

6. Environmental management measures

6.1 Mitigation of operational impacts

The majority of operational impacts of the project have been addressed through the concept design and include the following:

- Maintenance of access to existing roads and properties, addressed through the access strategy
- Management of traffic capacity constraints, addressed through the design and operation of traffic signals and other intersection treatments
- Provision of public transport capacity and priority, addressed through the design by provision of bus lanes in both directions along the length of The Northern Road
- Provision of active transport facilities, addressed through the design by provision of a shared path along the length of The Northern Road.

6.2 Mitigation of construction impacts

The majority of project impacts that cannot be removed through the concept design and are primarily impacts of construction. Environmental management measures would be required to minimise the impacts of construction and operation of the project on traffic and transport.

The key environmental management measure required to address the impacts of construction on traffic and transport would be Construction Traffic Management Plans (CTMPs) prepared as part of the Construction Environmental Management Plan (CEMP). These plans would be prepared by the construction contractor and would be required to outline the guidelines, general requirements and specific procedures to be used for any works that may have an impact on traffic operation. The TMP would be required to:

- Identify individual traffic management requirements at each phase of construction
- Outline the general principles and procedures for the development of specific construction Traffic Management Plans (CTMPs), taking into consideration where possible other construction works utilising similar haulage and access routes
- Ensure safe and continuous traffic movement for construction workers and the general public
- Maintain the capacity of existing roads where possible
- Identify the requirements for temporary speed restrictions where traffic may pose a safety risk to workers
- Maintain continuity of access to local roads and properties, particularly along the existing alignment of The Northern Road (may require temporary U-turn facilities)
- Provide temporary traffic control where necessary
- Identify requirements and placement of traffic barriers
- Provide appropriate warning and signage for traffic in the vicinity of work areas
- Include methods to minimise road user delays such as undertaking works around live traffic including tie-in and bridge work outside of peak periods
- Undertake construction activities off-line where possible to minimise the requirement to operate temporary traffic control and reduced speed zones
- Develop a communication plan to advise local residents and businesses of any changes to traffic conditions during construction
- Consult with bus operators regarding temporary bus stop relocations during construction and proposed bus stops during operation.

7. Residual impacts

The environmental management measures identified in Section 6 would generally be effective in mitigating the traffic and access impacts of the project both during construction and in operation to an acceptable level. However it is expected that a residual impact would remain following implementation of the environmental management measures. A summary of these residual impacts is presented below, including reasoning as to why avoidance or mitigation of these impacts would not be able to be achieved.

7.1 Construction

Potential residual impacts that may occur as a result of construction of the project would include:

- Reduced travel speeds and increased delays through construction areas. This would be necessary to ensure that construction work is carried out safely in and around operational roads. Residual delays as a result of reduced travel speeds are expected to be minor.
- Temporary changes to accessibility for pedestrian and cyclists when access to roadside areas may need to be restricted during construction. This would require pedestrians and cyclist to potentially travel further to reach their destination and would be necessary to undertake construction in these locations. The residual delays for pedestrians and cyclists as a result of temporary access changes are likely to be minor.
- Temporary changes to the location and accessibility of bus stops during relocation and construction. This would result in passengers not being able to board or alight from buses at the locations they are used to and may require them to travel further to and from temporary or relocated bus stops. These would be necessary to undertake construction in these areas. The residual delays for bus passengers travelling to and from temporarily relocated bus stops is likely to be minor.

7.2 Operation

Potential residual impacts that may occur following the completion of the project when it is in operation would include:

- Access to and from properties along The Northern Road would generally be restricted to left in and left out access arrangements due to the construction of a median along the centreline of The Northern Road. This would restrict right turn movements to intersections and U-turn bays, which would require motorists to travel further to access these facilities. Overall, this would result in longer travel distances and times for trips for those affected by this change in access. It would also increase traffic along the local roads that provide these turning facilities. This would be necessary as part of the design which includes a solid median along The Northern Road for the length of the project. Longer travel distances and higher travel times resulting from changes to access arrangements are likely to be minor.
- Bus stops would be relocated along The Northern Road. For some passengers, these stops may be closer to their destination, however for others they could potentially be further increasing the distance and time travelled to reach their bus stop, by as much as 650 m. This is necessary to place bus stops at strategic locations along the corridor, coinciding with major intersections and areas of primary public transport demand. Relocation of bus stops along The Northern Road to the exit side of intersections is likely to be a minor improvement in accessibility, particularly for bus passengers living on local roads adjacent to The Northern Road.
- Immediately after construction, it is likely that delays along The Northern Road would increase at existing intersections where traffic signals are proposed. These traffic signals would delay vehicles travelling north or south along The Northern Road, however this is unlikely to be the case for vehicles entering or exiting The Northern Road. Over time, as traffic growth is realised, this residual impact of traffic signal installation would decline. This would be necessary to maintain safe and efficient operation of these intersections under the proposed design speed and geometry. Travel speeds and

intersection performance are likely to improve and providing substantial travel time savings for traffic in the long-term when compared with a Do Minimum scenario.

- Traffic volumes along The Northern Road through Luddenham town centre are likely to decrease as a result of the project, as the project would provide a faster alternative for vehicles travelling between Eaton Road and Elizabeth Drive. This is a consequence of providing a high speed and high capacity alternative route past Luddenham town centre. The increase in amenity as a result of decreased heavy vehicle volumes and lower traffic volumes overall is likely to be substantial.

8. Summary and conclusions

8.1 Overview

Traffic modelling of the proposed The Northern Road Upgrade (between Mersey Road and Glenmore Parkway) has been undertaken using the Aimsun microsimulation modelling platform. The microsimulation model allows for detailed interactions between vehicles and is part of a wider model of The Northern Road corridor that is being used for assessing the functional performance of The Northern Road Upgrade between Mersey Road and Jamison Road.

8.2 Key findings

Overall, analysis of the road network performance under the 2021 and 2031 future horizon years shows that The Northern Road upgrade (between Mersey Road and Glenmore Parkway) is required to ensure that The Northern Road continues to operate at an acceptable level of service into the future. Upgrading The Northern Road between Mersey Road and Glenmore Parkway would improve access and travel times through the corridor and ensure the future M12 Motorway and Western Sydney Airport access to operate within a reasonable level of service.

The potential impacts to traffic and transport from the project would include the following potential positive impacts:

- Reduced delays and higher travel speeds for vehicles travelling along The Northern Road as well as improved safety for vehicles using current priority-controlled intersections
- Reduced road crashes along the corridor
- Improved pedestrian / cyclist safety due to the provision of formal crossings and shared paths
- Reduced number of heavy vehicles, including B-Doubles from the Luddenham town centre due to the realignment of The Northern Road which would increase safety for drivers, cyclists and pedestrians
- Reduced travel times along The Northern Road corridor between Mersey Road and Glenmore Parkway in future years with the upgrade in operation than without the upgrade.

The potential impacts to traffic and transport from the project would include the following potential negative impacts:

- Changes to access arrangements for the majority of properties that currently have access directly onto The Northern Road and some properties that have access along roads that connect to The Northern Road. The majority of these right turn movements into and out of The Northern Road would no longer be possible and would involve detours of up to 6.6 km for those properties worst affected
- Reduced speeds and increased delays for vehicles travelling along The Northern Road during construction
- Interruptions to bus operations during construction including temporary relocation of bus stops
- Although no formal pedestrian or cycling facilities are currently provided on The Northern Road, access to properties along The Northern Road for pedestrian and cyclists may be restricted during construction.

8.3 Recommendations

Traffic and transport impacts associated with construction of the project would need to be mitigated through environmental management measures. These measures would include the development and implementation of Traffic Management Plans (TMPs) prepared as part of the Construction Environmental Management Plan (CEMP). These plans would be prepared by the construction contractor and would be required to outline the guidelines, general requirements and specific procedures to be used for any works that may have an impact on traffic operation.

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Appendix A. Intersections included in traffic model

The following intersections within the study area have been included within the The Northern Road traffic model:

- The Northern Road and Mersey Road
- The Northern Road and Dwyer Road
- The Northern Road and Leppington Pastoral Company Access
- The Northern Road and Eaton Road south
- The Northern Road and Eaton Road north
- The Northern Road and IGA Access
- The Northern Road and Adams Road
- The Northern Road and Roots Avenue
- The Northern Road and Blaxland Avenue
- The Northern Road and Park Road
- The Northern Road and Elizabeth Drive
- The Northern Road and Littlefields Road
- The Northern Road and Gates Road
- The Northern Road and Longview Road
- The Northern Road and Kings Hill Road
- The Northern Road and Grover Crescent south
- The Northern Road and Grover Crescent south
- The Northern Road and Chain-O-Ponds Road
- The Northern Road and Defence Establishment Orchard Hills Access
- The Northern Road and Bradley Street.

Appendix B. Calibration and Validation Report



The Northern Road Upgrade Jamison Road between Mersey Road, Bringelly and Jamison Road, Penrith

Roads and Maritime Services

Traffic Model Calibration and Validation Report

IA086100-RP-TM-0055 | 00 (WIP)

November 2015

Contract No: 14.2166.0494-0007



The Northern Road Upgrade between Mersey Road, Bringelly and Jamison Road Penrith

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 Project manager: E. D'Angola
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Appendix A. Detailed calibration results

Appendix B. Regression Plots

Appendix C. Cumulative counter peak travel time graphs

1. Introduction

1.1 The project

Jacobs have been commissioned by the Transport for NSW to develop a microsimulation traffic model of The Northern Road between Mersey Road, Bringelly and Jamison Road, Penrith. The Northern Road microsimulation traffic model will provide a tool for the assessment the impacts of the proposed The Northern Road Upgrade between Mersey road and Jamison road (Hereafter referred to as The Northern Road Upgrade).

Microsimulation modelling provides a framework to undertake detailed assessment of the proposed route and any intersections along it, allowing for the assessment and visualisation of the corridor as a whole. The microsimulation traffic modelling work will also assist in the assessment and scoping of proposed intersections along the corridor as well as provide a tool to assist in the development of construction staging and traffic management

1.2 Modelling process

The microsimulation traffic model developed by Jacobs forms the last two steps in a three-tiered modelling approach. High-level land use forecasting and mode split has been undertaken using the Transport for NSW Sydney Strategic Transport Model (STM) which has been used to provide initial network structure and to generate future growth scenarios.

The Northern Road Upgrade model has been developed using the Aimsun modelling platform (version 8.1.0) and has been calibrated and validated according to the principles outlined in the Roads and Maritime Services *Traffic Modelling Guidelines, 2013*.

Following development of the microsimulation model, further assessment of intersection treatments will be undertaken using SIDRA intersection modelling, which will assist in developing optimised layouts and signal phasing for intersections along the corridor.

1.3 Purpose of this report

This report is intended to document the development, calibration and validation of the Northern Road Upgrade. It details the process undertaken to calibrate and validated the models and specifies the conformance of the models to relevant standards for calibration and validation.

1.4 Assumptions and limitations

The calibration and validation of the Parramatta Road Reconfiguration hybrid simulation traffic model is based on a number of assumptions:

- Peak period trip tables supplied by Transport for NSW are an accurate representation of peak period travel demand.
- Traffic count data supplied by Roads and Maritime are a true and accurate representation of existing traffic conditions.
- Public Transport data supplied by Transport for NSW are a true and accurate representation of existing traffic conditions.
- Signal timing data provided by Roads and Maritime is correct.

The calibration and validation of the model documented in this report is subject to the following limitations:

- Traffic model development has been limited to microsimulation modelling of the study corridor, focusing on The Northern Road between Mersey Road and Jamison Road with side roads modelled as approaches.
- The zoning system within the model is limited to some subdivision of the Sydney Strategic Transport Model zone system, and includes detailed zone disaggregation down to the level of local or collector roads where appropriate to match observed traffic counts.
- Traffic data, including counts, speed and flow profiles and travel time surveys were gathered from a number of sources, some of which were not consistent with one another. While every effort has been made to ensure continuity in these sources, some inconsistency in count data is expected, though is not considered likely to distort the basis of the result presented and conclusions drawn.

1.5 Report structure

This report details has been structured as follows:

- Section 2: *Study Area* – Describes the study area extents and existing conditions.
- Section 3: *Model Development* – Outlines the methodology used in the development of the model.
- Section 4: *Demand Matrix Development* – Outlines the methodology used to prepare the model demands.
- Section 5: *Model Calibration* – Details the Calibration procedures and results.
- Section 6: *Model Validation* – Details validation procedures and results.
- Section 7: *Summary and Conclusions* – Outlines the conclusions of the calibration and validation process.

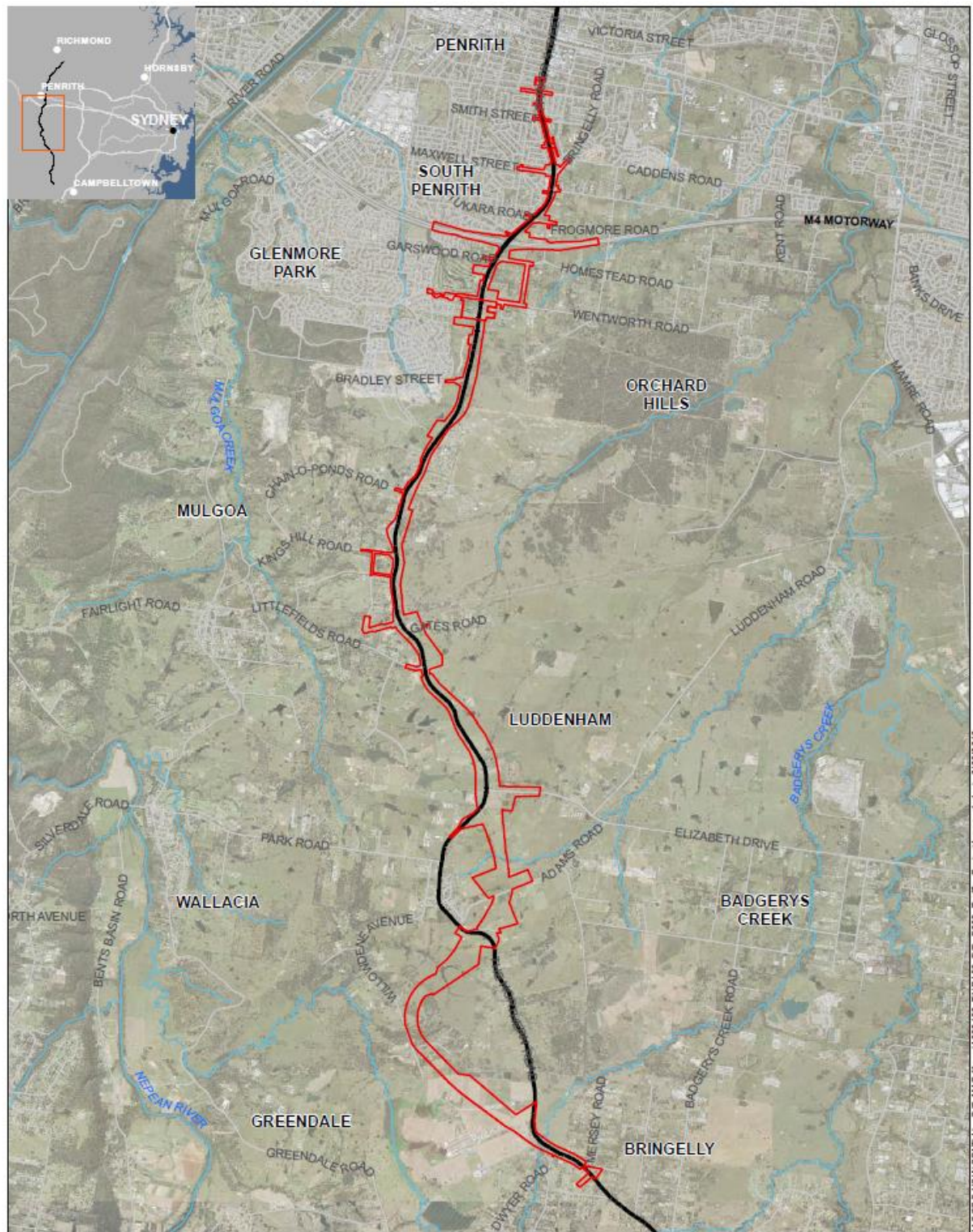
2. Study Area

2.1 Background

The Northern Road is an arterial road in Sydney's west that connects Narellan, in Sydney's South West with Penrith, in Sydney's North West. Primarily a two lane rural undivided road for the majority of its length, The Northern Road passes through the localities of Oran Park, Bringelly, Luddenham, Orchard Hills and Penrith. It is bordered by two large commonwealth land reservations, including the proposed Western Sydney Airport (WSA) site, which it crosses through, and the Defence Establishment, Orchard Hill (DEOH), passing along its western boundary.

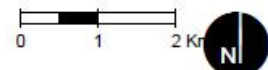
This report focuses on The Northern Road Stage upgrade between Mersey Road, Bringelly and Jamison Road, Penrith. A map of the study area is provided in Figure 2.1.

Figure 2.1 : The Northern Road Upgrade, Bringelly to Penrith study area



Legend

- The Northern Road
- Project area



2.2 Road network

For the majority of its length through the study area, The Northern Road is a two-lane rural road on a single carriageway. It provides a link between Narellan in the south, and Penrith in the north. Between Glenmore Parkway and Jamison Road The Northern Road widens to two lanes in each direction and it becomes an urban arterial road with divided carriageways between Smith Street and Jamison Road.

The majority of intersections along the project length are unsignalised. The signalised intersections along the project length are:

- M4 Western Motorway
- Maxwell Street and Bringelly Road
- Smith Street
- Jamison Road

There are also roundabouts, at Elizabeth Road and Glenmore Parkway. Both of these have two circulating lanes.

The Northern Road is generally 80 km/h between Mersey Road and Glenmore Parkway, with reduction to 60 km/h through Luddenham town centre. Between Glenmore Parkway and Jamison Road, The Northern Road is 70 km/h.

2.3 Existing traffic conditions

South of Glenmore Parkway, The Northern Road is generally uncongested and free-flowing during peak periods. Between the M4 Western Motorway and Jamison Road, congestion is usually observed on approach to the following intersections:

- M4 Western Motorway
- Bringelly Road and Maxwell Street
- Jamison Road

Congestion is also observed on some side roads along the Northern Road including:

- Glenmore Parkway
- Maxwell Street
- Jamison Road
- Bradley Street

3. Model development

3.1 Overview

The Northern Road Upgrade microsimulation model has been developed using the Aimsun traffic modelling platform. Aimsun allows for the development of static and dynamic traffic models within a unified platform, performing traditional static macroscopic modelling using volume delay functions as well as more detailed dynamic mesoscopic and microscopic simulation modelling. Dynamic traffic models are useful in modelling congested or capacity-constrained conditions where traffic demand exceeds available capacity and traffic diverts to seek less congested routes. These conditions result in queuing that builds up and dissipates over time and dynamic routing of traffic that is responsive to this build-up of delays.

The Northern Road Upgrade model has been developed using Aimsun version 8.1.0 and is based on an initial road network and traffic demand supplied by Transport for NSW, converted from the Roads and Maritime Strategic Traffic Assignment Model (STAM). This model has been built within Jacob's Greater Metropolitan Sydney network, which includes detail in coding from other projects within Sydney including the M4 Motorway and a large area of Western Sydney, and has used many of the existing volume delay functions and node delay functions that have been developed as a result of this work.

3.2 Model scope

3.2.1 Geographical coverage

A plot of the model extents is provided in Figure 3.1. The model covers the length of The Northern Road between the following roads:

- Mersey Road, Bringelly
- Jamison Road, Penrith

In addition to The Northern Road, the following sections of road were also modelled as side areas, including:

- Adams Road
- Littlefields Road
- Kings Hill Road
- Chain-O-Ponds Road
- Kingswood Road

3.2.2 Temporal coverage

The Northern Road Upgrade model covers the following time periods:

- Morning peak: 6am to 10am
- Evening peak: 3pm to 7pm

3.2.3 Vehicle classes

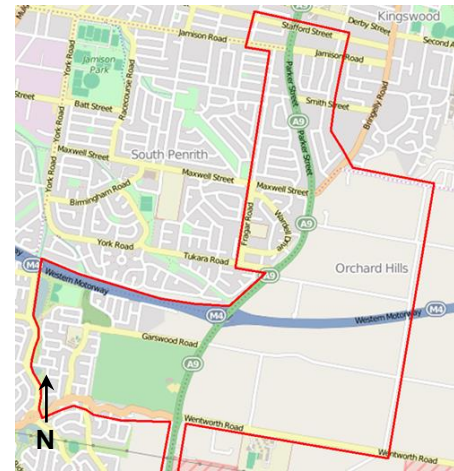
The Northern Road Upgrade model uses the following vehicle classes:

- Car, including cars and light commercial vehicles
- Rigid trucks
- Articulated trucks

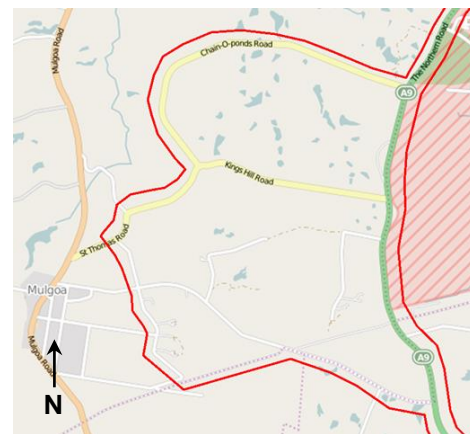
Figure 3.1 : The Northern Road Upgrade model extents



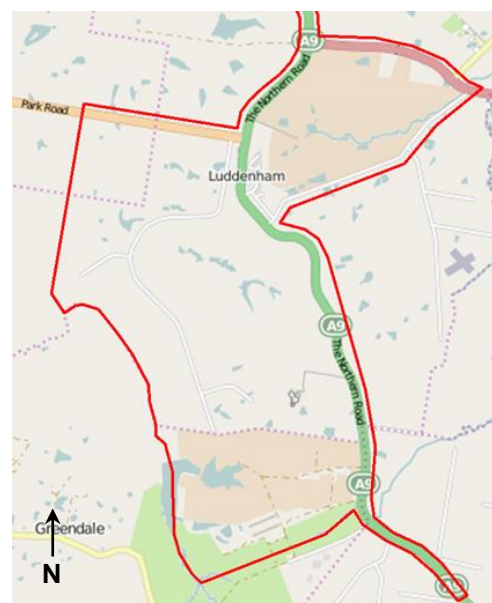
Overall model area



Orchard Hill area

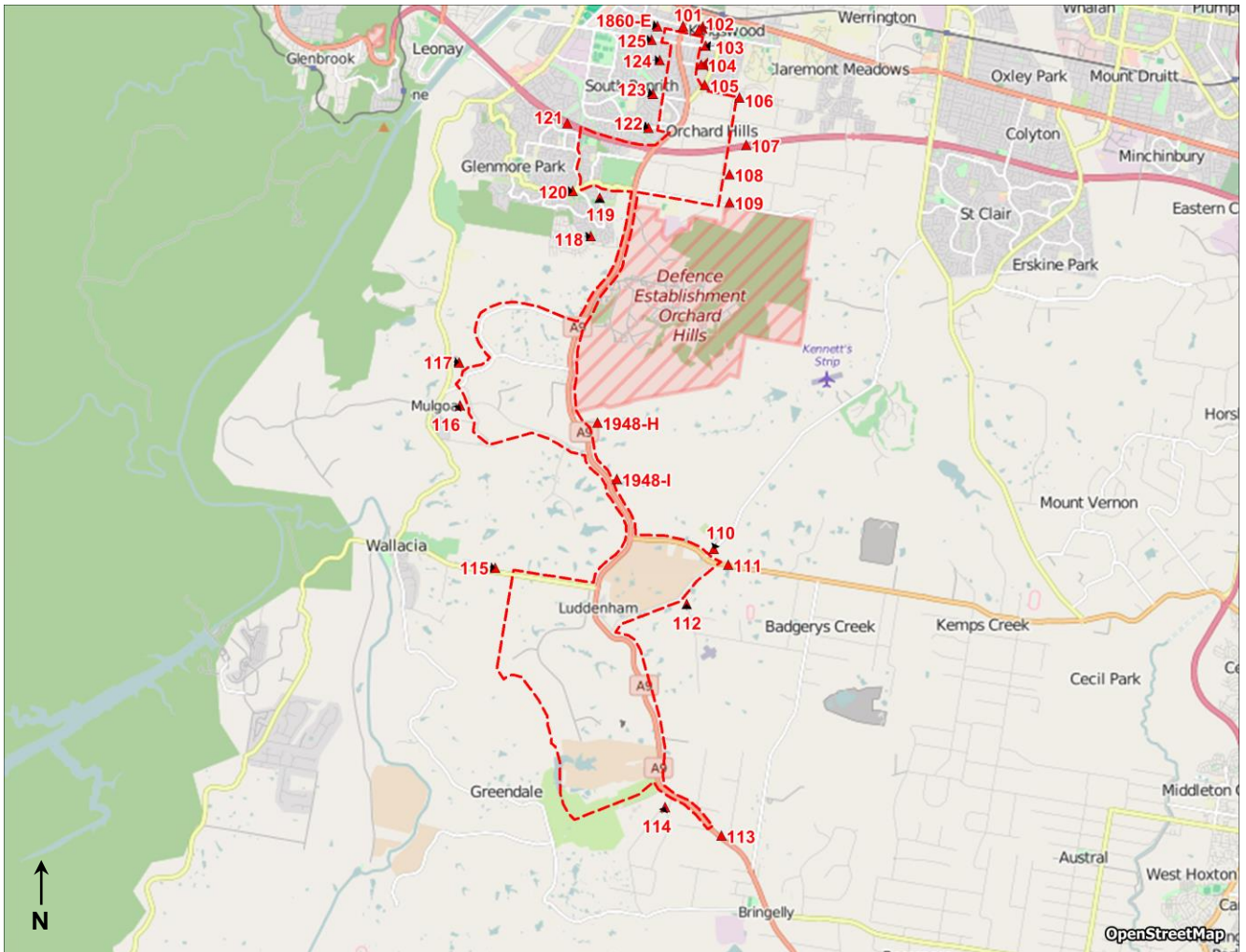


Mulgoa area



Luddenham Area

Figure 3.3 : Aimsun model external travel zones



The nominal external zones at Stafford Street West ("1860-E"), Gates Road ("1948-H") and a representative driveway at approximately 2787 The Northern Road, between Littlefields Road and Elizabeth Drive ("1948-I"), represent very small fractions of strategic model zones which do not appropriately connect in the Aimsun model area. These have been seeded based on the nearest comparable internal zones (1860 and 1948 respectively).

3.4 Model data

Traffic data used in the development of the Northern Road Upgrade was supplied by various agencies. These data sources included:

- Intersection turning movement surveys
- Automatic traffic counts
- SCATS detector counts
- Floating-car travel time surveys

3.4.1 Intersection turning movement counts

Intersection turning movement counts were undertaken by Roads and Maritime on 21 and 23 July, 2015 at the following locations:

- The Northern Road and Smith Street
- The Northern Road, Castle Street and Aspen Street
- The Northern Road and M4 Western Motorway
- The Northern Road, Hampstead Road and Garswood Road
- The Northern Road, Glenmore Parkway and Wentworth Road
- The Northern Road and Bradley Street
- The Northern Road and Defence Establishment Gates
- The Northern Road and Chain-O-Ponds Road
- The Northern Road and Kings Hill Road
- The Northern Road and Longview Road
- The Northern Road and Gates Road
- The Northern Road and Littlefields Road
- The Northern Road and Elizabeth Drive
- The Northern Road and Park Road
- The Northern Road and Blaxland Avenue
- The northern Road and Roots Avenue
- The Northern Road and Adams Road
- The Northern Road and Dwyer Road
- Elizabeth Drive and Luddenham Road

The following additional intersection turning movement counts were undertaken by Penrith Council between 15 and 21 November 2014:

- The Northern Road, Maxwell Street and Bringelly Road
- The Northern Road, Tukara Road and Frogmore Road
- The Northern Road and Jamison Road
- The Northern Road and Derby Street
- The Northern Road and Great Western Highway

A plot of the intersection count locations used in the development of the model is provided in Figure 3.4.

Figure 3.4 : Intersection count locations



3.4.2 Automatic traffic count data

Automatic traffic count data (ATC) was provided for the period between 22 and 29 July 2015. This count data covered the following locations along The Northern Road:

- Between Stafford Street and Jamison Road
- Between Smith Street and Maxwell Street
- Between Maxwell Street and M4 Motorway
- Between Homestead Road and Glenmore Parkway
- Between Glenmore Parkway and Bradley Street
- Between Chain-O-Pond Road and Kings Hill Road
- Between Littlefields Road and Elizabeth Drive
- Between Elizabeth Drive and Park Road
- Between Park Road and Blaxland Avenue
- Between Eaton Road and Dwyer Road
- Between Dwyer Road and Mersey Road

3.4.3 SCATS detector counts

SCATS detector counts were collected for the following signalised intersections:

- TCS 2306: The Northern Road and Westbound Ramps
- TCS 3669: The Northern Road and Eastbound Ramps

3.4.4 Floating-car travel time surveys

Floating-car travel time surveys were undertaken on 13 and 20 October 2015 during the morning and evening peak periods. Surveys were undertaken along the length of The Northern Road between Mersey Road, Bringelly and Stafford Street, Penrith. A total of 10 travel time observations were made in each direction during the morning and evening peak period. Analysis of the surveyed travel times showed that there was some localised variability in observed travel times, which is to be expected from the generally small sample sizes achievable using the floating-car survey method.

3.5 Development of Real Data Sets

Real Data Sets (RDS) of target volumes have been used for two purposes in The Northern Road Upgrade base model development:

- 1) Target volumes against which model calibration is measured
- 2) Target volumes to guide the matrix adjustment processes

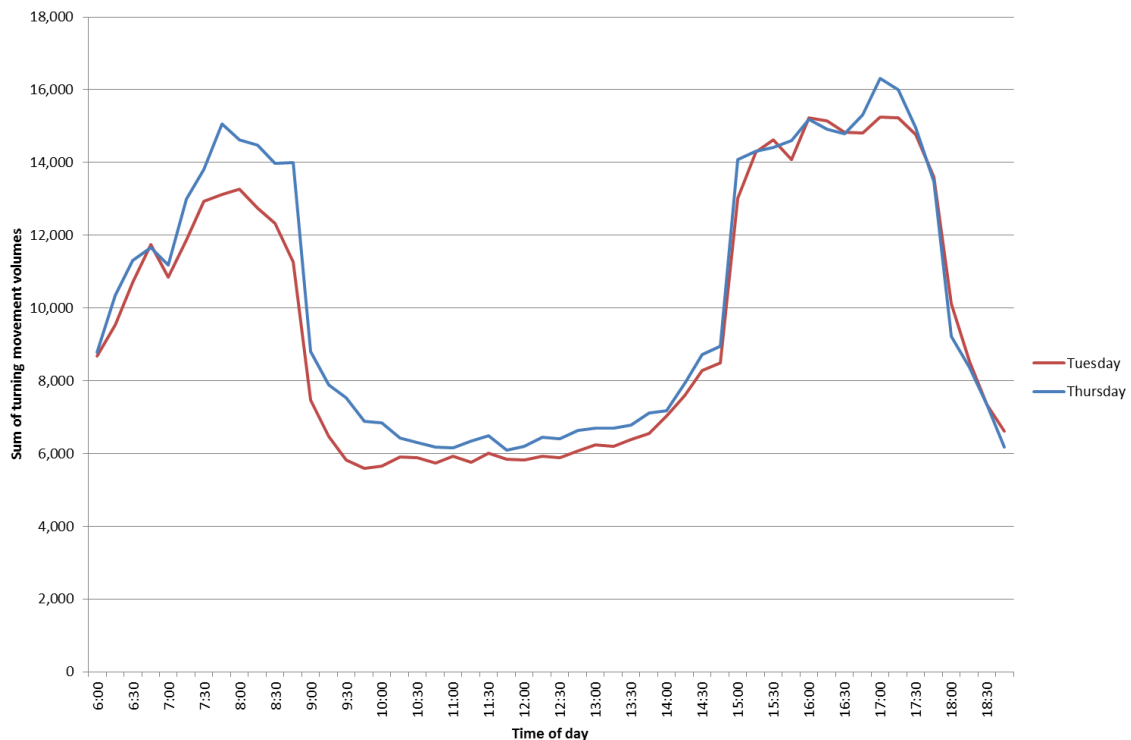
These two RDSs are not the same because the Aimsun adjustment processes require target volumes for every time interval in the modelled period, warm up and cool down, while the count data available covers different time periods in different locations. The available count data has been extrapolated to provide estimated targets for missing time periods in order to guide the adjustments, but only time periods with actual count data have been used as calibration targets.

SCATS detector data for the M4 interchange for the intersection survey day has been used to help guide the balancing of the intersection counts for consistency, but has not been used directly for calibration targets due to the level of uncertainty inherent in induction loop counts.

3.5.1 Count processing

As multiple days' worth of turning movement count data were supplied over a number of different time periods, analysis of the various surveys days was undertaken to determine which day had the highest overall traffic flow. A plot of the sum of turning movement flows for the Tuesday and Thursday surveys is shown in Figure 3.5.

Figure 3.5 : Analysis of traffic flow on survey days



Analysis of the Tuesday and Thursday surveys showed that there is variability in observed traffic flows through the study area, particularly in the morning peak where flows can vary in excess of 10 percent from day to day. Thursday was selected as the survey day for use in calibration of The Northern Road Upgrade traffic model, based on the higher observed traffic flows.

Real Data Sets were developed independently for light vehicles (cars) and heavy vehicles (trucks and articulated trucks), then added together to calculate the Real Data Set for total vehicles.

3.5.2 Infill of missing intervals

For the demand adjustment process, Aimsun requires that all the locations covered by the real data set have target volumes specified for each time interval. For the older (November 2014) intersection counts, which did not cover the full four hour peak periods to be modelled, the missing periods were filled in the following way:

- All turning movements were identified as northbound, southbound, or neutral (crossing The Northern Road).
- Average profiles for each direction of travel were calculated using the sum of directional movements across all of the 13 hour intersection surveys (those from July 2015). These were used to calculate the ratio of the 15 minute volume in each interval outside the November 2014 count period compared to closest interval in the November 2014 count period.
- A 'neutral' profile and corresponding ratios were calculated from the sum of northbound and southbound movements in the 13 hour surveys.
- These profiles were used to calculate missing intervals for the incomplete surveys.

3.5.3 Expansion to shoulder periods

The 13 hour surveys covered the cool down hour after the morning peak model period and the warm up hour for the evening peak model. Targets for these time periods could therefore be based directly on these counts, in the case of the 2015 surveys, or using the process described in Section 3.5 Development of Real Data Sets in the case of the 2014 surveys.

To synthesise the adjustment targets required for the hours before the morning peak period and after the evening period, the automatic traffic count data listed in Section 3.4.2 Automatic traffic count data was used. This was provided in one hour intervals. The ratio between the hour to be calculated and the nearest peak period hour, for each direction of travel and for the sum of both directions, was calculated. For each 15 minute interval in the hour to be extrapolated, this ratio was applied to the target volume for the corresponding interval in the adjacent hour.

3.5.4 Consistency checks and balancing

To provide a sound basis for calibration and demand adjustment, especially in view of the range of types and dates covered by the surveys, the counts have been adjusted for consistency. This also provides an additional check that the counts have been processed and imported into the model correctly.

The counts were found to have poor consistency between adjacent intersections in some cases, notably across the M4 interchange (between the eastbound and westbound ramp terminal intersections). The scale and pattern of the differences indicated that they could not be wholly related to the build-up or discharge of queues between intersections. The target volumes were therefore adjusted to enforce consistency between adjacent intersections unless adjacent land uses with access to The Northern Road, represented by a zone, were present.

Initially the targets were adjusted to achieve consistency without reducing any of the counted volumes. This yielded demands higher than the intersection capacity in some cases, especially at the M4 interchange and Bringelly Road / Maxwell Road.

The M4 interchange SCATS detector counts for the same day as the intersection surveys were therefore used as a guide. This data was checked and no detector problems or missing data was identified

The heavy vehicle targets calculated without reducing any surveyed volumes were retained.

At the M4 interchange, the light vehicle targets in each 15 minute interval were then capped so that the total volume for each signalised movement in each interval would not be more than 10% higher than the SCATS count.

Any inconsistency between the M4 intersections remaining after applying these caps was removed by reducing the contributing turns at the higher end of the section.

Finally, northbound and southbound light vehicle through volumes at intersections north of the M4 were propagated from the M4 targets. Turning movements at these intersections remained as surveyed.

South of the M4, the more conservative light vehicle targets calculated without reducing any surveyed volumes were used.

Balancing was applied in the same way to all time intervals, after deriving initial infill and shoulder period volumes as described in sections 3.5.2 Infill of missing intervals and 3.5.3 Expansion to shoulder periods.

3.5.5 Final calibration targets

The final calibration targets are the balanced volumes for each time interval for which survey data was included in the original data set.

3.6 Road network coding

3.6.1 Initial network coding

Coding of the road network was undertaken on the basis of updating Transport for NSW's latest Sydney GMA Aimsun network. Infilling of detail within the study area was undertaken on the basis of 2015 aerial photography provided by Roads and Maritime along with additional road network data from GIS, intersection layout plans and Google Street View. Intersections, interchanges and minor streets were added to the study area as part of the network coding process.

Additional time-dependent traffic management policies were coded in the network to reflect the following time-dependent features:

- School speed zones
- Time-dependent lane controls (including parking restrictions)

Parking restrictions were checked using roadside signage in Google Street View. This identified traffic lanes with parking prohibited in one or both peak periods. No time dependant parking lane coding was required for this model

The network coding was carried out to a high level of detail, including:

- Modelling of road gradients: In order to better reflect the impacts of steep grades on heavy vehicles, spot heights have been coded at nodes and at high and low points along The Northern Road and on the M4 Western Motorway ramps. These gradients affect the acceleration and deceleration profiles of heavy vehicles along the corridor
- Opposing lane overtaking: As The Northern Road is a two-lane rural road through much of the study area and due to the limited opportunities for overtaking, opposite-lane overtaking occurs through some sections of the corridor. This behaviour can be modelled in Aimsun using the two-way overtaking model, which has been enabled for sections of The Northern Road separated by a broken median line.

3.6.2 Network coding adjustments during calibration

During the calibration and validation process, a number of adjustments have been made to the network coding to better represent traffic behaviour and routing. These adjustments included:

- Adjustments to sight distances and look ahead distances at intersections to reflect realistic vehicle behaviour
- Increased acceleration and reduced reaction time to reflect more alert and impatient driver behaviour at:
 - Southern approach to Glenmore Parkway roundabout (high acceleration, reaction time -0.2 sec)
 - Western approach to Glenmore Parkway roundabout (medium acceleration, reaction time -0.15 sec)
 - Right turn into Castle Street (medium acceleration)
 - Stafford Street eastbound approach to The Northern Road (medium acceleration)
- Reduced initial gap (from 3.0 to 2.5 seconds) and reduced final give way time factor (from 2.0 to 1.5) to reflect more impatient driver behaviour at:
 - Southern approach to Glenmore Parkway roundabout (high acceleration)
 - Western approach to Glenmore Parkway roundabout (medium acceleration)
 - Right turn into Castle Street

3.7 Public transport network coding

Coding of the public transport network was undertaken based on bus stop, bus route and bus timetable data from the Transport for NSW Operational Spatial Database (OSD). This database provides the location of bus stops, bus routes and stopping patterns as well as timetables arrival times at each stop along each route.

A subset of the OSD was extracted that detailed the stops and routes for all public and school buses passing through the study area during the morning and evening peak periods. These bus stops were imported and the regular (non-school) bus routes created based on linking stops according to the shortest path between stops. Review and correction of imported routes was also undertaken to ensure that stops were imported in the correct locations and that routes operated along the correct roads.

As public transport performance is not a focus of this model and Opal data for the study area was not available, a standard dwell time of 20 seconds has been applied to all bus stops and routes, as agreed with Roads and Maritime.

3.8 Traffic signal settings

SCATS timing statistics and LX signal data for September 2015, provided by Roads and Maritime, was used as the basis for fixed-time traffic signal phase and cycle times and offsets for each modelled 15 interval.

A review of the timing statistics indicated significant differences between consecutive 15 minute intervals, reflecting the responsiveness of the SCATS system to variations in traffic volume. As the timing data available was not for the survey day, it has been used a starting point, and the phase times have been adjusted to suit the target volumes in each 15 minute interval.

Where possible, offsets were identified from the LX files. Maximum cycle times for each subsystem were also identified from the LX files. Cycle times were calculated from this information and the highest average cycle time in each subsystem, rounded up to the nearest 10 seconds, was used as the common subsystem cycle time.

3.9 Behavioural settings

The following behavioural settings were used in the development of The Northern Road Upgrade base model:

- Look-ahead distance variability: 40 per cent
- Simulation step: 0.8 seconds
- Mesoscopic reaction time (all vehicles): 1.2 seconds
- Mesoscopic reaction time at traffic lights (all vehicles): 1.3 seconds

- Microscopic reaction time: same as simulation step
- Microscopic reaction time (all vehicles): 0.85 seconds
- Microscopic reaction time at traffic lights (all vehicles): 0.95 seconds
- Global arrivals: exponential distribution

Based on advice from TSS (developers of Aimsun) as a general rule of thumb, reaction times used in mesoscopic simulation are generally 1.3 to 1.5 times those used in micro-simulation to account for simplifications of vehicle behaviour made by the mesoscopic simulator including instantaneous acceleration and limited lane choice opportunities. The reaction time for mesoscopic simulation has been selected based on this advice.

3.10 Traffic assignment and simulation

Unlike micro-simulation and static traffic models, Aimsun allows for a combination of assignment types in combination with different vehicle simulation methods. As route choice in the study area is very limited, and traffic volumes and travel patterns on competing routes can only be nominal due to a lack of count data, the Northern Road Upgrade base model has initially been developed using a two stage process:

- 1) Static equilibrium assignment using static traffic model
- 2) Stochastic assignment (one-shot assignment using converged static model paths) using microscopic simulator

In stage 1, travel paths were reviewed and adjusted using turn penalties where necessary to overcome the limits of the strategic volume delay functions and ensure travel paths were realistic. Demand estimation and departure adjustment was then undertaken using static equilibrium assignment. When a good match to target time interval volumes was achieved, and a profile of 15 minute demand matrices for each vehicle class had been developed, stage 2 microsimulation assignment was used to model dynamic effects on traffic conditions.

A standard seed value of 560 (the first seed value specified in the Roads and Maritime *Traffic Modelling Guideline, 2013*) has been used for all dynamic model runs.

As a next step, to improve the responsiveness of the model to potential new route choices in future option construction scenarios, Dynamic User Equilibrium will be introduced. The dynamic network will then be adjusted (for example by controlling the attractiveness of lower order competing routes) so that the base year route choice is a good match to the vetted static model routing upon which the demand matrices are based.

4. Demand matrix development

4.1 Traffic demand estimation methodology

Traffic demand estimation was undertaken using the Departure Adjustment method available in Aimsun. The following stages were used in the development of base traffic demand:

- Assignment of The Northern Road Upgrade base model and generation of morning and evening peak hour sub-area traversal matrices using static assignment.
- Expansion of the single hour traversal matrices in the strategic model zone system to four hour total matrices, plus one hour warm up and cool down period matrices, in the higher-resolution The Northern Road Upgrade zone system.
- Static adjustment using departure adjustment methodology within Aimsun to create 15-minute matrices based on modelled static assignment travel times and paths.

Each of these stages is described in further detail below.

4.1.1 Source demand matrices

The starting point for demand matrix development for The Northern Road Upgrade model was the morning and evening peak hour matrices derived from the Transport for NSW Sydney Strategic Transport Model (STM) which were included in the foundation Sydney Greater Metropolitan Area (GMA) model.

These initial strategic model demands were supplied by the WestConnex Delivery Authority (WDA) and consist of a combination of the WestConnex toll forecasting model base 2012 demands within the Sydney region and the STM 2011 demands for the remainder of the GMA. These in turn incorporated the then-current Freight Movement Model (FMM) heavy vehicle demands.

These initial strategic model demands were supplied as two-hour morning peak and three-hour evening peak matrices.

Traversal matrices for The Northern Road Upgrade model area were extracted from static assignments of these demands across the full GMA network.

4.1.2 Expansion of traversal matrices

The traversal matrices were first expanded to The Northern Road Upgrade model zone system using zone split factors based on land use areas.

The traversal matrices were then scaled up to a four hour total, using the average profile from all the target volumes for the relevant vehicle class (light or heavy) to calculate ratios between the four hour Aimsun period total flows and the relevant strategic model periods. The total target volume profiles were also used to calculate the ratios between peak hour and the hours before and after the Aimsun periods, in order to construct the six hour demand input to the departure adjustment process.

4.1.3 Static demand adjustment

The four-hour flat traffic demand for the sub-area traversal was refined to The Northern Road Upgrade zone system and adjusted to meet observed traffic flows throughout the network according to the 15 minute targets for each period using static departure adjustment. The departure adjustment procedure is an iterative matrix adjustment procedure that uses the paths and modelled travel time results from a static assignment to adjust the demand matrix and distribute trips in time so that their arrival profiles match observed flow profiles at count locations across the network. Trips between zones which were originally part of the same TZ06 source zones, or otherwise had no demand in the cordon matrices but were possible trips, were allowed for by introducing small seed values to empty cells at the start of the adjustment process. The demand adjustment was

undertaken on the basis of the target volumes in the Real Data Set described in Section 3.5 Development of Real Data Sets.

4.1.4 Departure adjustment and slicing

The aim of this process is to adjust and slice an origin-destination matrix that considers static model travel times to allocate trips to the correct departure matrix in order to reach the each count location at the correct time when running dynamic simulations. This allows for the time shifting of longer trips by considering static travel times in the adjustment. It should be emphasized that this process uses static travel times and hence dynamic factors such as congestion at signalised intersections are not considered.

The following are the parameters used in this project:

- Warm-up: 1 hour
- Matrix elasticity: (unbounded)
- Deviation matrix: none (no maximum deviation set)

The interval duration is the general time duration used for the slicing calculation. The cost multiplier is a conversion factor of the cost unit in macro functions. The matrix weight of 1 is used to maintain the total trip numbers of a particular matrix. In other words, a matrix weight of 0 would give complete freedom to the adjustment to change as much as required.

4.2 Demand adjustment results

Statistics showing the change in total traffic demand before and after this adjustment process are detailed in the figures below.

4.2.1 Trip length distribution

Frequency histograms of the morning and evening peak trip length distribution (6am to 10am and 3pm and 7pm respectively) are shown in Figure 4.1 and Figure 4.2.

Analysis of the car trip length distribution shows that the distribution profile has remained broadly similar before and after adjustment. The peak frequency locations remain the same, though the intensity of some peaks is modified:

- The seed matrix peaks between 6000m and 7000m are increased
- The 1000m, 9000m and 10000m peaks are reduced.

The lower frequency trips between 3000m and 4500m are also increased. These changes generally reflect the requirement to introduce longer trips where the original static model traffic demand did not assign trips to the study area as a consequence of the coarseness of zones in this part of the network.

Importantly, there is no increase in very short trips which could suggest unrealistic increases to specific local trips to match problematic counts.

Figure 4.1 : Trip length distribution comparison – AM peak

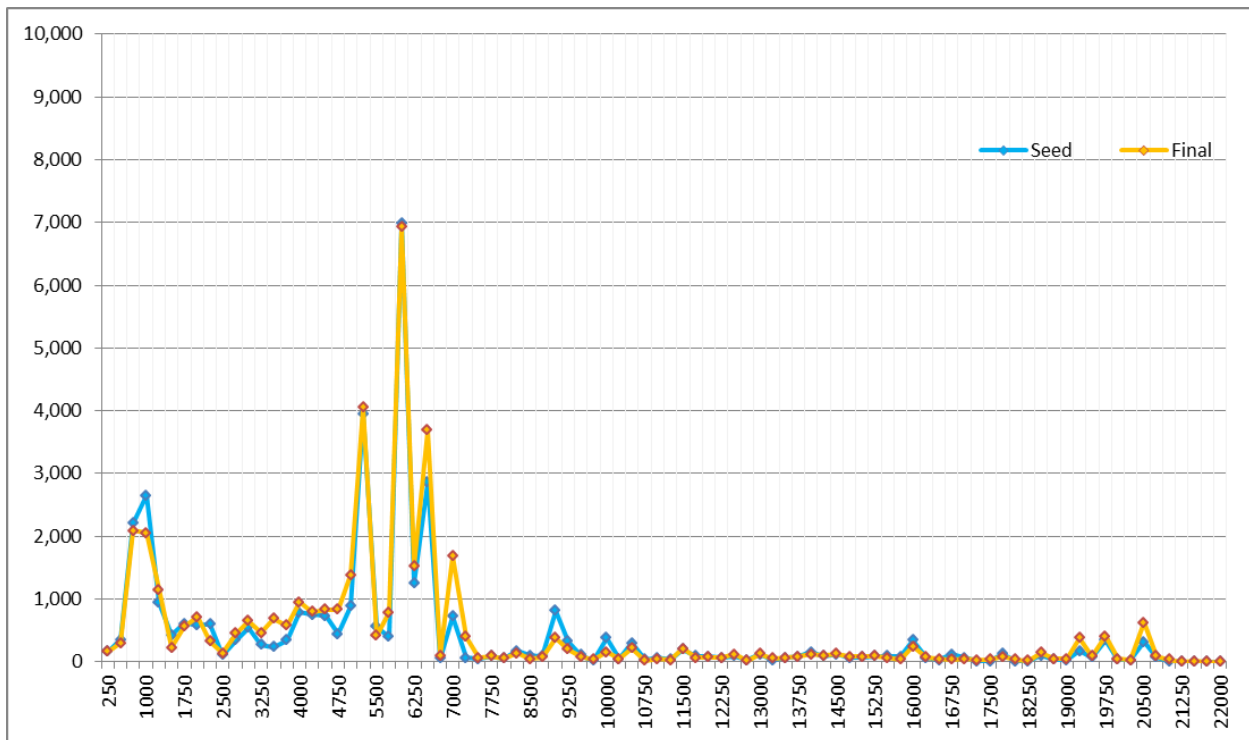
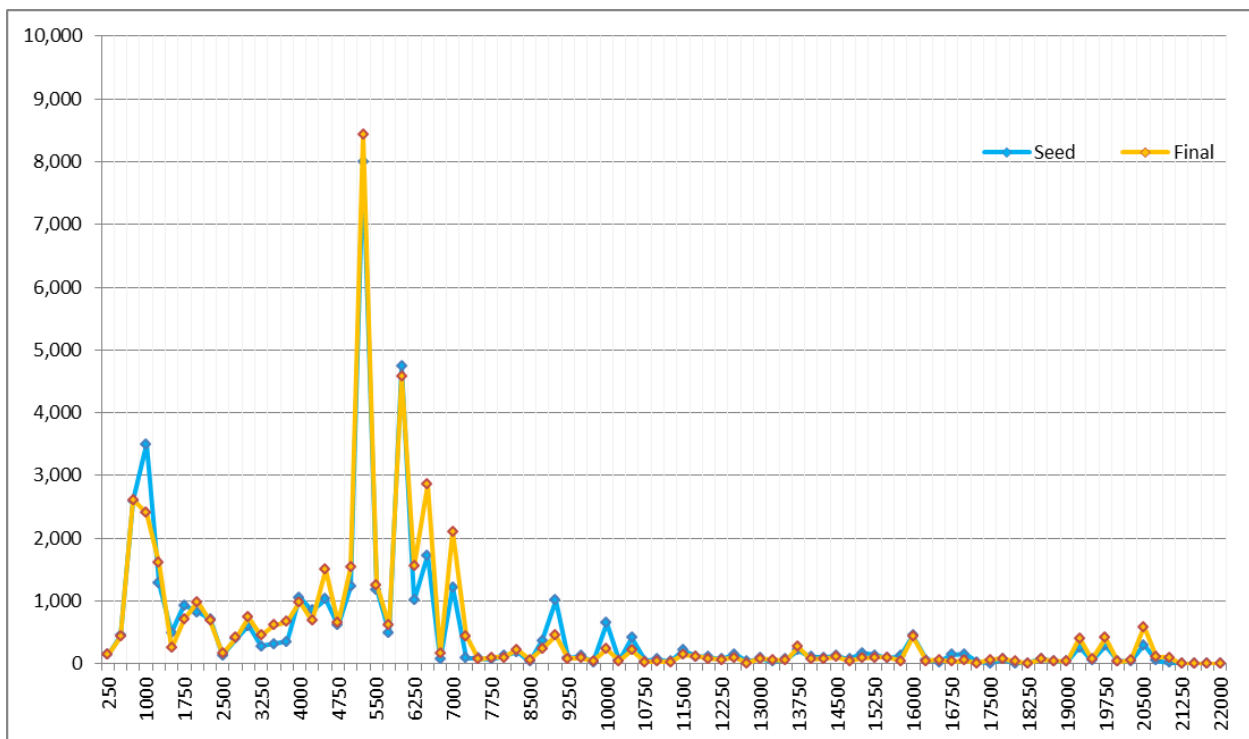


Figure 4.2 : Trip length distribution comparison – PM peak



5. Model calibration

5.1 Overview

The initial calibration of The Northern Road Upgrade base model has been undertaken with a view to meeting the targets for calibration provided in the Roads and Maritime *Traffic Modelling Guidelines, 2013* adapted for microsimulation where possible. The calibration has been undertaken based on hourly turning movement counts over the four-hour morning and evening peak periods.

Base model calibration has been undertaken in two stages:

- Calibration of the static assignment parameters iteratively alongside demand adjustment to ensure that the adjustment is undertaken using valid static assignment routing.
- Calibration of the traffic signals and microscopic simulation parameters were undertaken after static adjustment was completed.

Although the static assignment and adjustment processes uses separate network parameters to the microscopic simulation, some additional parameters accounting for model delay were also calibrated in the static assignment model on the basis of signal timings derived from the mesoscopic simulation.

5.2 Calibration targets

The GEH statistic is used in the calibration of traffic models to compare the differences between modelled and observed traffic flows. The GEH statistic is defined as follows:

$$GEH = \sqrt{\frac{(V_{observed} - V_{modelled})^2}{0.5 \times (V_{observed} + V_{modelled})}}$$

Based on the calibration and validation requirements presented in the Roads and Maritime *Traffic Modelling Guidelines, 2013*, a calibrated model should conform to the following 'network-wide' standard:

- No flow comparisons with GEH values greater than 10.
- At least 85 per cent of flow comparisons with GEH less than 5.

In addition to GEH comparisons, regression analysis of observed versus modelled flows was also undertaken. The following criteria for regression analysis were adopted:

- R² greater than 0.95
- Slope between 1.05 and 0.95

The R² generally represents the closeness of fit of the observed data points to modelled data points and the slope of the trend line gives an indication of whether the model is general over-assigning (greater than 1) or under-assigning (less than 1) traffic across the network.

In addition to these criteria, following criteria should also be met for the model "core area":

- Flows < 99 – to be within 10 vehicles of the observed value
- Flows 100 to 999 – to be within 10 per cent of observed value
- Flows 1000 to 1999 – to be within 100 vehicles of observed value
- Flows > 2000 – to be within 5 per cent of observed value.

For The Northern Road Upgrade model, there is no specific 'core area' – the data is of equal quality and density along the full corridor. The variability between counts on different days and between adjacent intersections also shows significantly more variation from day to day and from site to site than the 'core area' targets. While the model calibration has aimed to get as close to these targets as possible; in some locations where observed traffic volumes vary more than calibration tolerances, or where adjustments to counts have been made in excess of these tolerances, it is expected that modelled flows may not be within these tolerance bands and still reflect on-site traffic conditions.

5.3 Calibration results

A summary of the target network-wide count comparison statistics for the microsimulation assignment, for all vehicles, is presented in Table 5.1. Detailed results for each turning movement are presented in Appendix A.

Table 5.2 shows the classified network-wide calibration results in the form of regression statistics for light and heavy vehicles.

Regression plots for each hour, for total, light and heavy vehicles respectively, are provided in Appendix B.

These results show that the network achieves a high degree of calibration, at a network-wide level, for total vehicles and for light vehicles. Each hour is well within the targets identified in section 5.2 Calibration targets with respect to GEH values and regression statistics.

The results for heavy vehicles are less accurate. Although the R^2 statistics are good, the results show a slight underestimation of heavy vehicles overall across each peak. This is to be expected, as heavy vehicle volumes are generally much lower than car volumes throughout the study area.

Table 5.1 : Summary of microsimulation turning movement comparisons – Total vehicles, 'network-wide' criteria

Period	GEH less than 5	GEH greater than 5	R^2	Slope
6am to 7am	181 (98%)	3 (2%)	0.998	0.977
7am to 8am	183 (99%)	1 (1%)	0.998	0.983
8am to 9am	181 (98%)	3 (2%)	0.999	1.005
9am to 10am	149 (99%)	1 (1%)	0.997	0.982
6am to 10am (Aggregate)	694 (99%)	8 (1%)	0.998	0.989
3pm to 4pm	181 (98%)	3 (2%)	0.997	0.983
4pm to 5pm	180 (98%)	4 (2%)	0.998	1.010
5pm to 6pm	181 (98%)	3 (2%)	0.998	0.995
6pm to 7pm	148 (99%)	2 (2%)	0.998	0.992
3pm to 7pm (Aggregate)	690 (98%)	12 (2%)	0.998	0.992

Table 5.2 : Summary of microsimulation turning movement comparisons – Classified vehicles, ‘network-wide’ criteria

Period	Light vehicles (cars)		Heavy vehicles (trucks + heavy trucks)	
	R ²	Slope	R ²	Slope
6am to 7am	0.998	0.982	0.959	0.906
7am to 8am	0.998	0.985	0.942	0.938
8am to 9am	0.999	1.007	0.953	0.990
9am to 10am	0.997	0.994	0.977	0.878
6am to 10am (Aggregate)	0.998	0.993	0.956	0.925
3pm to 4pm	0.997	0.993	0.968	0.838
4pm to 5pm	0.998	1.016	0.971	0.885
5pm to 6pm	0.998	0.992	0.955	1.061
6pm to 7pm	0.998	0.990	0.930	1.008
3pm to 7pm (Aggregate)	0.997	1.000	0.954	0.896

The turns with GEH greater than 5 in any hour are summarised in Table 5.3. For context, Table 5.4 shows the target volumes for these turns, and Table 5.5 shows the modelled volumes. As these tables show, all of these turns are in non-critical locations and involve small volumes.

No turning movements had a GEH of greater than 10 in any hour.

Table 5.3 : Summary of microsimulation turning movements with GEH > 5 in any hour - GEH

Intersection	Approach	Direction	GEH : hour starting							
			6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00
The Northern Rd / Jamison Rd	East	Right	6.6	0.8	2.3		2.3	7.1	0.3	
The Northern Rd / Maxwell St / Bringelly Rd	West	Left	5.2	1.9	0.0		0.3	1.7	0.1	
The Northern Rd / Castle Rd / Aspen St	W to N+E		8.3	4.9	4.7	6.3	6.2	5.0	5.4	5.9
The Northern Rd / Homestead Rd / Garswood Rd	South	Right	0.8	0.6	5.7	0.2	2.6	2.3	2.6	1.8
The Northern Rd / Chain-O-Ponds Rd	West	Left	1.8	1.8	1.0	1.1	0.3	1.3	5.1	2.0
The Northern Rd / Kings Hill Rd	West	Left	3.7	0.2	3.4	1.5	2.5	1.1	2.0	5.1
The Northern Rd / Blaxland Ave	East	Right	1.3	5.3	2.1	2.1	1.6	0.3	0.3	1.5
The Northern Rd / Dwyer Rd	North	Right	1.4	0.0	3.9	0.5	0.2	0.6	5.4	0.8
Park Rd / Campbell St	East	Left	2.0	2.8	6.3	3.2	4.9	5.7	4.2	3.5
Park Rd / Campbell St	South	Right	1.4	2.4	5.1	2.8	5.3	2.4	2.8	2.0
Park Rd / Campbell St	West	Right	2.7	4.9	4.0	0.3	5.8	7.1	4.4	4.7

Table 5.4 : Summary of microsimulation turning movements with GEH > 5 in any hour – Target volumes

Intersection	Approach	Direction	Target volume							
			6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00
The Northern Rd / Jamison Rd	East	Right	12	14	20		18	18	13	
The Northern Rd / Maxwell St / Bringelly Rd	West	Left	26	19	31		50	38	45	
The Northern Rd / Castle Rd / Aspen St	W to N+E		45	12	11	30	45	40	46	41
The Northern Rd / Homestead Rd / Garswood Rd	South	Right	58	148	70	25	51	29	22	18
The Northern Rd / Chain-O-Ponds Rd	West	Left	3	19	13	9	15	8	2	6
The Northern Rd / Kings Hill Rd	West	Left	104	150	119	58	62	60	47	37
The Northern Rd / Blaxland Ave	East	Right	7	15	23	11	7	13	11	5
The Northern Rd / Dwyer Rd	North	Right	11	16	14	16	34	29	24	26
Park Rd / Campbell St	East	Left	2	4	20	5	12	16	9	6
Park Rd / Campbell St	South	Right	0	3	13	4	14	3	4	2
Park Rd / Campbell St	West	Right	34	53	81	13	31	31	17	11

Table 5.5 : Summary of microsimulation turning movements with GEH > 5 in any hour – Modelled volumes

Intersection	Approach	Direction	Modelled volume							
			6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00
The Northern Rd / Jamison Rd	East	Right	48	17	11		29	63	14	
The Northern Rd / Maxwell St / Bringelly Rd	West	Left	60	28	31		48	49	44	
The Northern Rd / Castle Rd / Aspen St	W to N+E		4	0	0	4	12	14	16	11
The Northern Rd / Homestead Rd / Garswood Rd	South	Right	52	156	127	24	34	18	36	11
The Northern Rd / Chain-O-Ponds Rd	West	Left	7	12	17	6	14	12	18	12
The Northern Rd / Kings Hill Rd	West	Left	145	148	85	70	83	52	62	75
The Northern Rd / Blaxland Ave	East	Right	11	44	34	5	12	14	10	9
The Northern Rd / Dwyer Rd	North	Right	16	16	33	14	35	26	59	30
Park Rd / Campbell St	East	Left	0	0	0	0	0	0	0	0
Park Rd / Campbell St	South	Right	0	0	0	0	0	0	0	0
Park Rd / Campbell St	West	Right	20	23	49	12	6	2	3	0

Table 5.6 shows the performance of the model against the more stringent ‘core area’ criteria. Most of the turning movements in each hour meet the desirable targets, with only one movement over 2000 vph outside this range. Over 85% of all counts above 100 vph are within the desirable limits.

Table 5.6 : Summary of microsimulation turning movement comparisons – Total vehicles, ‘core area’ criteria

Period	Percentage of turns within target				
	Total	< 99 vph	100 – 999 vph	1000 – 1999 vph	> 2000 vph
6am to 7am	81%	73%	89%	100%	n/a
7am to 8am	83%	73%	88%	100%	100%
8am to 9am	77%	66%	83%	100%	100%
9am to 10am	81%	80%	80%	86%	n/a
6am to 10am (Aggregate)	80%	73%	85%	98%	100%
3pm to 4pm	80%	71%	88%	91%	50%
4pm to 5pm	82%	74%	84%	100%	100%
5pm to 6pm	80%	73%	81%	100%	100%
6pm to 7pm	83%	80%	87%	100%	n/a
3pm to 7pm (Aggregate)	81%	74%	85%	97%	83%

The main reason for the differences between the target and modelled volumes are the differences in travel speed between the static and dynamic models, affecting the arrival time for longer trips, and the build-up of queues between intersections, which is not allowed for in the balancing of target volumes. Given the variability and inconsistency in observed traffic flows outlined in Section 3.5 Development of Real Data Sets, this is considered acceptable.

5.4 Calibration key findings

Analysis of the GEH and regression statistics show that the model conforms to the Roads and Maritime standards for microsimulation models for both total and light vehicle traffic, with:

- At least 98 per cent of total vehicle turning movement volumes showing GEH of 5 or less in each hour, exceeding the target of 85 per cent
- R^2 greater than 0.99 in each hour, exceeding the target of 0.95
- Slope between 0.975 and 1.02 in each hour, exceeding the target of 0.95 to 1.05

Regression statistics for the much lower heavy vehicle volumes are not as accurate, with slight overall underestimation of approximately 5 per cent compared to the (conservatively high) targets, but do indicate a reasonable degree of calibration for the intended use.

Based on these comparison statistics, the model can be considered adequately calibrated.

6. Model validation

6.1 Overview

Validation of The Northern Road Upgrade microsimulation model has been undertaken on the basis of travel times. Private vehicle travel time comparisons have been undertaken along The Northern Road between Mersey Road and Jamison Road based on floating-car travel time surveys as detailed in Section 3.4.4 Floating-car travel time surveys. In addition to this quantitative validation, qualitative validation of congestion along the corridor has also been undertaken based on inspection of modelled vehicle density.

6.2 Travel time validation

Travel time validation has been undertaken on the basis of floating car travel time surveys along The Northern Road. As recommended by Roads and Maritime *Traffic Modelling Guidelines, 2013* the target for validation of each route in each hour is for the modelled average travel time for the route to be within one minute, or 15 per cent (whichever is higher).

The performance of the model against these targets is summarised in Table 6.1.

Table 6.1 : Summary of travel time validation results

Direction of travel	Time (hour starting)							
	6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00
Northbound								
Observed Ave	18:33	18:01	22:43	19:09	19:30	21:53	20:34	19:07
Target Min	15:46	15:19	19:19	16:17	16:35	18:36	17:29	16:15
Target Max	21:10	20:41	25:39	21:48	22:26	25:06	23:21	21:50
Modelled Ave	19:27	21:13	22:08	20:33	21:38	22:09	22:58	20:58
Southbound								
Observed Ave	20:06	20:35	20:35	19:10	23:05	20:19	24:11	23:12
Target Min	17:05	17:30	17:30	16:18	19:37	17:16	20:33	19:43
Target Max	23:06	23:37	23:36	21:56	26:17	23:19	27:29	26:02
Modelled Ave	20:27	21:29	23:24	20:41	22:49	23:00	23:01	20:57

Graphs of modelled and observed cumulative travel time in the peak direction along The Northern Road are provided in Figure 6.1 to Figure 6.8. Additional travel time comparisons for the counter-peak direction are provided in Appendix C.

In these graphs, the modelled average time is shown in red. The heavy black line shows the observed average, while the lighter grey lines show individual observed times. The dashed green lines show an indicative target envelope, based on the one minute/15 per cent criteria.

These results show that the validation target is met in all cases except northbound between 7:00 and 8:00 AM, where the modelled average is 32 seconds above the target range. The profile for this result is shown in Figure 6.2. This shows that the difference is mainly due to a slightly but consistently lower speed in the model south of Glenmore Parkway, compared to the survey. This may be due to more aggressive overtaking in reality, reduced overtaking opportunities in the model due to conservatively high target volumes, or higher maximum speeds on some parts of the corridor than in the model (which assumes the posted speeds are not exceeded). This profile suggests that delays at the key intersections are close to the observed. This result is therefore not expected to affect the model's suitability for the development and assessment of upgrading options.

Figure 6.1 : Cumulative travel time, model vs observed – northbound, 6am to 7am

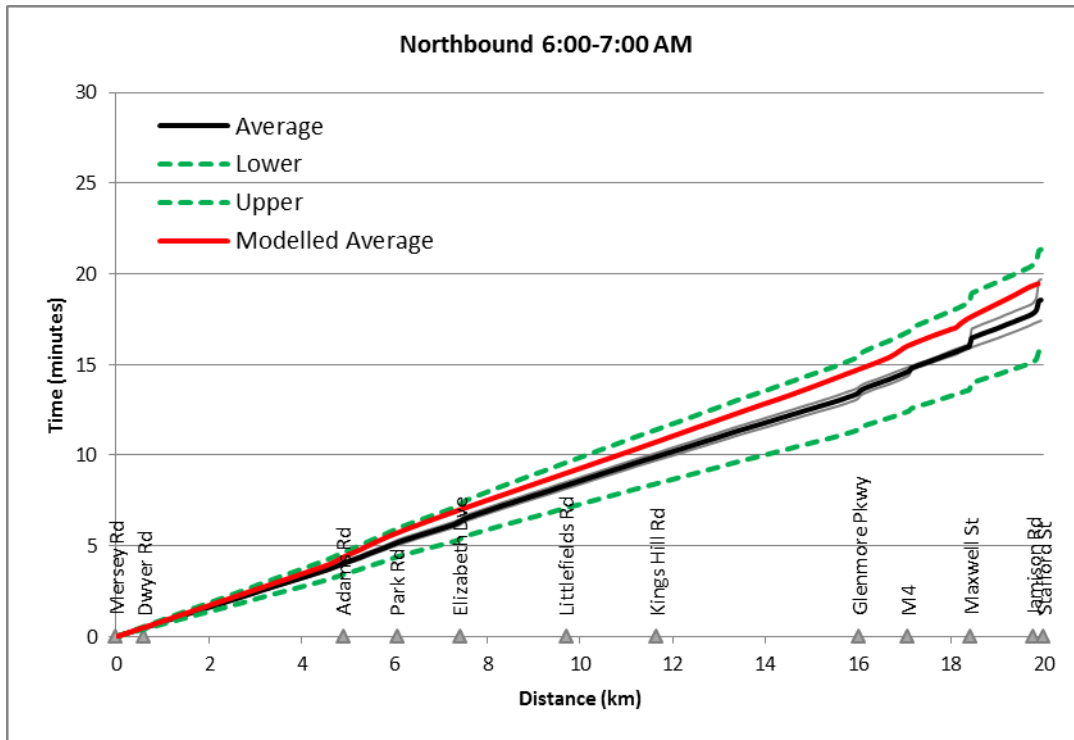


Figure 6.2 : Cumulative travel time, model vs observed – northbound, 7am to 8am

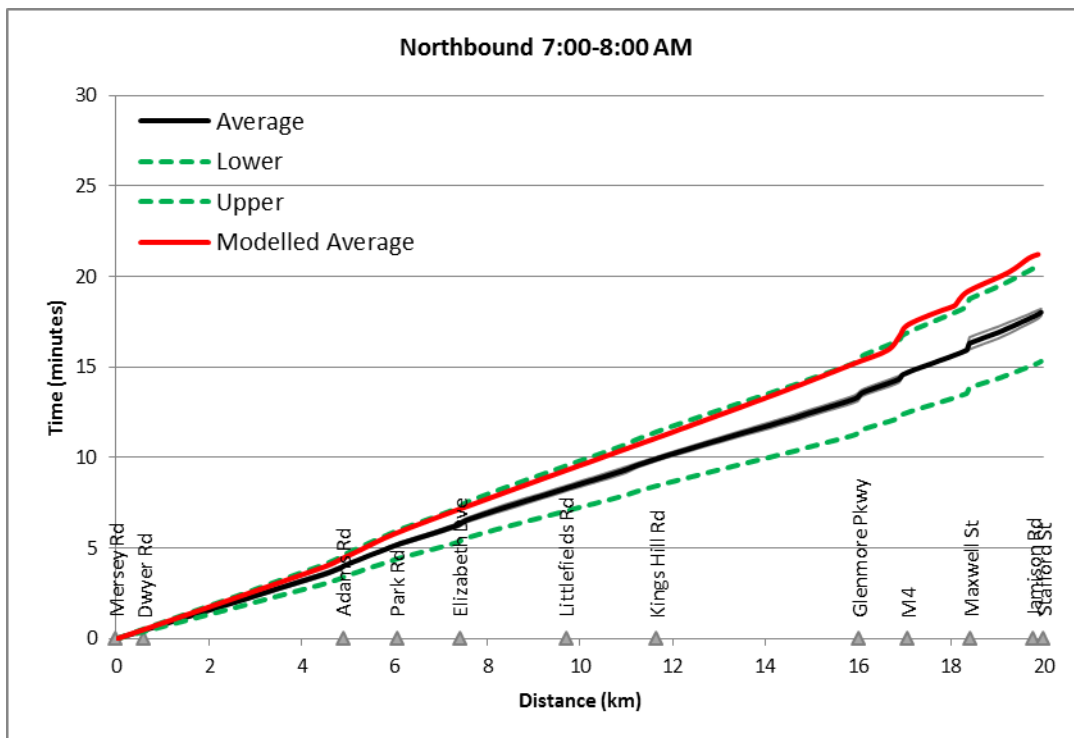


Figure 6.3 : Cumulative travel time, model vs observed – northbound, 8am to 9am

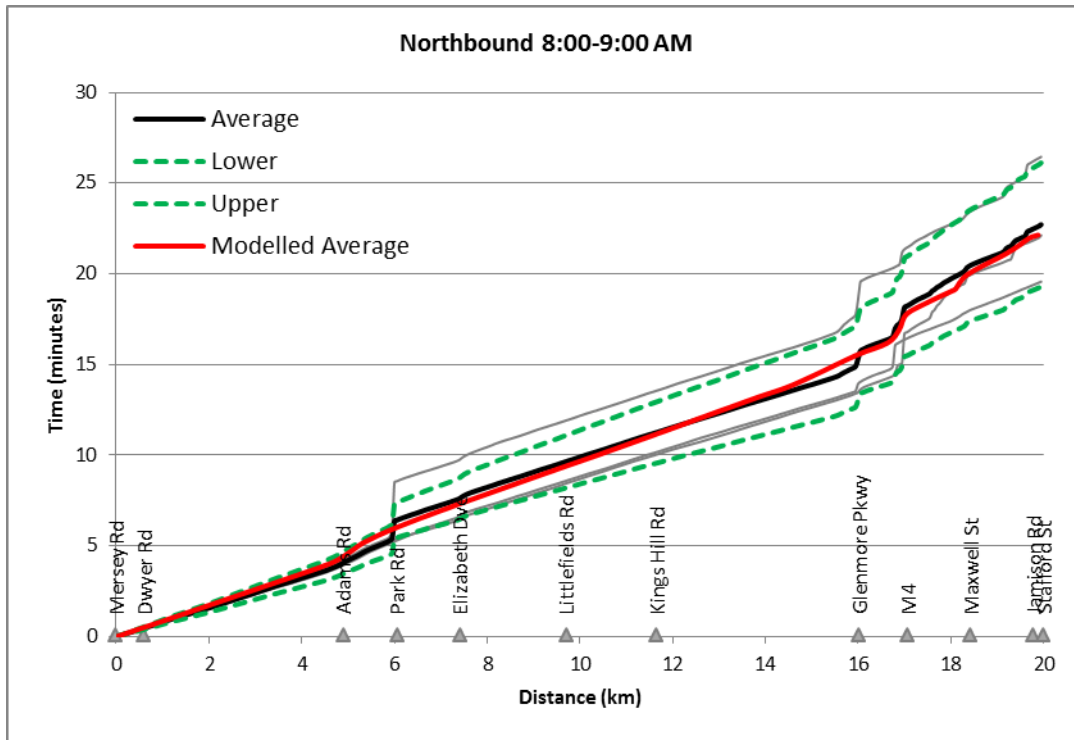


Figure 6.4 : Cumulative travel time, model vs observed – northbound, 9am to 10am

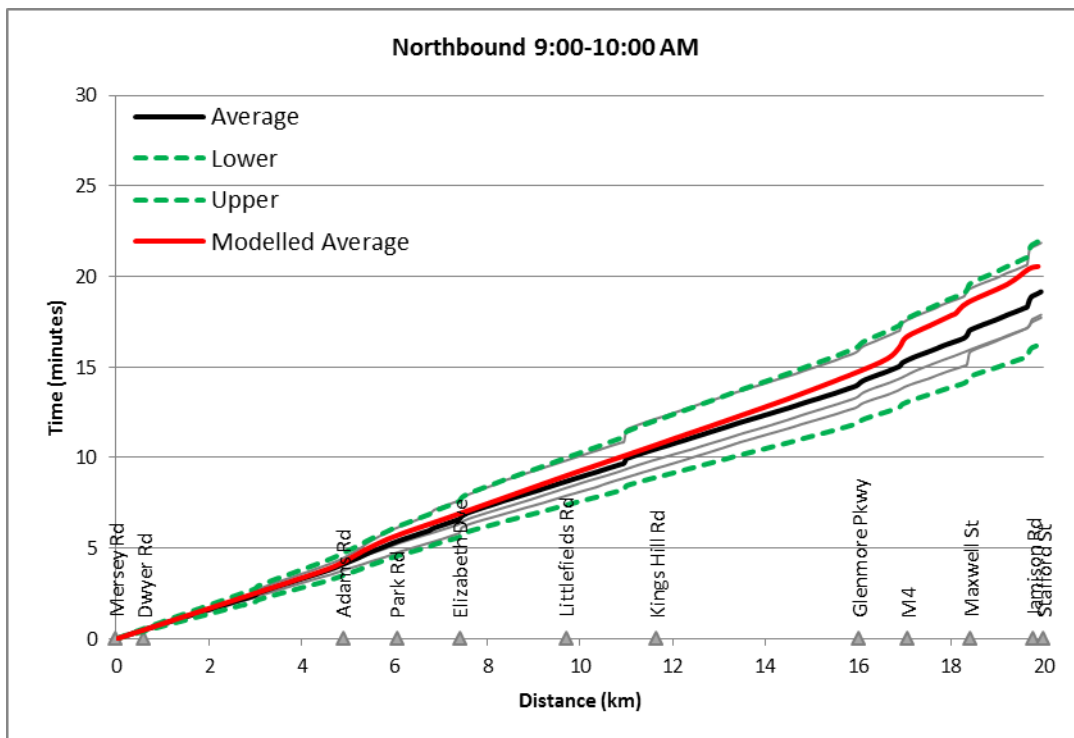


Figure 6.5 : Cumulative travel time, model vs observed – southbound, 3pm to 4pm

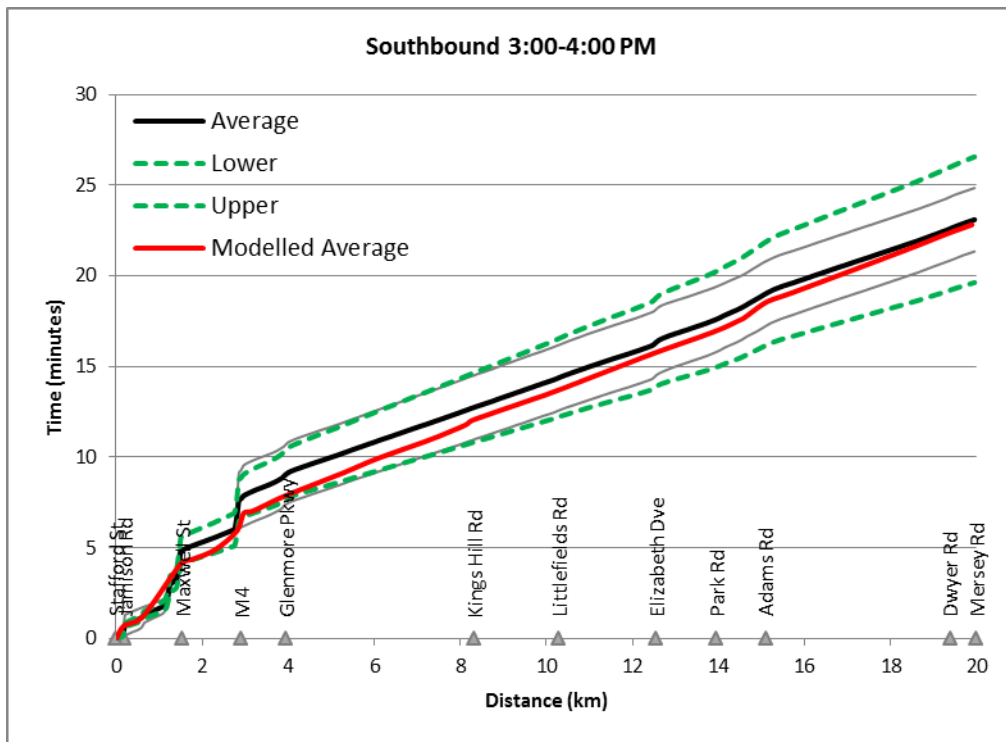


Figure 6.6 : Cumulative travel time, model vs observed – southbound, 4pm to 5pm

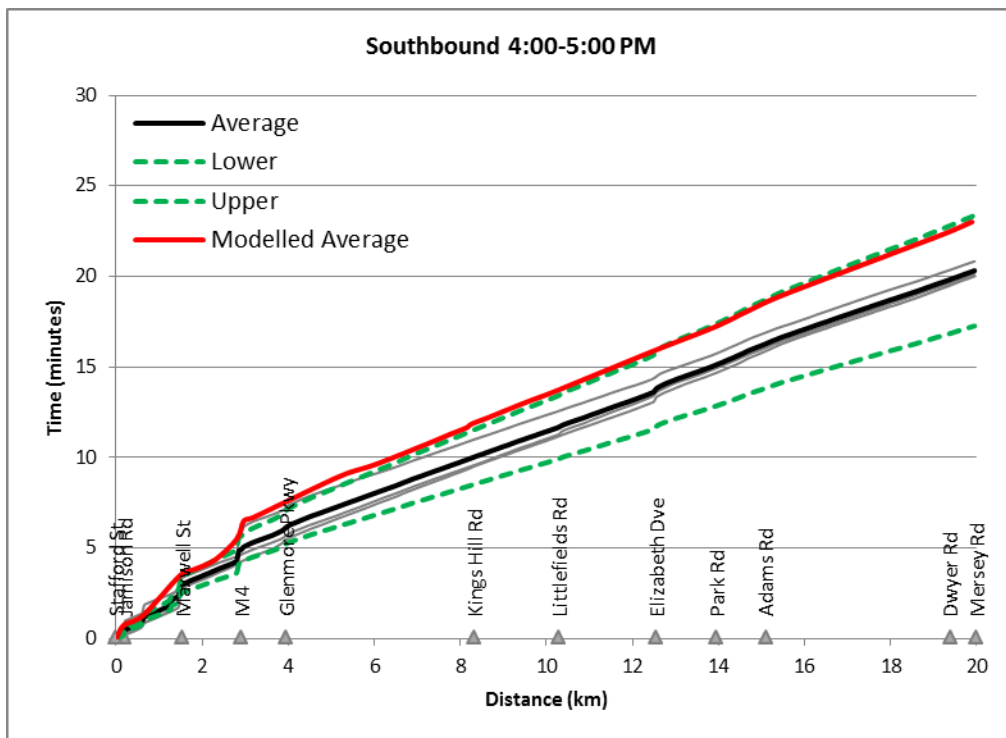


Figure 6.7 : Cumulative travel time, model vs observed – southbound, 5pm to 6pm

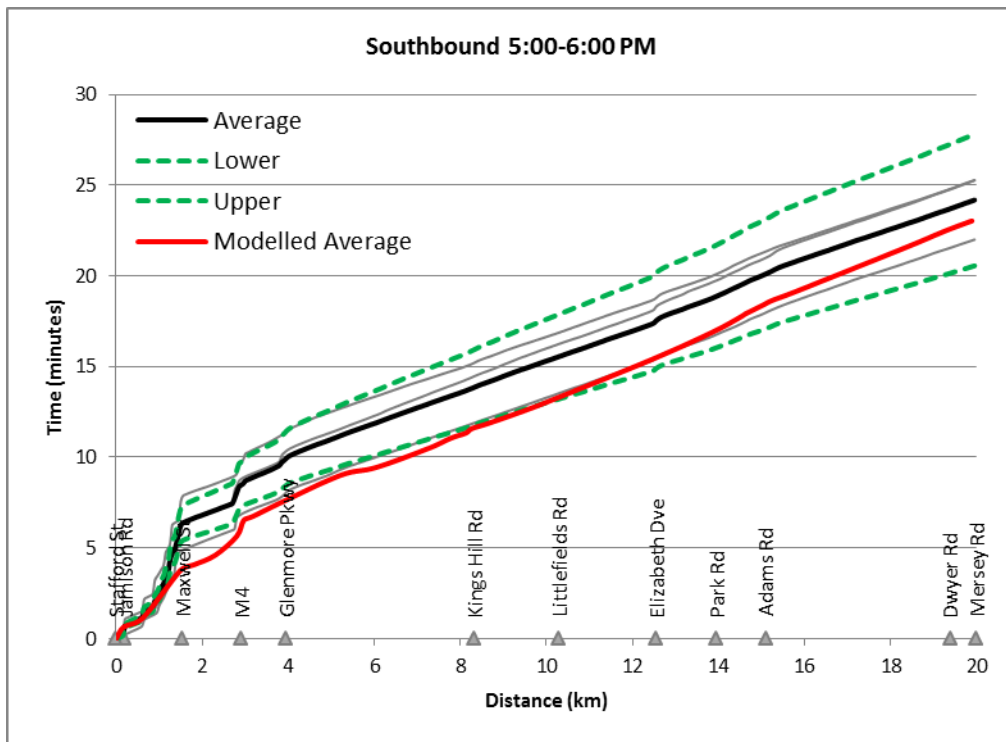
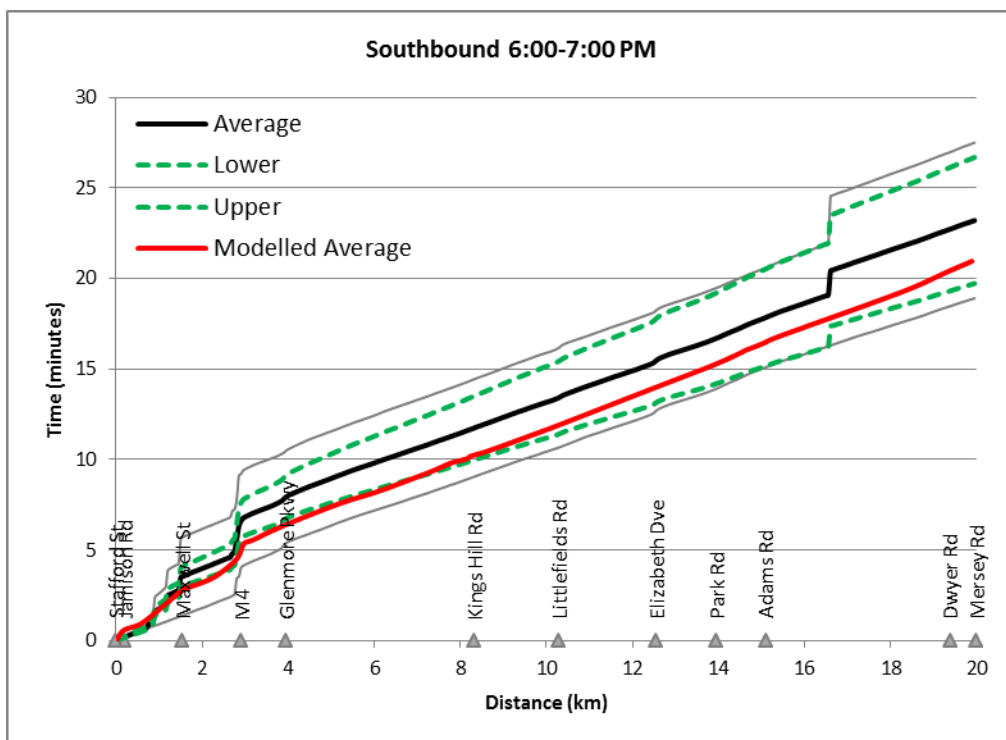


Figure 6.8 : Cumulative travel time, model vs observed – southbound, 6pm to 7pm



6.3 Congestion validation

Plots of the key congestion areas along The Northern Road are shown in Figure 6.9 and Figure 6.10. These plots show the modelled congestion in key areas including:

- The M4 Western Motorway interchange
- On the approaches to Bringelly Road / Maxwell Street
- The Glenmore Parkway roundabout
- Jamison Street

Figure 6.9 : Key congestion areas, AM peak (8:30am)

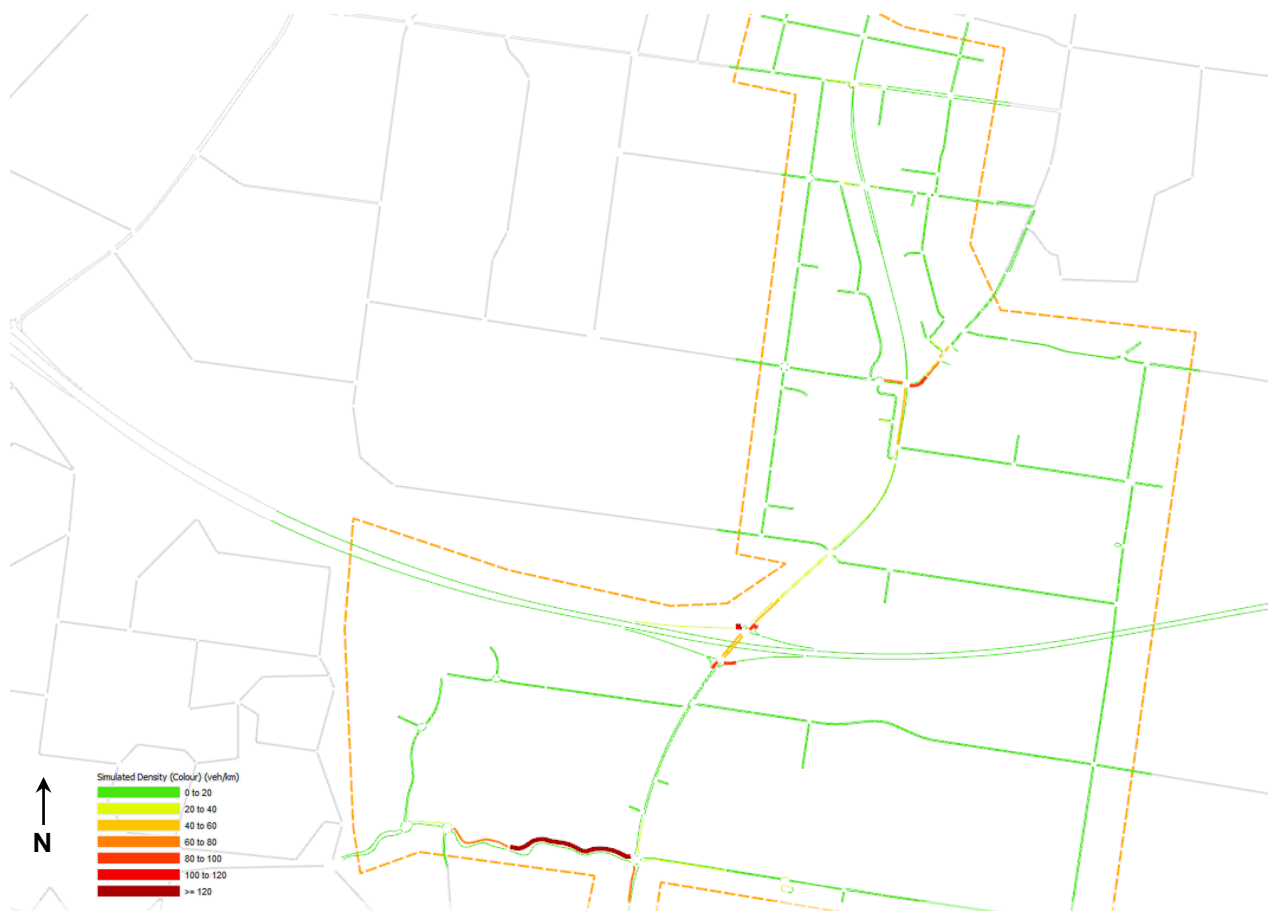
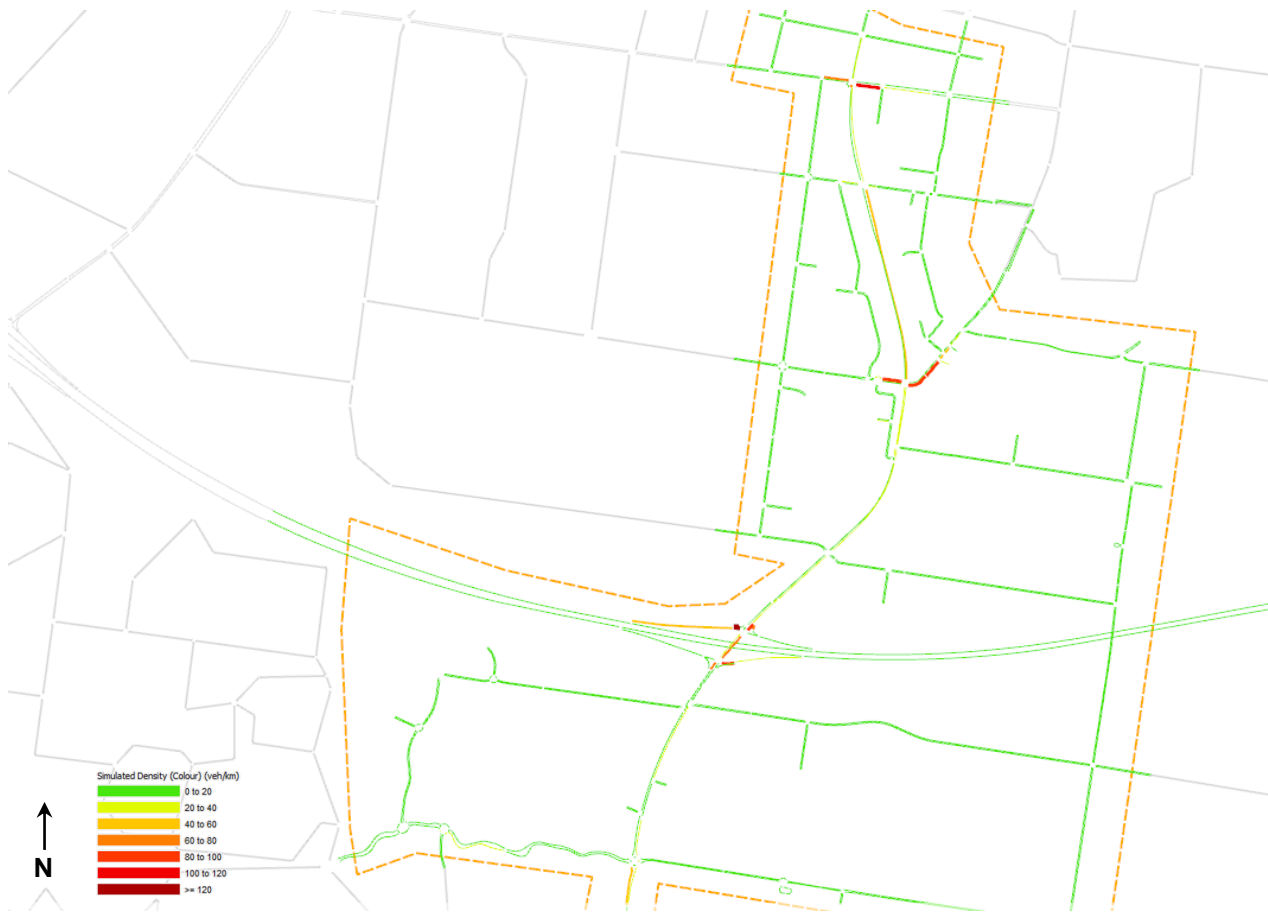


Figure 6.10 : Key congestion areas, PM peak (4:45pm)



6.4 Validation key findings

Analysis of travel time and modelled congestion along The Northern Road indicates that the model generally meets the requirements for travel time comparisons, with modelled peak direction travel times being within the required 15 per cent of observed in all cases except one. This result is close to the target and is not considered substantial difference from the observed travel time that would affect the model's suitability for this study (as discussed in Section 6.2 Travel time validation).

Furthermore, the model replicates congestion that is observed in the field, particularly around the M4 Western Motorway interchange, Bringelly Road / Maxwell Street, and the Glenmore Parkway roundabout. This indicates that the model is well-validated and suitable for use in the testing of future options.

7. Summary and conclusions

7.1 Overview

This report covers the calibration and validation results of The Northern Road Upgrade base model as part of The Northern Road Upgrade between Mersey Road, Bringelly and Jamison Road, Penrith. This model has been prepared to assist in the assessment of design options and construction staging of the Northern Road Upgrade.

7.2 Calibration findings

The results presented in this report indicate that the Northern Road Upgrade model is adequately calibrated on the basis of turning movement comparisons and meets the standards for microsimulation model calibration outlined in the Roads and Maritime *Traffic Modelling Guidelines, 2013*.

7.3 Validation findings

Comparison of modelled travel times with observed data shows that the model is generally replicating the pattern of delays observed along The Northern Road. Analysis of observed and modelled travel times shows that the model generally meets the standards for microsimulation model validation outlined in the Roads and Maritime *Traffic Modelling Guidelines, 2013*, and the single exception is close to the target and not substantial enough to affect the model's suitability. Analysis of modelled congestion and vehicle density across the network also shows that the model is replicating congestion that is observed in the field.

Based on the calibration and validation statistics presented in this report, The Northern Road Upgrade model is suitable for use in assessing future upgrade options and construction staging.

Appendix A. Detailed calibration results

Traffic Volume Calibration Results : Total Vehicles

Traffic Volume Calibration Results : Total Vehicles

Micro OS1

[illegible]

THE NORTHERN ROAD STAGES 3 & 4 AIMSUN MODEL
Traffic Volume Calibration Results : Total Vehicles

v03 Micro OS1

[illegible]

THE NORTHERN ROAD STAGES 3 & 4 AIMSUN MODEL

v03

Micro OS1

Traffic Volume Calibration Results : Light Vehicles

Intersection		Approach Direction		Target volume								Modelled volume								Modelled vs target volume								Ave Target (vph)		Ave Modelled (vph)	
				6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00	6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00	6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00	AM	PM	AM	PM
The Northern Rd S of Derby St		Northbound		1,151	1,427	1,461		1,101	1,253	1,126		1,099	1,390	1,500		1,139	1,193	1,156		-52	-37	39		38	-60	30		1,346	1,160	1,330	1,163
The Northern Rd S of Derby St		Southbound		823	946	935		1,249	1,401	1,397		810	942	960		1,282	1,413	1,361		-13	-4	25		33	12	-36		901	1,349	904	1,352
The Northern Rd / Jamison Rd		North	Right	74	112	171		173	227	233		90	121	168		211	231	254		16	9	-3		38	4	21		119	211	126	232
The Northern Rd / Jamison Rd		North	Through	754	881	948		1,492	1,410	1,365		765	904	977		1,481	1,437	1,306		11	23	29		-11	27	-59		861	1,422	882	1,408
The Northern Rd / Jamison Rd		North	Left	1	5	9		12	10	22		10	14	15		4	15	25		9	9	6		-8	5	3		5	15	13	15
The Northern Rd / Jamison Rd		East	Right	12	14	20		16	17	13		48	17	11		27	63	14		36	3	-9		11	46	1		15	15	25	35
The Northern Rd / Jamison Rd		East	Through	74	116	172		158	204	182		61	124	176		155	186	162		-13	8	4		-3	-18	-20		121	181	120	168
The Northern Rd / Jamison Rd		East	Left	20	27	40		64	75	38		29	40	30		88	101	53		9	13	-10		24	26	15		29	59	33	81
The Northern Rd / Jamison Rd		South	Right	14	27	36		12	9	16		21	22	33		18	15	11		7	-5	-3		6	6	-5		26	12	25	15
The Northern Rd / Jamison Rd		South	Through	908	1,360	1,467		1,073	1,013	1,079		921	1,327	1,483		1,100	1,006	1,088		13	-33	16		27	-7	9		1,245	1,055	1,244	1,065
The Northern Rd / Jamison Rd		South	Left	48	107	212		166	165	134		36	95	204		193	148	128		-12	-12	-8		27	-17	-6		122	155	112	156
The Northern Rd / Jamison Rd		West	Right	76	111	103		165	236	187		66	106	86		160	237	166		-10	-5	-17		-5	1	-21		97	196	86	188
The Northern Rd / Jamison Rd		West	Through	67	119	119		128	164	142		51	133	103		138	178	142		-16	14	-16		10	14	0		102	145	96	153
The Northern Rd / Jamison Rd		West	Left	100	119	131		108	159	100		125	104	112		105	192	99		25	-15	-19		-3	33	-1		117	122	114	132
The Northern Rd / Smith St		North	Right	30	54	81	70	105	88	134	89	34	61	75	61	111	98	119	94	4	7	-6	-9	6	10	-15	5	59	104	58	106
The Northern Rd / Smith St		North	Through	817	957	987	820	1,610	1,616	1,449	973	803	974	1,013	776	1,580	1,668	1,392	977	-14	17	26	-44	-30	52	-57	4	895	1,412	892	1,404
The Northern Rd / Smith St		North	Left	3	8	23	6	6	17	7	14	21	14	9	4	23	12	17	8	18	6	-14	-2	17	-5	10	-6	10	11	12	15
The Northern Rd / Smith St		East	Right	7	9	30	11	13	7	9	9	14	16	26	11	16	14	11	4	7	7	-4	0	3	7	2	-5	14	10	17	11
The Northern Rd / Smith St		East	Through	18	27	88	37	80	55	72	45	22	44	85	31	70	56	72	34	4	17	-3	-6	-10	1	0	-11	43	63	46	58
The Northern Rd / Smith St		East	Left	4	14	18	8	19	20	7	4	10	14	14	10	13	21	13	4	6	0	-4	2	-6	1	6	0	11	13	12	13
The Northern Rd / Smith St		South	Right	10	25	58	20	21	18	21	8	21	29	42	24	29	13	25	15	11	4	-16	4	8	-5	4	7	28	17	29	21
The Northern Rd / Smith St		South	Through	941	1,433	1,621	1,020	1,181	1,130	1,180	832	933	1,394	1,609	1,048	1,213	1,115	1,181	827	-8	-39	-12	28	32	-15	1	-5	1,254	1,081	1,246	1,084
The Northern Rd / Smith St		South	Left	20	24	49	42	63	55	58	31	26	37	41	28	60	50	74	40	6	13	-8	-14	-3	-5	16	9	34	52	33	56
The Northern Rd / Smith St		West	Right	38	57	61	37	83	103	83	37	30	48	74	34	89	81	81	34	-8	-9	13	-3	6	-22	-2	-3	48	77	47	71
The Northern Rd / Smith St		West	Through	34	74	146	55	73	84	78	63	43	87	154	77	81	91	92	67	9	13	8	22	8	7	14	4	77	75	90	83
The Northern Rd / Smith St		West	Left	22	52	64	51	57	50	40	32	29	47	71	52	57	61	41	26	7	-5	7	1	0	11	1	-6	47	45	50	46
The Northern Rd / Maxwell St / Bringelly Rd		North	Right	17	28	41		101	88	86		18	32	28		85	78	94		1	4	-13		-16	-10	8		29	92	26	86
The Northern Rd / Maxwell St / Bringelly Rd		North	Through	831	979	1,005		1,593	1,641	1,441		821	987	1,057		1,556	1,676	1,386		-10	8	52		-37	35	-55		938	1,558	955	1,539
The Northern Rd / Maxwell St / Bringelly Rd		North	Left	11	21	20		18	10	12		12	14	19		20	14	17		1	-7	-1		2	4	5		17	13	15	17
The Northern Rd / Maxwell St / Bringelly Rd		East	Right	8	35	56		48	37	15		15	37	45		56	53	18		7	2	-11		8	16	3		33	33	32	42
The Northern Rd / Maxwell St / Bringelly Rd		East	Through	49	103	174		214	187	228		39	107	184		201	200	237		-10	4	10		-13	13	9		109	210	110	213
The Northern Rd / Maxwell St / Bringelly Rd		East	Left	167	184	230		343	413	328		183	190	220		299	426	303		16	6	-10		-44	13	-25		194	361	198	343
The Northern Rd / Maxwell St / Bringelly Rd		South	Right	260	432	470		246	239	255		255	403	467		236	227	270		-5	-29	-3		-10	-12	15		387	247	375	244
The Northern Rd / Maxwell St / Bringelly Rd		South	Through	938	1,431	1,648		1,171	1,131	1,201		924	1,408	1,653		1,225	1,086	1,212		-14	-23	5		54	-45	11		1,339	1,168	1,328	1,174
The Northern Rd / Maxwell St / Bringelly Rd		South	Left	40	76	64		121	153	122		47	78	56		121	159	119		7	2	-8		0	6	-3		60	132	60	133
The Northern Rd / Maxwell St / Bringelly Rd		West	Right	267	293	229		231	262	246		283	264	213		239	268	252		16	-29	-16		8	6	6		263	246	253	253
The Northern Rd / Maxwell St / Bringelly Rd		West	Through	56	117	112		105	112	86		54	112	121		126	132	106		12	-5	9		21	20	20		95	101	96	121
The Northern Rd / Maxwell St / Bringelly Rd		West	Left	25	16	24		46	35	43		39	27	20		38	41	42		14	11	-4		-8	6	-1		22	41	29	40
The Northern Rd / Castle Rd / Aspen St		North	Through	1,255	1,440	1,420	1,138	2,132	2,281	1,999	1,308	1,266	1,406	1,455	1,132	2,047	2,344	1,920	1,300	11	-34	35	-6	-85	63	-79	-8	1,313	1,930	1,315	1,903
The Northern Rd / Castle Rd / Aspen St		North	Left	10	16	44	22	35	35	16	6	21	32	30	19	28	37	31	15	11	16	-14	-3	-7	2	15	9	23	23	26	28
The Northern Rd / Castle Rd / Aspen St		East	Right	0	3	2	9	4	4	5	6	4	11	6	11	17	12	13	6	4	8	4	2	13	8	8	0	4	5	8	12
The Northern Rd / Castle Rd / Aspen St		East	Left	45	61	52	31	69	60	39	29	35	51	59	34	71	61	48	28	-10	-10	7	3	2	1	9	-1	47	49	45	52
The Northern Rd / Castle Rd / Aspen St		S+W to E		37	40	51	29	33	38	35	25	22	44	43	13	22	32	28	24	-15	4										

THE NORTHERN ROAD STAGES 3 & 4 AIMSUN MODEL

v03

Micro OS1

Traffic Volume Calibration Results : Light Vehicles

Intersection			Approach Direction			Target volume								Modelled volume								Modelled vs target volume								Ave Target (vph)		Ave Modelled (vph)	
			6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00	6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00	6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00	AM	PM	AM	PM			
The Northern Rd / M4 EB ramps			South	Through	1,388	1,710	1,792	939	1,101	984	1,015	674	1,380	1,629	1,783	909	1,127	973	1,065	655	-8	-81	-9	-30	26	-11	50	-19	1,457	944	1,425	955	
The Northern Rd / M4 EB ramps			South	Left	135	235	317	313	373	419	348	304	127	238	327	296	407	425	387	332	-8	3	10	-17	34	6	39	28	250	361	247	388	
The Northern Rd / Homestead Rd / Garswood Rd			North	Through	737	1,040	947	660	1,638	1,810	1,777	1,255	715	1,020	1,006	707	1,543	1,897	1,753	1,247	-22	-20	59	47	-95	87	-24	-8	846	1,620	862	1,610	
The Northern Rd / Homestead Rd / Garswood Rd			North	Left	15	34	59	26	71	44	73	50	24	27	48	26	79	50	80	64	9	-7	-11	0	8	6	7	14	34	60	31	68	
The Northern Rd / Homestead Rd / Garswood Rd			East	Right	21	17	21	25	63	44	45	30	21	25	25	18	73	47	61	28	0	8	4	-7	10	3	16	-2	21	46	22	52	
The Northern Rd / Homestead Rd / Garswood Rd			East	Left	15	29	36	26	127	108	86	44	25	44	37	42	132	99	87	50	10	15	1	16	5	-9	1	6	27	91	37	92	
The Northern Rd / Homestead Rd / Garswood Rd			South	Right	50	145	67	20	48	26	19	15	48	154	118	22	33	17	30	8	-2	9	51	2	-15	-9	11	-7	71	27	86	22	
The Northern Rd / Homestead Rd / Garswood Rd			South	Through	1,288	1,693	1,822	1,057	1,236	1,232	1,184	820	1,281	1,628	1,853	968	1,291	1,234	1,236	804	-7	-65	31	-89	55	2	52	-16	1,465	1,118	1,433	1,141	
The Northern Rd / Homestead Rd / Garswood Rd			South	Left	31	45	54	38	147	144	105	88	28	48	53	15	129	133	107	69	-3	3	-1	-23	-18	-11	2	-19	42	121	36	110	
The Northern Rd / Homestead Rd / Garswood Rd			West	Left	213	234	266	170	175	127	133	128	214	211	256	187	175	125	146	140	1	-23	-10	17	0	-2	13	12	221	141	217	147	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			N to S,W,N		810	923	810	698	1,427	1,700	1,711	1,123	731	885	860	711	1,364	1,803	1,623	1,116	-79	-38	50	13	-63	103	-88	-7	810	1,490	797	1,477	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			S,E,N to N		775	1,242	1,444	657	1,042	1,002	1,014	540	764	1,225	1,439	645	1,116	1,043	994	536	-11	-17	-5	-12	74	41	-20	-4	1,030	900	1,018	922	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			Circ past N		24	105	92	15	40	25	27	11	34	125	80	32	28	22	50	18	10	20	-12	17	-12	-3	23	7	59	26	68	30	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			W to N		594	641	579	297	309	320	374	303	586	613	587	338	348	331	350	341	-8	-28	8	41	39	11	-24	38	528	327	531	343	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			E to W,N,E		28	220	327	53	247	114	118	41	30	235	297	83	269	108	114	36	2	15	-30	30	22	-6	-4	-5	157	130	161	132	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			W,S,E to E		58	285	202	32	94	49	53	25	77	275	202	47	74	40	68	34	19	-10	0	15	-20	-9	15	9	144	55	150	54	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			Circ past E		114	133	114	36	41	36	38	22	117	135	120	33	26	38	54	18	3	2	6	-3	-15	2	16	-4	99	34	101	34	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			N to E		53	196	184	38	180	59	25	31	41	188	235	52	196	64	37	50	-12	-8	51	14	16	5	12	19	118	74	129	87	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			S to N,E,S		754	1,138	1,249	595	847	869	883	456	741	1,132	1,249	577	881	890	903	466	-13	-6	0	-18	34	21	20	10	934	764	925	785	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			N,W,S to S		782	916	737	552	1,065	1,137	1,011	607	711	897	752	550	990	1,216	982	577	-71	-19	15	-2	-75	79	-29	-30	747	955	728	941	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			Circ past S		142	140	187	182	403	599	738	538	137	123	228	194	401	624	693	561	-5	-17	41	12	-2	25	-45	23	163	570	171	570	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			E to S		14	42	24	18	40	18	17	15	32	23	30	11	21	22	13	16	18	-19	6	-7	-19	4	-4	1	25	23	24	18	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			W to E,S,W		148	313	224	53	95	60	64	36	160	284	242	48	72	56	72	34	12	-29	18	-5	-23	-4	8	-2	185	64	184	59	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			E,N,W to W		125	151	227	158	415	555	698	484	110	137	257	177	406	558	666	510	-15	-14	30	19	-9	3	-32	26	165	538	170	535	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			Circ past W		45	209	287	77	235	158	158	95	57	219	269	101	264	174	140	88	12	10	-18	24	29	16	-18	7	155	162	162	167	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			S to W		79	96	91	111	160	220	164	106	78	101	89	105	162	207	192	128	-1	5	-2	-6	2	-13	28	22	94	163	93	172	
The Northern Rd / Bradley St			North	Right	106	261	282	198	366	426	400	273	115	259	280	198	329	461	374	274	9	-2	-2	0	-37	35	-26	1	212	366	213	360	
The Northern Rd / Bradley St			North	Through	690	697	479	372	739	729	632	349	629	673	495	361	677	778	640	321	-61	-24	16	-11	-62	49	8	-28	560	612	540	604	
The Northern Rd / Bradley St			South	Through	569	820	744	462	783	799	715	433	579	835	742	431	834	788	731	434	10	15	-2	-31	51	-11	16	1	649	683	647	697	
The Northern Rd / Bradley St			South	Left	19	18	36	16	61	74	111	47	22	25	33	15	58	71	124	45	3	7	-3	-1	-3	13	-2	22	73	24	75		
The Northern Rd / Bradley St			West	Right	91	83	69	38	60	40	116	159	99	94	72	42	74	57	114	129	8	11	3	4	14	17	-2	-30	70	94	77	94	
The Northern Rd / Bradley St			West	Left	264	414	596	244	224	290	332	129	256	421	561	255	218	321	340	142	-8	7	-35	11	-6	31	8	13	380	244	373	255	
The Northern Rd / Defense Establishments Gates			North	Through	670	685	483	385	790	761	740	506	619	680	479	379	731	823	735	447	-51	-5	-4	-6	-59	62	-5	-59	556	699	539	684	
The Northern Rd / Defense Establishments Gates			North	Left	111	95	65	25	10	8	2	112	83	91	29	19	7	24	8	1	1	-12	26	4	9	-1	16	6	74	7	79	15	
The Northern Rd / Defense Establishments Gates			East	Right	7	16	90	14	102	82	38	20	22	22	93	20	119	73	36	17	15	6	3	6	17	-9	-2	-3	32	61	39	61	
The Northern Rd / Defense Establishments Gates			East	Left	8	3	6	7	13	16	12	2	4	7	6	4	12	12	7	3	-4	4	0	-3	-1	-4	-5	1	6	11	5	9	
The Northern Rd / Defense Establishments Gates			South	Right	34	29	16	8	0	0	0	0	22	17	38	12	1	2	3	1	-12	-12	22	4	1	2	3	1	22	0	22	2	
The Northern Rd / Defense Establishments Gates			South	Through	581	822	690	464	743	791	788	459	580	846	675	427	779	778	821	460	-1	24	-15	-37	36	-13	33	1	639	695	632	710	
The Northern Rd / Chain-O-Ponds Rd			North	Right	2	4	9	12	10	6	10	13	6	12	5	2	12	19	11	8	4	8	-4	-10	2	13	1	-5	7	10	6	13	
The Northern Rd / Chain-O-Ponds Rd			North	Through	676	684	480	380	793	769	742	495	619	678	482	376	735	811	739	448	-57	-6	2	-4	-58	42	-						

THE NORTHERN ROAD STAGES 3 & 4 AIMSUN MODEL

v03

Micro OS1

Traffic Volume Calibration Results : Light Vehicles

Intersection	Approach Direction		Target volume								Modelled volume								Modelled vs target volume								Ave Target (vph)		Ave Modelled (vph)	
			6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00	6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00	6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00	AM	PM	AM	PM
The Northern Rd / Littlefields Rd	South	Left	20	23	38	16	41	50	51	18	21	18	29	20	36	55	49	28	1	-5	-9	4	-5	5	-2	10	24	40	22	42
The Northern Rd / Littlefields Rd	West	Right	37	61	43	20	22	32	17	13	38	56	39	22	27	25	27	18	1	-5	-4	2	5	-7	10	5	40	21	39	24
The Northern Rd / Littlefields Rd	West	Left	18	33	19	19	29	8	15	12	30	32	32	25	33	26	11	15	12	-1	13	6	4	18	-4	3	22	16	30	21
The Northern Rd / Elizabeth Dr	In from N		606	684	459	346	593	629	512	290	596	665	456	310	573	641	523	271	-10	-19	-3	-36	-20	12	11	-19	524	506	507	502
The Northern Rd / Elizabeth Dr	Out to N		448	645	582	396	627	731	690	317	456	694	547	347	634	731	693	332	8	49	-35	-49	7	0	3	15	518	591	511	598
The Northern Rd / Elizabeth Dr	Circ past N		290	359	186	84	121	99	104	39	316	391	183	99	110	124	136	39	26	32	-3	15	-11	25	32	0	230	91	247	102
The Northern Rd / Elizabeth Dr	In from E		181	173	209	151	401	469	491	238	195	187	195	141	412	445	489	239	14	14	-14	-10	11	-24	-2	1	179	400	180	396
The Northern Rd / Elizabeth Dr	Out to E		512	635	346	180	218	223	214	93	551	672	329	192	205	245	251	93	39	37	-17	12	-13	22	37	0	418	187	436	199
The Northern Rd / Elizabeth Dr	Circ past E		384	408	299	250	496	505	402	236	361	385	309	217	477	519	409	217	-23	-23	10	-33	-19	14	7	-19	335	410	318	406
The Northern Rd / Elizabeth Dr	In from S		639	898	645	395	583	625	568	273	663	964	629	371	571	647	590	290	24	66	-16	-24	-12	22	22	17	644	512	657	525
The Northern Rd / Elizabeth Dr	Out to S		466	475	385	316	732	769	667	391	449	451	404	279	717	756	656	380	-17	-24	19	-37	-15	-13	-11	-11	411	640	396	627
The Northern Rd / Elizabeth Dr	Circ past S		99	106	123	85	165	205	226	83	107	121	101	76	172	207	243	77	8	15	-22	-9	7	2	17	-6	103	170	101	175
The Northern Rd / Park Rd	North	Right	61	46	68	54	194	207	224	125	47	60	72	57	201	182	220	131	-14	14	4	3	7	-25	-4	6	57	188	59	184
The Northern Rd / Park Rd	North	Through	421	422	312	256	514	543	442	261	401	383	337	230	518	544	457	251	-20	-39	25	-26	4	1	15	-10	353	440	338	443
The Northern Rd / Park Rd	South	Through	411	615	472	318	480	533	492	241	393	658	479	308	473	570	482	253	-18	43	7	-10	-7	37	-10	12	454	437	460	445
The Northern Rd / Park Rd	South	Left	28	40	39	42	68	105	95	45	25	44	28	36	75	90	81	42	-3	4	-11	-6	7	-15	-14	-3	37	78	33	72
The Northern Rd / Park Rd	West	Right	56	45	48	47	40	35	29	27	50	40	40	54	31	34	21	29	-6	-5	-8	7	-9	-1	-8	2	49	33	46	29
The Northern Rd / Park Rd	West	Left	228	283	172	71	103	85	70	32	269	301	144	70	97	95	87	34	41	18	-28	-1	-6	10	17	2	189	73	196	78
The Northern Rd / Blaxland Ave	North	Through	452	440	333	292	532	552	454	265	443	417	349	283	520	548	464	254	-9	-23	16	-9	-12	-4	10	-11	379	451	373	447
The Northern Rd / Blaxland Ave	North	Left	1	4	15	5	15	6	8	7	7	11	16	3	20	15	10	20	6	7	1	-2	5	9	2	13	6	9	9	16
The Northern Rd / Blaxland Ave	East	Right	7	15	23	11	6	13	11	4	11	44	34	5	12	14	10	9	4	29	11	-6	6	1	-1	5	14	9	24	11
The Northern Rd / Blaxland Ave	East	Left	7	8	11	4	10	9	3	2	8	10	5	6	12	10	11	6	1	2	-6	2	2	1	8	4	8	6	7	10
The Northern Rd / Blaxland Ave	South	Right	1	2	9	2	17	16	11	5	6	11	15	8	12	13	15	13	5	9	6	6	-5	-3	4	8	4	12	10	13
The Northern Rd / Blaxland Ave	South	Through	408	608	472	333	531	623	544	262	396	649	466	332	528	638	536	283	-12	41	-6	-1	-3	15	-8	21	455	490	461	496
The Northern Rd / Roots Ave	North	Right	9	16	25	3	21	6	10	3	15	14	25	10	17	24	21	15	6	-2	0	7	-4	18	11	12	13	10	16	19
The Northern Rd / Roots Ave	North	Through	450	432	319	294	521	553	447	264	434	414	330	279	515	532	456	245	-16	-18	11	-15	-6	-21	9	-19	374	446	364	437
The Northern Rd / Roots Ave	South	Through	388	575	429	323	506	619	535	259	373	616	450	318	516	627	525	271	-15	41	21	-5	10	8	-10	12	429	480	439	485
The Northern Rd / Roots Ave	South	Left	11	25	35	10	22	18	42	29	15	18	24	15	29	28	41	37	4	-7	-11	5	7	10	-1	8	20	28	18	34
The Northern Rd / Roots Ave	West	Right	36	58	57	12	57	26	37	24	33	52	58	24	59	46	30	22	-3	-6	1	12	2	20	-7	-2	41	36	42	39
The Northern Rd / Roots Ave	West	Left	21	35	52	12	42	21	20	8	29	44	33	21	25	24	25	25	8	9	-19	9	-17	3	5	17	30	23	32	25
The Northern Rd / Adams Rd	North	Through	481	472	362	299	564	569	478	285	456	452	357	292	553	566	476	262	-25	-20	-5	-7	-11	-3	-2	-23	404	474	389	464
The Northern Rd / Adams Rd	North	Left	5	18	14	7	14	10	6	4	10	15	25	15	17	16	8	7	5	-3	11	8	3	6	2	3	11	9	16	12
The Northern Rd / Adams Rd	East	Right	3	10	5	4	10	8	9	2	4	4	8	2	7	13	7	11	1	-6	3	-2	-3	5	-2	9	6	7	5	10
The Northern Rd / Adams Rd	East	Left	32	31	32	41	70	84	71	35	17	29	22	27	54	64	65	37	-15	-2	-10	-14	-16	-20	-6	2	34	65	24	55
The Northern Rd / Adams Rd	South	Right	46	69	49	34	57	57	33	19	43	51	20	25	54	53	37	22	-3	-18	-29	-9	-3	-4	4	3	50	42	35	42
The Northern Rd / Adams Rd	South	Through	396	590	459	329	518	629	568	286	385	629	467	330	534	645	553	296	-11	39	8	1	16	16	-15	10	444	500	453	507
The Northern Rd / Dwyer Rd	North	Right	11	10	13	13	29	26	20	23	12	12	30	8	33	25	49	20	1	2	17	-5	4	-1	29	-3	12	25	16	32
The Northern Rd / Dwyer Rd	North	Through	512	454	348	289	522	595	481	276	483	459	356	296	515	576	502	264	-29	5	8	7	-7	-19	21	-12	401	469	399	464
The Northern Rd / Dwyer Rd	South	Through	456	592	419	324	519	616	489	234	440	634	404	329	548	616	498	255	-16	42	-15	5	29	0	9	21	448	465	452	479
The Northern Rd / Dwyer Rd	South	Left	2	5	6	14	8	8	9	3	3	10	14	8	8	8	8	3	1	5	8	-6	0	0	-1	0	7	7	9	7
The Northern Rd / Dwyer Rd	West	Right	8	6	4	9	8	8	5	3	10	14	7	11	15	12	9	5	2	8	3	2	7	4	4	2	7	6	11	10
The Northern Rd / Dwyer Rd	West	Left	25	36	22	14	12	20	12	18	10	41	30	17	19	40	25	22	-15	5	8	3	7	20	13	4	24	16	25	27
Elizabeth Dr / Luddenham R	North	Right	41	45	56	32	122	136	113	76	50	36	57	31	122	118	104	72	9	-9	1	-1	0	-18	-9	-4	44	112	44	104
Elizabeth Dr / Luddenham R	North	Left	45	58	48	35	107	108	92	40	40	47	37	43	103	101	101	39	-5	-11	-11	8	-4	-7	9	-1	47	87	42	86
Elizabeth Dr / Luddenham R	East	Right	80	110	76	55	77	109	83	40	55	81	52	57	66	98	77	40	-25											

THE NORTHERN ROAD STAGES 3 & 4 AIMSUN MODEL

v03

Micro OS1

Traffic Volume Calibration Results : Heavy Vehicles

Intersection		Approach Direction		Target volume								Modelled volume								Modelled vs target volume								Ave Target (vph)		Ave Modelled (vph)		
				6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00	6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00	6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00	AM	PM	AM	PM	
The Northern Rd S of Derby St		Northbound		114	68	65		89	67	40		114	56	64		87	53	48		0	-12	-1		-2	-14	8		82	65	78	63	
The Northern Rd S of Derby St		Southbound		59	84	67		94	69	27		62	79	60		77	67	34		3	-5	-7		-17	-2	7		70	63	67	59	
The Northern Rd / Jamison Rd		North	Right	6	18	2		12	13	0		9	13	5		9	8	2		3	-5	3		-3	-5	2		9	8	9	6	
The Northern Rd / Jamison Rd		North	Through	66	65	68		81	69	46		57	67	60		71	76	43		-9	2	-8		-10	7	-3		66	65	61	63	
The Northern Rd / Jamison Rd		North	Left	1	0	0		0	0	0		0	0	0		0	0	0		-1	0	0		0	0	0		0	0	0	0	
The Northern Rd / Jamison Rd		East	Right	0	0	0		2	1	0		0	0	0		2	0	0		0	0	0		0	-1	0		0	1	0	1	
The Northern Rd / Jamison Rd		East	Through	3	2	9		3	6	4		9	7	15		4	10	3		6	5	6		1	4	-1		5	4	10	6	
The Northern Rd / Jamison Rd		East	Left	1	1	2		2	0	0		5	2	2		2	0	0		4	1	0		0	0	0		1	1	3	1	
The Northern Rd / Jamison Rd		South	Right	6	0	0		0	0	0		1	0	3		1	0	2		-5	0	3		1	0	2		2	0	1	1	
The Northern Rd / Jamison Rd		South	Through	108	58	84		87	57	37		97	47	64		69	40	39		-11	-11	-20		-18	-17	2		83	60	69	49	
The Northern Rd / Jamison Rd		South	Left	4	6	6		3	4	5		6	5	5		13	5	3		2	-1	-1		10	1	-2		5	4	5	7	
The Northern Rd / Jamison Rd		West	Right	5	4	7		6	1	0		16	9	9		3	3	0		11	5	2		-3	2	0		5	2	11	2	
The Northern Rd / Jamison Rd		West	Through	7	7	4		6	5	5		14	8	7		7	9	4		7	1	3		1	4	-1		6	5	10	7	
The Northern Rd / Jamison Rd		West	Left	15	7	8		12	10	5		30	11	16		20	13	9		15	4	8		8	3	4		10	9	19	14	
The Northern Rd / Smith St		North	Right	1	4	0	4	2	3	1	1	1	4	0	3	5	10	3	3	0	0	0	-1	3	7	2	2	2	2	2	2	5
The Northern Rd / Smith St		North	Through	70	64	77	100	85	66	45	25	77	68	70	84	70	62	42	23	7	4	-7	-16	-15	-4	-3	-2	78	55	75	49	
The Northern Rd / Smith St		North	Left	1	2	0	0	2	1	0	1	0	6	0	0	1	5	0	0	-1	4	0	0	-1	4	0	-1	1	1	2	2	
The Northern Rd / Smith St		East	Right	4	2	4	3	2	3	3	1	8	4	7	0	2	4	3	0	4	2	3	-3	0	1	0	-1	3	2	5	2	
The Northern Rd / Smith St		East	Through	0	2	2	0	1	1	0	0	3	1	2	0	2	0	0	0	3	-1	0	0	1	-1	0	0	1	1	2	1	
The Northern Rd / Smith St		East	Left	1	2	1	2	1	0	1	0	0	0	3	0	0	0	0	1	-1	-2	2	-2	-1	0	-1	1	2	1	1	0	
The Northern Rd / Smith St		South	Right	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	
The Northern Rd / Smith St		South	Through	102	61	85	108	82	56	37	25	97	48	64	104	81	42	41	41	-5	-13	-21	-4	-1	-14	4	16	89	50	78	51	
The Northern Rd / Smith St		South	Left	5	3	4	4	2	4	3	2	2	6	2	5	5	7	4	3	-3	3	-2	1	3	3	1	1	4	3	4	5	
The Northern Rd / Smith St		West	Right	6	5	4	6	9	3	3	2	4	1	3	2	7	3	5	0	-2	-4	-1	-4	-2	0	2	-2	5	4	3	4	
The Northern Rd / Smith St		West	Through	1	2	1	0	1	1	0	0	2	0	0	0	0	0	0	0	1	-2	-1	0	-1	-1	0	0	1	1	1	0	
The Northern Rd / Smith St		West	Left	12	1	1	1	7	2	3	1	0	1	0	0	0	0	0	0	-12	0	-1	-1	-7	-2	-3	-1	4	3	0	0	
The Northern Rd / Maxwell St / Bringelly Rd		North	Right	5	2	22		10	6	6		4	3	14		6	3	2		-1	1	-8		-4	-3	-4		10	7	7	4	
The Northern Rd / Maxwell St / Bringelly Rd		North	Through	66	64	59		80	60	39		71	62	58		71	57	44		5	-2	-1		-9	-3	5		63	60	64	57	
The Northern Rd / Maxwell St / Bringelly Rd		North	Left	7	5	2		4	3	6		4	5	3		2	5	0		-3	0	1		-2	2	-6		5	4	4	2	
The Northern Rd / Maxwell St / Bringelly Rd		East	Right	0	2	8		3	1	0		1	0	1		2	1	0		1	-2	-7		-1	0	0		3	1	1	1	
The Northern Rd / Maxwell St / Bringelly Rd		East	Through	1	0	1		1	1	0		0	0	0		0	1	0		-1	0	-1		-1	0	0		1	1	0	0	
The Northern Rd / Maxwell St / Bringelly Rd		East	Left	15	20	28		27	5	5		17	22	37		33	14	6		2	2	9		6	9	1		21	12	25	18	
The Northern Rd / Maxwell St / Bringelly Rd		South	Right	18	15	28		13	6	10		23	8	39		10	10	7		5	-7	11		-3	4	-3		20	10	23	9	
The Northern Rd / Maxwell St / Bringelly Rd		South	Through	106	59	76		78	57	38		76	53	54		73	39	43		-30	-6	-22		-5	-18	5		80	58	61	52	
The Northern Rd / Maxwell St / Bringelly Rd		South	Left	4	4	4		7	6	5		5	3	9		5	4	3		1	-1	5		-2	-2	-2		4	6	6	4	
The Northern Rd / Maxwell St / Bringelly Rd		West	Right	10	5	7		6	10	8		12	8	2		6	10	9		2	3	-5		0	0	1		7	8	7	8	
The Northern Rd / Maxwell St / Bringelly Rd		West	Through	1	3	0		2	1	2		0	5	0		0	1	0		-1	2	0		-2	0	-2		1	2	2	0	
The Northern Rd / Maxwell St / Bringelly Rd		West	Left	1	3	7		4	3	2		21	1	11		10	8	2		20	-2	4		6	5	0		4	3	11	7	
The Northern Rd / Castle Rd / Aspen St		North	Through	90	61	67	90	86	70	46	21	87	53	57	64	71	65	53	19	-3	-8	-10	-26	-15	-5	7	-2	77	56	65	52	
The Northern Rd / Castle Rd / Aspen St		North	Left	1	28	27	19	27	5	6	7	13	39	40	21	38	17	6	9	12	11	13	2	11	12	0	2	19	11	28	18	
The Northern Rd / Castle Rd / Aspen St		East	Right	21	10	3	17	5	4	2	5	22	17	5	17	11	6	4	3	1	7	2	0	6	2	2	2	13	4	15	6	
The Northern Rd / Castle Rd / Aspen St		East	Left	5	34	30	15	21	14	9	12	5	29	37	8	20	11	6	6	0	-5	7	-7	-11	-3	-3	-6	21	14	20	8	
The Northern Rd / Castle Rd / Aspen St		S+W to E		13	12	2	18	12	6	8	10	9	14	4	16	21	6	23	10	-4	2	2	-2	9	0	15	0	11	9	11	15	
The Northern Rd / Castle Rd / Aspen St		S to N+E		94	78	104	121	101	64	54	34	87	61	100	119	93	52	68	41	-7	-17	-4	-2	-8	-12	14	7	99	63	92	64	
The Northern Rd / Castle Rd / Aspen St		South	Left	37	14	7	28	10	14	8	5	38	12	8	37	10	12	6	4	1	-2	1	9	0	-2	-2	-1	22	9	24	8	
The Northern Rd / Castle Rd / Aspen St		W to N+E		27	2	2	18	5	9	3	5	4	0	0	4	4	2	3	3	-23	-2	-2	-14	-1	-7	0	-2	12	6	2	3	
The Northern Rd / Castle Rd / Aspen St		S+W to N		108	68	104	121	94	67	49	29	81	48	96	107	77	48	49	34	-27	-20	-8	-14	-17	-19	0	5	100	60	83	52	
The Northern Rd / Tukara Rd / Frogmore Rd		North	Through	91	90	96		105	79	53		83	77	90		77	72	56		-8	-1											

THE NORTHERN ROAD STAGES 3 & 4 AIMSUN MODEL

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Traffic Volume Calibration Results : Heavy Vehicles

Intersection			Approach Direction		Target volume								Modelled volume								Modelled vs target volume								Ave Target (vph)		Ave Modelled (vph)		
					6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00	6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00	6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00	AM	PM	AM	PM	
The Northern Rd / M4 EB ramps			South	Through	79	69	66	72	71	66	46	24	74	47	48	72	51	51	52	24	-5	-22	-18	0	-20	-15	6	0	72	52	60	45	
The Northern Rd / M4 EB ramps			South	Left	16	7	16	26	20	21	12	15	17	6	20	26	12	24	16	17	1	-1	4	0	-8	3	4	2	16	17	17	17	
The Northern Rd / Homestead Rd / Garswood Rd			North	Through	78	81	78	83	107	108	74	45	75	71	77	59	86	89	61	31	-3	-10	-1	-24	-21	-19	-13	-14	80	84	71	67	
The Northern Rd / Homestead Rd / Garswood Rd			North	Left	10	14	20	6	12	11	7	5	6	24	18	7	20	17	6	6	-4	10	-2	1	8	6	-1	1	13	9	14	12	
The Northern Rd / Homestead Rd / Garswood Rd			East	Right	6	3	2	0	1	2	0	1	7	4	0	5	2	6	0	0	1	1	-2	5	1	4	0	-1	3	1	4	2	
The Northern Rd / Homestead Rd / Garswood Rd			East	Left	2	4	1	3	7	5	1	1	0	9	5	7	5	5	1	3	-2	5	4	4	-2	0	0	2	3	4	5	4	
The Northern Rd / Homestead Rd / Garswood Rd			South	Right	8	3	3	5	3	3	3	3	4	2	9	2	1	1	6	3	-4	-1	6	-3	-2	-2	3	0	5	3	4	3	
The Northern Rd / Homestead Rd / Garswood Rd			South	Through	88	71	78	96	86	83	56	36	75	46	65	83	58	64	67	42	-13	-25	-13	-13	-28	-19	11	6	83	65	67	58	
The Northern Rd / Homestead Rd / Garswood Rd			South	Left	7	4	3	0	6	6	3	10	3	5	3	4	7	3	5	2	-2	-1	1	7	-3	2	-8	-1	4	6	5	3	
The Northern Rd / Homestead Rd / Garswood Rd			West	Left	1	2	2	2	4	4	2	2	1	5	3	3	10	4	4	1	0	4	1	1	8	0	2	-1	2	2	5	2	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			N to S,W,N		71	78	74	85	93	96	53	25	71	74	86	66	71	80	44	16	0	-4	12	-19	-22	-16	-9	-9	77	67	74	53	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			S,E,N to N		66	52	75	105	86	69	62	34	57	37	77	87	55	59	69	34	-9	-15	2	-18	-31	-10	7	0	75	63	65	54	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			Circ past N		1	4	1	1	5	1	2	0	4	4	3	0	5	2	6	4	3	0	2	-1	0	1	4	4	2	2	3	4	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			W to N		25	15	18	6	8	11	7	9	27	13	9	7	8	11	10	13	2	-2	-9	1	0	0	3	4	16	9	14	11	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			E to W,N,E		4	9	11	7	17	7	1	7	0	7	8	2	6	1	9	6	-4	-2	-3	-5	-11	-6	8	-1	8	8	4	6	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			W,S,E to E		1	10	2	1	5	3	2	0	4	7	3	0	5	2	6	3	3	-3	1	-1	0	-1	4	3	4	3	4	4	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			Circ past E		5	3	0	0	3	1	0	1	1	6	1	0	2	1	0	1	-4	3	1	0	-1	0	0	0	2	1	2	1	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			N to E		2	11	13	5	15	1	2	3	3	2	2	0	7	0	1	0	1	-9	-11	-5	-8	-1	-1	-3	8	5	2	2	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			S to N,E,S		61	50	66	89	75	58	63	25	58	34	73	78	54	55	68	33	-3	-16	7	-11	-21	-3	5	8	67	55	61	53	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			N,W,S to S		66	67	65	66	87	62	43	22	64	64	75	51	71	50	36	14	-2	-3	10	-15	-16	-12	-7	-8	66	54	64	43	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			Circ past S		10	14	9	19	9	35	10	4	9	16	11	16	3	31	8	3	-1	2	2	-3	-6	-4	-2	-1	13	15	13	11	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			E to S		0	1	0	0	2	1	0	0	0	0	0	0	7	2	7	2	0	-1	0	0	5	1	7	2	0	1	0	5	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			W to E,S,W		5	9	1	0	3	3	0	1	1	9	1	0	2	1	0	0	-4	0	0	0	-1	-2	0	-1	4	2	3	1	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			E,N,W to W		8	17	10	9	10	30	10	2	6	16	11	10	3	26	10	4	-2	-1	1	1	-7	-4	0	2	11	13	11	11	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			Circ past W		6	6	10	17	16	12	1	9	3	7	8	8	6	6	7	5	-3	1	-2	-9	-10	-6	6	-4	10	10	7	6	
The Northern Rd / Glenmore Pkwy / Wentworth Rd			S to W		11	20	21	19	5	9	7	14	11	29	15	15	12	7	12	10	0	9	-6	-4	7	-2	5	-4	18	9	18	10	
The Northern Rd / Bradley St			North	Right	13	14	12	10	7	5	12	3	9	9	13	12	10	1	11	2	-4	-5	1	2	3	-4	-1	-1	12	7	11	6	
The Northern Rd / Bradley St			North	Through	55	55	53	56	85	58	31	19	56	54	63	39	66	53	33	12	1	-1	10	-17	-19	-5	2	-7	55	48	53	41	
The Northern Rd / Bradley St			South	Through	68	58	75	101	69	60	61	37	67	58	82	89	61	58	66	41	-1	0	7	-12	-8	-2	5	4	76	57	74	57	
The Northern Rd / Bradley St			South	Left	1	2	1	4	4	4	4	0	3	2	0	4	3	4	7	1	2	0	-1	0	-1	0	3	1	2	3	2	4	
The Northern Rd / Bradley St			West	Right	15	13	13	10	10	6	9	16	14	20	18	5	19	3	8	21	-1	7	5	-5	9	-3	-1	5	13	10	14	13	
The Northern Rd / Bradley St			West	Left	4	12	12	7	11	7	9	2	1	6	7	4	3	9	10	4	-3	-6	-5	-3	-8	2	1	2	9	7	5	7	
The Northern Rd / Defense Establishments Gates			North	Through	66	67	64	66	94	63	38	34	69	72	79	45	87	54	39	32	3	5	15	-21	-7	-9	1	-2	66	57	66	53	
The Northern Rd / Defense Establishments Gates			North	Left	4	1	2	0	1	1	2	1	3	1	1	1	0	1	1	3	-1	0	-1	1	-1	0	-1	2	2	1	2	1	
The Northern Rd / Defense Establishments Gates			East	Right	0	1	3	2	0	3	1	0	4	0	3	3	1	2	0	0	4	-1	0	1	1	-1	-1	0	2	1	3	1	
The Northern Rd / Defense Establishments Gates			East	Left	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
The Northern Rd / Defense Establishments Gates			South	Right	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	0	0	0	0	1	0	0	0	
The Northern Rd / Defense Establishments Gates			South	Through	69	59	73	103	73	61	64	37	65	59	81	92	62	60	73	43	-4	0	8	-11	-11	-1	9	6	76	59	74	60	
The Northern Rd / Chain-O-Ponds Rd			North	Right	0	0	0	1	1	0	1	0	0	2	1	0	0	0	0	0	0	2	1	-1	-1	0	-1	0	0	1	1	0	0
The Northern Rd / Chain-O-Ponds Rd			North	Through	66	67	64	65	93	63	37	33	68	72	76	47	85	56	39	31	2	5	12	-18	-8	-7	2	-2	66	57	66	53	
The Northern Rd / Chain-O-Ponds Rd			South	Through	69	58	73	104	69	61	64	37	62	58	81	94	60	59	74	39	-7	0	8	-10	-9	-2	10	2	76	58	74	58	
The Northern Rd / Chain-O-Ponds Rd			South	Left	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	
The Northern Rd / Chain-O-Ponds Rd			West	Right	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	-1	0	0	0	0	
The Northern Rd / Chain-O-Ponds Rd			West	Left	0	1	1	0	4	0	0	0	2	0	0	0	0	1	0	1	2	2	-1	-1	0	-3	0	1	2	1	1	1	1
The Northern Rd / Kings Hill Rd			North	Right	0	0	0	2	2	5	3	2	2	2	6	3	5	8	3	5	2	2	6	1	3	3	0	3	1	3	3	5	
The Northern Rd / Kings Hill Rd			North	Through	70	63	54																										

THE NORTHERN ROAD STAGES 3 & 4 AIMSUN MODEL

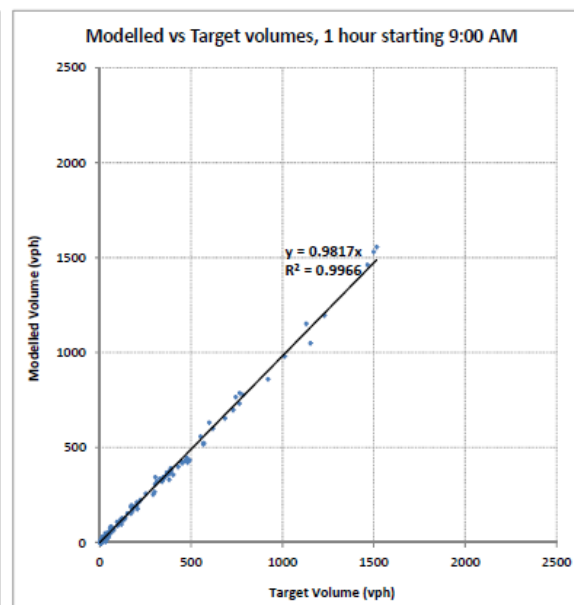
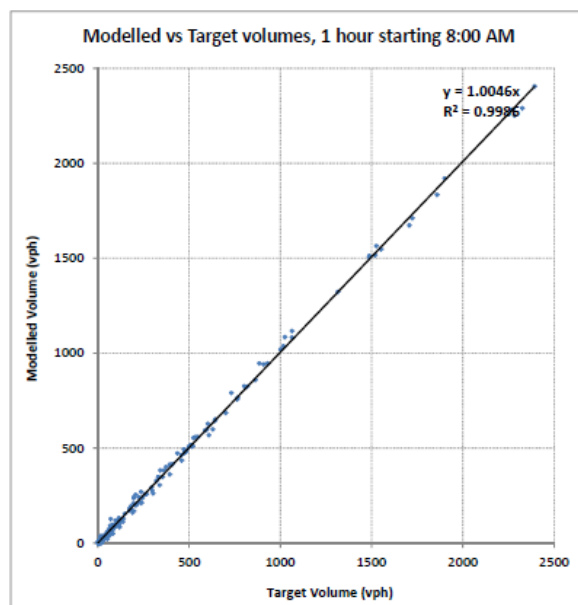
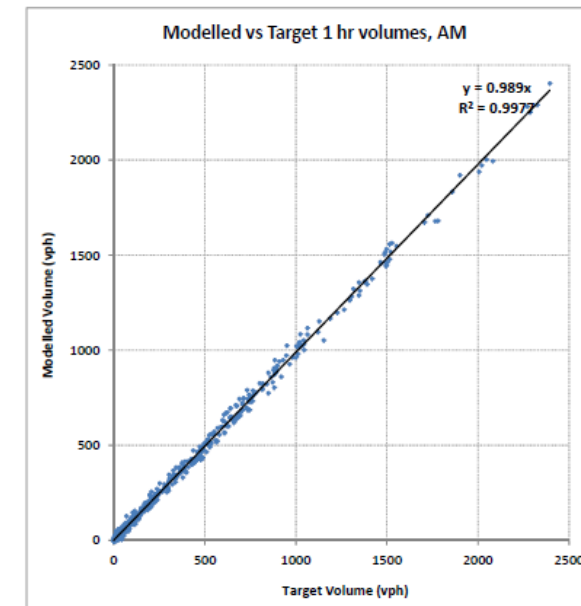
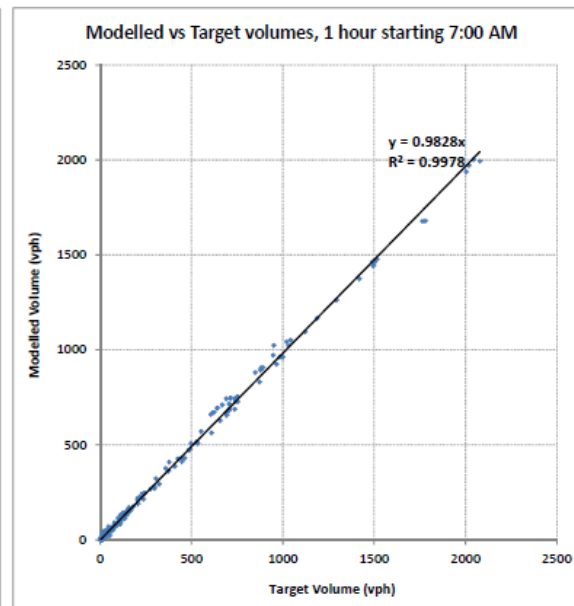
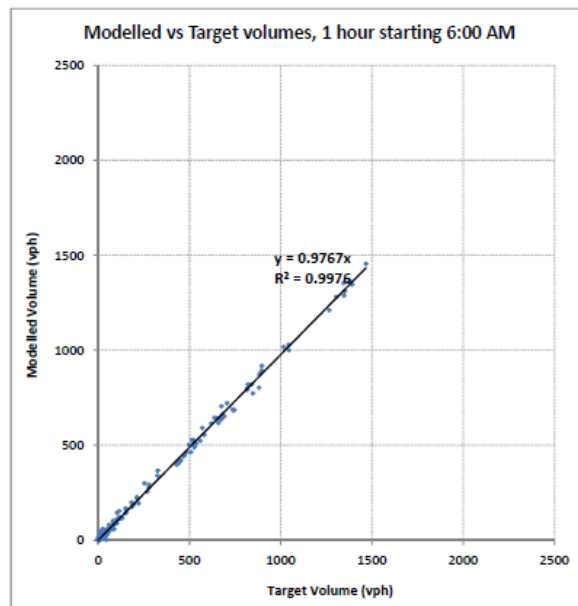
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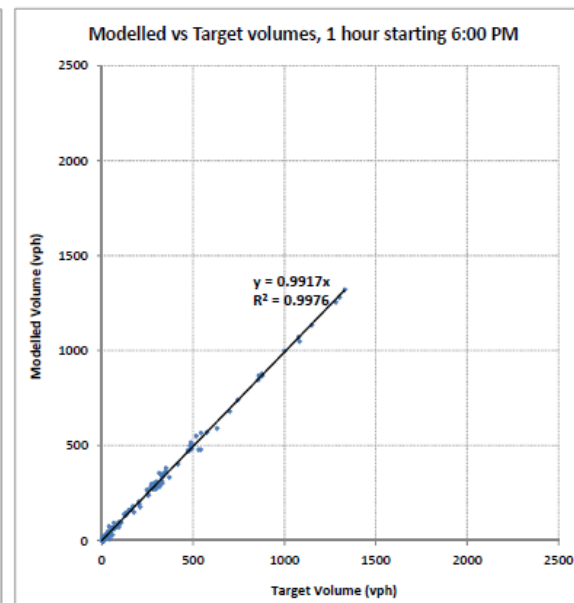
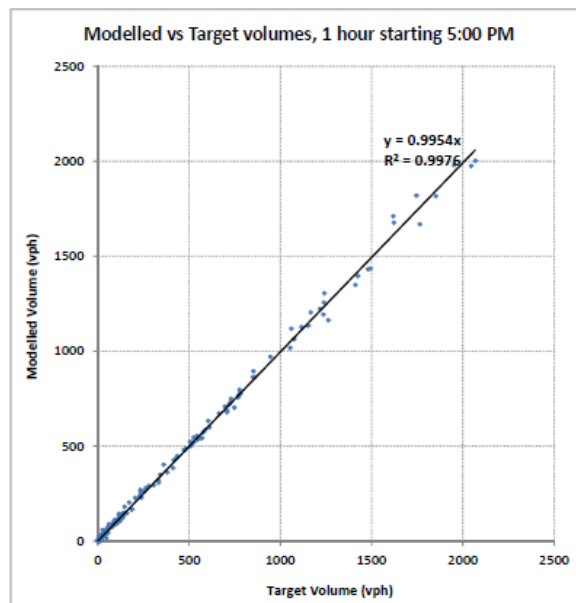
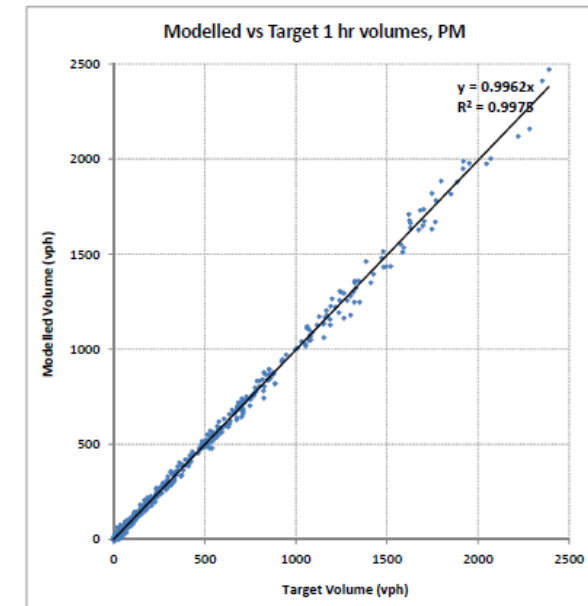
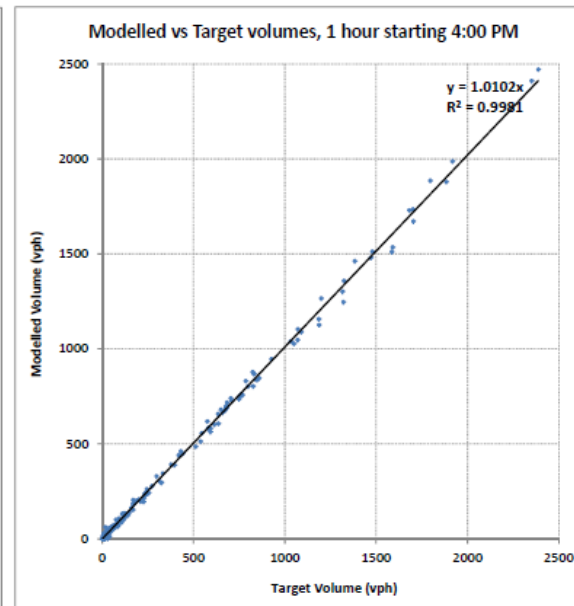
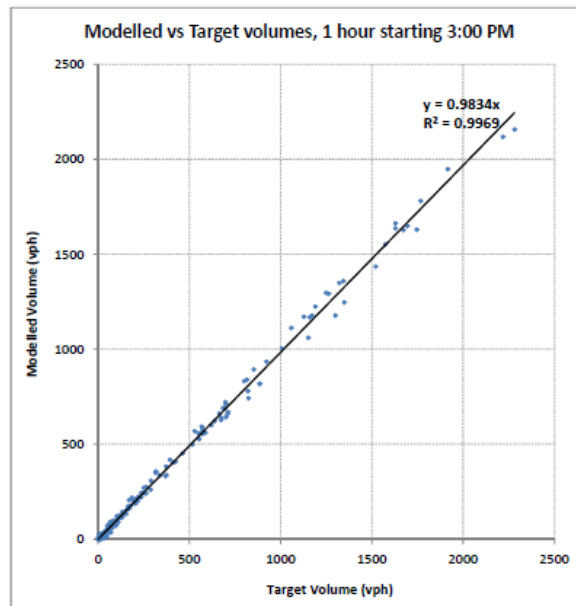
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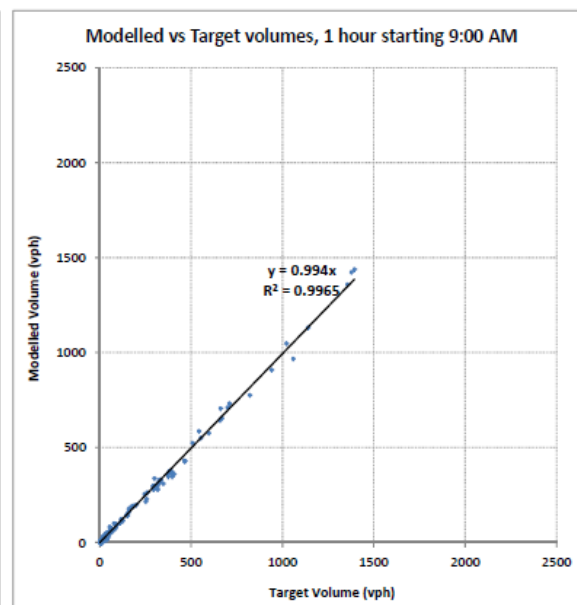
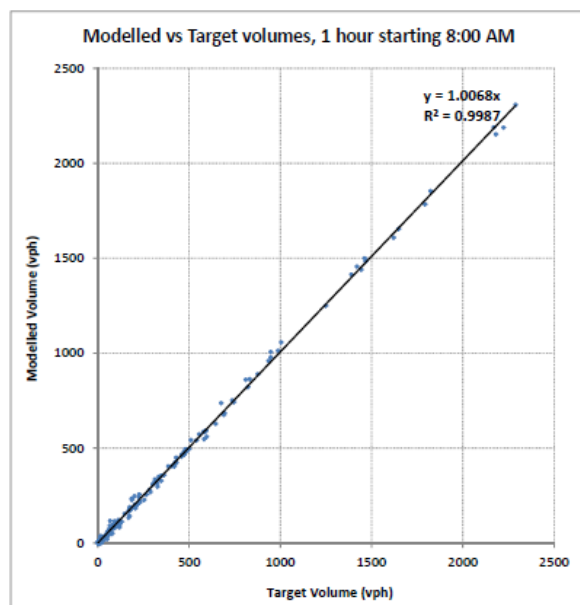
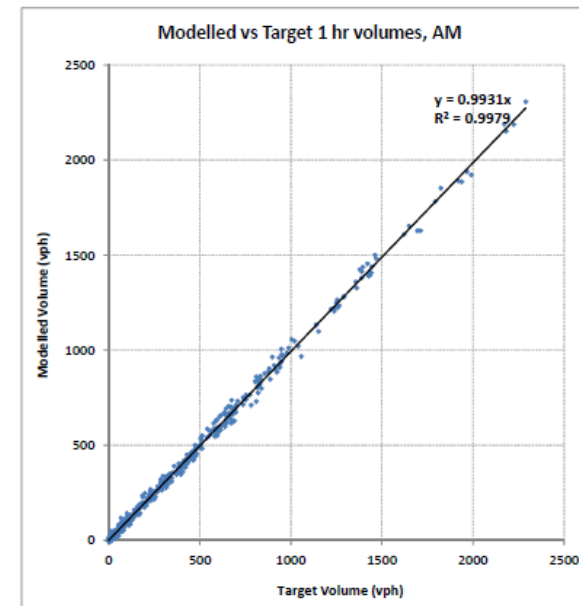
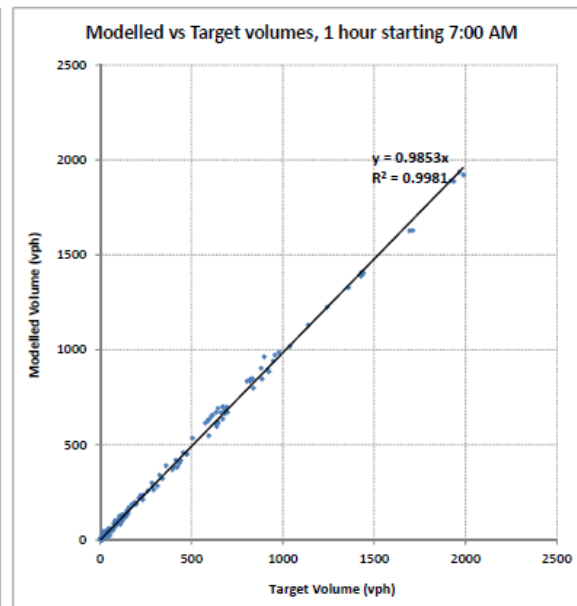
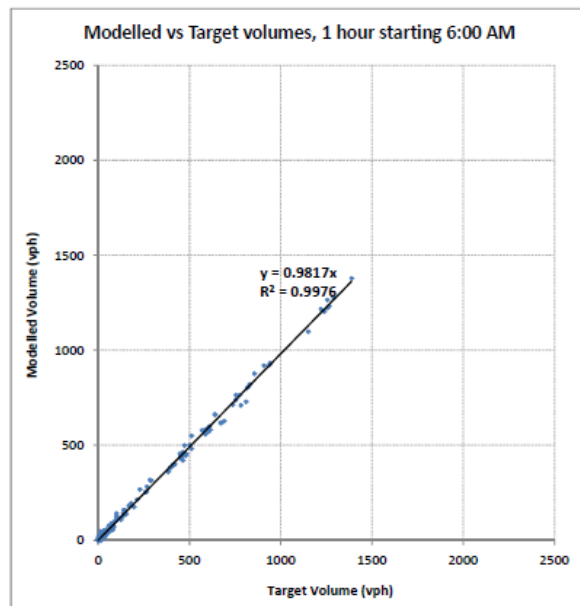
Traffic Volume Calibration Results : Heavy Vehicles

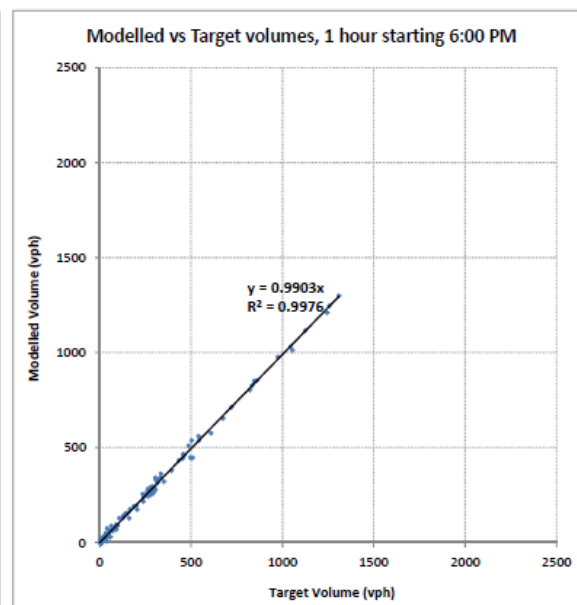
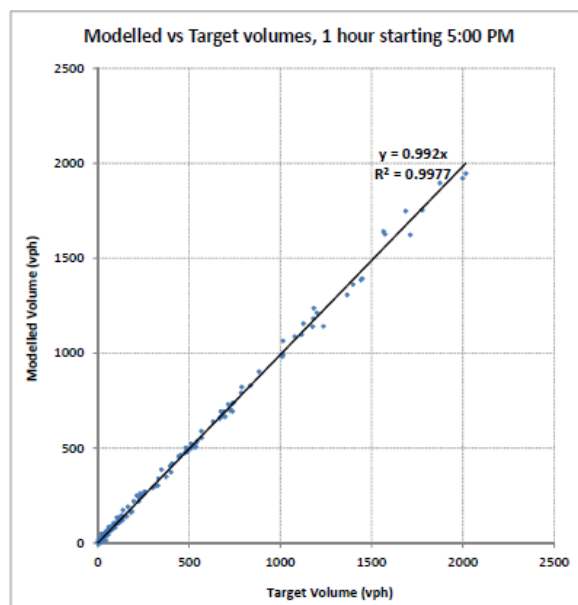
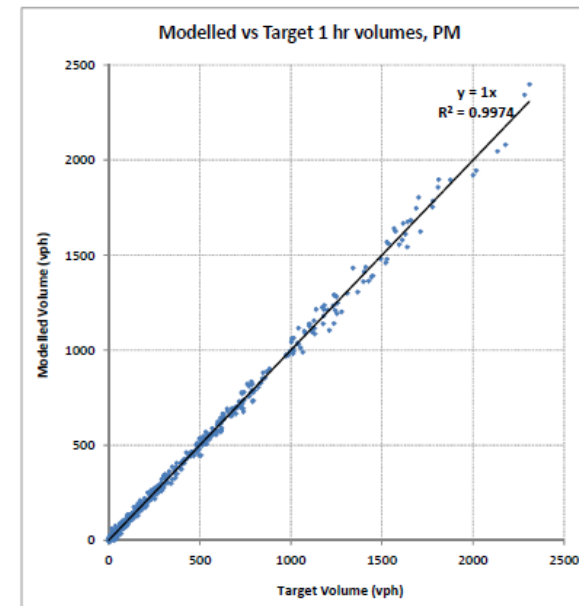
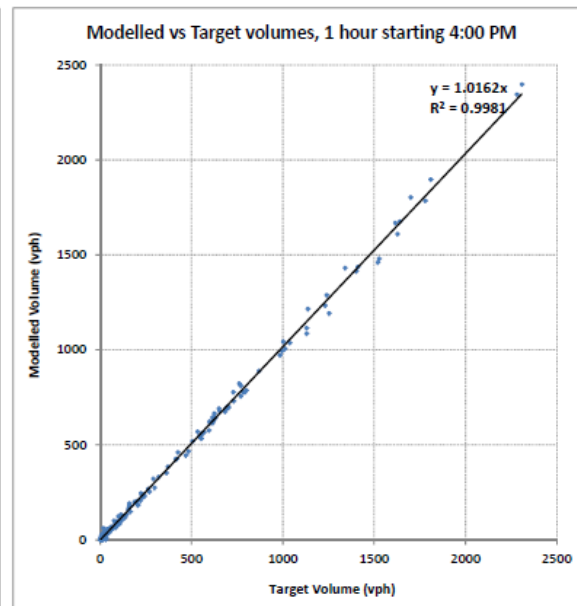
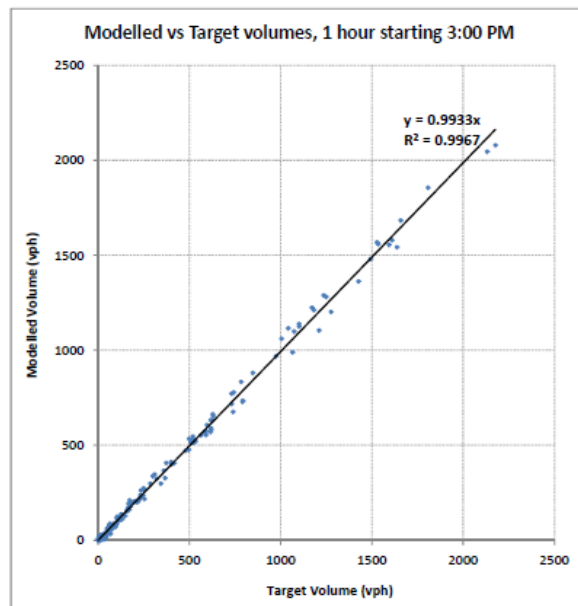
Intersection	Approach	Direction	Target volume								Modelled volume								Modelled vs target volume								Ave Target (vph)		Ave Modelled (vph)	
			6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00	6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00	6:00	7:00	8:00	9:00	15:00	16:00	17:00	18:00	AM	PM	AM	PM
The Northern Rd / Littlefields Rd	South	Left	4	1	0	3	1	4	1	1	2	3	2	3	6	8	4	0	-2	2	2	0	5	4	3	-1	2	2	3	5
The Northern Rd / Littlefields Rd	West	Right	3	3	0	1	2	1	2	1	0	5	0	0	0	1	0	0	-3	2	0	-1	-2	0	-2	-1	2	2	1	0
The Northern Rd / Littlefields Rd	West	Left	4	1	0	0	0	0	0	0	0	1	2	0	3	1	1	0	-4	0	2	0	3	1	1	0	1	0	1	1
The Northern Rd / Elizabeth Dr	In from N		76	55	55	54	83	51	32	21	60	65	56	47	66	46	30	24	-16	10	1	-7	-17	-5	-2	3	60	47	57	42
The Northern Rd / Elizabeth Dr	Out to N		49	45	48	83	67	68	39	17	47	49	53	75	58	71	57	17	-2	4	5	-8	-9	3	18	0	56	48	56	51
The Northern Rd / Elizabeth Dr	Circ past N		35	17	22	28	20	10	10	3	25	18	16	22	23	7	8	1	-10	1	-6	-6	3	-3	-2	-2	26	11	20	10
The Northern Rd / Elizabeth Dr	In from E		32	31	35	54	62	43	29	12	32	22	42	36	42	41	30	7	0	-9	7	-18	-20	-2	1	-5	38	37	33	30
The Northern Rd / Elizabeth Dr	Out to E		58	34	47	41	45	20	18	7	41	39	34	32	38	16	15	5	-17	5	-13	-9	-7	-4	-3	-2	45	23	37	19
The Northern Rd / Elizabeth Dr	Circ past E		53	38	30	41	58	41	24	17	44	44	38	37	51	37	23	20	-9	6	8	-4	-7	-4	-1	3	41	35	41	33
The Northern Rd / Elizabeth Dr	In from S		66	52	56	79	56	51	37	15	59	59	56	76	52	48	44	14	-7	7	0	-3	-4	-3	7	-1	63	40	63	40
The Northern Rd / Elizabeth Dr	Out to S		67	59	51	63	89	57	41	24	63	56	69	52	64	47	33	23	-4	-3	18	-11	-25	-10	-8	-1	60	53	60	42
The Northern Rd / Elizabeth Dr	Circ past S		18	10	14	32	31	27	12	5	13	10	11	21	29	31	20	4	-5	0	-3	-11	-2	4	8	-1	19	19	14	21
The Northern Rd / Park Rd	North	Right	9	17	20	20	29	20	14	6	10	9	23	15	25	13	10	4	1	-8	3	-5	-4	-7	-4	-2	17	17	14	13
The Northern Rd / Park Rd	North	Through	48	40	30	42	57	36	29	18	44	46	46	36	39	35	22	20	-4	6	16	-6	-18	-1	-7	2	40	35	43	29
The Northern Rd / Park Rd	South	Through	35	28	39	52	37	43	30	11	21	36	37	52	28	48	38	13	-14	8	-2	0	-9	5	8	2	39	30	37	32
The Northern Rd / Park Rd	South	Left	7	6	9	6	10	8	8	0	8	5	10	4	10	10	10	2	1	-1	1	-2	0	2	2	2	7	7	7	8
The Northern Rd / Park Rd	West	Right	17	12	14	10	6	2	4	4	18	13	9	11	6	4	5	2	1	1	-5	1	0	2	1	-2	13	4	13	4
The Northern Rd / Park Rd	West	Left	25	21	17	26	21	4	7	3	31	23	18	20	21	2	2	1	6	2	1	-6	0	-2	-5	-2	22	9	23	7
The Northern Rd / Blaxland Ave	North	Through	74	52	41	49	55	41	30	27	63	59	52	49	42	34	23	26	-11	7	11	0	-13	-7	-7	-1	54	38	56	31
The Northern Rd / Blaxland Ave	North	Left	0	2	0	1	5	0	0	0	0	0	2	0	3	3	0	0	0	-2	2	-1	-2	3	0	0	1	1	1	2
The Northern Rd / Blaxland Ave	East	Right	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	-1	0	1	0	0
The Northern Rd / Blaxland Ave	East	Left	1	0	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	-1	0	0	0	1	0	1	0
The Northern Rd / Blaxland Ave	South	Right	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0
The Northern Rd / Blaxland Ave	South	Through	45	31	45	57	43	56	43	8	28	44	44	56	42	54	49	14	-17	13	-1	-1	-1	-2	6	6	45	38	43	40
The Northern Rd / Roots Ave	North	Right	0	0	0	2	3	1	0	0	0	0	0	0	0	3	0	0	0	0	0	-2	-3	2	0	0	1	1	0	1
The Northern Rd / Roots Ave	North	Through	75	52	42	47	53	40	30	27	64	59	53	49	42	31	23	26	-11	7	11	2	-11	-9	-7	-1	54	38	56	31
The Northern Rd / Roots Ave	South	Through	41	31	43	56	43	55	43	8	27	44	43	56	42	53	48	14	-14	13	0	0	-1	-2	5	6	43	37	43	39
The Northern Rd / Roots Ave	South	Left	3	5	2	3	12	1	1	5	4	4	1	10	12	4	2	4	1	-1	-1	7	0	3	1	-1	3	5	5	6
The Northern Rd / Roots Ave	West	Right	4	7	5	1	4	6	0	0	16	4	9	6	6	6	1	1	12	-3	4	5	2	0	1	1	4	3	9	4
The Northern Rd / Roots Ave	West	Left	4	1	2	1	0	1	0	0	1	0	1	0	0	2	0	0	-3	-1	-1	-1	0	1	0	0	2	0	1	1
The Northern Rd / Adams Rd	North	Through	78	57	47	48	56	46	30	27	69	64	59	52	48	37	24	27	-9	7	12	4	-8	-9	-6	0	58	40	61	34
The Northern Rd / Adams Rd	North	Left	1	2	0	0	1	0	0	0	9	0	3	3	0	0	0	0	8	-2	3	3	-1	0	0	0	1	0	4	0
The Northern Rd / Adams Rd	East	Right	1	3	0	1	2	1	0	0	4	4	0	4	2	1	2	3	3	1	0	3	0	0	2	3	1	1	3	2
The Northern Rd / Adams Rd	East	Left	3	0	2	1	2	1	2	0	0	0	0	0	1	2	10	3	-3	0	-2	-1	-1	8	3	2	1	0	4	4
The Northern Rd / Adams Rd	South	Right	4	1	2	1	7	2	2	4	1	1	0	1	3	4	0	0	0	0	-1	-1	0	-4	2	-2	2	3	2	2
The Northern Rd / Adams Rd	South	Through	43	33	45	58	53	55	44	13	27	44	44	62	52	58	46	15	-16	11	-1	4	-1	3	2	2	45	41	44	43
The Northern Rd / Dwyer Rd	North	Right	0	6	1	3	5	3	4	3	4	4	3	6	2	1	10	10	4	-2	2	3	-3	-2	6	7	3	4	4	6
The Northern Rd / Dwyer Rd	North	Through	68	42	45	39	47	41	24	16	72	49	58	40	50	32	21	23	4	7	13	1	3	-9	-3	7	49	32	55	32
The Northern Rd / Dwyer Rd	South	Through	25	25	40	41	49	56	36	11	21	37	31	40	46	61	47	12	-4	12	-9	-1	-3	5	11	1	33	38	32	42
The Northern Rd / Dwyer Rd	South	Left	0	0	2	0	1	0	2	0	0	0	0	0	0	0	3	0	0	0	-2	0	-1	0	1	0	1	1	0	1
The Northern Rd / Dwyer Rd	West	Right	4	5	0	1	1	0	0	1	9	5	0	0	1	2	0	0	5	0	0	-1	0	2	0	-1	3	1	4	1
The Northern Rd / Dwyer Rd	West	Left	6	3	2	4	2	0	3	0	6	5	2	4	1	0	0	0	0	2	0	0	-1	0	-3	0	4	1	4	0
Elizabeth Dr / Luddenham R	North	Right	0	3	4	1	3	4	7	4	1	1	10	3	4	6	0	3	1	-2	6	2	1	2	-7	-1	2	5	4	3
Elizabeth Dr / Luddenham R	North	Left	0	1	0	5	3	5	2	0	0	2	0	4	3	3	12	2	0	1	0	-1	0	-2	10	2	2	3	2	5
Elizabeth Dr / Luddenham R	East	Right	6	1	0	1	9	1	1	0	4	4	0	0	6	0	1	0	-2	3	0	-1	-3	-1	0	0	2	3	2	2
Elizabeth Dr / Luddenham R	East	Through	49	35	28	46	54	55	26	5	37	25	35	39	38	46	28	4	-12	10	7	-7	-16	-9	2	-1	40	35	34	29
Elizabeth Dr / Luddenham R	West	Through	18	48	49	44	35	16	8	0	27	36	33	32	28	11	7	2	9	-12	-16	-12	-7	-5	-1	2	40	15	32	12
Elizabeth Dr / Luddenham R	West	Left	0	2	4	4	1	1	2	0	13	0	2	2	1	1	5	0	13	-2	-2	-2	0	0	3	0	3	1	4	2
Park Rd / Campbell St	East	Through	15	23	27	26	38	27	20	6	18	14	33	19	35	22	21	6	3	-9	6	-7	-3	-5	1	0	23	23	21	21
Park Rd / Campbell St	East	Left	0	0	2	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	-2	0	-1	-1	-1	0	1	1	0	0
Park Rd / Campbell St	South	Right	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	0	0	0	0	0	0	0
Park Rd / Campbell St	South	Left	1	1	1	0	2	1	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	0	-2	-1	0	0	1	1	0	0
Park Rd / Campbell St	West	Right	3	0	2	1	0	0	1	0	0	0	0	0	0	0	0	0	-3	0	-2	-1	0	0	-1	0	2	0	0	0
Park Rd / Campbell St	West	Through	42	33	31	35	26	6	11	7	49	36	27	31	27	6	7	3	7	3	-4	-4	1	0	-4	-4	35	13	36	11

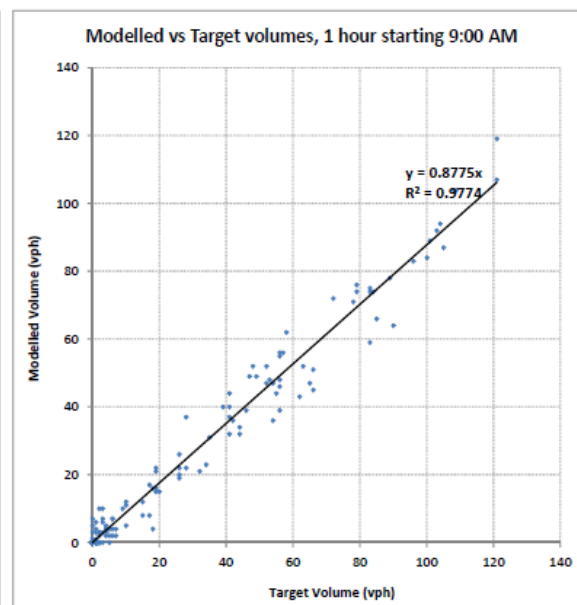
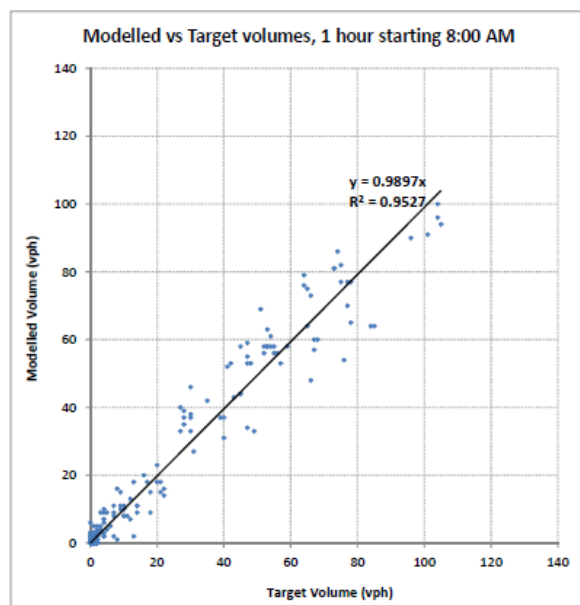
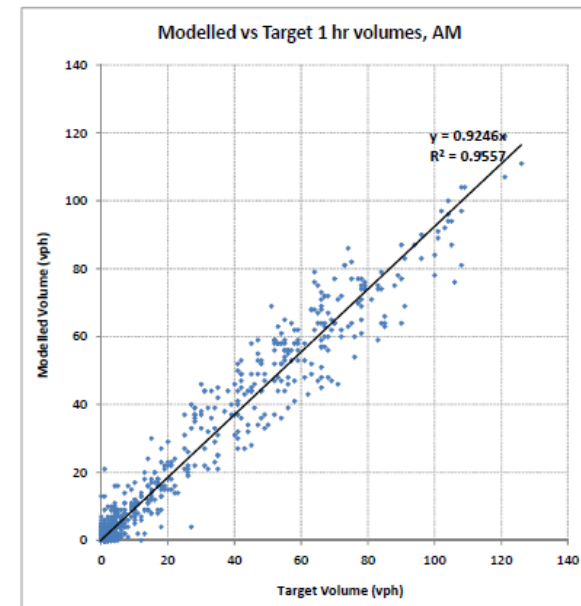
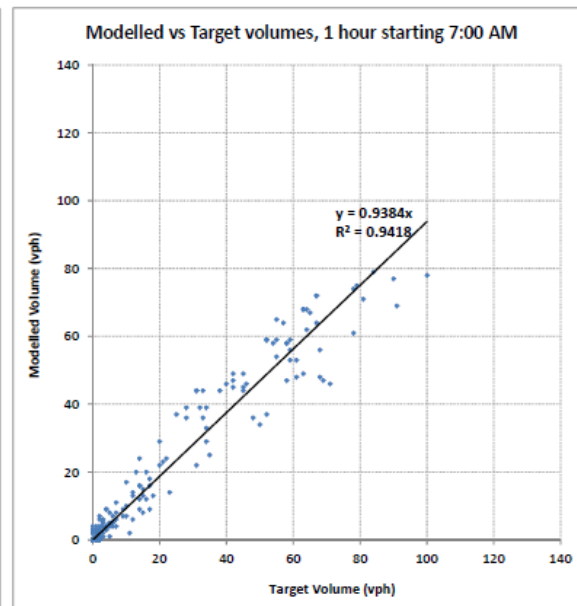
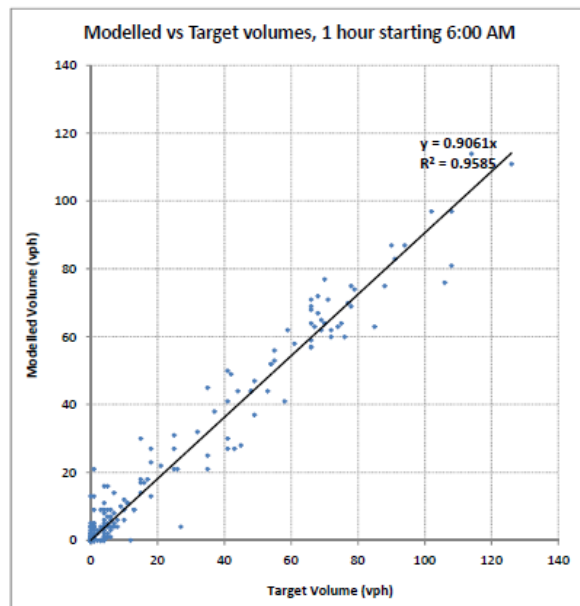
Appendix B. Regression Plots

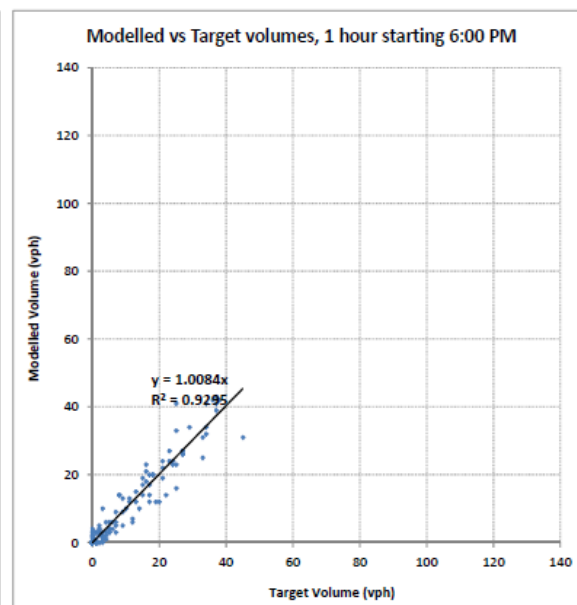
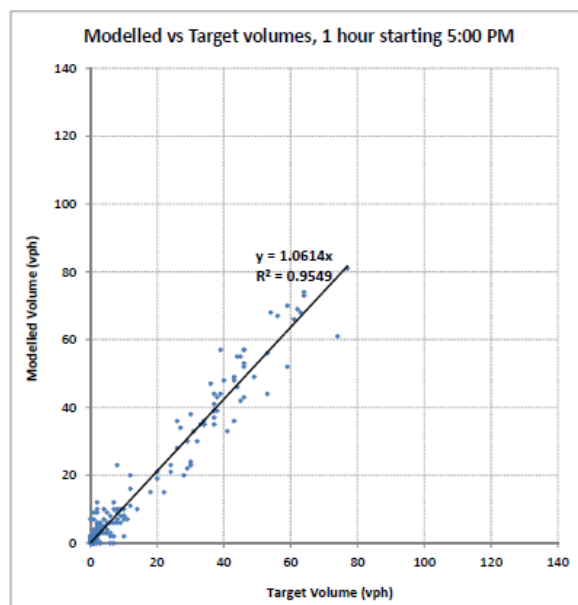
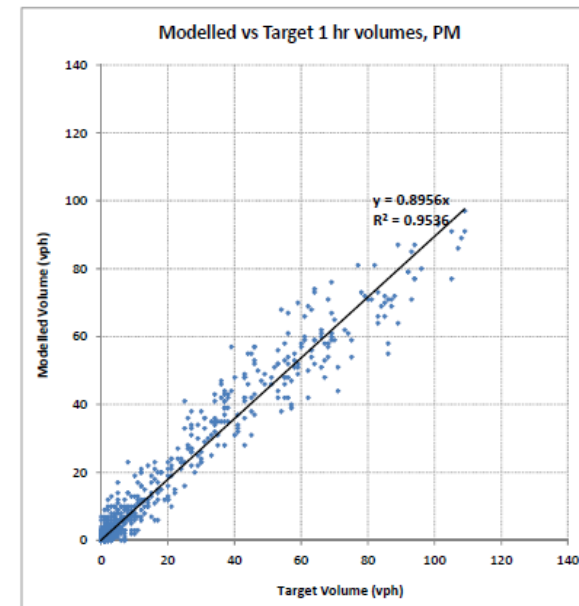
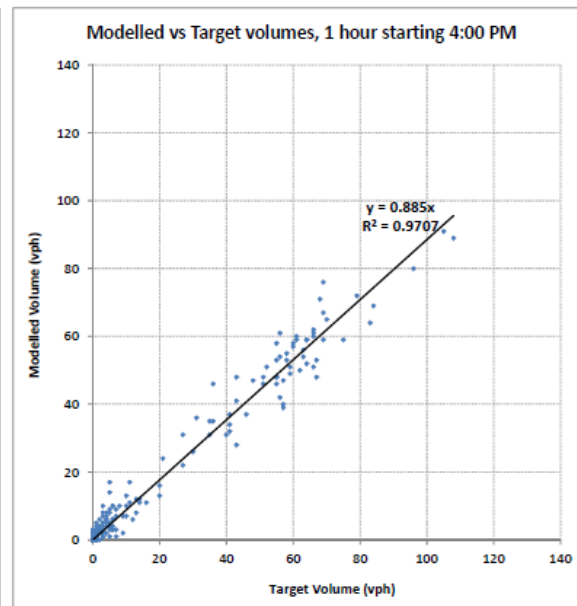
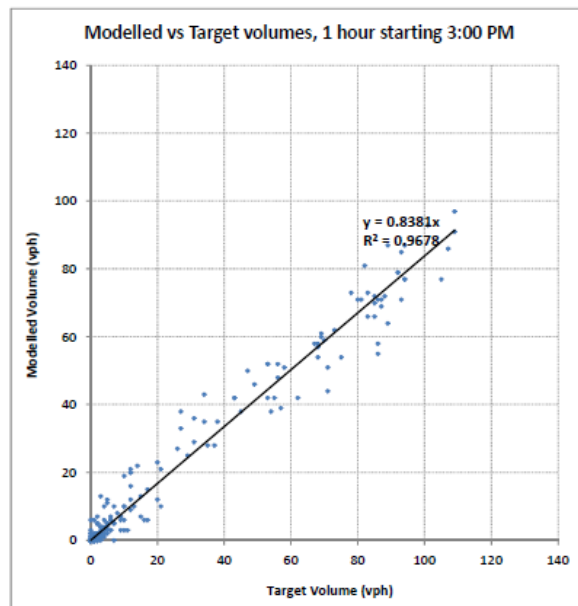












Appendix C. Cumulative counter peak travel time graphs

Figure C.1 : Cumulative travel time, model vs observed – counter peak direction, 6am to 7am

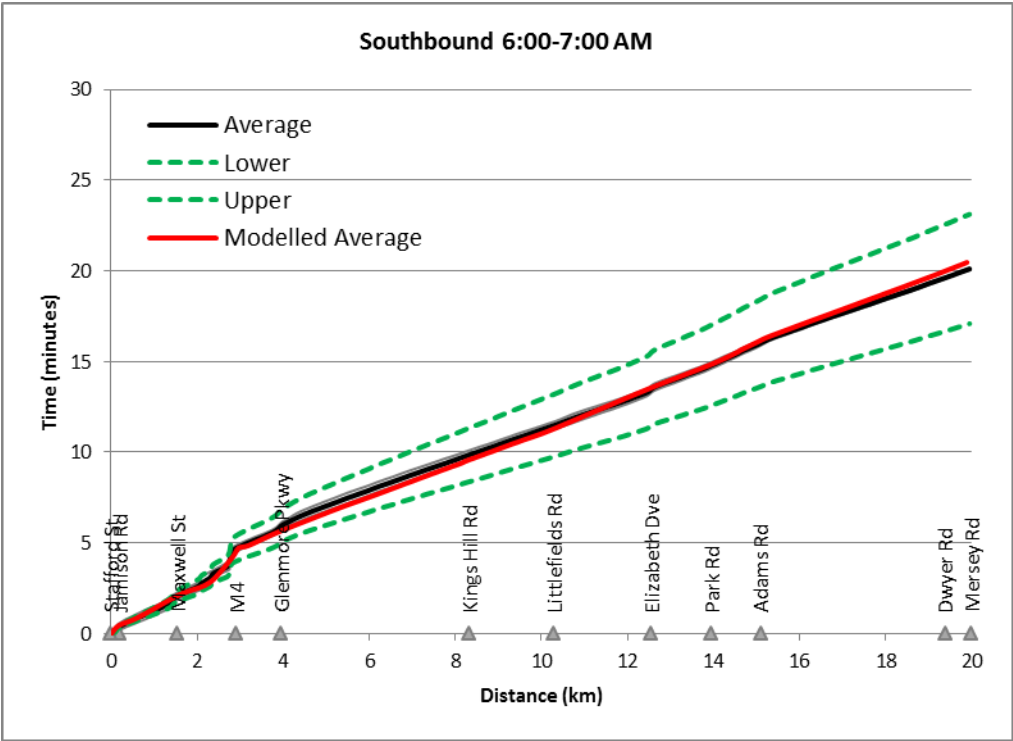


Figure C.2 : Cumulative travel time, model vs observed – counter peak direction, 7am to 8am

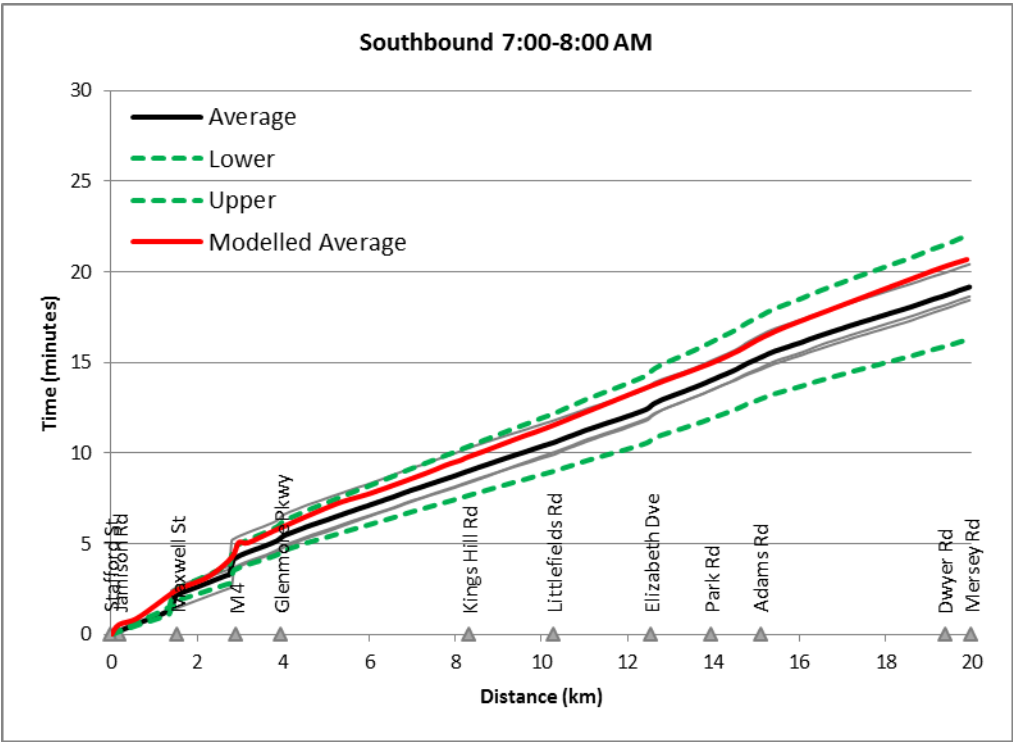


Figure C.3 : Cumulative travel time, model vs observed – counter peak direction, 8am to 9am

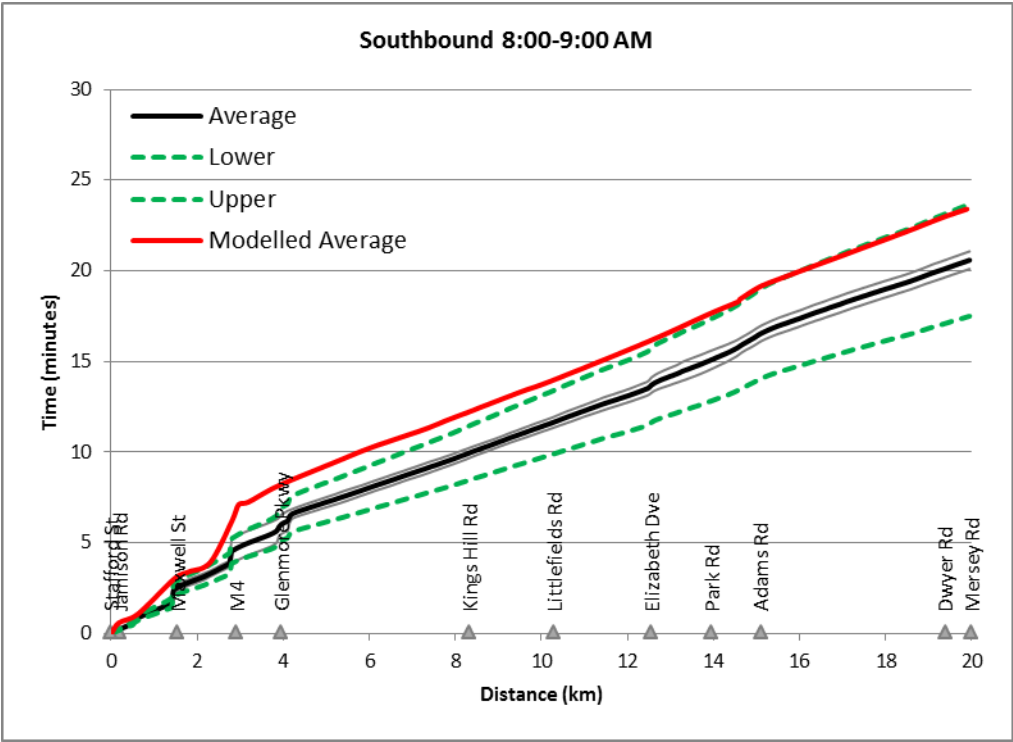


Figure C.4 : Cumulative travel time, model vs observed – counter peak direction, 9am to 10am

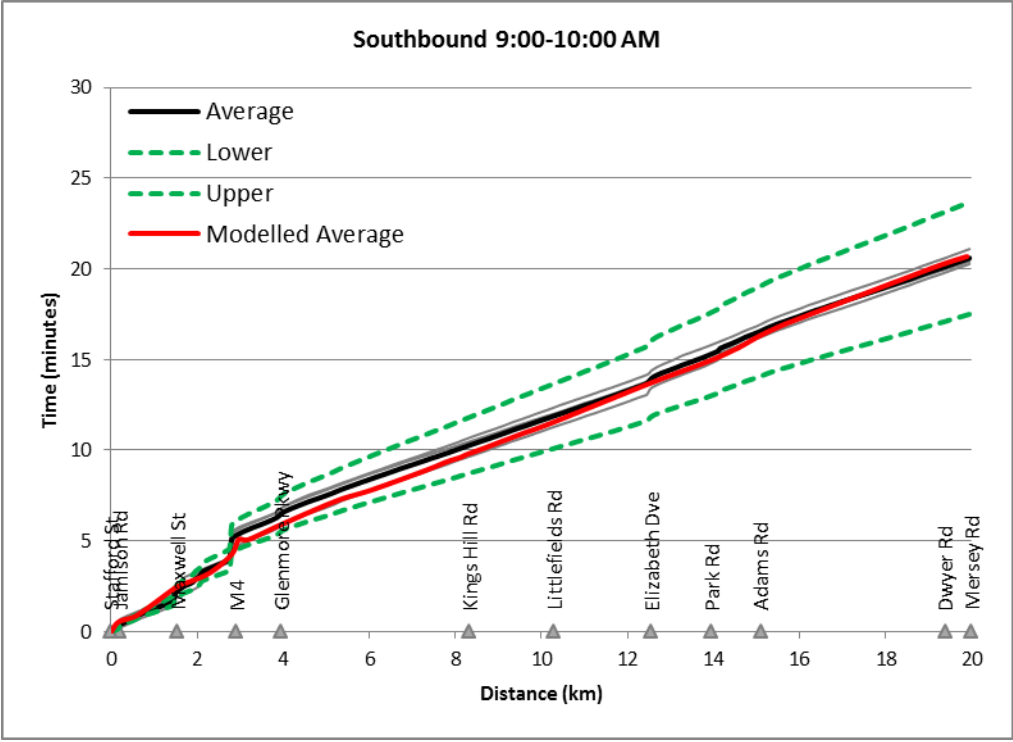


Figure C.5 : Cumulative travel time, model vs observed – counter peak direction, 3pm to 4pm

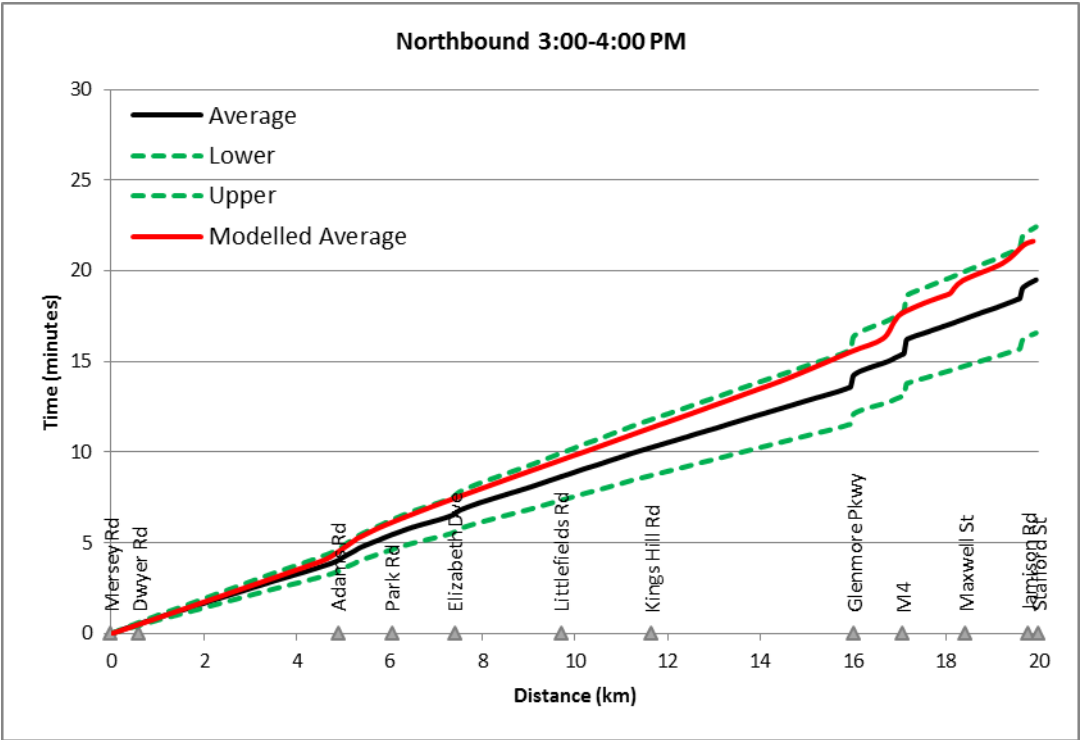


Figure C.6 : Cumulative travel time, model vs observed – counter peak direction, 4pm to 5pm

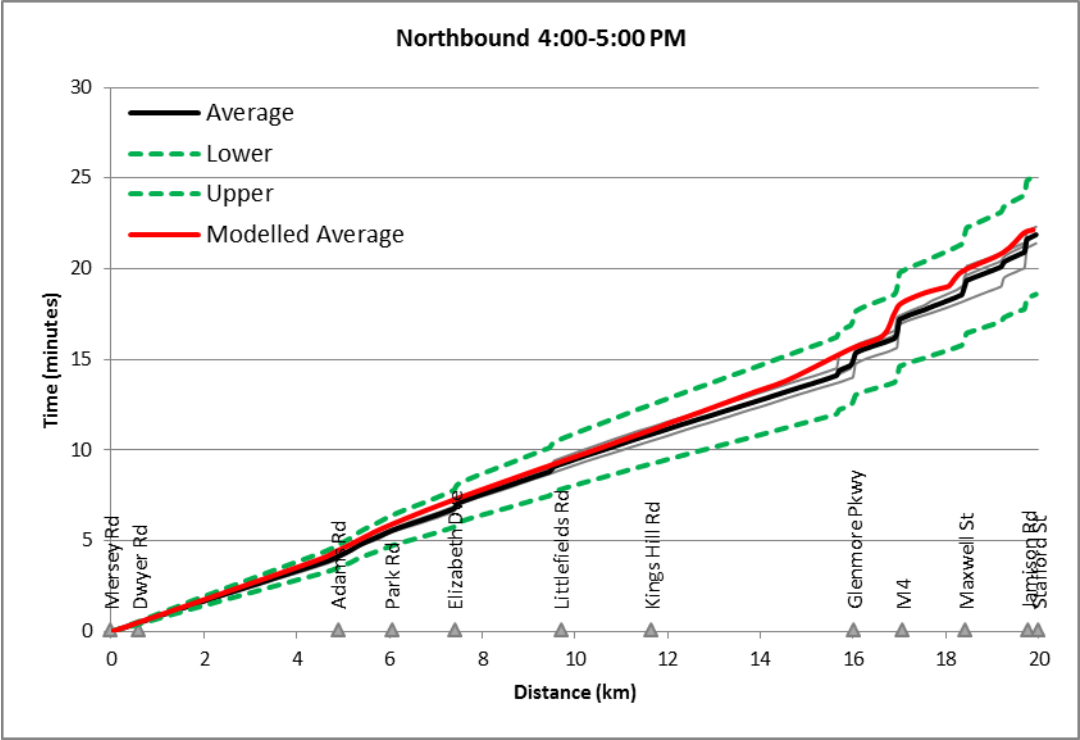


Figure C.7 : Cumulative travel time, model vs observed – counter peak direction, 5pm to 6pm

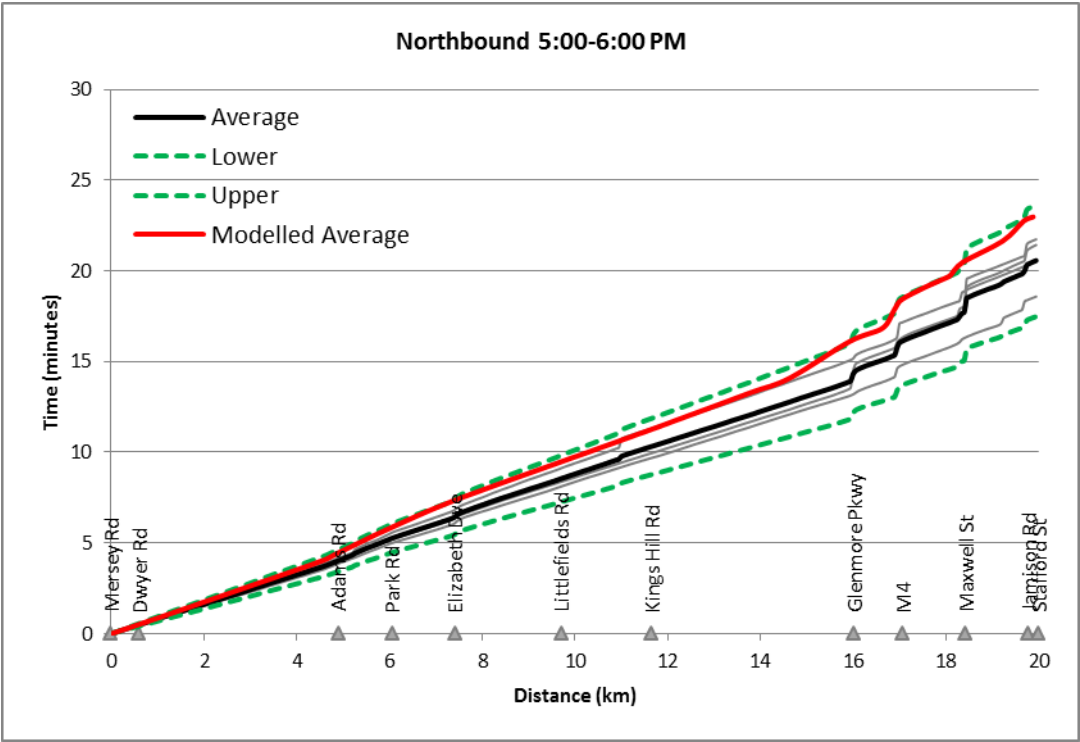
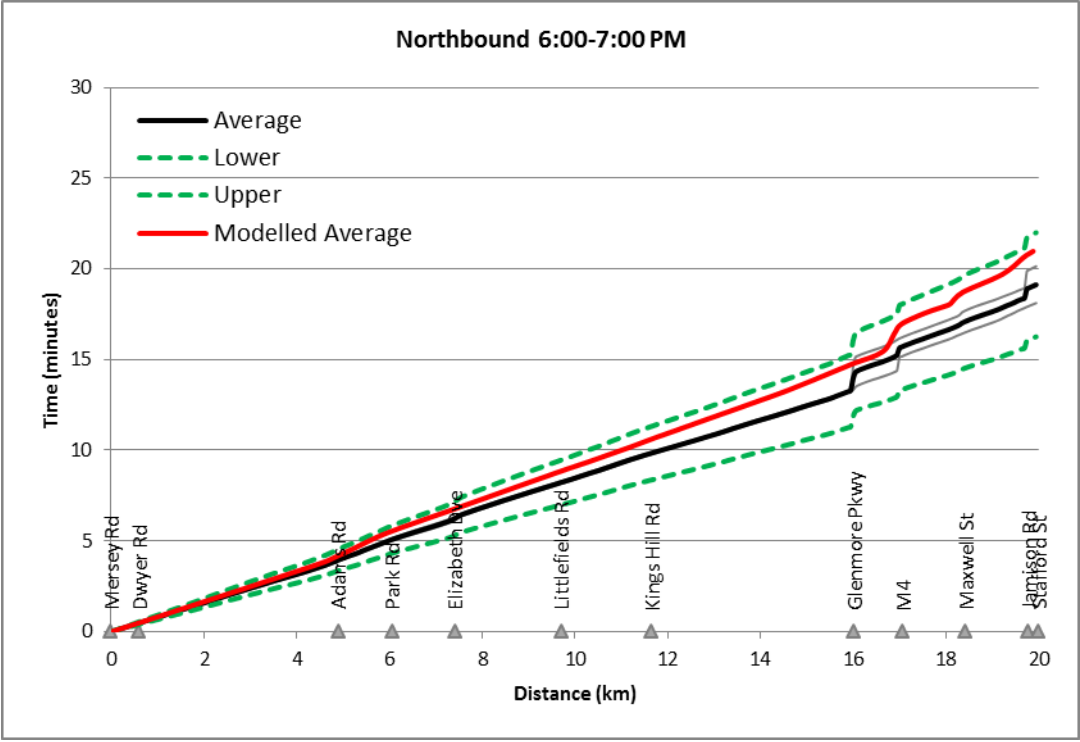


Figure C.8 : Cumulative travel time, model vs observed – counter peak direction, 6pm to 7pm



Appendix C. Elizabeth Drive Technical Note

C.1 Introduction

This technical note presents an assessment of the relative traffic performance on options for provision of connections between Elizabeth Drive and Luddenham (existing The Northern Road) and the realigned and upgraded The Northern Road as part of the upgrade of The Northern Road between Mersey Road, Bringelly and Glenmore Parkway, Glenmore Park. The options considered are:

- Two signalised T-intersections offset by around 500m; and
- 4-way signalised intersection formed by a realignment of Elizabeth Drive

The purpose of this assessment is to identify any differences in the traffic performance of the proposed options.

C.2 Methodology

To assess the relative merits of the proposed 4-way against two signalised T-intersections the following methodology was undertaken:

- Code and optimise 4-way intersection for 2041 horizon year in Aimsun;
- Code and optimise two signalised T-intersections for 2041 horizon year in Aimsun; and
- Cordon out a sub-model area (M12 Motorway to Adams Road) and model both options within this sub-area under micro simulation.

The cordoned out sub-area model is shown below.



C.3 Results

Optimisation of the proposed four-way intersection design determined that the following design changes would be required to achieve Level of Service D or better in 2041:

- Duplication of the right turn bay on The Northern Road (north approach)
- Duplication of the right turn bay on Old Northern Road (west approach)

A comparison of travel speeds along The Northern Road, network statistics including Vehicle Kilometres of Travel (VKT), Vehicle Hours of Travel (VHT), average network speed and overall intersection Level of Service for AM and PM peak is provided in Tables C1 to C4. A summary of network statistics is provided in Table C5.

Table C1: The Northern Road Travel Time and Speed – Adams Road to M12 (2041 AM Peak)

AM Peak	Northbound			Southbound		
	T	Cross	Diff.	T	Cross	Diff.
Travel Time (s)	189.8	181.3	4%	199.4	187.7	6%
Distance (m)	3,230	3,230	0%	3,344	3,344	0%
Average Speed (km/hr)	61.3	64.1	-5%	60.4	64.1	-6%

Table C2: The Northern Road Travel Time and Speed – Adams Road to M12 (2041 PM Peak)

PM Peak	Northbound			Southbound		
	T	Cross	Diff.	T	Cross	Diff.
Travel Time (s)	185.7	192.8	-4%	193.9	194.0	0%
Distance (m)	3,230	3,230	0%	3,344	3,344	0%
Average Speed (km/hr)	62.6	60.3	4%	62.1	62.1	0%

Table C3: Overall Intersection Level of Service (2041 AM Peak)

AM Peak	Average Delay (sec)		LoS	
	T	Cross	T	Cross
The Northern Road/Elizabeth Drive	49	46	D	D
The Northern Road/Park Road	35	-	C	-

Table C4: Overall Intersection Level of Service (2041 PM Peak)

PM Peak	Average Delay (sec)		LoS	
	T	Cross	T	Cross
The Northern Road/Elizabeth Drive	41	55	C	D
The Northern Road/Park Road	35	-	C	-

Table C5: Network Statistics

Total	AM Peak			PM Peak		
	T	Cross	Diff.	T	Cross	Diff.
Vehicle Kilometres of Travel (VKT)	106,129	105,539	1%	128,402	127,436	1%
Vehicle Hours of Travel (VHT)	1,735	1,634	6%	2,155	2,137	1%
Average Network Speed (km/hr)	61.2	64.6	-6%	59.6	59.6	0%

C.4 Summary and Conclusion

Analysis of the traffic performance of the proposed two signalised T-intersections and 4 way intersection shows that there is minimal difference between either options under the 2041 forecast year.

Based on the tables presented in Section C.3, overall traffic performance would be very similar between two signalised T-intersections option and one 4-way intersection. The two signalised T-intersections provide better intersection Level of Service due to the less complex phasing required to operate the two signalised T-intersections when compared with a single cross, however these cannot be directly compared. While the individual levels of service at each of the individual T-intersections (LOS C) appears better than the overall performance of the 4 way intersection (LOS D), the level of service is based on average delays and this result indicates that motorists on average experience slightly less delay at each of the T-intersections than they would at the one 4 way intersection. For any motorist that was travelling through both the T intersections, the overall delay would (on average) be greater than for the individual 4 way intersection.

Analysis of travel speed along The Northern Road indicates that average travel speeds would be higher under the 4-way intersection option than 2 T-intersections option in the morning peak but lower in the evening peak. In the morning peak with less traffic volume the 2 T-intersections option causes more stops with 2 intersection delays while in the evening peak with more traffic volume the 2 T-intersections option provide more capacity causing less congested delays compared to the 4-way intersection option.

The comparative performance of the two options depends largely on the volume of traffic travelling from Elizabeth Drive to the existing The Old Northern Road (east to west) and from the existing The Northern Road to Elizabeth Drive (west to east). Current traffic forecasts show that this movement is comparatively low.

Based on this analysis, either option would perform acceptably under the forecast demand, however the cross-intersection would perform better from an overall network perspective. The difference in traffic performance between the two options is small and may be outweighed by other factors such as community consideration, traffic signal operational factors, constructability, property impacts or cost.

While it is understood there was an overall community preference for less traffic signals located along The Northern Road, there are a multitude of other factors (as identified above) that require consideration. These factors will be considered further by the project team and would be the subject of further reporting.