass and McCaffrey Drive for northbound traffic (on-ramp) and southbound traffic (off-ramp).

3.1 Model runs

Model scenarios have been run in accordance with Roads and Maritime traffic modelling guidelines. Observations of traffic performance were undertaken of the traffic models for each scenario. Key observations for each scenario are as follows:

Scenario 1 - Do Minimum

- In future years with predicted traffic growth the existing network becomes increasingly congested as constraints on traffic capacity at existing bottlenecks worsen.
- Capacity issues at the Croudace Street/Dent Street/Newcastle Road intersection are particularly evident for westbound through movements on Newcastle Road with queues extending off the model extents in the evening peak. The right turn movements from both the eastbound and northbound approaches are inhibited by lack of capacity at the intersection.
- In the morning peak, at Jesmond roundabout queues for the southbound approach right turn movement extend back onto the Newcastle Inner City Bypass. Congestion on the eastbound approach is evident in the morning period with queues on Newcastle Road extending back to the model extents.
- In the evening peak, queues from southbound movements on Croudace Street at its intersection with Russell Road extend back through the Croudace Street/Dent Street/Newcastle Road intersection and inhibit turning movements from Newcastle Road due to lack of available space on the departure side of the intersection.

Scenario 2 - 2007 Strategic Design (with hospital left in/left out):

- There are capacity constraints at the northern interchange where the two-lane roundabout shows significant congestion, particularly in the evening peak period. This is due to the imbalance of flows at the roundabout through introduction of additional movements, primarily the right turn movement from the west and the limited traffic capacity of the two-lane roundabout.
- Resulting queues forming on the Newcastle Road westbound approach to the roundabout extend back to and inhibit the flow of traffic through the Croudace Street/Dent Street/Newcastle Road intersection with similar issues in the eastbound direction.
- The southern interchange design also presents similar capacity issues due to the interchange arrangement which has two sets of traffic lights and lack of sufficient capacity for the strong:
  - Right turn movement from McCaffrey Drive onto Lookout Road southbound
  - Single lane northbound off-ramp movement through to Lookout Road northbound.

Scenario 3 - Refined Strategic Design with left-in/left-out hospital access

- General observations as per Scenario 4 below, however the left-in/left-out arrangement at the hospital access requires traffic wanting to turn right out of the hospital to travel north onto the bypass to instead have to use the existing route of Lookout Road, Croudace Street and Newcastle Road. This requires additional travel distance (four kilometres versus 1.5 kilometres), travel time and an increased number of stops. This traffic also mixes with other traffic on the existing route increasing delays for other motorists.
- Traffic from the south heading to the hospital would be less inhibited by the left-in/left-out arrangement at the western hospital access, as they can continue to use the existing eastern hospital main entrance off Lookout Road which is a shorter distance (one kilometre versus 2.5 kilometres) although it has to pass through two intersections controlled by traffic lights.

Scenario 4 - Refined strategic design (with half interchange for hospital access)

- This scenario addresses traffic capacity and priority issues at the northern interchange through replacement of the existing two lane roundabout with a larger intersection below the bypass (immediately to the east) controlled by traffic lights to improve traffic flow. The intersection has three lanes in both directions on Newcastle Road and two turning lanes in most directions to improve traffic capacity and traffic flow through the intersection.
- The half- interchange provides a southbound off-ramp to enter the hospital and a northbound on-ramp to exit the hospital. As such motorists from the north would use the proposed new western connection off the bypass to access the hospital. This substantially reduces travel times and distance (1.5 kilometres versus four kilometres) for hospital trips to/from the north, with eight sets of traffic lights bypassed on the existing route. This provides additional traffic flow improvements along the existing route of Lookout Road, Croudace Street and Newcastle Road in the northbound direction, compared to Scenario 3 left-in/left-out connection.
- The half-interchange design provides northern access via a new western entrance to the hospital and southern access via the existing eastern entrance to the hospital, with a forecast 50/50 split of traffic between the western and eastern hospital accesses.
- At the southern interchange, the provision of a two-lane off-ramp bridge on Lookout Road to take northbound traffic over the bypass provides substantial improvements to traffic flow
- Upgrade works in McCaffrey Drive to provide a second right turn lane out onto Lookout Road increases traffic capacity and improves traffic flow on both McCaffrey Drive and Lookout Road
- Extending the left turn merge out of McCaffrey Drive improves traffic flow with Lookout Road
- Extension of the right and left turn lanes on McCaffrey Drive provides increased capacity and traffic flow for eastbound traffic.

Scenario 5 - Refined strategic design (with full interchange for hospital access)

- General observations as per Scenario 4 above.
- The addition of the south facing ramps at the western hospital access reduces the amount of traffic wanting to use the two-lane off-ramp bridge on Lookout Road to go over the bypass and enter the hospital via the existing eastern main entrance off Lookout Road. However, due to the relatively low volumes forecast to use the south facing ramps and the shorter travel distance to the existing eastern main hospital entrance, the ramps provide minimal benefit to the surrounding road network on Lookout Road.

- Motorists from the south can continue to use the existing eastern hospital access off Lookout Road, which provides a shorter travel distance than the proposed full interchange (one kilometre versus 2.5 kilometres) although motorists would need to pass through two sets of traffic lights on the existing route.

Scenario 6 - Refined Strategic Design plus McCaffrey Drive ramps

- The modelling shows about 20 to 30 vehicles per hour using each ramp in the morning peak period and the same in the afternoon peak period.
- On observation the model operation appears very similar to the refined strategic design (Scenario 4) due to the low volume of traffic using each ramp.
- Due to the low volumes on each ramp, this traffic has negligible effect on the operation of the McCaffrey Drive and Lookout Road intersection.

4 Economic Appraisal

4.1 Overview

Economic analysis has been conducted as part of the options assessment process to determine whether the five modelled scenarios would provide value for money. The appraisal measures the economic benefits generated and compares them to the expenditure required to implement.

The analysis has been conducted in accordance with Transport for NSW Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives (April 2013).

4.2 General economic appraisal parameters

The general economic parameters that have been assumed for the project for the purposes of the analysis are set out in **Error! Reference source not found.**.

Table 2: General economic appraisal parameters (Source: Roads and Maritime)

Parameter	Value
Price year	2015/16
Discount year	2015/16
Discount rate	7%
Construction years	2017/18 to 2020/21 (b)
First full year of benefits	2021/22(b)
Last year of benefits	2050/51
Appraisal period	30 years
Annual benefits expansion factor (a)	1,923

(a) Derived from TfNSW (2013) Appendix 4 (November 2013 update) Table 65

(b) Timing of construction is for comparative purposes only and is subject to project approval and further detailed assessment of construction methodology timeframes during the concept design phase as site conditions and design inputs are confirmed.

4.3 Network statistics – traffic modelling outputs

In assessing and comparing the network performance levels of each scenario, the following criteria were used based on outputs from the traffic modelling:

- **Vehicle hours travelled (VHT):** measures the total travel time of all vehicles on the network during the modelled peak period. VHT corresponds to the delay and congestion in a network and as such a lower VHT correlates to lower congestion.
- **Vehicle kilometres travelled (VKT):** similar to VHT, measures the total distance travelled by all vehicles during the modelled peak period.
- **Total number of stops:** The total number of stops corresponds to congestion, delay and travel time and measures the total stops for all vehicles within the modelled peak hour. It is used to calculate the additional vehicle operating costs associated with stopping and accelerating from rest. In an uncongested network the number of stops is infrequent as higher proportions of vehicles travel at free flow with lower occurrences of stopping behind queued vehicles.
- **Average Network Speed:** Recorded for all traffic in the network over the modelled period. It is calculated by dividing the vehicle kilometres travelled (VKT) by the vehicle hours travelled (VHT). Average network speed correlates to congestion and delay – higher average network speeds are indicative of a network in which traffic is able to flow more readily.

4.4 Project costs

Error! Reference source not found. shows the strategic cost estimates prepared for the five scenarios.

They cover all project related costs including such items as design, property acquisition, site investigations, environmental assessment, community consultation, project management and construction.

The strategic cost estimates are for comparative purposes only. During the concept design phase as site conditions, design inputs and construction methodology are confirmed, the project estimate will be further refined.

Table 3: Strategic cost estimates (P50 Out-turn dollars)

Scenario	Strategic Cost Estimate
1. Do Minimum	Not applicable
2. 2007 strategic design with left-in/left-out only	$250 million
3. Refined strategic design with hospital left-in/left-out only	$270 million
4. Refined strategic design with hospital half-interchange	$280 million
5. Refined strategic design with hospital full-interchange	$290 million
6. Refined Strategic Design with hospital half-interchange and with McCaffrey Drive ramps	$305 million

Incremental maintenance costs of the four-lane road have been allowed for in the economic analysis using an annual maintenance cost of $12,000 per lane-kilometre, i.e. $163,000 per year for the additional 13.6 lane-kilometres, rounded up to be $170,000 per year. The current cost of maintaining roads on the existing route continues in both the base case and the project case. However savings could be expected in the project case due to a reduction of traffic on the existing route.

4.5 Project benefits

4.5.1 Value of benefits

The valuation of road user benefits has used the parameter values as outlined below.

Travel time cost savings

The weighted average value of travel time was calculated as $28.05 per vehicle hour for all time periods. This value is applied to the difference between vehicle hours of travel in the base case (Do Minimum) and the project case multiplied by the annual benefits expansion factor.

Vehicle operating cost savings

Vehicle operating costs relate to the speeds travelled on the road. The weighted average value of vehicle operating cost was calculated as 41 cents per kilometre. These values were applied to the modelled average travel speeds and vehicle kilometres of travel for the base case (Do Minimum) and the project case.

Vehicle stopping cost savings

The weighted average vehicle cost per stop was calculated as 17 cents per vehicle stop. This value is applied to the difference between the number of vehicle stops in the base case (Do Minimum) and the project case multiplied by the annual benefits expansion factor.

Crash cost savings

The average cost per crash for use in the appraisal was calculated as $98,000. This value is applied to the estimated annual reduction in crashes with the project case. For the purposes of the analysis, for the project case the reduction in crashes was assumed to be about half the reduction in traffic volumes on the existing route. A more detailed road safety analysis will be undertaken during the concept design phase with specific crash types assessed based both the proposed changes in the road network and traffic redistribution across the network.

4.6 Economic analysis results - options

Error! Reference source not found. shows the results of the economic analysis for the four option scenarios compared to the base case (Do Minimum) scenario.

The results are presented in terms of two key economic indicators:

- **Benefit-cost ratio (BCR)** - BCR measures the benefits received per dollar of project cost. It is used to indicate value for money. BCR is calculated by dividing the present value of all benefits by the present value of all costs (including recurring operating and maintenance). A project with a BCR greater than one means that the present value of benefits exceeds the present value of costs and is considered to provide value for money.
- **Incremental Benefit-cost ratio (IBCR)** - IBCR measures the incremental benefits received per dollar of incremental costs when comparing one option over another. An option with an IBCR greater than one means that the present value of additional benefits exceeds the present value of additional costs and is considered to provide value for money.

Table 4: Economic analysis results for options scenarios (Source: Roads and Maritime)

Scenario	Strategic Cost Estimate $M (2015 dollars)	BCR		
2. 2007 strategic design with left-in/left-out only	$250 million	<1.0		
3. Refined strategic design with hospital left-in/left-out only	$270 million	4.7	IBCR	Comment of IBCR
4. Refined strategic design with hospital half-interchange	$280 million	4.6	3.7 (compared to Scenario 3)	Additional $10 million for Scenario 4 provides strong economic benefits for the surrounding road network with a high IBCR of 3.7
5. Refined strategic design with hospital full-interchange	$290 million	4.5	0.4 (compared to Scenario 4)	Additional $10 million for Scenario 5 provides low economic benefits for the surrounding State road network with IBCR <1.0
6. Refined Strategic Design with hospital half-interchange and with McCaffrey Drive ramps	$305 million	4.3	0.1 (compared to Scenario 4)	Additional $25 million for Scenario 6 provides very low economic benefits with IBCR <1.0

In reviewing the economic analysis results the following conclusions can be derived:

- The 2007 strategic design (Scenario 2) does not provide value for money with a BCR less than one. This is primarily due to poor traffic performance of its northern and southern interchange layouts (refer to Section 3.1)
- Scenario 4 with a half-interchange for the hospital offers strong economic benefits with a BCR of 4.6. This is primarily due to its substantially improved traffic performance of the three interchanges (refer to Section 3.1)
- Scenario 4 with a half-interchange for the hospital offers strong economic benefits with an IBCR of 3.7 compared to the hospital access compromising of left-in/left-out only (Scenario 3). This is primarily due to the northbound on-ramp which provides substantial travel time savings compared to this movement having to use the existing route (refer to Section 3.1)
- The extra $10 million for the addition of the south facing ramps to Scenario 4 is not considered to offer value for money for the surrounding road network with an IBCR of less than one. There may however be additional economic benefits for the hospital internal road system which have not been considered in the economic analysis.
- The extra $25 million for the addition of the McCaffrey Drive ramps to Scenario 4 offers minimal benefits and does not offer value for money with an IBCR of less than one (compared to the Southern Interchange with south-facing ramps only).

Based on the options assessment process including input from value management workshops, traffic modelling and economic analysis, Scenario 4 with a half interchange for the hospital access is considered the preferred option providing the best value for money with a strong BCR of 4.6

4.7 Economic analysis results – preferred option (refined strategic design: Scenario 4)

Error! Reference source not found. shows the results of the economic analysis for the preferred option (Refined Strategic Design: Scenario 4) compared to the base case (Do Minimum) Scenario 1.

The results are presented in terms of five key economic indicators:

- **Benefit-cost ratio (BCR) -** BCR measures the benefits received per dollar of project cost. It is used to indicate value for money. BCR is calculated by dividing the present value of all benefits by the present value of all costs (including recurring operating and maintenance). A project with a BCR greater than one means that the present value of benefits exceeds the present value of costs and is considered to provide value for money.
- **Net present value (NPV)** - NPV measures the difference between benefits and costs, while accounting for their varying timing. Net cash flows are discounted at a specified discount rate, reflecting the concept that future benefits and costs have less value compared to current benefits and costs. A project with a NPV greater than zero means that the present value of benefits exceeds the present value of costs and is considered economically worthwhile.
- **Net present value per dollar of investment (NPVI)** - NPVI measures the benefit received per dollar of investment or capital outlay. It is used to indicate capital efficiency. NPVI is calculated by dividing the net present value by the present value of capital costs (those used to initially complete the project). A project with a NPVI greater than zero means that the net economic benefit of the project exceeds its requirement for initial capital expenditure.
- **First year rate of return (FYRR)** – FYRR measures the benefits received in the first full year of a project's operation per dollar of capital cost. It is used to indicate the best start date for a project's implementation. FYRR is calculated by dividing the present value of first year benefits by the present value of capital costs (those used to initially complete the project). The timing of a project which has a FYRR greater than the specified discount rate is considered to be economically appropriate. The implementation of a project which has a FYRR less than the specified discount rate should be deferred until the FYRR exceeds the discount rate.
- **Internal rate of return (IRR)** – IRR is the discount rate at which the present value of benefits equals the present value of costs. An IRR greater than the discount rate indicates an economically worthwhile project.

Table 5: Results of cost-benefit analysis (2015/16 prices, Source: Roads and Maritime)

Present Value	Incremental to base case

Present Value	Incremental to base case
Costs ($'000)	
Capital cost	215,550
Incremental maintenance cost	1,500
Total costs	**217,060**
Benefits ($'000)	
- Travel time savings (79 per cent)	793,531
- Vehicle operating cost savings (20 per cent)	20,894
- Crash cost savings (1 per cent)	10,045
Total benefits	**1,004,470**
Economic indicators	
Net present value ($ million)	787,410
Net present value/Capital cost	3.65
Benefit-cost ratio	4.6
First year rate of return	25%
Internal rate of return	26%

(a) Discounted to 2015/16 at 7 per cent real discount rate and incremental to the Do Minimum Base Case.

In reviewing the economic analysis outputs for the refined strategic design the following conclusions can be derived:

- The project would provide high value for money with a benefit-cost ratio of 4.6
- The project would provide strong economic benefits and generate a net present value of $787 million
- The first year rate of return (FYRR) of 25 per cent is high which indicates that the proposed timing of the project is economically appropriate
- The primary benefits of the project are travel time savings which provide about 79 per cent of the project benefits.
- It is noted that the above economic analysis results are likely to understate the totality of benefits from this project due to the following reasons:
- The analysis does not include the value of reduced emissions and other environmental benefits
- The analysis does not estimate wider economic benefits. These could include the benefits of increased competiveness and productivity of local firms from an improved road network, as well as broader road network benefits of completing a major road link in an urban environment.

This project would generate some of these benefits and as such the economic analysis for this project should thus be considered conservative.

4.8 Traffic modelling outputs – preferred option (refined strategic design: Scenario 4)

As outlined above two of the key traffic modelling outputs which measure the network performance benefits of the project on the surrounding road network are vehicle hours travelled (VHT) and total number of stops. Both of these are a measure of the total delay and congestion in a network. As such a lower VHT and lower number of stops, correlates to lower congestion and improved traffic flow. Conversely, the higher the average network speed the less congestion and improved travel times.

Figure 7 to Figure 10 show the morning and afternoon peak network performance outputs for the modelled road network for the refined strategic design (Scenario 4) compared to the Do Minimum (Scenario 1) in 2020 and 2030.

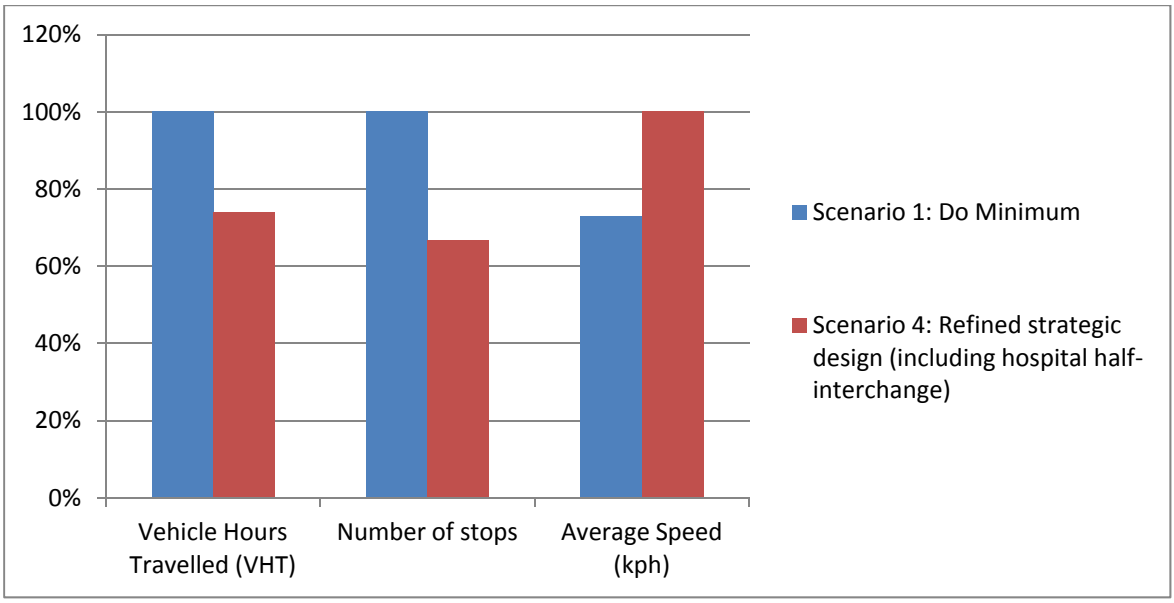

Figure 7 Network performance outputs - Morning Peak 2020

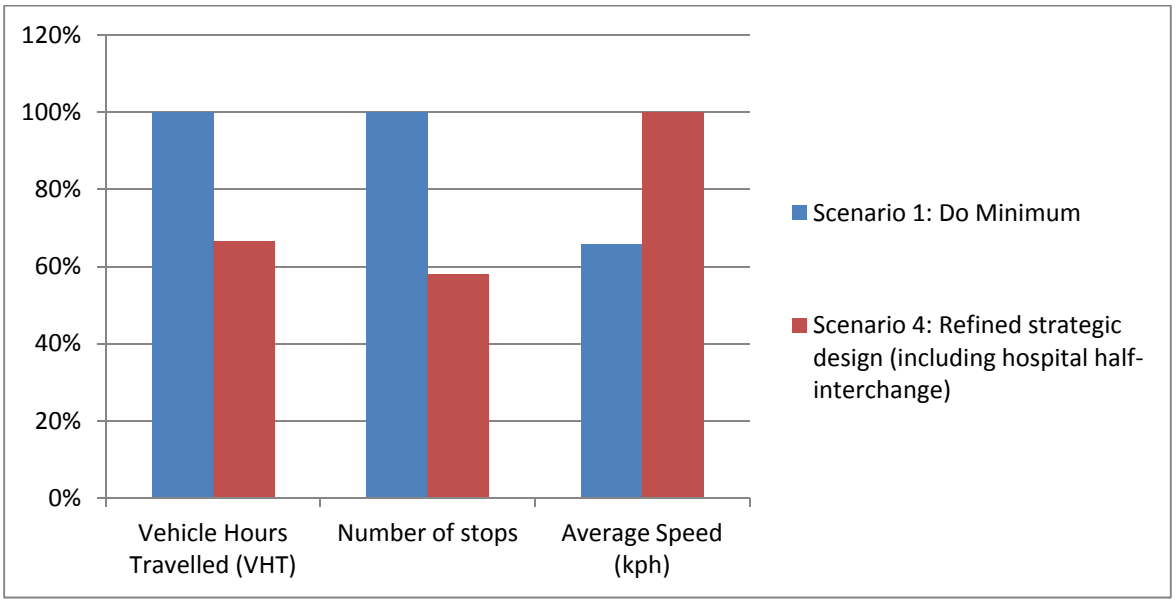

Figure 8 Network performance outputs - Afternoon Peak 2020

In reviewing the network performance data for 2020 the following conclusions can be derived:

- Congestions levels are predicted to reduce with VHT reduced by about 26 per cent in the morning peak and 33 per cent in the afternoon peak
- Similarly, the number of stops are reduced by about 33 per cent in the morning peak and 42 per cent in the afternoon peak
- Travel times are predicted to improve with the average travel speed to increase by about 27 per cent in the morning peak and 34 per cent in the afternoon peak

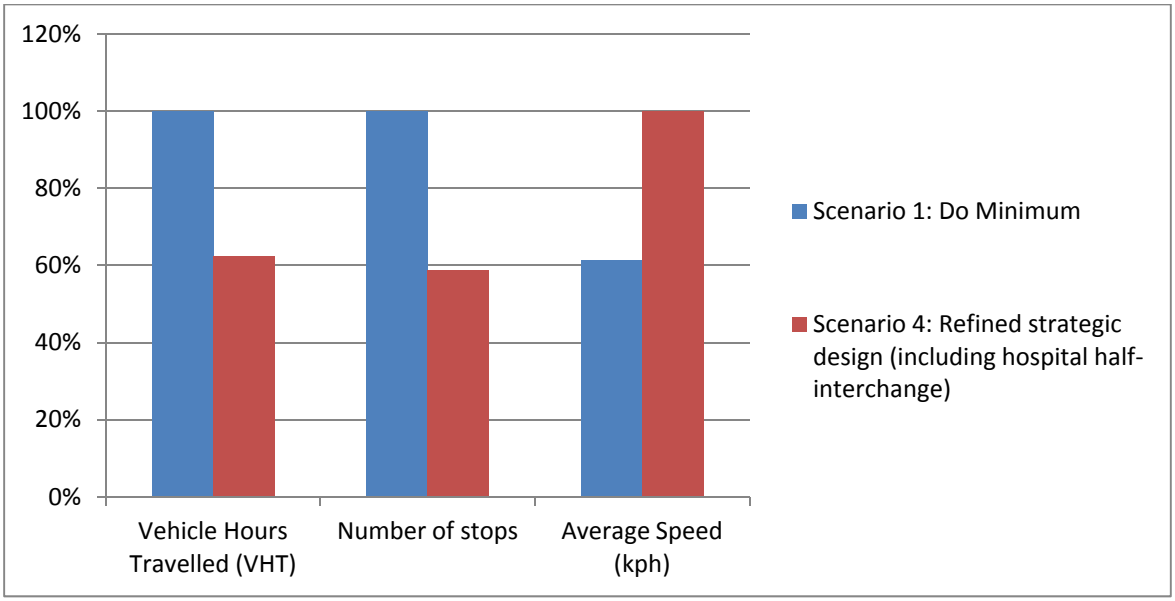

Figure 9 Network performance outputs - Morning Peak 2030

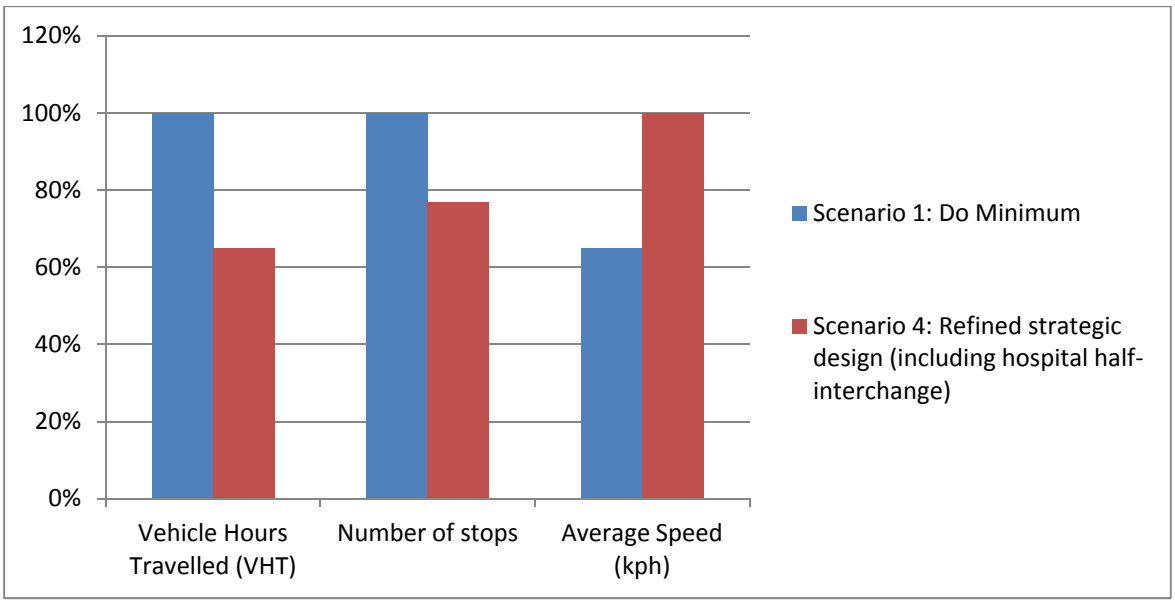

Figure 10 Network performance outputs - Afternoon Peak 2030

In reviewing the network performance data for 2030 the following conclusions can be derived:

- Congestions levels are predicted to further reduce relative to the Do Minimum case with VHT reduced by about 38 per cent in the morning peak and 35 per cent in the afternoon peak
- Similarly, the number of stops are reduced by about 42 per cent in the morning peak and 41 per cent in the afternoon peak
- Travel times are predicted to further improve relative to the Do Minimum case with average travel speed to increase by about 39 per cent in the morning peak and 35 per cent in the afternoon peak

In summary, in reviewing traffic modelling results, the following conclusions can be derived about the recommended refined strategic design (Scenario 4):

- The project is predicted to provide major benefits for motorists using the bypass with substantial improvements in travel time for both northbound and southbound journeys, relative to the Do Minimum case.
- The project is also predicted to improve travel times for north-south trips on the existing route and for east-west trips on Newcastle Road.

As such, the recommend refined strategic design meets the primary objectives for the project which are to:

- Reduce travel times and improve traffic flow on the Newcastle Inner City Bypass
- Provide traffic relief on key parts of the surrounding road network.
- Provide continuity of the Newcastle Inner City Bypass between Bennetts Green and Sandgate

5 Conclusion

Traffic modelling has been undertaken in support of options development as part of the refined strategic design investigation for the Newcastle Inner City Bypass: Rankin Park to Jesmond project. A traffic model was developed in the Q-Paramics microsimulation software representing traffic conditions for the morning and evening peak periods for the base year of 2014. This model is part of an overarching methodology utilising two tiers of modelling assessment: strategic modelling using the Lower Hunter Traffic Model (LHTM) to understand wide area traffic growth and redistribution as a result of the project, and microsimulation modelling using traffic demands from the LHTM to assess the the operational performance of the options developed.

Six option scenarios have been considered, representing the following cases for 2020, 2030 and 2040 future years:

- Do Minimum (existing network without improvements)
- 2007 Strategic Design with hospital interchange left in/left out only
- Refined Strategic Design with hospital interchange left in/ left out only
- Refined Strategic Design (including half hospital interchange)
- Refined Strategic Design (including full hospital interchange)
- Refined Strategic Design (including half hospital interchange) with McCaffrey Drive ramps

Observations of model runs indicate significant congestion in the Do Minimum scenario as a result of congestion at existing bottlenecks such as Jesmond roundabout being exacerbated by the traffic growth in future years.

The 2007 Strategic Design also does not perform adequately in the longer term due to congestion at the northern interchange as a result of flow imbalance through the introduction of additional movements and the limited capacity of the two lane roundabout. In addition, the southern interchange does not perform adequately in the longer term due to lack of a capacity for key turning movements

The refined strategic design addresses capacity issues at the:

- Northern Interchange through replacing the existing roundabout with a higher capacity intersection controlled by traffic signals.
- Southern Interchange through provision of a northbound bridge over the bypass for Lookout Road traffic and various upgrade works within McCaffrey Drive

Statistics have been extracted from the model providing metrics for network wide performance. The outputs have also been used to undertake economic analysis to understand the expected benefits relative to cost for each modelled scenario. A benefit cost ratio (BCR) has been produced for each scenario revealing the following:

- The 2007 Strategic Design has a BCR of <1.0 and does not provide value for money reflecting the poor level of traffic performance of this option.
- The Refined Strategic Design provides a BCR of 4.6, providing major economic benefits as a result of the predicted improvements in traffic performance over the network.
- The additional $10M required to provide a half interchange at the Hospital provides a high IBCR of 3.7 relative to a left in/ left out arrangement, providing value for money.
- Provision of a full interchange with an additional $10M provides minimum benefits (i.e IBCR of <1.0)
- Additional ramps at McCaffrey Drive also offer minimal benefits relative to the Refined Strategic Design with south facing ramps only, again with an IBCR less than one.

Appendix A
Demand flow tables

Morning Period

			Flow							
Intersection	Approach	Movement	Base 2014	Do Min 2020	Do Min 2030	Do Min 2040	RP2J 2014	RP2J 2020	RP2J 2030	RP2J 2040
Northern Interchange	ICB North	Left	1,411	1,621	1,956	2,241	667	731	852	993
		Thru	-	-	-	-	1,048	1,187	1,425	1,683
		Right	819	937	1,135	1,332	819	888	1,003	1,117
	Newcastle East	Left	-	-	-	-	15	15	16	16
		Thru	1,985	2,194	2,543	2,891	1,801	1,911	2,094	2,277
		Right	1,808	2,004	2,228	2,544	831	939	1,151	1,410
	ICB South	Left	-	-	-	-	421	440	476	512
		Thru	-	-	-	-	1,792	1,921	2,144	2,365
		Right	-	-	-	-	10	11	11	11
	Newcastle West	Left	1,828	1,985	2,262	2,557	1,828	1,998	2,283	2,567
		Thru	3,163	3,386	3,759	4,122	2,975	3,144	3,425	3,706
		Right	-	-	-	-	628	666	731	805
Newcastle/Croudace	Dent	Left	53	59	69	79	53	91	155	219
		Thru	365	407	457	524	333	361	409	457
		Right	72	80	94	108	72	77	85	94
	Newcastle East	Left	548	610	683	774	433	448	472	496
		Thru	1,988	2,214	2,622	3,107	2,003	2,153	2,462	2,817
		Right	136	151	185	240	136	148	169	189
	Croudace	Left	1,732	1,903	2,054	2,220	572	619	697	776
		Thru	308	329	356	375	243	262	292	322
		Right	1,040	1,066	1,147	1,296	645	686	759	839
	Newcastle West	Left	18	20	23	26	18	21	25	29
		Thru	3,192	3,459	3,925	4,364	3,203	3,407	3,761	4,135
		Right	1,363	1,529	1,768	1,974	432	458	502	546
Croudace/Howe	Croudace North	Left	419	464	538	612	419	459	525	591
		Thru	1,857	2,083	2,371	2,660	778	808	858	908
	Howe	Left	67	75	88	102	67	76	91	109
		Right	483	542	640	737	483	526	597	668
	Croudace South	Thru	2,597	2,757	2,918	3,154	978	1,041	1,151	1,268
		Right	139	141	146	150	139	157	191	227
Lookout/Russell	Lookout North	Left	57	63	72	81	57	58	60	62
		Thru	2,043	2,286	2,604	2,923	964	999	1,059	1,121
	Russell	Left	971	1,055	1,195	1,300	971	1,021	1,107	1,196
		Right	44	48	54	61	44	46	47	49
	Lookout South	Thru	2,773	2,932	3,091	3,326	1,153	1,229	1,364	1,508
		Right	1,391	1,450	1,486	1,563	1,391	1,453	1,561	1,677
Lookout/Hospital Access	Lookout North	Thru	2,092	2,329	2,635	2,907	1,238	1,315	1,446	1,581
		Right	661	727	836	945	434	440	451	464
	Lookout South	Left	1,285	1,310	1,414	1,522	978	1,063	1,215	1,393
		Thru	3,835	4,049	4,237	4,542	2,297	2,430	2,663	2,914
	Hospital Access	Left	258	261	266	270	152	157	165	173
		Right	355	359	365	372	279	301	338	395
ICB/Hospital Access	ICB North	Left	-	-	-	-	532	626	796	989
		Thru	-	-	-	-	1,160	1,242	1,379	1,515
	Hospital Access	Left	-	-	-	-	-	-	-	-
		Right	-	-	-	-	190	220	280	338
	ICB South	Left	-	-	-	-	-	-	-	-
		Thru	-	-	-	-	2,057	2,178	2,381	2,583
Lookout/McCaffrey	Lookout North	Thru	2,092	2,308	2,580	2,819	1,246	1,325	1,465	1,605
		Right	355	379	420	460	270	291	330	371
	Lookout South	Left	448	467	513	568	367	372	378	384
		Thru	3,847	4,081	4,365	4,770	2,309	2,454	2,705	2,980
	McCaffrey	Left	1,272	1,277	1,286	1,294	965	1,038	1,174	1,328
		Right	734	737	742	746	644	651	660	671
Lookout/Grandview	Lookout North	Thru	2,763	2,977	3,246	3,481	2,978	3,133	3,397	3,661
		Right	63	68	76	84	63	75	97	119
	Lookout South	Left	81	83	87	90	61	66	74	83
		Thru	3,992	4,220	4,509	4,927	4,430	4,679	5,098	5,538
	Grandview	Left	303	328	369	411	303	326	366	409
		Right	-	-	-	-	-	-	-	-
Lookout/Cardiff	Lookout North	Thru	2,410	2,598	2,823	3,014	2,599	2,697	2,862	3,028
		Right	353	379	423	467	380	436	535	632
	Lookout South	Left	348	357	370	384	348	375	421	473
		Thru	3,417	3,615	3,881	4,258	3,763	3,922	4,187	4,456
	Cardiff	Left	657	689	715	758	729	823	986	1,164
		Right	734	751	780	809	734	789	891	1,005
Lookout/Carnley	Lookout North	Left	631	672	740	782	668	699	753	809
		Thru	2,513	2,677	2,862	3,041	2,664	2,787	3,001	3,225
	Carnley	Left	906	927	963	998	906	974	1,093	1,229
		Right	465	476	494	512	510	533	572	612
	Lookout South	Thru	3,300	3,496	3,757	4,130	3,601	3,764	4,035	4,317
		Right	1,481	1,515	1,574	1,632	1,481	1,591	1,790	2,015

Evening Period

			Flow							
Intersection	Approach	Movement	Base 2014	Do Min 2020	Do Min 2030	Do Min 2040	RP2J 2014	RP2J 2020	RP2J 2030	RP2J 2040
Northern Interchange	ICB North	Left	2,196	2,512	3,045	3,628	1,003	1,099	1,282	1,494
		Thru	-	-	-	-	1,662	1,801	2,038	2,282
		Right	1,407	1,610	1,947	2,285	1,407	1,528	1,729	1,930
	Newcastle East	Left	-	-	-	-	21	22	22	22
		Thru	2,654	2,939	3,413	3,888	2,479	2,618	2,850	3,082
		Right	1,490	1,609	1,821	2,145	930	1,055	1,288	1,576
	ICB South	Left	-	-	-	-	682	717	781	853
		Thru	-	-	-	-	1,085	1,201	1,406	1,629
		Right	-	-	-	-	37	37	38	39
	Newcastle West	Left	748	824	949	1,065	748	828	960	1,093
		Thru	2,684	2,874	3,190	3,506	2,434	2,548	2,738	2,928
		Right	-	-	-	-	556	582	629	679
Newcastle/Croudace	Dent	Left	54	60	70	80	54	81	127	173
		Thru	592	661	762	812	533	570	633	696
		Right	31	35	41	46	31	36	44	53
	Newcastle East	Left	1,172	1,305	1,502	1,644	1,027	1,058	1,111	1,165
		Thru	2,577	2,875	3,385	3,963	2,599	2,817	3,218	3,671
		Right	167	186	218	249	167	178	195	213
	Croudace	Left	1,535	1,638	1,809	2,023	801	841	898	956
		Thru	276	285	301	316	224	241	270	300
		Right	775	792	832	872	475	494	529	566
	Newcastle West	Left	40	43	49	55	40	46	57	68
		Thru	2,876	3,133	3,624	4,136	2,912	3,086	3,396	3,736
		Right	1,964	2,210	2,562	2,943	521	552	605	658
Croudace/Howe	Croudace North	Left	553	613	714	814	553	603	686	770
		Thru	3,175	3,562	4,112	4,585	1,527	1,577	1,663	1,749
	Howe	Left	162	181	214	247	162	169	182	196
		Right	607	681	804	926	607	638	689	740
	Croudace South	Thru	1,979	2,034	2,138	2,285	893	938	1,008	1,083
		Right	147	150	154	159	147	174	223	279
Lookout/Russell	Lookout North	Left	70	77	89	101	70	70	71	71
		Thru	3,418	3,831	4,425	4,941	1,771	1,825	1,920	2,015
	Russell	Left	976	1,061	1,201	1,342	976	1,109	1,341	1,577
		Right	54	59	66	74	54	55	56	58
	Lookout South	Thru	2,180	2,227	2,317	2,449	1,094	1,159	1,269	1,387
		Right	1,120	1,174	1,212	1,286	1,120	1,152	1,208	1,267
Lookout/Hospital Access	Lookout North	Thru	4,049	4,510	5,183	5,779	2,516	2,700	3,020	3,344
		Right	231	255	296	336	114	116	120	125
	Lookout South	Left	451	460	473	487	343	373	430	498
		Thru	2,367	2,444	2,543	2,709	1,503	1,587	1,730	1,880
	Hospital Access	Left	602	620	639	671	369	380	400	424
		Right	1,175	1,188	1,209	1,231	871	948	1,080	1,250
ICB/Hospital Access	ICB North	Left	-	-	-	-	223	253	310	374
		Thru	-	-	-	-	2,015	2,152	2,381	2,609
	Hospital Access	Left	-	-	-	-	-	-	-	-
		Right	-	-	-	-	538	617	767	943
	ICB South	Left	-	-	-	-	-	-	-	-
		Thru	-	-	-	-	1,277	1,352	1,477	1,601
Lookout/McCaffrey	Lookout North	Thru	3,991	4,385	4,947	5,431	2,459	2,651	2,979	3,328
		Right	1,233	1,313	1,446	1,578	928	997	1,129	1,267
	Lookout South	Left	944	987	1,011	1,052	816	824	837	850
		Thru	2,215	2,282	2,371	2,511	1,350	1,429	1,558	1,697
	McCaffrey	Left	604	622	645	685	495	532	602	681
		Right	792	796	801	806	671	677	688	698
Lookout/Grandview	Lookout North	Thru	4,568	4,947	5,484	5,944	4,929	5,230	5,743	6,272
		Right	215	233	263	294	215	245	298	357
	Lookout South	Left	180	185	192	199	135	145	164	185
		Thru	3,024	3,121	3,214	3,375	3,308	3,458	3,706	3,962
	Grandview	Left	135	147	168	188	135	146	166	187
		Right	-	-	-	-	-	-	-	-
Lookout/Cardiff	Lookout North	Thru	3,881	4,203	4,608	4,909	4,187	4,357	4,643	4,934
		Right	688	745	876	1,035	742	873	1,100	1,337
	Lookout South	Left	666	681	708	734	666	715	805	906
		Thru	2,725	2,816	2,896	3,046	2,920	3,032	3,217	3,406
	Cardiff	Left	479	490	509	528	524	571	653	741
		Right	658	673	699	725	658	709	802	907
Lookout/Carnley	Lookout North	Left	534	574	640	706	570	596	641	687
		Thru	4,005	4,303	4,667	4,928	4,275	4,470	4,805	5,154
	Carnley	Left	1,678	1,718	1,783	1,849	1,678	1,803	2,029	2,284
		Right	762	780	810	840	815	851	914	980
	Lookout South	Thru	2,629	2,717	2,794	2,940	2,770	2,897	3,108	3,332
		Right	797	816	847	878	797	856	964	1,085

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