CRAIG MCGEOCH
Principal Manager Road Network Analysis
Roads and Maritime Services

craig.mcgeoch@rms.nsw.gov.au

INTEGRATION OF MEGA PROJECTS INTO THE EXISTING NETWORK – THE CRITICAL ROLE OF TRAFFIC MODELLING

The NSW Government is committed to achieving one of the most ambitious infrastructure delivery tasks of recent times. The NSW State Infrastructure Strategy prioritises the delivery of a number of major public transport and road infrastructure projects to tackle congestion and sustain productivity growth in major centres and regional communities of NSW.

Roads and Maritime Services has a key role to ensure the success of these major transport projects including through expert planning and preparation for integration of these projects into the existing road network. This paper provides a high level overview of the technical analyses carried out by Roads and Maritime to inform planning for two major projects, the M4 Widening of WestConnex and the CBD and South East Light Rail, into the Sydney road network.

The paper outlines transport modelling analyses carried out to assess the forecast performance of the adjacent road network with these major projects and the integration measures identified through this modelling analysis to enable their successful implementation.

1. Introduction

Roads engineering construction in NSW is picking up, led by the ‘mega road projects’. NSW Roads and Maritime Services (Roads and Maritime) has a key role in planning and delivering these projects, including how they integrate with existing road networks, whether urban or rural. In many cases this means enhancing existing road networks with enabling works to provide additional capacity and/or connectivity as part of the major project, or identifying mitigating works to safeguard performance on the adjacent road network impacted by the project. Traffic modelling plays a critical role in informing this planning.

This paper notes the ‘Wave’ of major projects currently planned for delivery in NSW and the role that traffic modelling has and will continue to play in assessing how they will integrate with existing road networks. Some key challenges in modelling are briefly discussed.

Two case studies are presented, the M4 Widening and the CBD and South East Light Rail. Traffic modelling carried out to understand the impacts these projects are expected to have on existing road networks is described, and the responses identified from the modelling analysis to address forecast impacts are briefly discussed.

1.1 The ‘Wave’ of major projects

Roads and Maritime has an ambitious task ahead to deliver the largest series of infrastructure investments in the State’s history. Major project capital expenditure is expected to more than double to $16 billion in the next five years to transform the State’s roads, freight and maritime network. This expanded program of works is being described as the ‘Wave’ (Roads and Maritime Services, 2016). This program is illustrated in Figure 1.

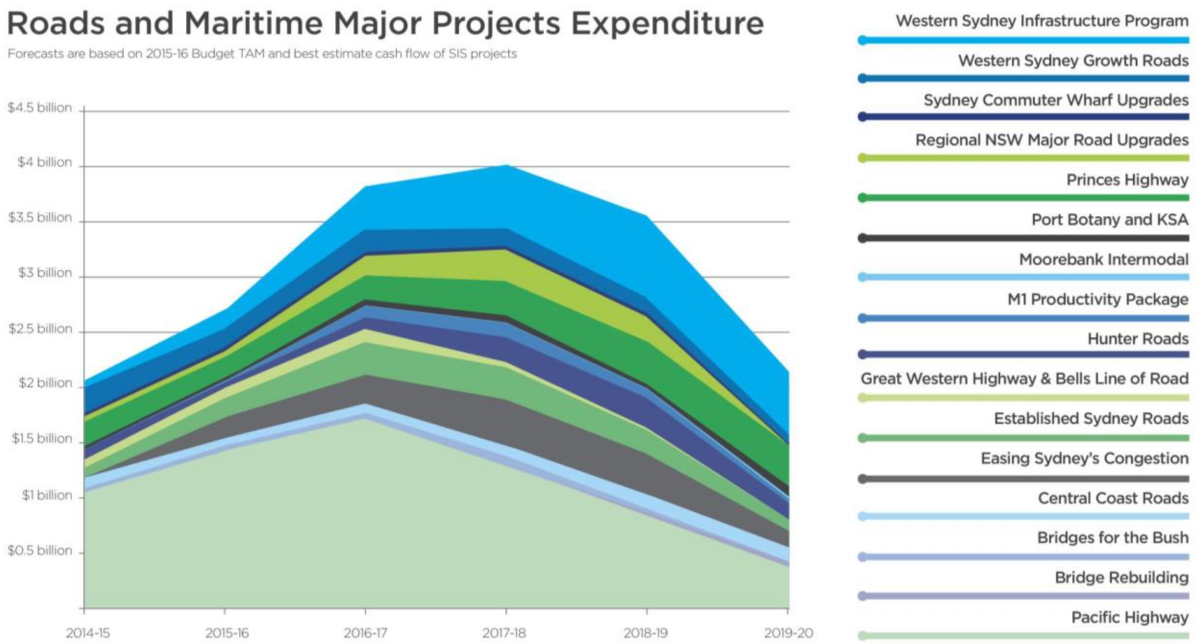

Figure 1 'The Wave' (Roads and Maritime Services, 2015)

In addition to the Wave projects, Roads and Maritime, as the Government client for the WestConnex motorway, has entered into a contractual arrangement with Sydney Motorway Corporation to design, build, own and operate the WestConnex motorway on behalf of the NSW Government. WestConnex is one of Australia's largest infrastructure projects. Roads and Maritime and Sydney Motorway Corporation are working together to manage the project planning processes for this mega project (Sydney Motorway Corporation, 2016).

1.2 The roles of Roads and Maritime

Roads and Maritime's purpose is enabling safe and efficient journeys throughout NSW. To achieve this, Roads and Maritime has the following roles (Roads and Maritime Services, 2015b):

1. To build, manage and maintain the state road and waterway network and assets.
2. To maximise the customer benefits and service potential of our networks.
3. ***To integrate our networks with private motorways, local roads and the broader transport system.***
4. To use our networks to facilitate economic and social development and growth in NSW.

Major projects such as those being planned under the Wave program and WestConnex directly impact existing road networks, through direct connections that are provided to the existing network and through the changes in travel and traffic patterns that are brought about by new major infrastructure. Roads and Maritime has a responsibility to plan integration of these projects so the existing road network can continue to operate efficiently. Traffic modelling is an essential tool for carrying out this task.

2. Modelling for future network performance

Modelling is increasingly being used to justify and prioritise investment in transport infrastructure. Modelling provides a tool not only to inform project design, so that capacity is provided to meet forecast future travel demands, or to test effects of policy interventions to manage use of the transport network, but also to produce quantified outputs for environmental, economic and in some cases financial evaluations of proposed infrastructure.

Projects of all sizes can and are now being assessed for expected performance using traffic models, ranging from local treatments to improve congestion at pinch points, through to upgrades of corridors through growth areas (such as the Northern Road in western Sydney or the Oxley Highway in Port Macquarie) and city-shaping urban infrastructure investments such as WestConnex, Sydney Metro and light rail projects in the CBD and Parramatta.

Roads and Maritime's Network Optimisation branch uses economic evaluations and business cases that are often developed from traffic modelling analyses to rank and prioritise proposed road projects to obtain best value from investment in road infrastructure. The success of this process relies upon the application of consistent, robust modelling practices. To aid this, Roads and Maritime has produced traffic modelling guidelines that provide guidance on modelling practice (Roads and Maritime Services, 2013).

The traffic modelling guidelines are intended to provide guidance on modelling to internal teams and those carrying out work for Roads and Maritime, in order to develop consistency in traffic modelling practice and promote high quality model outputs that will lead to high quality project design. The traffic modelling guidelines provide the *minimum level required for model development, calibration and validation*. The guidelines are specifically intended to provide guidance without being prescriptive or limiting the practitioner building the model.

2.1 Forecasting the benefits and impacts of major road projects

The case for investment in improving transport networks and infrastructure may be made through the requirement to provide increased mobility to sustain economic growth and productivity for growing populations (Infrastructure NSW, 2014). The NSW State Infrastructure Strategy 2014 update identifies that keeping Sydney's roads moving as demand grows is one of the principal infrastructure challenges faced by Sydney. The Wave program of works is appropriate and timely in responding to this challenge.

The role of modelling in supporting analyses for infrastructure investment is usually (at least) twofold:

1. Informing the scope and design of projects to achieve some desirable standard of operational performance for the proposed project. Modelling is used to 'size' anything from intersections (through defining numbers of lanes at stop lines) to numbers of lanes for major underground toll motorways as in the case of WestConnex.
2. Quantifying the road user benefit improvements in transport network performance resulting from project investments.

The normal approach in traffic modelling practice is to develop a 'base year' model that reflects current day network operations, then go on to forecast expected future network operations and performance under a 'do minimum' or 'business as usual' scenario and then compare this to a scenario in the future that includes a particular project(s) under investigation.

The project under investigation is then evaluated for the transport and road user benefits it produces; depending on the size of the project these may be local or may be felt across large sectors of the road network.

In planning for integration of major projects it is important to define desirable 'standards' for future operational performance of the project and the road network. Major transport projects deliver improved outcomes across large areas of the network, and it is usually straightforward to identify performance on the major project itself. At some locations major projects may introduce new impacts, for example a new light rail line passing through an existing intersection. In these locations standards or targets for desirable performance in what can sometimes be already congested[1] areas need to be defined. Examples of such standards could be: 'performance at critical locations should be no worse than it would otherwise be in the future without the project' or more absolute requirements such as 'performance should be no less than Level of Service (X)'. This could be for sections of road or for key intersections, whether as a whole or for every individual movement at impacted intersections. Defining the 'list' or an area of impacted streets/intersections is also a key consideration in assessing integration of mega projects.

2.1.1 Modelling a realistic base case

The evaluation of road user benefits arising from road projects requires the development of business as usual models for future years that do not include the project under investigation. This can be an area of potential pitfalls in operational modelling, particularly for mega projects.

The experience of modelling in NSW cities and towns is that forecast road traffic growth is often closely linked to population growth. The additional travel expected to be generated by increasing population forecasts can be readily dealt with in strategic demand models, as these will simply assign the entire forecast travel demand to the network, optimising the choices of route that flows of vehicles make, even where the choices may be (equally) poor in terms of forecast travel times and speeds.

Identifying the localised works necessary to integrate major projects into the road network requires a more detailed level of modelling than is provided in strategic modelling, and micro-simulation or micro-models are typically used for this analysis.

These micro-level models place real limits on the ability of the model network to carry traffic. The experience on several large project evaluations in NSW recently has been that future forecast traffic demands produced by strategic models that are in excess of the operational model network's capacity are unreleased and the demands that are released can lead to gridlock within the model, leading to an inability to measure network performance in future years. This has been seen in micro-simulation and in mesoscopic modelling.

This perhaps raises some wider questions around the ability of our road networks to carry ever increasing travel demands under a status quo outlook for travel behaviour, and also the potential

[1] It is worthwhile and interesting to note that traffic models do not output a value for 'congestion' *per se* and are not able to directly forecasts savings or reductions in 'congestion'. Instead, traffic models produce proxy indicators including volume/capacity ratios (which can be misleading as indicators of congestion as these are based on non-linear functions for volume and speed so that a v/c ratio on one type of link may result in a proportional decrease in speed from free-flow that is very different for the same v/c ratio on another class of link), lane densities, ratios of forecast travel speeds to posted or free-flow speeds ('delay index'), Level of Service among others that require interpretation to represent congestion. Congestion is commonly understood to occur when traffic volumes exceed roadway capacity. BTRE (2007) provides an illuminating discussion on definitions of congestion. It notes that congestion is a measure of the difference between actual traffic flows (and costs) and the *economically optimal* traffic flows. The optimal traffic flow is not one at which everyone can travel at free-flow speeds, this would require an inordinate investment in infrastructure capacity to achieve.

influence of technology developments, in particular driverless cars. However at this time, while work is being done on dynamic traffic assignment to better reflect real world capacity constraints (e.g. Bliemer, Raadsen, de Romph and Smits, 2013 and Bliemer, Raadsen, Smits, Zhou and Bell, 2014) and on driverless cars (Department of Main Roads, 2016), a practical approach is not yet widely in use for dynamic modelling of large networks, nor is there yet a sufficient evidence base for the impacts of driverless cars to an extent that the impacts of these can be forecast practically in road project planning.

A challenge then in operational modelling for integration of major projects is to develop realistic future year business as usual operational models. Selection of methodologies to develop future year demands for use in operational modelling is a key methodological consideration. The Roads and Maritime traffic modelling guidelines note that it is not acceptable to simply take forecast demands directly from a strategic model and assume that these are appropriate for forecasts in operational modelling. In the absence of wide-area dynamic models and strategic models with time of day choice sub-models, a pragmatic response that has been used in recent studies is to reflect assumptions around peak spreading.

3. Case Studies

3.1 M4 Widening Road Network Performance Mitigation Plan (RNPMP)

The M4 widening project currently under construction will provide four lanes in each direction between Church Street, Parramatta and Homebush Bay Drive, Homebush. By providing an extra lane for motorists using this section of the motorway, it will help to alleviate congestion around the James Ruse Drive ramps, and provide quicker and more reliable journeys for motorists and freight. New access points into and out of Parramatta will also cut down travel times for workers and businesses using the M4 every day (WestConnex Delivery Authority, 2013).

The M4 Widening project is shown in Figure 2.

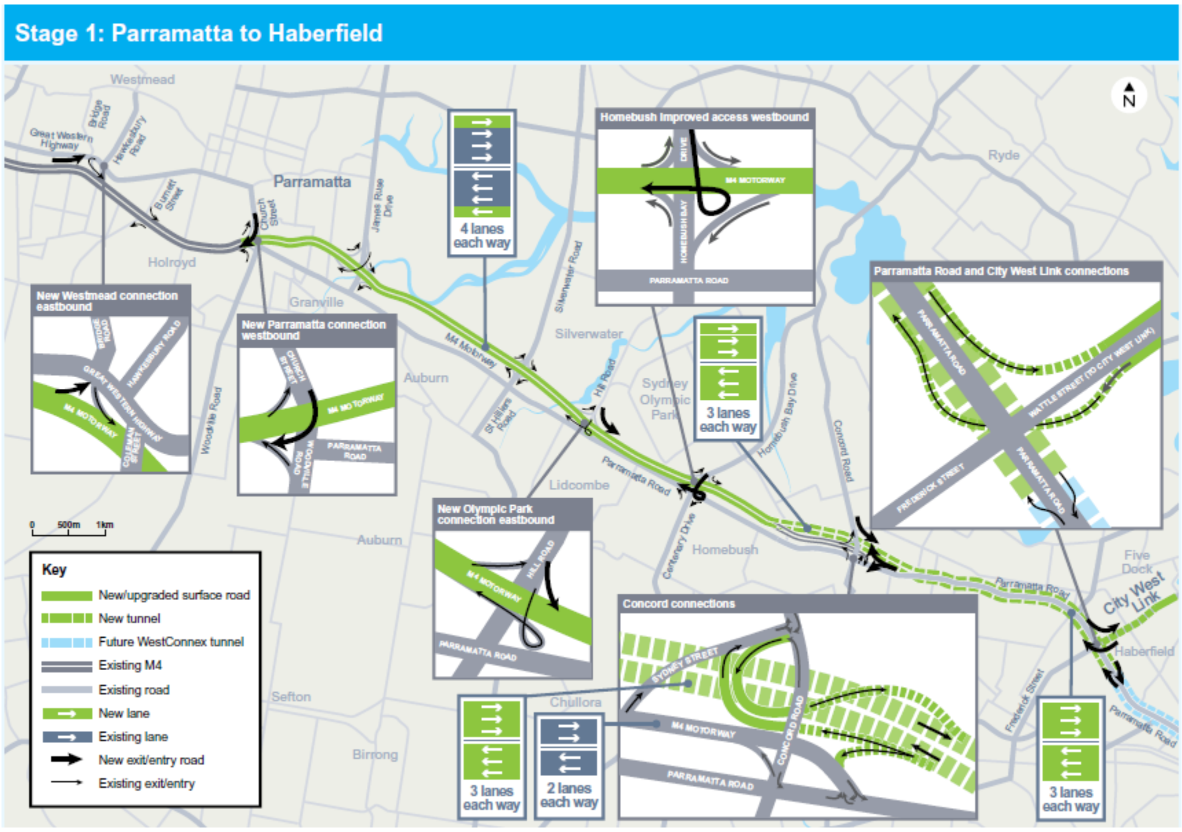

Figure 2 WestConnex M4 Widening (WestConnex Delivery Authority, 2013)

On 21 December 2014, the NSW Government Minister for Planning granted approval to the State Significant Infrastructure (SSI) application for the WestConnex M4 Widening Environmental Impact Statement (EIS). The infrastructure approval, which is regulated under Section 115ZB of the Environmental Planning and Assessment Act 1979, is subject to the Minister's conditions of approval for the SSI.

The conditions of approval process is administered by the NSW Department of Planning and Environment (DP&E) and delivered by the Proponent – in this case Roads and Maritime Services. The conditions of approval for M4 Widening are structured by administrative and technical workstreams (within five parts); with deliverable dates based on a pre and post construction project schedule.

Part B of the conditions includes conditions for technical workstreams that fall under the banner of environmental performance. Several of the Minister's approval conditions contained within sub-section B12-B18 are applicable to Transport and Access and in reference to the EIS Appendix D: Traffic and Transport Working Paper – Working Paper 4.

3.1.1 M4 Widening Conditions of Approval B15 and B16

Condition B15 requires that Roads and Maritime, as proponent for the M4 Widening, prepares a Road Network Performance Mitigation Plan (RNPMP). The purpose of the RNPMP is to set out how Roads and Maritime will manage the operational performance impacts of the project on the adjoining road network; by identifying mitigation measures for areas where traffic performance may be unsatisfactory before and after the M4 Widening opens to traffic. The mitigation measures identified fall into two categories, those that will be implemented before completion of construction of the project and those that may be implemented after completion of the project, subject to actual road network performance in the period after opening of the project.

3.1.2 Modelling for the RNPMP

These conditions required Roads and Maritime to assess the expected future performance of the existing road network and key interchanges both with and without the M4 Widening project in place. Importantly, Roads and Maritime was required to identify and develop a plan for implementing mitigating works *before* the M4 Widening project becomes operational.

The application of traffic modelling analysis was the only means to properly address this requirement.

Roads and Maritime developed the M4 Widening RNPMP with the purpose of setting out how the agency will manage the operational performance impacts of the M4 Widening on the adjoining road network, by identifying mitigation measures for areas where traffic performance may be unsatisfactory before and after the M4 Widening opens to traffic.

LinSig (version 3) and SIDRA (version 6) were selected as the appropriate software tools to model the operational performance of signalised interchanges and intersections within the study area for existing and future year scenarios. The majority of intersections were assessed using LinSig, which is a modelling platform capable of assessing the performance of co-ordinated networks of signalised intersections. One of the strengths of LinSig is that it allows for the optimisation of traffic signal timings across the network in accordance with the release of traffic demand, therefore providing for the greatest network benefits to be captured. Some isolated intersections were individually assessed using SIDRA. Intersections for assessment using coordinated operations in LinSig were grouped into 'clusters' as shown in Figure 3 and Figure 4.

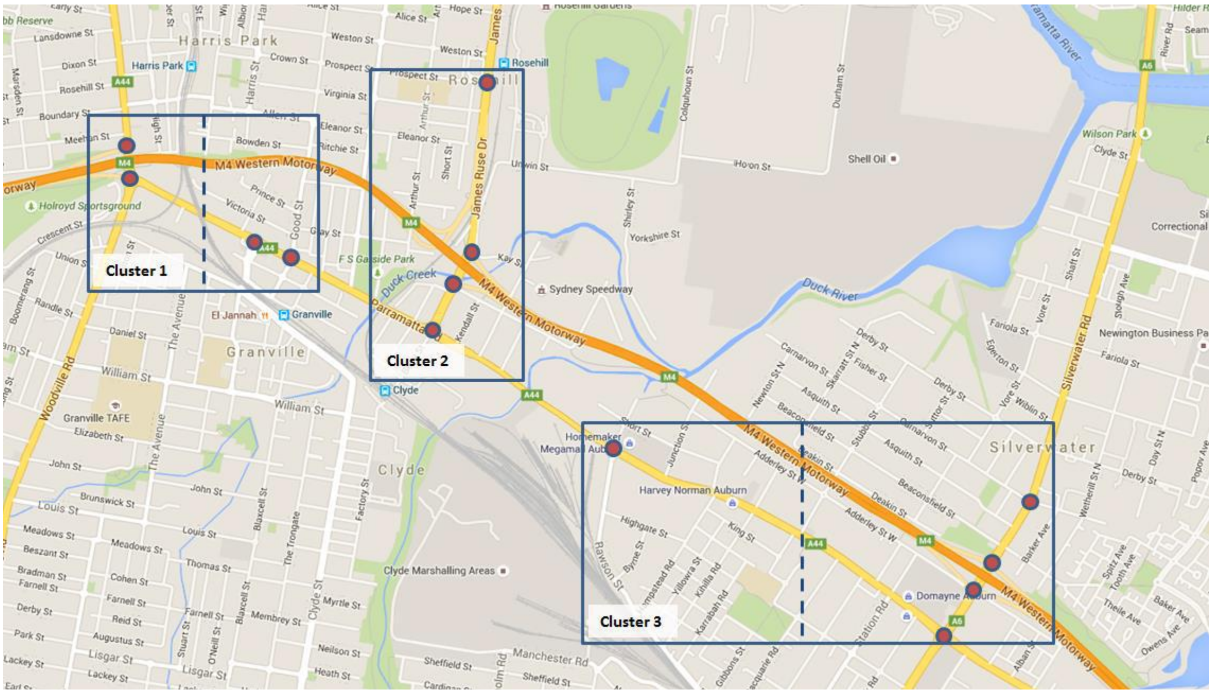

Figure 3 Modelled LinSig analysis clusters – western sector (Roads and Maritime, 2016b)

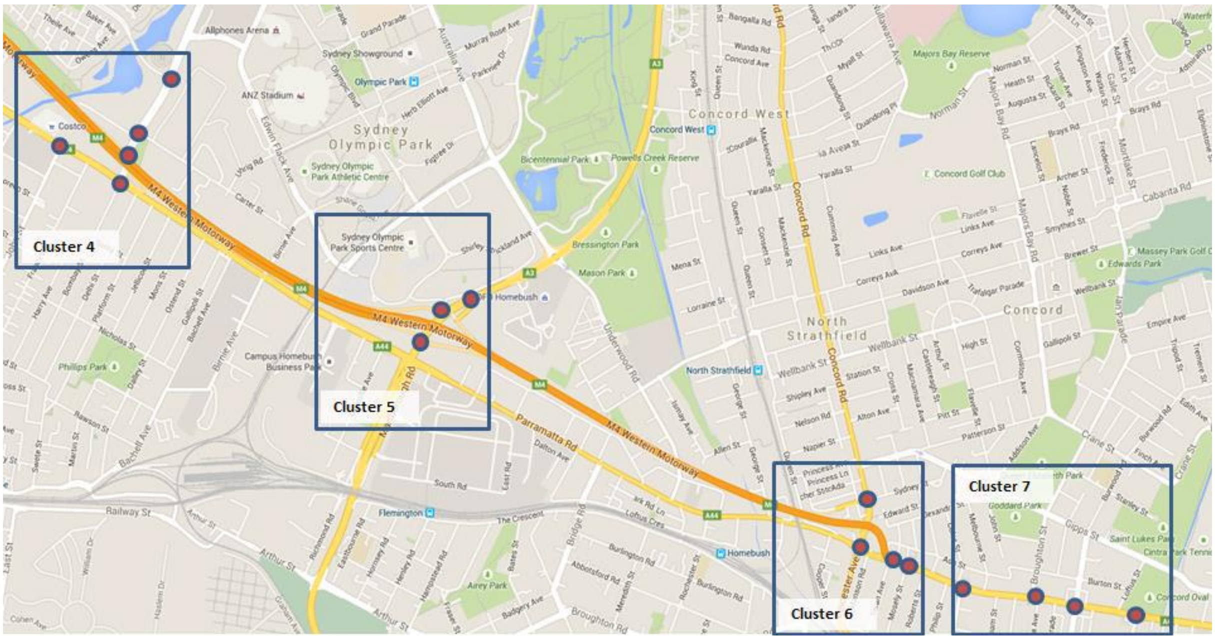

Figure 4 Modelled LinSig analysis clusters – eastern sector (Roads and Maritime, 2016b)

Critical criteria in the assessment of existing and future conditions for M4 Widening were selected as the intersection Level of Service (LoS) index and traffic queueing on the most affected approach road.

3.1.3 Future year demand

A previous section of this paper discussed the importance of developing robust future year demand scenarios. Strategic modelling for the M4 Widening project was carried out using the WestConnex Road Traffic Model (WRTM), which forecast traffic and growth in traffic volumes on the M4 Widening and Parramatta Road transport corridor and other key roads in the study area based on expected land use changes and proposed road network improvements. This model provided the source of strategic level growth forecasts for the network surrounding the M4 Widening project both with and without the project. For scenarios with the project, the WRTM includes forecasting of induced demand.

From the strategic demand forecasts estimated by WRTM, the absolute growth on the network could be derived for each of the modelling scenarios (i.e. with and without M4 Widening). This absolute growth in movements within the study area was then applied additively to the base year balanced vehicle turning counts, derived from surveys undertaken on the network, and used to create the traffic flows utilised in the future year modelling.

This approach, which is consistent with Roads and Maritime traffic modelling guidelines (Roads and Maritime Services (2013), p.200), makes best use of observed traffic count data as the basis for future year travel demand volumes and patterns. More specifically, this approach provided the most accurate representation of how the modelled future traffic growth would affect existing observed network traffic demands and the resultant network operation.

3.1.4 Summary results

A total of 42 pre-opening mitigation measures were developed with the aim of maximising the operational efficiency of the existing road network when the M4 Widening is open to traffic.

The objective of reviewing modelling results for the with and without mitigation scenarios was to illustrate the predicted operational impacts of the pre-opening mitigation measures in comparison to the future road network with the M4 Widening and subsequent WestConnex stages being open to traffic. The modelling results indicated that, in the 2021 AM peak forecast period:

- All of the modelled intersections are predicted to perform at similar or better operational levels in comparison to the RNPMP Base 'Do something' scenario
- Three intersections are predicted to operate with a reduction in average delay, including Hill Road and Carter Street within Cluster 4, which shows a significant improvement in performance levels.

The modelling results indicated that, in the 2021 PM peak period:

- All of the modelled intersections are predicted to perform at similar or better operational levels in comparison to the RNPMP Base 'Do something' scenario
- Seven intersections are predicted to operate with relatively minor reductions in average delay

The M4 Widening RNPMP traffic modelling results indicate that a combination of pre-opening and potential post-opening mitigation measures could significantly improve the operational performance of the Parramatta Road transport corridor; if implemented before and after the M4 Widening opens to traffic.

Initially, the implementation of the RNPMP will be critical in determining the success of its pre-opening mitigation measures and their operational objectives.

The implementation of potential post-opening mitigation measures will be the subject of detailed assessments underpinned by traffic volumes that will be recorded once the M4 Widening is open to traffic and operating under stable conditions.

3.2 City and South East Suburbs Light Rail (CSELR)

In December 2012, the NSW Government announced it would extend light rail from Circular Quay to Kingsford and Randwick, through the heart of the Sydney CBD via George Street. The CSELR proposal is shown in Figure 5.

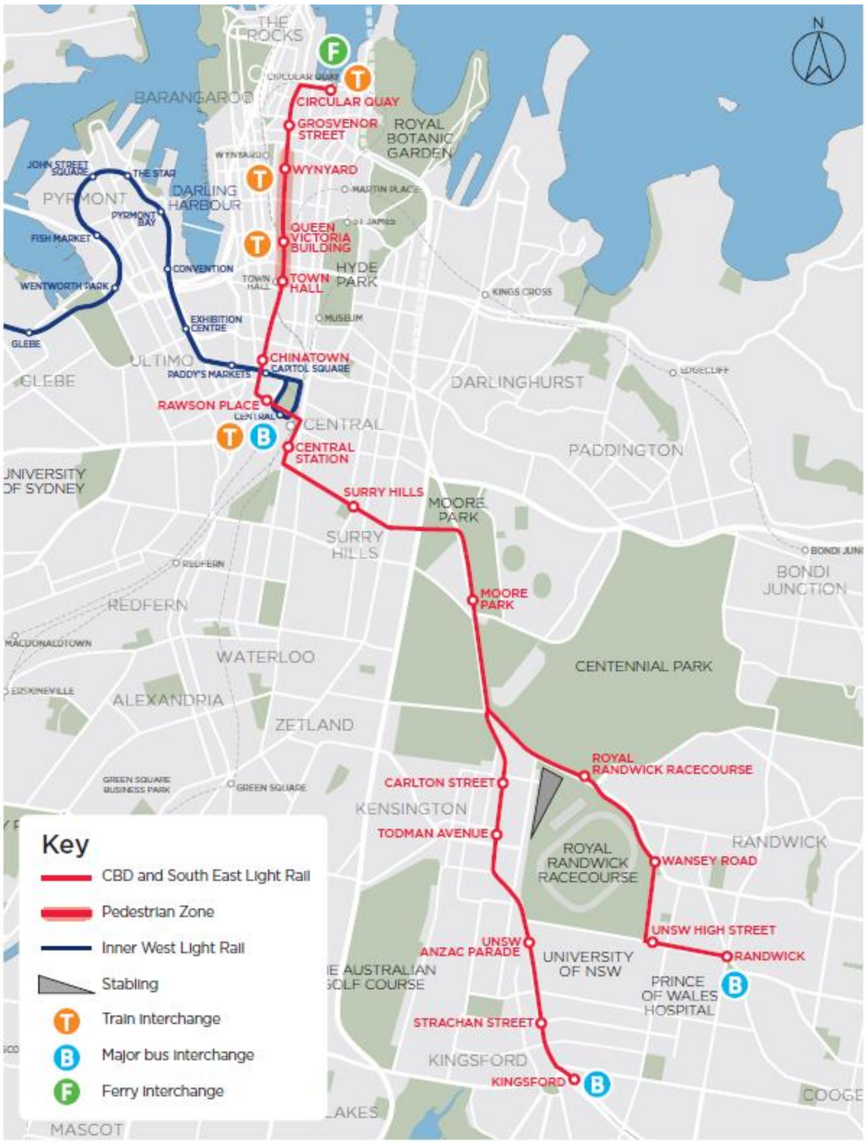

Figure 5 CBD and South East Light Rail (Transport for NSW, 2015)

The Project includes 19 stops and will integrate with both the bus network and heavy rail stations at Circular Quay, Wynyard, Town Hall and Central. Services will be provided by 67 metre low-floor light rail vehicles, providing capacity for up to 466 customers (the equivalent of five standard length buses). The line will operate in a dedicated light rail lane, minimising competition with other modes of transport such as cars and buses. In addition, light rail will be given signal priority at intersections where possible to deliver service reliability substantially better than existing bus services (TfNSW, 2013).

3.2.1 Integrating with the road network

A light rail system, by its nature as a road based public transport mode, needs to be designed into the road network and requires detailed consideration of all modes and associated management issues.

Introduction of the CSELR and the associated supporting bus network changes in the CBD and South East Sydney will result in a considerable change to current traffic operating patterns. Providing a segregated route for the light rail to maximise public transport network carrying capacity will necessarily displace some road-based traffic.

The most significant change in Sydney's CBD with CSELR is the transformation of George Street from a vehicle-based north-south corridor to a part-pedestrianised public transport spine, dedicated to the efficient delivery of light rail services to the heart of the city. The pedestrianised zone being delivered in conjunction with light rail yields substantial sustainability and amenity benefits, however the impacts of traffic displaced from this spine to other areas of the road network need to be acknowledged. The EIS for CSELR examined appropriate mitigation strategies to manage those consequences, informed by detailed traffic modelling (TfNSW, 2013).

3.2.2 Modelling analysis to integrate CSELR

A two-tiered modelling approach was adopted for the analysis of the EIS to first address localised design issues and secondly identify the wider network effects.

This first tier of assessment used LinSig to assess co-ordinated signal operations on sections of the light rail corridor. SIDRA was also used to assess a number of isolated intersection operations and optimise designs.

A VISSIM micro-simulation model was used to assess the impacts of an at-grade light rail crossing of South Dowling Street in the Surry Hills precinct. VISSIM was used due to its ability to model light rail priority through selective vehicle detection and signal actuations.

Commuter nano-simulation models were also developed for:

- South Dowling Street
- Anzac Parade / Alison Road / Dacey Avenue
- Kingsford / Nine Ways

to assess critical light rail interactions with road traffic at these locations. Modelling with Commuter at these locations led to the improvements and modifications being adopted for the reference design for the light rail.

To provide analysis on broader future network and corridor operations with the introduction of light rail, a second tier of modelling was carried out by TfNSW in collaboration with Roads and Maritime. This analysis developed an area-wide mesoscopic model implemented in the Aimsun platform, with a large part modelled using a hybrid model concept. The hybrid simulator concept allowed for dynamic simulation of an area large enough to account for regional route diversion (as shown in Figure 6), as well as micro-simulation modelling of smaller pockets that require representation of individual vehicle dynamics in the detailed road network.

Figure 6 CSELR mesoscopic model area

3.2.3 Signal operations

CSELR operations propose that Light Rail Vehicles (LRVs) will progress through intersections under signal control. The proposed light rail route will pass through some 60 signalised intersections.

Traffic signals are proposed to be designed to detect the approach of an LRV in sufficient time to activate a ‘call’ green signal for the LRV as it approaches the intersection. The traffic light controller would ensure that other conflicting movements (i.e. cross roads and pedestrian crossings) face red or stop signals.

The design intent is for LRVs to be able to proceed through all intersections with minimal delay (TfNSW, 2013). However, the design of each intersection must have regard to all road users and the overall performance of the transport network including road traffic.

The Sydney Coordinated Adaptive Traffic System (SCATS) is designed to ensure the operation of each intersection achieves the optimal performance for the network as a whole. With some 140 SCATS controlled intersections in Sydney CBD, SCATS provides critical control of road network operations in the city centre.

During the CSELR tender process, Roads and Maritime and TfNSW agreed to update the EIS Aimsun mesoscopic model to incorporate SCATS, in order to better understand the operational impacts of light rail operations on the city centre road network. This was understood to be the first time that an Aimsun mesoscopic had dynamic SCATS operations incorporated into it.

Roads and Maritime and TfNSW are now proceeding with further development of the CSELR end state Aimsun model, which will include SCATS operations and modelling of LRVs through inclusion of a micro-simulation corridor within the model to represent progression of individual vehicles through the road network. This will be the first attempt at having a fully integrated light rail and road model to assess the operational impacts of CSELR on the CBD and South East road network.

3.2.4 Future year for modelling and road traffic demands

A future assessment year of 2021 was adopted for the analysis of the CSELR EIS. Future year strategic road traffic demands for this year were sourced from the TfNSW Public Transport Project Model (PTPM) and Freight Movement Model (FMM), however PTPM only provides AM peak period forecasts.

From each of these models, the difference between the 2011 base year and the two 2021 forecast scenarios (one scenario with CSELR and one without) was calculated. As the PTPM does not forecast PM travel, a methodology for calculating PM demands was developed based on transposing the AM peak period forecasts. Furthermore, as the strategic models produce two-hour peak period forecasts and the mesoscopic model simulates a four-hour period, the demand forecasting process included expansion of two-hour demand to four-hour demands based on the base year mesoscopic model profiles.

The resulting growth for the four-hour AM and PM peak periods calculated from the strategic models was applied using an additive method to the four-hour AM and PM base year mesoscopic model matrices to generate future year demands for operational modelling.

Again, the question of forecasting 'reasonable' future year demands was an issue. Due to the level of 'congestion' evident on the network of the future year PM peak model, a flat demand profile across the four-hour period was applied reflecting an assumption of peak spreading.

3.2.5 Summary results

The modelling analysis of the EIS for CSELR reported on the following network performance measures:

- Global network statistics (VKT, VHT)
- Network traffic volumes
- Network speeds
- Intersection delays

The EIS for CSELR describes that broadly speaking, the traffic analysis demonstrates that the CSELR project can be introduced into the road network without significant detrimental impact to general traffic and buses. A number of key intersections have been identified where further design and optimisation work is under way to provide increased capacity (TfNSW, 2013).

To address the effects of the identified future traffic patterns, TfNSW and Roads and Maritime are working together to develop an appropriate Network Management Plan (NMP). This will include intersection modifications, traffic signal changes and traffic management measures that integrate to deliver the overall strategy for network operations with CSELR in place. This work is ongoing and the modelling assessment of the EIS represents the first stage in the development of this wider NMP. As this plan is refined further improvement to the operation of the network is likely to be achieved.

4. Conclusion

Investment in transport infrastructure is necessary to provide increased mobility required to sustain economic growth and productivity for growing populations. The NSW State Infrastructure Strategy 2014 update identifies that keeping Sydney's roads moving as demand grows is one of the principal infrastructure challenges faced by Sydney.

In responding to this, Roads and Maritime has an ambitious task ahead to deliver the single largest series of infrastructure investments in the State's history. Planning for these mega projects must include assessment of how the projects will integrate with the existing road network. Traffic modelling is essential to this task.

Operational traffic modelling for integration of mega road projects is not without its challenges. The experience on several large project evaluations in NSW recently has found future forecast traffic demands produced by strategic models are in excess of the operational model network's capacity, leading to an inability to measure network performance in future years. A challenge then in operational modelling for integration of major projects is to develop realistic future year business as usual models.

Traffic modelling was and continues to be used extensively for the WestConnex and CSELR mega projects to aid Roads and Maritime in planning how to integrate these projects into the existing road network.

In the case of the M4 Widening project of WestConnex, the conditions of approval for this State Significant Infrastructure application required Roads and Maritime to develop a Road Network Performance Mitigation Plan to identify how the agency will manage the operational performance impacts of the SSI on the adjoining road network.

Roads and Maritime used LinSig and SIDRA modelling to assess a range of potential pre- and post-opening measures. The RNPMP traffic modelling results indicate that a combination of pre-opening and potential post-opening mitigation measures could significantly improve the operational performance of the Parramatta Road transport corridor.

For CSELR, a two-tiered modelling approach was adopted for the analysis of the Environmental Impact Statement to first address localised design issues and secondly identify the wider network effects.

Localised design issues were assessed using SIDRA, LinSig, VISSIM and Commuter models. Regional route diversion effects were assessed through development of an area-wide mesoscopic model implemented in the Aimsun platform, with a large part modelled using a hybrid model concept.

The EIS for CSELR describes that broadly speaking, the traffic analysis demonstrates that the CSELR project can be introduced into the road network without significant detrimental impact to general traffic and buses.

TfNSW and Roads and Maritime are working together to develop an appropriate Network Management Plan (NMP) for implementation of CSELR. This will include intersection modifications, traffic signal changes and traffic management measures that integrate to deliver the overall strategy for network operations with CSELR in place. To inform this, Roads and Maritime and TfNSW are now proceeding with development of the CSELR end state Aimsun model, which will include SCATS operations and modelling of LRVs. This will be the first attempt at having a fully integrated light rail and road model to assess the operational impacts of CSELR on the CBD and South East road network.

5. References

Bliemer, M., Raadsen, M., de Romph, E. and Smits, E-S. (2013). *Requirements for traffic assignment models for strategic transport planning: A critical assessment*. Institute of Transport and Logistics Studies, the University of Sydney. Retrieved from http://sydney.edu.au/business/__data/assets/pdf_file/0015/180042/ITLS-WP-13-16.pdf

Bliemer, M., Raadsen, M., Smits, E-S., Zhou, B. and Bell, M.G.H. (2014). *Quasi-dynamic traffic assignment with residual point queues incorporating a first order node model*. Transportation Research Part B: Methodological, 2014, vol. 68, issue C, pages 363-384

Bureau of Transport and Regional Economics (2007). *Working Paper 71: Estimating urban traffic and congestion cost trends for Australian cities*. Retrieved from https://bitre.gov.au/publications/2007/wp_071.aspx

Department of Main Roads, Queensland (2016). *Conceptual sensitivity modelling and analysis on the introduction of autonomous vehicles*. Brisbane, Qld: Author.

Infrastructure NSW (2014). *State Infrastructure Strategy Update 2014 – Recommendations to the NSW Government* (p.28). Retrieved from http://www.infrastructure.nsw.gov.au/media/43622/inf_j14_871_sis_report_book_web_new.pdf

Roads and Maritime Services (2013). *Traffic Modelling Guidelines*. Retrieved from http://www.rms.nsw.gov.au/business-industry/partners-suppliers/documents/technical-manuals/modellingguidelines.pdf

Roads and Maritime Services (2015). *Major Projects 2020 Forum*. Retrieved from http://www.rms.nsw.gov.au/documents/about/corporatepublications/major-projects-2020-forum.pdf

Roads and Maritime Services (2015b). *2014-15 Annual Report*, p.8. Sydney, NSW: Author

Roads and Maritime Services (2016). *Easing Sydney's Congestion Program Office*. Retrieved from http://www.rms.nsw.gov.au/projects/easing-sydneys-congestion/index.html

Roads and Maritime Services (2016b). *WestConnex M4 Widening: Road Network Performance Mitigation Plan*. Sydney, NSW: Author

Sydney Motorway Corporation (2016). *About Sydney Motorway Corporation*. Retrieved from http://www.westconnex.com.au/about/about_sydney_motorway_corporation.html

Transport for NSW (2013). *CBD and South East Light Rail Project. Environmental Impact Statement: Volume 2, Technical Paper 1, Transport Operations Report*. Retrieved from http://www.sydneylightrail.transport.nsw.gov.au/information/resources?type=CSELR-Environmental-Impact-Statement

Transport for NSW (2015). *CBD and South East Light Rail Route Map*. Retrieved from http://www.sydneylightrail.transport.nsw.gov.au/information/maps

WestConnex Delivery Authority (2013). *WestConnex Stage 1: Parramatta to Haberfield, Fact Sheet*. Retrieved from http://www.westconnex.com.au/documents/westconnex_factsheet_m4_stage1_sep2013.pdf