Willumsen Advisory Services

North East Link Authority: Environmental Effect Statement (EES) for North East Link

Transport Model Peer Review Report

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Prepared for:

North East Link Authority

Melbourne

Australia

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1. Introduction

1.1. The assignment

North East Link Authority (NELA) is preparing an Environment Effects Statement (EES) in respect of the proposed North East Link (NEL) project. I have been retained by Clayton Utz on behalf of NELA to undertake a technical peer review of the strategic transport model and associated strategic transport modelling reports prepared for the EES (Transport Modelling Reports).

I understand that the objective of my peer review is to ensure that the Transport Modelling Reports:

a. adequately address the relevant requirements of the EES Scoping Requirements and the "public works" declaration; and

b. are suitable to represent the strategic transport effects of the NEL project.

In this regard my peer review is expected to assess the process, methodology and assessment undertaken in preparation of the Transport Modelling Reports including any assessment criteria applied and assumptions relied upon. In addition, my peer review is to identify any additional matters which should be considered in order to address the EES Scoping Requirements, 'public works' Order or to otherwise adequately assess the strategic transport effects of the Project.

1.2. The peer review process in outline

In undertaking this peer review I had to:

- Review background material on the project itself and other interventions in the city;
- Review the appropriate standards applicable to transport demand modelling and forecasting;
- Review the scope adopted for the strategic transport model
- Read the Reports identifying assumptions, methodology and parameter values;
- Contrast these with international best practice;
- Review the data collection planned and delivered and how it was used to calibrate the base year.
- Visit the site to gain familiarity with conditions and expectations;
- Hold meetings with modellers and forecasters that prepared the traffic projections in order to clarify issues not always present in reports;

- Review the assumptions supporting the growth in traffic and whether this can be considered robust and acceptable;
- Specify and review additional work that may be necessary to deliver projections of the necessary strength to provide the required confidence;

I received a number of documents in preparation for the peer review:

- North East Link Business Case documents including Executive Summary, Modelling Report, Option Assessment, Transport Assessment and the 14 chapters of the full report.
- Multiple Reports, Notes and Spreadsheet from the Veitch Lister Consulting (VLC) including:
  1. Commercial Vehicles Note: CV Tech Note RevB;
  2. NEL model development report (base case model assumptions);
  3. NEL model specification spreadsheet (summary of model assumptions);
  4. Model wide validation;
  5. NEL Local Area Model validation;
  6. Backcasting summary report;
  7. Review of Travel Forecasting Methodologies;
  8. Model calibration reports - generic calibration reports, explaining how the model works (40 reports);
  9. Value of Travel Time Savings VTTS Report;
  10. Speed Flow relationship review;
  11. Local area model calibration Model C (the version used for the EES).

I travelled to Melbourne at the end of July beginning of August to perform a field visit, travelling along the route and area of influence with a consultant familiar with the model and project. I also had extensive discussions with the VLC modelling team. As a result of these discussions I requested further clarifications and the production of an overall summary report. As I wanted to examine the parameter values calibrated or chosen for the model I requested a detailed list of them and their source including any used in forecasting. As I was particularly interested in the assumed behaviour in the toll choice model as this has been a source of miscalculation in the past, I requested more information on them. I also found that the treatment of uncertainty and risk did not go deep enough, in particular dealing with the advent of Mobility as a Service (MaaS) and

Connected and Automated Vehicles (CAV). As a result of these requests the following files and documents were subsequently provided:

12 Transport Modelling Summary, the requested document including appendices A, B and C;

13 Model Forecasting Assumptions;

14 Destination Choice Parameters;

15 Mode Choice Parameters;

16 PT Assignment Parameters;

17 Traffic Assignment Parameters;

18 Toll diversion curves;

19 Note commenting on parameter values;

20 Memo presenting possible additional scenarios;

21 NEL Project Description for EES Specialists Updated project description as provided to specialists;

22 Modelled outputs depicting travel time savings as provided by VLC.

Following my initial review of the materials received I recommended a framework to prepare formal scenarios to deal with future uncertainty. This was then addressed and reported by VLC[1].

During the performance of this peer review I also considered a number of separate documents stating the recommended modelling practice in Australia, and Victoria in particular. These included:

23 ATAP Australian Transport Assessment and Planning Guidelines

24 Transport Modelling Guidelines Victoria Volume 2 Strategic Modelling Version Draft 3 April 2012

25 Strategic Transport Model Elasticity Guidelines. DEDJTR 2015

26 Presentation to Senate, Economic References Committee Inquiry: Toll Roads in Australia

27 Victoria State Government Guidance on risk and uncertainty

28 Infrastructure Victoria Guidance on automated and zero emissions vehicles

[1] VLC(2019) Alternative Future Scenarios – Emerging Technologies. Report dated January 2019

29 Transport Infrastructure Victoria Evidence Report on automated and zero emissions vehicles.

I also considered similar documents produced in the UK Department of Transport, in particular WebTag, that complement the guidelines above.

2. The North East Link Project

2.1. Context

It has been argued that North East Melbourne lacks sufficient high quality infrastructure and that this results in heavy traffic using what are, in effect, arterial access roads to residential areas. Moreover, there is evidence of not just congestion but also significant variability on travel times trying to bridge this gap between the Eastern Freeway and the M80.

The North East Link will complete the “missing link” in Melbourne’s orbital freeway network and establish a continuous freeway-standard orbital road around Melbourne, between Altona in the west and Frankston in the south.

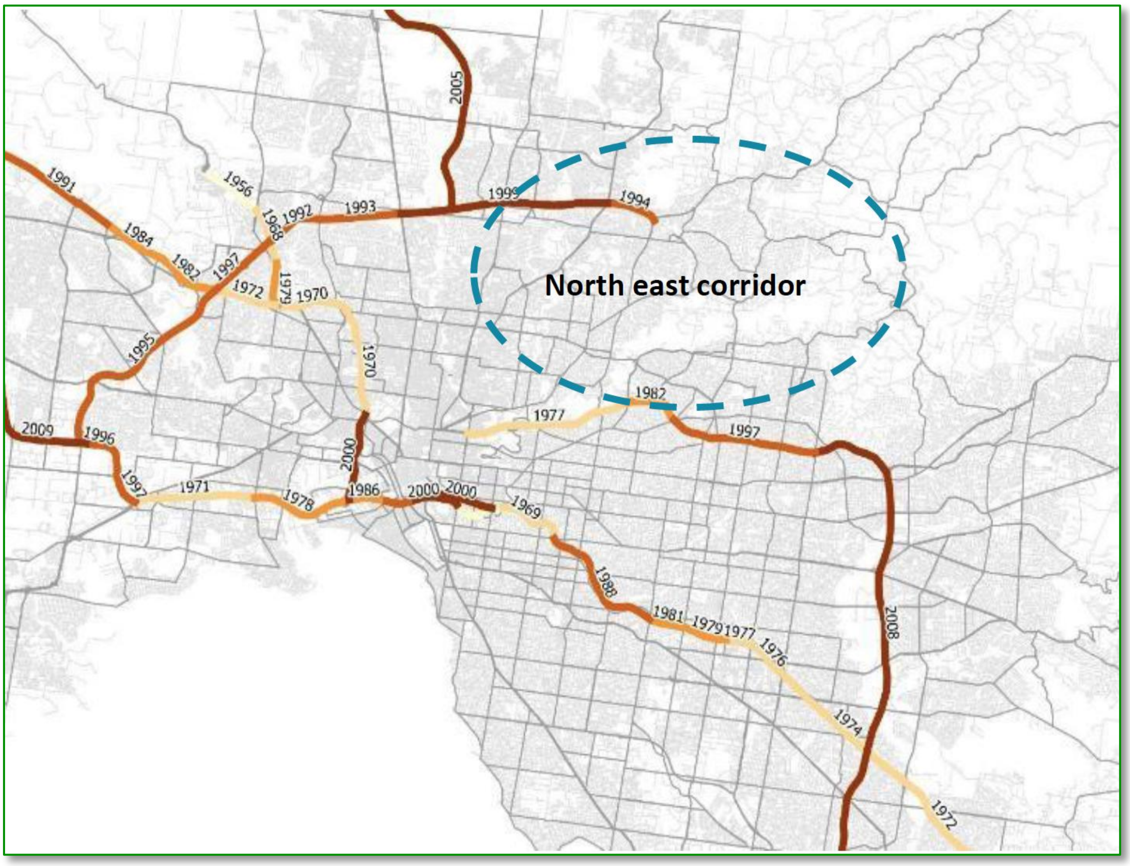

Figure 1 Context for the North East Link.

Source: NEL Business Case

2.2. North East Link

The proposed new North East Link will begin on the Eastern Freeway at Springvale Road before connecting via a new roadway to the M80 Ring Road at Greensborough. The main roadway will extend approximately 11 kilometres from the eastern end of the M80 to the Eastern Freeway at Bulleen and will be tolled. The northern section of the new link will run at surface before descending into a cutting near Watsonia Road and into tunnels at Lower Plenty Road, and then transitioning to a viaduct structure just north of Koonung Creek to connect to the Eastern Freeway. Connections will be provided between the freeway and Greensborough Bypass, Grimshaw Street, Lower Plenty Road and Manningham Road.

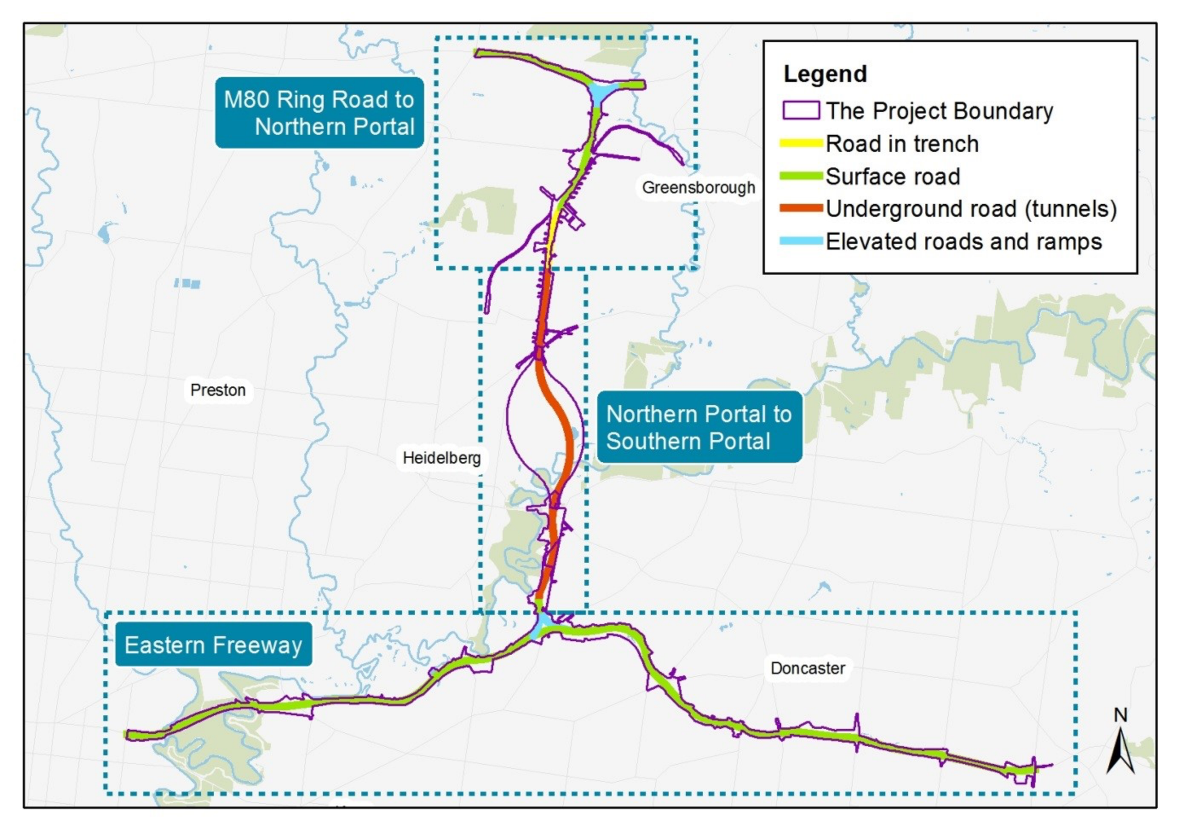

Figure 2 The North East Link

Source: NEL Project Description for EES Specialists - Specialists Issue 4

Infrastructure Victoria identified the North East Link as a high priority infrastructure project for the state in its 30-Year Infrastructure Strategy, released in 2016. Infrastructure Victoria noted that the link will enhance access to major suburban business and employment centres, improve orbital road connectivity across Melbourne and boost the capacity of the city's freight network.

In October 2017, the Victorian Government's Victorian Infrastructure Plan confirmed North East Link as one of several 'catalyst', state-shaping infrastructure projects designed to stimulate economic growth, create jobs and deliver positive, long-term benefits for Victorians.

2.3. Expected impact

The North East Link is expected to provide the main means of connecting the M80 in the north with the Eastern Freeway absorbing traffic that currently uses signal controlled local roads and shortening significantly the travel time between the two motorways. According to the NEL Business Case the impacts would be:

a. Significant reductions in travel times, including up to 30 minutes in reduced travel time between the Eastern Freeway and the M80, and a 40 per cent reduction in travel time along the Eastern Freeway

b. Significant traffic reductions across arterial roads in the north east

c. 15,000 fewer trucks on arterial roads in the north east

d. Faster and more reliable travel times for cross-city and orbital freight movements

e. Congestion relief at the five north-south bridge crossings of the Yarra River

f. Traffic relief along the M1 corridor, allowing it to operate more efficiently with reduced traffic volumes

g. Up to 30 per cent reduction in travel time for buses along the Eastern Freeway.

Moreover, the Modelling Report[2] in support of the Business Case shows an estimate of the impact of the project on current Yarra river crossings screenline; this provides a broad perspective on how different elements of travel behaviour are changed by the project. The results are shown in the figure below:

[2] North East Link Project. Appendix R, Transport Modelling Report, February 2018

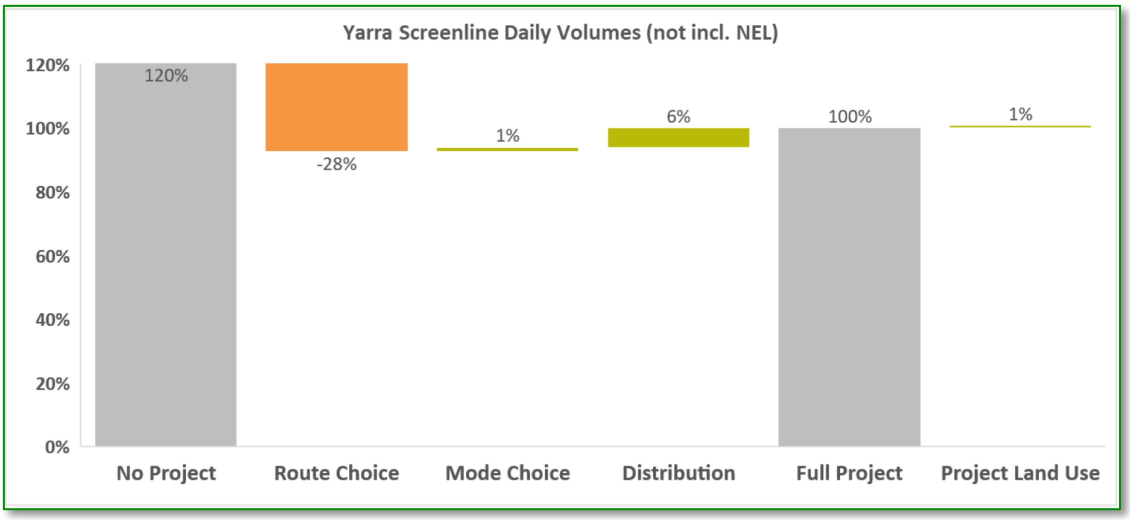

Figure 3 Impact of NEL over current Yarra river crossing screenline

Source: Figure 25 in Appendix R Transport Modelling Report

Just removing 15,000 trucks on arterial roads should produce environmental benefits that when coupled with the other impacts will be very significant. Confidence in the eventuation of these environmental benefits depends on the quality and expected reliability of the transport model used to forecast and estimate these impacts.

The main element of my own assignment is to peer review this model to provide additional support, or otherwise, to the estimation of impacts for the Environment Effects Statement.

3. The Transport Model

3.1. Introduction

The North East Link Authority (NELA) appointed Veitch Lister Consulting (VLC) to supply strategic transport modelling services for the North East Link (NEL) project. This included:

- set up and model preparation for the North East Link transport model;
- provide input into the options assessment;
- preparation of the business case forecasts for the preferred project; and
- input into the reference design and environmental effects statement (EES).

The scope for this assignment for VLC was to estimate the impact of the inclusion of the new link on the transport system using a strategic transport model. This model was used to forecast the impact of the new road on travel patterns across two distinct areas: Metropolitan Melbourne, defined by the Australian Bureau of Statistics' Greater Capital City Statistical Area (GCCSA), and the project study area, which includes part or all of the Local Government Areas (LGAs) of Banyule, Boroondara, Darebin, Manningham, Maroondah, Nillumbik, Whitehorse, Whittlesea and Yarra. Therefore the model provides impacts for more or less the whole of Melbourne and also a more localized area. The strategic model was also used to provide inputs to microsimulation modelling of the local impact of the NEL project.

VLC used its Zenith model to instrument this task. The Zenith model is a particular approach to implement a classic four-stage strategic model[3]developed, calibrated and validated by VLC. It is claimed that it has proved more accurate than other models applied in Australia, in particular in respect of toll road forecasting[4]. The model is effectively implemented in OmniTrans[5], a software package developed in Europe and used in a number of projects internationally. The classic four-stage model is illustrated in the following figure.

This is the approach followed internationally in most assessments of this kind as it allows the assessment of local and city-wide impacts of a project of this strategic importance.

[3] Ortúzar, J. d D. and Willumsen, L. (2011) Modelling Transport Fourth Edition. John Wiley & Sons, Chichester.

[4] VLC (2018) Transport Modelling Summary Report. August 2018, Table 1.1, page 4.

[5] OmniTrans: http://archief.dat.nl/en/products/omnitrans/

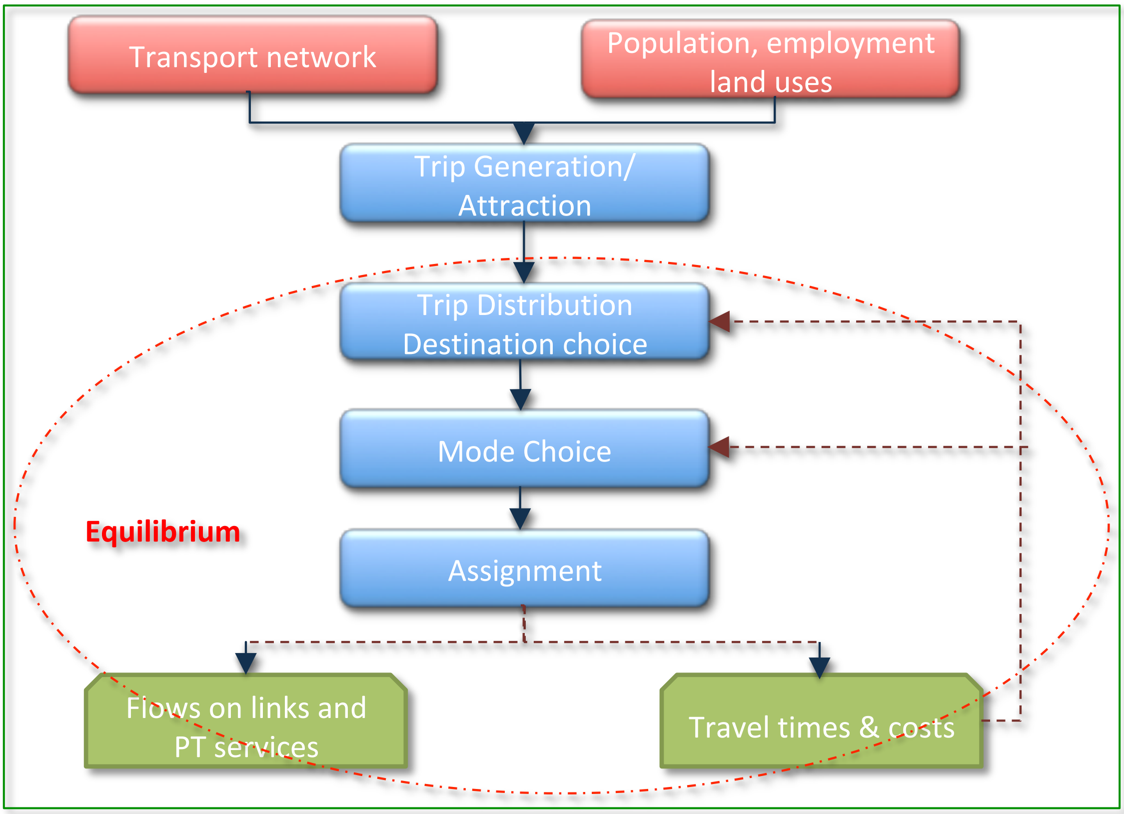

Figure 4 The classic transport model

Source: Adapter from Ortúzar and Willumsen (2011)

As the NEL project progressed, the model was adjusted to include up to date data and assumptions. Several versions of the model were produced as follows:

Model A was used in an early evaluation of the North East Link project.

Model B was developed for the North East Link project evaluation, incorporating the options assessment process.

Model C was developed for use in the preparation of the business case. It has a base year of 2016 and contains updated assumptions from version 1.09 of the reference case as provided by Transport for Victoria (TfV).

Model C2 has been developed for use in EES. It is largely consistent with Model C, with the following upgrades:

- Additional observed data used to improve the model validation; and
- Updated reference design of the NEL project.

The Zenith model was recalibrated in 2014 using model parameters generated from the latest available Victorian Integrated Survey of Travel and Activity, and validated to 2011 traffic and public transport patronage estimates. The model was then further re-validated to 2016 data as part of the evaluation of the North East Link project.

The Zenith model for the NEL project considers four time periods:

- AM Peak from 7:00 to 9:00
- Inter-peak from 9:00 to 16:00
- PM Peak 16:00 to 18:00
- Off-peak 18:00 to 7:00, not reported in detail.

Each of the components of this model is now discussed in detail.

3.2. Zones, Networks and segmentation

The modelled area is divided into travel zones. The model uses a travel zone system that was originally developed specifically for large infrastructure projects in Victoria. It is based on an aggregation of the Zenith Small Area Travel Zone System. There are 3,477 zones across the entire travel zone coverage specific for this study (a sub-set of the zone for the whole of Victoria).

The two main networks, road and public transport, are modelled with a sufficient level of detail to represent with reasonable accuracy travel times and route choice.

In the case of road links four different travel time – flow formulations are used for:

- Non managed motorway
- Managed motorway
- Arterial
- Managed ramps

These have been calibrated using existing data and validated using traffic counts. On inspection of the curves[6] they responded to the normal expectations for this type of road. There is no detailed modelling of junctions as is normal practice when dealing with strategic models like this one. Detailed modelling of junctions may appear attractive in terms of representing current conditions better. However, there are two critical problems associated with them. First, it is generally a guess what the characteristics of the signal timings will be in the future and therefore results cannot be entirely reliable. Second, detailed modelling of junction delays is likely to create problems for convergence of the model thus weakening confidence even further, see Ortúzar and Willumsen (2011), section 11.4.3.

[6] Traffic Assignment Parameters. Excel spreadsheet provided by VLC on request by the author.

The model considers the following trip making segmentation, or trip purposes:

- Home based work (white collar)
- Home based work (blue collar)
- Home based education (primary)
- Home based education (secondary)
- Home based education (tertiary)
- Home based shopping
- Home based recreation
- Home based other

In my view, this is more than sufficient to capture the different aspects of travel choice in the study area.

3.3. Trip generation

The trip generation model was a Home Based Trip Production Model for the eight segments presented above. Separate predictive models were estimated by VLC and validated for each of the above trip purposes. Each predictive model was developed using the number of trips recorded (for each trip purpose) by each household which took part in the VISTA survey.

The household variables which were used as predictors were:

- Household size;
- Number of white collar workers;
- Number of blue collar workers;
- Number of dependants aged 0-17;
- Number of dependants aged 18-64;
- Number of dependants aged 65+; and
- Number of cars owned.

The results, are presented in[7] and appear reasonable in my experience.

The Non Home Based Trip Production Models were produced for the following trip purposes, based again on the VISTA Surveys:

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[7] Paper 4a – Home Based Trip Production Model. Zenith Model Recalibration and Validation Version 3.0.1. May 2014

- Work Based Work (WBW)
- Work Based Shopping (WBS)
- Work Based Other (WBO)
- Shopping Based Shopping (SBS)
- Shopping Based Other (SBO)
- Other Non-Home Based (OHNB)

Trip attractions are modelled separately and included in the Destination Choice model.

3.4. Destination choice

The destination choice model, sometimes called distribution model, is described in Destination Choice Model Zenith Victoria[8] . The type of model used is a singly constrained Gravity Model for all trip purposes. This model can also be interpreted as a multi-nomial Logit choice model where the utility function is:

$$V_d = \beta GC_{od} + \ln(A_d) + \alpha \ln(GC_{od}) + U_d$$

Where

V_d is the utility function for trips to destination *d*

GC_{od} is the generalised cost of travelling from origin *o* to destination *d*

A_d is the attractiveness of destination *d,* for example the number of jobs at that zone

U_d is a destination specific constant that can be adjusted to make the model more realistic.

$\alpha \; and \; \beta$ are calibration parameters

This is a variation on the standard model as described in Ortúzar and Willumsen. It adds the destination specific constant that plays a role similar to k factors in recognising that just destination characteristics and the separation provided by generalised costs is not sufficient to explain the pattern of trips in a study area. The destination specific constants have been estimated for each combination of trip purpose and car ownership and four different areas in Melbourne: Central Business District (CBD) core, CBD non-core, CBD frame and CBD outer frame. These areas are also used later on to provide different estimates of parking costs. This seems to be a sensible variation on the standard model.

The destination choice model was estimated using the VISTA data for each trip purpose and four levels of household car ownership: no car, one, two or 3 plus cars.

[8] Destination Choice Model Zenith Victoria - Technical Note 8. March 2013.

The models have been validated against observed data, in particular the production of Trip Length Distributions and sector to sector travel (22 sectors) movements. The calibration seems satisfactory.

The NEL model then allocates trips to different times of the day following the observations of the VISTA survey[9]. This allocation does not depend on the costs of travelling between different locations in the study area but it depends on the four different areas of Melbourne mentioned above: CBD core, non-core, frame and outer frame.

It must be recognised that the Gravity Model, or any other practical Destination Choice model, is probably the weakest sub-model in the group. This is because it is trying to explain very complex behaviour about the choice of job and residence essentially on the basis of Trip Ends (generations and attractions) and separation. Moreover, it has been shown that the calibration parameters α and β are related to the size of the study area and the average generalised cost.

When used in forecasting mode, the Gravity Model will exaggerate the speed with which individuals will be able to change jobs, home locations or preferred shopping area in response to perhaps small changes in costs. Moreover, as populations and cities grow the values of α and β should change, otherwise the Gravity Model tends to artificially increase the number of short trips at the cost of some inevitable longer trips in order to maintain the average generalised cost; this is not expected to occur in practice as trip length is often observed to grow with size.

Despite these shortcomings, the Gravity and Logit Destination Choice models are almost universally used but care must be taken to control its evolution over time to avoid unreasonable modelled responses.

3.5. Mode Choice

As shown in Figure 3 above, the impact of NEL on mode choice is somewhat limited. The main influences would be the major improvement to the Eastern Freeway corridor Bus Rapid Transit (BRT) system (not captured by the Yarra screenline) and the general reduction in congestion in arterials close to the project.

Nevertheless, VLC has deployed a major effort to improve the model mode treatment of mode choice. The improved model is a Nested Logit Choice Model. This is a favoured structure in most studies aiming for an accurate representation of mode choice in complex systems[10]. It is also the structure recommended by the Australian Transport

[9] Technical Note 6 Period allocation and vehicle occupancy, VLC

[10] Ortúzar, J. de D. and Willumsen, L. (2011) Modelling Transport, Fourth Edition. Section 7.4

Assessment and Planning (ATAP) Guidelines[11]. This is a very flexible structure that permits capturing the essential elements of mode choice. The structure adopted and calibrated in this case by VLC is depicted in Figure 5:

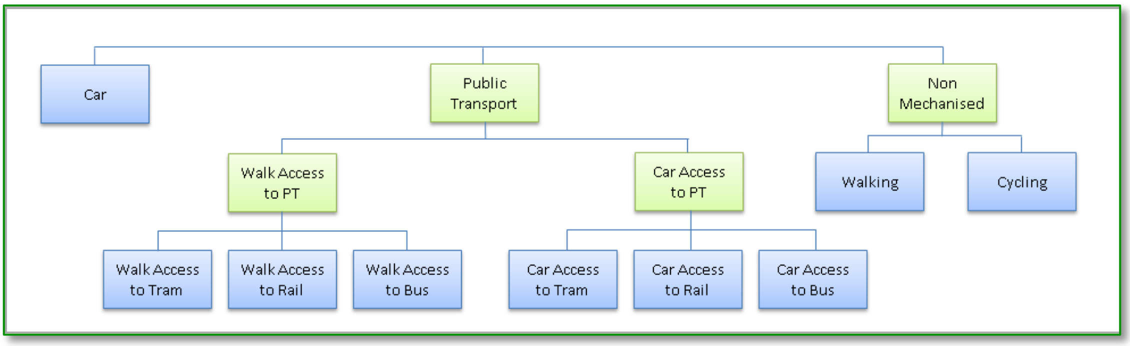

Figure 5 The Nested Logit Mode Choice Structure

Source: Zenith Victoria – Technical Note 7 – Mode Choice

The model was calibrated, again, using the VISTA survey.

The characteristics (attributes) considered in the model are:

- Car: Travel time, fuel costs, tolls and destination type (the four areas CBD core, non-core, frame and outer frame) as a proxy for parking costs.
- Walking and Cycling: travel time
- Public Transport: walking time, feeder mode time, waiting time, in-vehicle-time, number of transfers, fare and off-street parking if available for rail trips.

In my view the model is more than sufficiently detailed for this type of exercise. The mode choice model has the potential to reflect in a very realistic manner the nuances of mode choice and reflects a major effort in achieving this aim. I would have found acceptable even a simpler set of explanatory variables than this one. However, in this case a well-developed mode choice like this one is useful in identifying the impact of future public transport projects in Melbourne on the demand likely to use the new NEL facility. This is an important component of delivering a reliable NEL EES.

[11] Australian Transport Assessment and Planning (ATAP) Guidelines. T1 Travel Demand Modelling. August 2016, Section 3.2.3

3.6. Assignment

As shown again in Figure 3, the most important behavioural response associated with the new link is expected and likely to be a reassignment of routes in the area of influence of the project. As the NEL is planned to be a tolled facility this brings an additional requirement to conventional assignment techniques. The accuracy of toll road forecasting as been questioned in recent years and I have been personally involved in some of the efforts to make this a more reliable forecasting exercise[12].

VLC provides some evidence of the accuracy of their approach when using the Zenith model in Table 1.1[13], reproduced below, for toll roads in Australia.

Toll Road	Actual daily traffic volume	Winning bid forecast daily traffic volume (difference)	Zenith forecast daily traffic volume (difference)
Cross City Tunnel, Sydney	32,500	90,000 (+57,000 / +175%)	30,000 (-2,500 / -8%)
Lane Cove Tunnel, Sydney	57,000	~115,000 (+58,000 / +100%)	62,000 (+5,000 / +9%)
Clem 7, Brisbane	26,000	109,000 (+83,000 / +320%)	34,000 (+8,000 / +31%)
Airport Link, Brisbane	53,300	195,000 (+142,000 / +265%)	54,000 (+700 / +1%)

Table 1 Comparison of forecasts and outturn for toll roads with Zenith

Source: Table 1.1 in Transport Modelling Summary Report August 2018

VLC forecasts were produced before the schemes opened but not in support of any bid for them. They were produced in a similar context as the current one, that is independently of any private sector pressure. These results give some confidence that the model and the approach adopted by VLC can achieve, and have achieved, greater accuracy than some well publicised failures by international consultants.

The Route Choice and Assignment model is a fairly standard Static Traffic Assignment run to equilibrium incorporating a Toll Choice model (separate for cars and trucks) to represent the behavioural response to tolls.

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[12] Willumsen, L. (2014) Better Traffic and Revenue Forecasting. Maida Vale Press. And my contribution to the study and Final Report on Initiatives to Improve Toll Road Patronage Forecasting performed for BITRE in https://infrastructure.gov.au/infrastructure/infrastructure_reforms/files/GHD_Improving_toll_road_data_and_modelling_Stage_2.pdf

[13] VLC Transport Modelling Summary Report August 2018, page 4.

Link details incorporate Link Type and Length, Free Flow Speed, link Capacity, Turn Restrictions plus Tolls and Toll Caps (maximum toll payable); a link property is also used to represent constraints to truck movements recognising that not all links are available to trucks at all times. The toll Choice parameters are meant to capture the behavioural aspect of toll choice. In common with static assignment demand is represented by Origin destination trip matrices for the period modelled. A peak-hour factor is used when the modelled period is longer than one hour; this is appropriate.

I have already commented on the reasonableness of the speed-flow relationships and the fact that junctions are not modelled in detail; I consider turn penalties sufficient for a model of this scope and coverage.

The key element for this project is the Toll Choice Model. This is not my preferred approach to modelling the impact of tolls on route choice behaviour. However, as I recognise in[14] the use of toll choice models is practically unavoidable when there is a complex set of toll roads and a tolling cap is applicable. This is the case in Melbourne and therefore I consider the approach followed appropriate.

As in most modelling cases, the key is in the detail application of a toll choice model and in this the approach adopted by VLC is, again, fitting.

VLC uses a Logit toll choice model to estimate what proportion of travellers from each origin to each destination would choose to pay a toll to save time. The model considers two routes: the best untolled (free) route and representative tolled routes, estimated as a combination of only time and (toll) money. When more than one tolled route is possible, VLC uses a Nested Logit formulation:

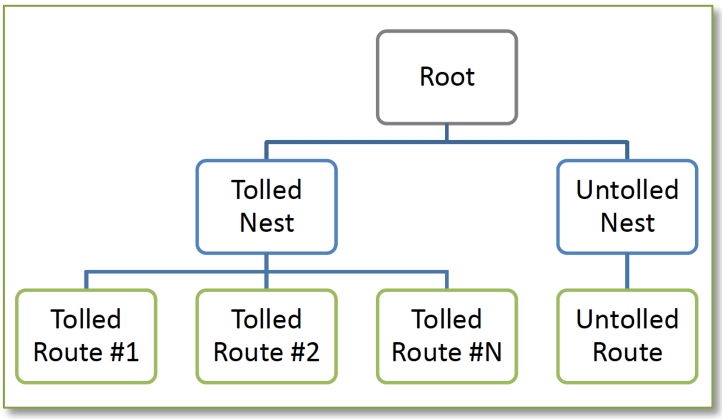


Figure 6 Nested Logit formulation when more than one tolled route is possible.

Source: Zenith Technical Note - Static Traffic Assignment - Methodology

[14] Willumsen, L. (2014) Better Traffic and Revenue Forecasting. Maida Vale Press.

This is a sensible approach. The model also ensures that no proportion of trip makers selects a tolled route when this takes longer than the best free route.

Inevitably, in this type of formulation, a small proportion of travellers is estimated to select a tolled route even if it provides only a small or even no time saving. This type of behaviour is observed in practice for at least a couple of reasons. One of them is that tolled routes offer an advantage in terms of travel time reliability, security and quality of ride that is not actually reflected in a model that considers only time and money. The other one is that drivers not fully familiar with the untolled alternatives may overestimate their travel time and select a more obvious route even if tolled. It is important, however, to ensure that this proportion is not unreasonably high.

To ensure VLC's toll choice model was reasonable I requested additional details on its parameters and assumptions. VLC provided these in a couple of Excel spreadsheets, one for cars and another one for commercial vehicles. I have reviewed and used these spreadsheets, changed values to explore their performance under different conditions and adapted the outputs to my preferences.

The model distinguished six different car user classes:

1. Company Car South
2. Non-company Car South
3. Company Car North
4. Non-company Car North
5. Airport Car
6. Commercial Vehicle

The willingness to pay tolls to save time is represented by the ratio of the parameters in the multiplying toll value over that multiplying time resulting in an "Implied Value of Travel Times Savings", or Implied Value of Time, as shown in the following table in Australian dollars of 2008.

	Non Company Car North	Non Company Car South	Company Car North	Company Car South	Airport Car	Commercial Vehicle
Implied Value of Time ($/min)	$ 0.82	$ 0.97	$ 1.14	$ 1.58	$ 1.58	$ 10.71
Implied Value of Time ($/hr)	$ 48.97	$ 58.47	$ 68.48	$ 94.50	$ 94.50	$ 642.86

Table 2 Values of Time. Source: VLC provided spreadsheet

As can be seen, Airport Car and Company Car South have equivalent average values of time and these are higher than for Non-company cars. This is a reasonable relationship as those travelling in company cars are less sensitive to tolls (generally covered by the employer) and trips to the Airport are particularly sensitive to travel time and its reliability.

These implied values of time are on the high side, in particular for commercial vehicles, but probably reasonable compared to other projects and countries bearing in mind the average income levels in Australia and Victoria. The Values of Time for Commercial Vehicles were determined from observations of their elasticities to toll changes when this occurred in Victoria; the observed elasticities were used to adjust the choice parameters. The final test is in the proper calibration of a model in a context with multiple toll roads in operation as is the case in Melbourne. An overestimation of the values of time would result in poor validation values. This is not the case of the Zenith model used in this case.

The responses implied by these, and other parameter values, in the toll choice model are illustrated in the following figure:

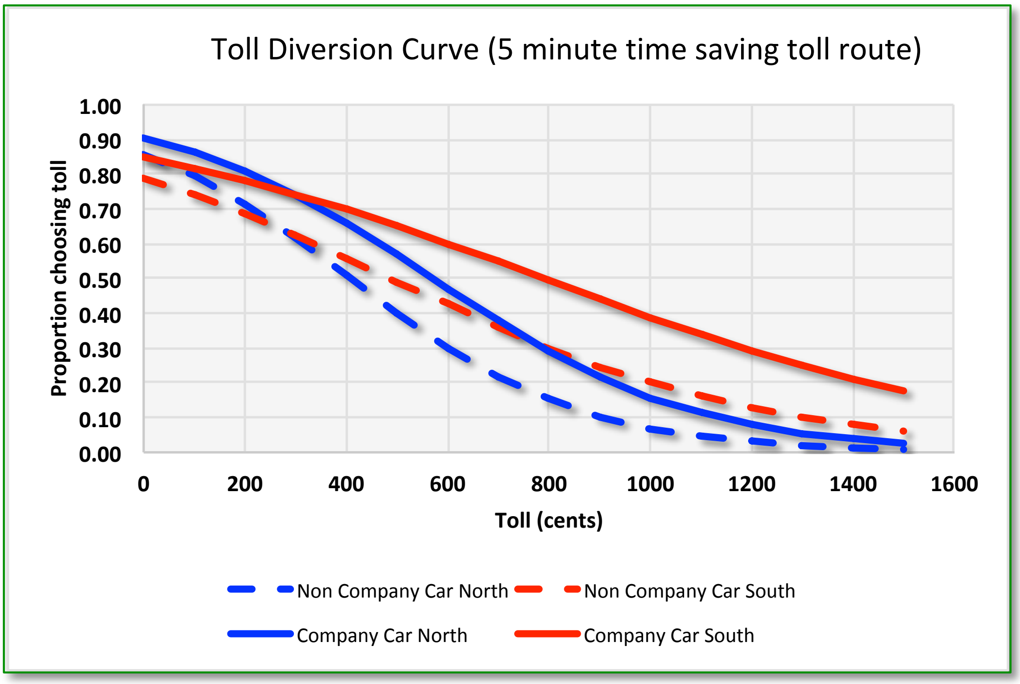


Figure 7 Proportion of drivers willing to pay a given toll for a 5 minute saving.

Source: adapted from parameter values provided by VLC.

It can be seen that the curves allow a dispersion of routes as even for a tolled option provided for free (zero toll) not all travellers select it even if it saves them 5 minutes. Another way of visualising the same toll choice model is to consider the proportion using a toll route with a cost of, say, AU$ 8.00 for different time savings.

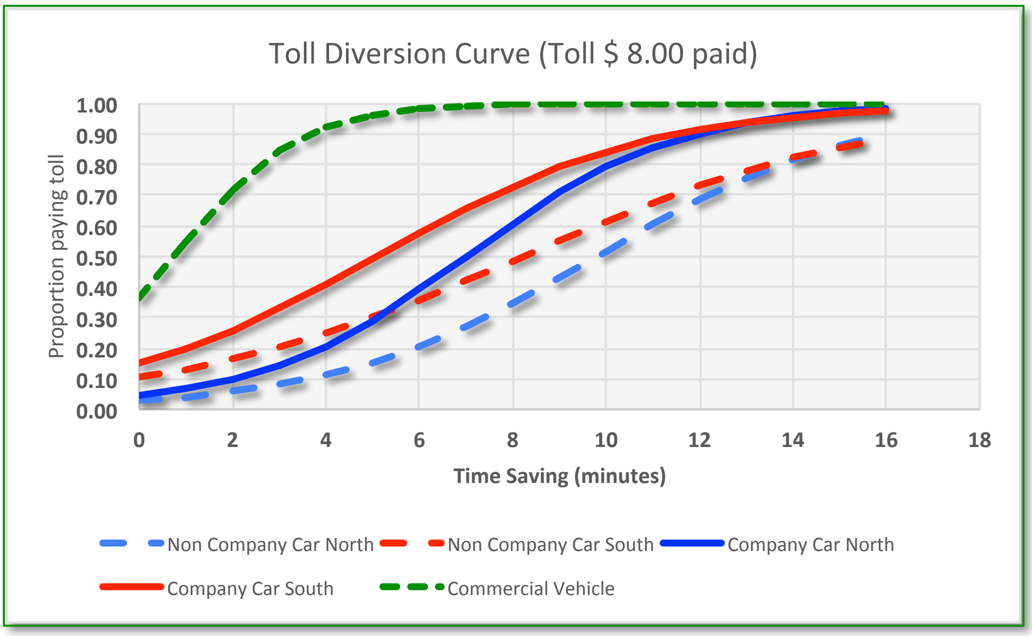


Figure 8 Proportion of drivers willing to pay a $8.00 toll for different time savings.

Source: adapted from parameter values provided by VLC.

The proportion of drivers paying a toll for no time saving is small, around 10% in most cases. This proportion increases for time savings above 5 minutes and it is higher for company cars (and Airport trips) than for non-company cars. Commercial Vehicles are very sensitive to time savings. This is likely to reflect two additional characteristics affecting Commercial Vehicles: (1) their operating costs go up very sharply with stops (as experienced in urban roads) and are lower on free flowing roads; (2) contractual conditions, for example “just in time” contracts that place high value to travel time reliability.

The Implied Values of Travel Time Savings are grown at 1.55% per year in real terms to account for the growth in per capita incomes in the area. This has been taken to reflect the expected evolution of per capita income. In order to consider the inevitable uncertainty about this evolution I would have preferred to grow this explicitly as a function of GDP per capita or Income per Capita. This would have simplified testing the sensitivity of demand more realistically to economic growth. However, it is not considered a poor estimation of how willingness to pay is likely to increase with incomes.

The assignment process is run iteratively and convergence is achieved using the Method of Successive Averages (MSA[15]). The criterion for convergence is when the Relative Gap (a standard measure of the degree of convergence) is less than 1%. I concur that this should be satisfactory for this type of exercise.

3.7. Equilibration

The classic transport model, as depicted in Figure 4 above, must use consistent values for key variables in each of its sub-models. For example, the travel times for each mode that result from the application of MSA during assignment should be the same used in the mode choice model to ensure consistency. As the classic model is generally applied sequentially it is necessary to develop a good iterative process to achieve this consistency.

There are two key questions in addressing this issue. The first one refers to the general method to be followed to achieve this consistency. A frequently used approach is to "feed back" the results, say travel times, from assignment to the other sub-models and repeat the process iteratively until a degree of convergence and consistency is achieved. The second question is how far up should this feed back loop reach: should it cover just Mode Choice or should it also include Distribution and eventually Time of Travel Choice and Trip Generation?

The first question is an interesting one as it has been shown that direct feed back of times and costs may not be a convergent process, see Ortúzar and Willumsen (2011) section 11.3; it shows that even for a very simple system there are conditions when convergence is not achieved[16]. Indeed, a better method than direct feed back of costs would be to apply the MSA approach to the whole model. However, this is seldom undertaken in practice, apparently because it is considered more difficult to implement, and most models tend to use direct feedback with a limited number of iterations.

[15] The MSA converges to equilibrium over a number of iterations. It is robust but not as fast as Frank-Wolfe or other more recently developed algorithms, see Ortúzar and Willumsen (2011) Chapter 11.

[16] Another way to describe this issue is that the elasticity of demand to changes in costs and times should be decreasing the higher the model is in the classic structure. In other words, changes in destination should be less sensitive to changes in costs than changes in mode and these in turn should be less elastic that changes in route. As the sub-models are generally calibrated separately, it is possible that this condition is violated in practice and thus preventing equilibration. The issue is further obscured as often the segmentation of demand and the generalised cost functions are different in each sub-model.

The second question is a more pragmatic one. It is generally recognised that it would be of little value to extend the feed back effect to Trip Generation even if the model has some sensitivity to congestion. Extending it to Trip Distribution is sometimes done and seems to be the recommended practice of Guidelines for Transport Modelling and Economic Appraisal in Victoria (these guidelines, produced in 2017 seem to be no longer available in late 2018). However, as already discussed, the Gravity Model generally used in Trip Distribution, exaggerates the response of changing jobs or residences when travel costs change thus making equilibration a more difficult task.

The VLC model follows normal practice of feeding back directly the costs from assignment to higher sub-models. However, the model uses the costs of the first iteration to run Distribution and Mode Choice and feed back costs of subsequent iterations only to mode choice. VLC calls this "dampened" or "single distribution" approach in contrast with "loop through distribution" method. In my view, both approaches risk failing to achieve convergence; the "loop through distribution" method runs a higher risk and to an extent VLC is right to call their approach a "dampening technique".

VLC undertook a "backcasting" exercise to show that its approach is more consistent with the observed evolution of total vehicle kilometres. The results are consistent with my expectation and provide further support to the approach adopted by VLC.

Most of the models I had been tasked to review treat this issue in a pragmatic but theoretically poor way. This does not seem to have detracted much from their ability to produce reliable forecasts. The approach adopted by VLC is, in a way, better than most in that it controls or dampens wild oscillations present when direct feed back on distribution and mode choice are implemented to aim for convergence.

3.8. Growth

VLC is applying a classic Strategic Transport Model to North East Link and therefore demand growth results directly from Population, Employment and other activities growth in Victoria.

Growth in these key drivers must be accompanied by planned changes on the supply side, that is planned changes to the public transport and road networks and services for each of the forecasting horizons.

VLC has provided a very extensive set of tables describing what has been assumed in the Base Case in respect of growth and network changes.

I am not in a position to comment on whether the list of projects and expected growth is consistent with current thinking in Victoria. I can confirm that the lists are long and apparently exhaustive; in fact longer and more detailed than many other studies of a similar nature and scope.

The following forecasting horizons were considered in addition to the 2016 base year:

- 2026 Base Case (no project)
- 2026 North East Link Project scenario
- 2036 Base Case (no project)
- 2036 North East Link Project scenario

3.9. Model limitations

Perhaps unusual in this type of work the reports contain a very good record of the main limitations of the model. These are consistent with the limitations of models of this nature, see Appendix A of the Transport Modelling Summary Report. The most relevant here are:

- Results are dependent on Land Use inputs and assumptions
- There is no explicit model of peak-spreading. This means that the model overestimates peak demand and underestimates inter-peak and off-peak demand. Total demand should be roughly unchanged.
- Imperfect modelling of delay (queueing behaviour) under heavy congestion; delays on at-level junctions may be underestimated in future years.
- Unconstrained parking capacity.
- Consistency of travel behaviour with the observations of VISTA. Behaviour changes over time as values evolve in ways that are difficult to predict.

4. Model review

4.1. Introduction

In this section I consider the efforts made to collect data to calibrate the model, the level of calibration achieved, the parameters used in the model and the reasonableness of the results as supported by sensitivity analysis.

In general terms many of the model parameters have been calibrated using the Victoria Integrated Surveys of Travel and Activity (VISTA07 and VISTA09) recalibrated in 2014 and validated using 2011 traffic and public transport data. It has been further updated and re-validated to 2016 data. This blend of data from different years is not unusual. The task of collecting a full set of data for a single base year is not only formidable but also extremely expensive.

4.2. Most recent data collection

A local set of truck movements was obtained using camera Origin-Destination surveys. These were used, together with the toll elasticities for commercial vehicles mentioned above, to improve the goods vehicle trip matrices and choice parameters.

A total of 485 traffic counts for "average week days" during school term "reflecting" 2016 conditions were used for validation of the updated model. The quotes are present here because in these cases one usually gets traffic counts obtained in different days and weeks and an effort is made to achieve the representativeness of the data for average weekdays in term time.

- Screenline counts were undertaken on six screenlines in the study area, again representing 2016 conditions.
- A total of 30 survey locations were used to obtain camera Origin Destination data in the Eastern Freeway, a key element of demand for NEL.
- A total of 34 peak and 18 inter-peak travel time surveys were undertaken to ensure speeds and travel times were accurately represented in the model.
- Flows were additionally obtained from toll roads in Melbourne, in particular CityLink and EastLink. This data is commercial in confidence and is not displayed in the reports.
- Public Transport patronage data was also obtained to validate this sub-model.

The scope and coverage of the data collected to validate the model is, in my view, appropriate to the task.

4.3. Calibration/Validation

Appendix B of the Transport Modelling Summary report provides abundant evidence of the extent and accuracy of the local validation for the EES model (Model C2).

Table 3.1 of that report displays a summary of the validation exercise (in terms of comparison with traffic counts) contrasted with VicRoads validation guidelines. This is reproduced below:

Statistics	VicRoads Targets	AWDT AM	AWDT PM	AWDT Total
R-square	>0.9	0.905	0.923	0.978
Gradient	Between 0.9 and 1.1	0.986	0.988	0.994
% RMSE	<30	26.7	23.8	13.7
All	as above	✓	✓	✓

Table 3 Comparison of validation of Model C2 against VicRoads Criteria

Source: Table 3.1 Transport Modelling Summary report

The validation effort extends beyond the simple comparison of traffic counts. Journey to work trip matrices were contrasted against the 2016 ABS Journey to Work survey. A comparison at the LGA to LGA level resulted in an R^2 of 0.962 showing a good match.

Scatter comparison of traffic counts against modelled flows showed R^2 values above 0.9 for modelled periods and above 0.97 for daily totals. However, the results point to a slight underestimation of daily flows (0.6%) and a slightly bigger underestimation of peak flows (1.4% AM and 1.2% PM peak). This is not unusual as it is extremely unlikely that total flows will be perfectly matched.

The model results on the base year were also compared across six screenlines shown below:

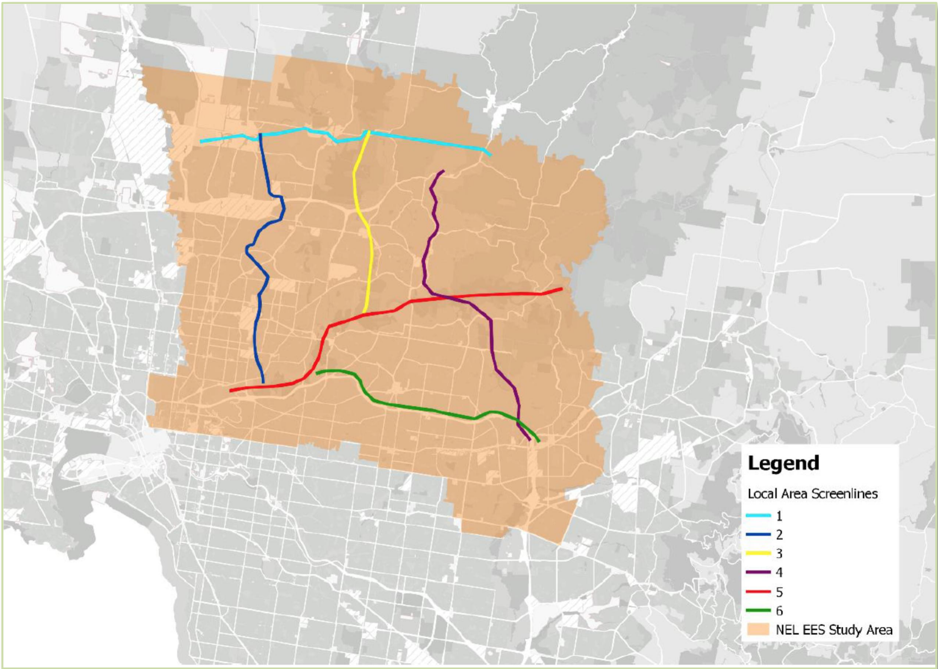


Figure 9 Six screenlines for validation.

Source, Figure 2.2 from VLC's Transport Modelling Summary report

The results are shown graphically. For example, for the AM peak period:

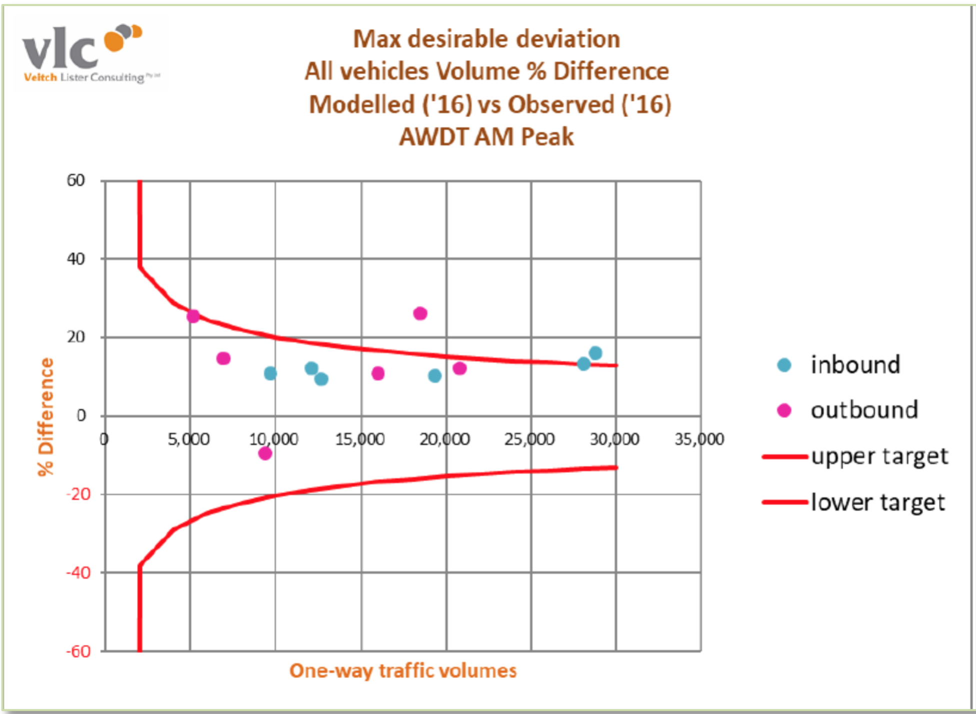
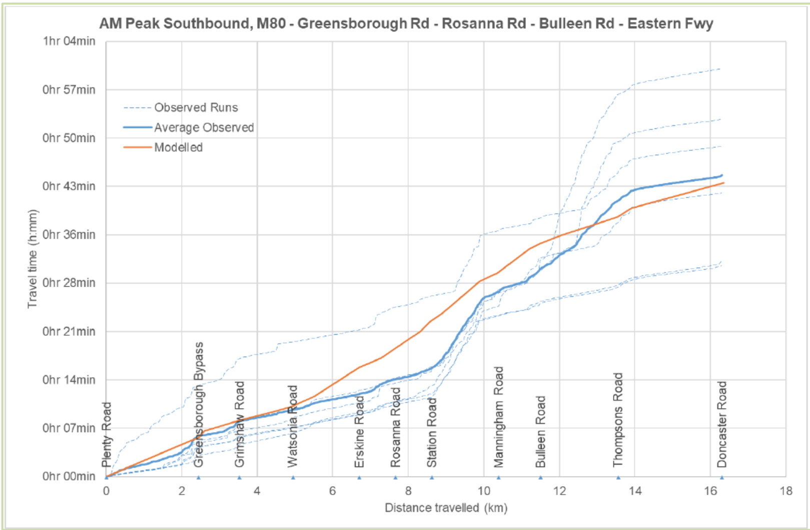


Figure 9 Screenlines validation AM Peak.

Source, Figure 4.8 from VLC's Transport Modelling Summary report

As can be seen only two cases are just outside the acceptable bounds and this I consider acceptable for a model of this nature and coverage. Indeed, the results for the PM peak and the full days are better.

VLC also validated the model against observed travel times. This is an important and difficult test as several floating vehicle runs are necessary to get a reasonable representation of travel times along a route, in particular when junctions are controlled by traffic lights. These comparisons are best made using plots of cumulative travel times along longer routes to avoid too much variability on shorter links. There is an extensive set of such plots, some displaying better match than others. I consider the most critical plots those along the Greensborough Road, Rosanna Road, Bulleen Road corridor. A couple of examples are shown below.



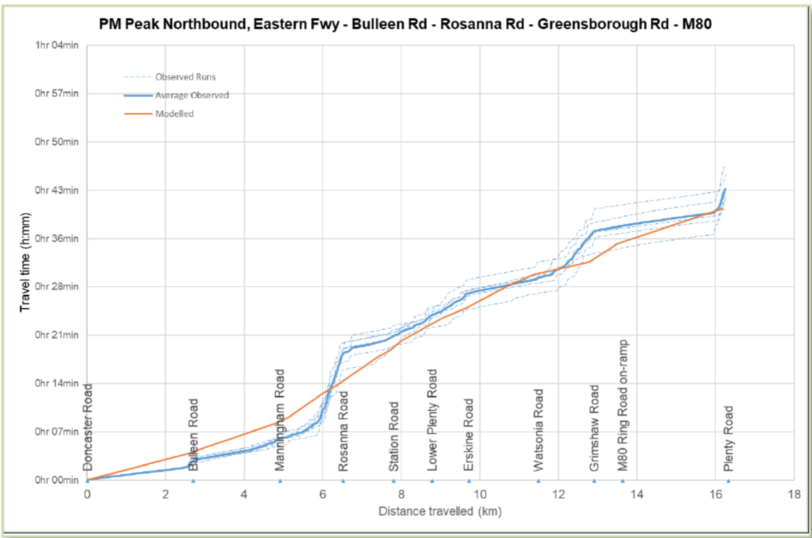


Figure 10 Two cumulative travel time comparisons.

Source, Figure 4.13 and 4.14 from VLC's Transport Modelling Summary report

The figures show the degree of variability of observed travel times and how the modelled travel times, representing an average, reflect reasonably well travel times along the corridor.

Overall, I am satisfied that the model used to prepare the EES for North East Link has been sufficiently well validated to be used for that purpose.

4.4. Convergence

Both the traffic assignment model and the complete model, as depicted in Figure 3 above, run sufficient iterations to achieve convergence, that is consistency in the costs among the chosen routes from each origin to each destination (Equilibrium Assignment) and the costs in the demand models.

VLC uses four different indicators of assignment convergence in the study for the EES, Relative Gap, Average Absolute Difference (AAD), the Relative Average Absolute Difference (RAAD) and the Percentage of Links with a volume change in successive iterations of less than 5% (PDiff). The targets for these measures are RGAP <0.01, AAD <1, RAAD <1% and PDiff better than 95%. Naturally, the model takes longer to converge under congested conditions but is stable much faster for inter-peak and evening off-peak conditions.

VLC reports that these targets are all met for assignment for both public transport and vehicular traffic. This is reassuring as it supports the assertion that the model produces consistent results.

Convergence for the complete model has no specific targets in Australia or Victoria. In general, this issue is treated looking at the Percentage Root Mean Square of Error (variation in successive iterations) of the generalised costs as they are what is targeted to be consistent.

VLC reports levels for %RMSE for costs and daily flows; these are around 0.50 after four iterations. I understand that this is the level of convergence achieved in all runs and seems sufficient for the purpose of this exercise.

4.5. Parameters

Validation on a base year is not enough. A peer reviewer would like to be satisfied that the parameters adopted and calibrated in the model are reasonable. Major departures from expectations borne from longstanding practice may be justified but the reviewer needs to be confident that these departures may not lead to bias or significant errors when the model is used for forecasting many years ahead and under more demanding congested conditions.

The original reports provided did not cover the values of these parameters in sufficient details. Therefore, I asked for a more detailed account of all these parameters. This was provided in a set of spreadsheets:

1. Destination Choice Parameters;
2. Mode Choice Parameters;
3. PT Assignment Parameters;
4. Traffic Assignment Parameters;

The full model has over 1000 parameters to consider. Most of them result from model calibration and estimation efforts and they must be seen in the context of a complete model, not necessarily one parameter at the time. The reason for this is that some combinations of parameters may be reasonable even if one or two are beyond the range of my own personal expectations and experience.

I reviewed these and provided comments on those parameters that turned out, after calibration, to be slightly outside my expected range. VLC replied with comments on them in a separate note. This was a useful and transparent dialogue that enable me to form an opinion of the overall quality and consistency of the model parameters.

I have already commented on the relatively high Value of Time, in particular for trucks in assignment. These values must be interpreted in the context of toll choice curves. VLC responded that they have done two sensitivity tests on these curves:

- Test one - 2036 NEL project and the implied VOT for CV toll diversion of a low value ~ $100/hr ; this resulted in a significant reduction of around 30% of truck traffic mid-block in each direction on NEL.
- Test two - 2036 NEL project & halving the implied VOT for CV toll diversion to ~ $320/hr; this resulted in only a very small reduction in traffic mid-block on NEL of around 3% for LCV and HCVs

I concur with VLC that these results indicate that NEL CV forecasts are relatively insensitive to the Value of Time and that NEL can be expected to attract a significant number of commercial vehicles away from local arterials. This is due in part to the time savings NEL provides and the free flowing nature of its traffic, an important feature for commercial vehicles.

The exchange of views on other parameters include the following:

Time weight for car access to transit (3.85). This is higher than usual as I would expect a value in the range 1 to 2.5. VLC's response was that the "value use was estimated by analysing mode choices in the Victorian Integrated Survey of Travel and Activity (VISTA) travel surveys. During estimation, the parameter was quite stable, i.e. fairly independent from functional form tested". I accept this as reflecting some of the preferences in Victoria for particular modes.

Time weight for waiting time (0.85). I found this value lower than my expectation (range 1.0 to 2.5). VLC's response was "the value used was estimated by analysing mode choices in the VISTA travel surveys. During estimation, the value was quite stable. VLC has found a very similar value using household travel surveys in Sydney. The low factor here might be related to the calculation of wait time itself (which is based on half the headway)". I accept that using half of the headway may be overstating waiting time as many people would aim to be at the stop/station a few minutes before the service is due and therefore wait for less than half of the headway.

Transfer penalties. These were, in my view rather high values, above 7 to 12 minutes I would expect. VLC agreed that "these are higher than is often assumed. Again, they were estimated by analysing mode choices in the VISTA travel surveys. Again, the values were consistently around this order of magnitude during estimation. It may reflect that people do not like interchanging in Australian cities". I accept this as my own experience is mostly based on cities with denser public transport systems that have been operating for a long time and travellers may be accustomed to interchange.

Overall, I am satisfied that the combination of parameters results in a defensible model that seems a reliable source for the estimation of impact for an EES.

4.6. Forecasting assumptions

The following forecasting horizons were considered in addition to the 2016 base year:

- 2026 Base Case (no project)
- 2026 North East Link Project scenario
- 2036 Base Case (no project)
- 2036 North East Link Project scenario

VLC has provided tables describing what has been assumed in the Base Case in respect of growth and network changes. These are extensive, comprehensive and detailed. I am not in a position to comment on whether the list of projects and expected growth is consistent with current thinking in Victoria. I can confirm that the lists are long and apparently exhaustive and more detailed than many other studies of a similar nature and scope.

Sensitivity tests were undertaken, reported below, to ensure that the forecasts produced using these assumptions and the model were reasonable. This is an important test in forecasting mode.

4.7. Results

The results are reported extensively in the main text as well as in detailed tables. It is interesting to understand where the additional demand comes from and this is shown in the figure below extracted from the Summary Report.

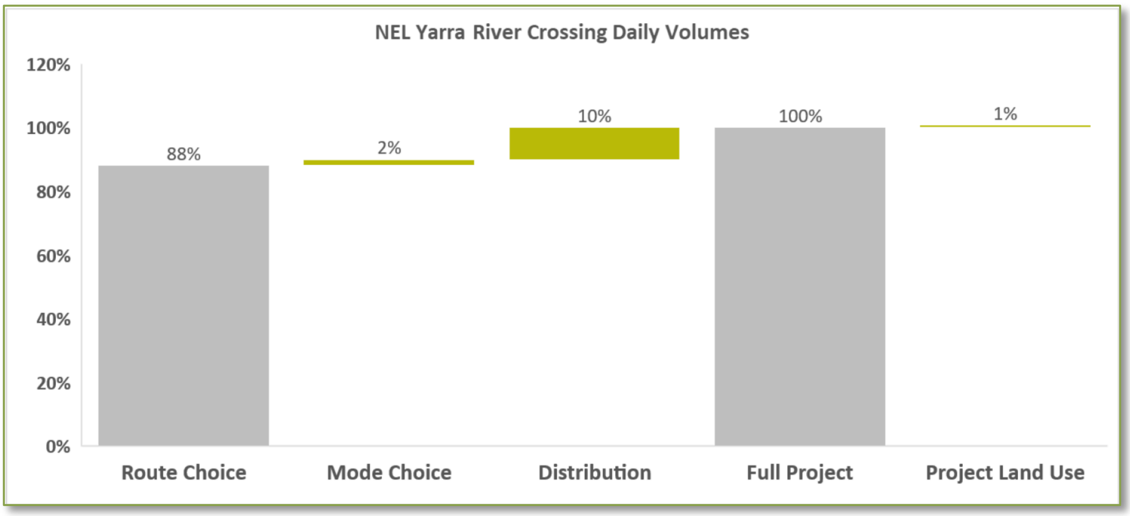


Figure 11 NEL Yarra River crossing volumes attracted to the project.

Source: Figure 5.3 from Summary Report

The figure shows that across this screenline, one that does not intercept the new Bus Rapid Transit facility, shifts in mode contribute about 2% to the flow on NEL and re-distribution of trips another 10%. The most significant effect is, as can be expected, the change in route to use the tunnel and managed freeway even when tolled; 88% of the demand on NEL is from re-assignment.

VLC provides several figures depicting from which origins to which destinations trips use NEL and they show reasonable capture areas providing additional confidence in results.

4.8. Realism of results

It is always desirable to check whether the results of a model are realistic enough to provide confidence in the results. Realism is usually tested against expectations. Some of these are intuitive. However, most of the time it is possible to compare the implicit elasticities in the model with observed elasticities obtained from observations. It is generally recognised that it is often difficult to isolated an elasticity in the real world when many other factors are changing so care should be taken when extracting and interpreting them.

This has been the approach adopted by VLC and it has used an appropriate measure of elasticity **ε** that is more reliable across a range of independent variables:

$$\in = \frac{\log(Demand\ after) - \log\ (Demand\ before)}{log(value\ after) - \log\ (value\ before)}$$

This compares the demand, let say traffic, before and after a change in one of the values that are assumed to affect demand, for example fuel price.

VLC reports the model elasticities to a number of independent variable changes in the model and concludes that the model passes a realism tests. Rather than repeat the results here I comment only on some particular values.

The model displays an elasticity of Vehicle Kilometres travelled to fuel prices of -0.33. This is a textbook value that is occasionally observable. There is a very low elasticity for car tips to fuel costs -0.06, as one could expect.

The average public transport trips elasticity to public transport fares implicit in the model is -0.20, a bit lower for peak periods and higher in the off-peak as can be expected. This is slightly lower than London but a reasonable value in the acceptable range.

Overall, I concur with the view that the model produces realistic results.

4.9. Sensitivity analysis

Eleven sensitivity tests were undertaken for the EES for 2036.

These were:

- 1 and 2: **High** and **low** population and land use growth scenarios;
- 3 a **project-specific land use** scenario, assuming persons or businesses who relocate to take advantage of the project.
- 4 and 5: 20% **increase/decrease** in the toll price on the NEL project;
- 6 reducing **willingness to pay tolls by commercial vehicles** (CV) by halving their implied value of time savings
- 7: Extending the existing north east **truck curfews** to 24-hour operation;
- 8: Assessment of an alternative North East Link / Manningham Road interchange layout;
- 9: E6 freeway commencing at the M80 Ring Road between Dalton Road and Plenty Road, and terminating at the Hume Freeway north of Donnybrook Road;
- 10: **Outer Metropolitan Ring** (OMR) road commencing at the M80 Ring Road between Dalton Road and Plenty Road, and terminating at the Princes Freeway West north of Little River Road
- Inclusion of Alphington paper mill and the Gas and Fuel redevelopment sites.

The results are summarised below:

	Sensitivity Test	% Difference NEL Volumes
1	High Land Use	+5%
2	Low Land Use	-5%
3	Project specific land us	Less than -1%
4	+20% Toll Price	-4%
5	-20% Toll Price	+4%
6	Reduced willingness to pay commercial vehicles	-2% for CVs
7	North East Truck Curfew	Less than 1%
8	Manningham Road Interchange	Less than -1%
9	E6 Freeway Project	+5%
10	OMR Road	5%
11	Inclusion of redevelopments	Less than -1%

Table 4 Sensitivity tests.

Source Table 5.3 Transport Modelling Summary Report

There is a relatively low sensitivity to toll price, consistent with relatively high Implied Values of Time and the time savings offered by NEL. I recognise that in the case of toll roads there are no universal elasticities than can be used for comparison. This is because toll road traffic is heavily influenced not just by willingness to pay of potential users but more significantly by the time on the alternative routes. In this case, it is clear that NEL offers significant time savings to a major proportion of the demand in the North East of Melbourne. This explains why an elasticity value to toll price that would appear low compared with other existing toll roads is in effect likely in this case.

All other results in the sensitivity tests are within the range of my own expectations.

I also requested the graphical depiction of travel time savings achieved by some key trips. I received from VLC a set of graph showing different ranges of travel time saving estimates for 2036. These are reproduced below. The figures show that time savings of zero to five minutes will be incurred fairly broadly across the network, which implies the scale of general road network decongestion benefits provided by the project. Time savings of five minutes or more tend to be concentrated around the project itself, with the very large time savings (over 20 minutes) situated near each end of the project.

Figure 12 AM peak travel time benefits for cars, by origin and time saving intervals (minutes), 2036

Source: Spreadsheet provided by VLC

VLC also provided a graph showing the distribution of daily time savings as follows

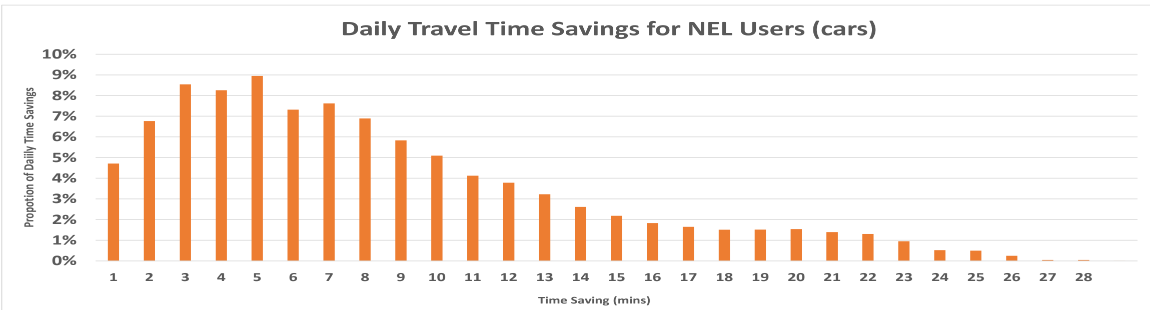


Figure 13 Distribution of daily time savings (minutes), 2036

Source: Spreadsheet provided by VLC

While there is a wide distribution of time savings the bulk will be achieved in the range 2 to 10 minutes. Nevertheless, there are many vehicles benefiting from time savings between 15 and 30 minutes.

These results give me additional assurance that the model is behaving as well as can be expected for the purposes of an EES.

5. Dealing with uncertainty

5.1. Approach adopted

There are three main sources of uncertainty in traffic forecasting: data uncertainty about the future, model uncertainty from its components and parameters, and scenario uncertainty, disruptions that may materialise in the future and are not accounted for in the future data. Ideally, the treatment of uncertainty must cover all three.

VLC has adopted an approach that covers these three main sources of uncertainty using three complementary methods.

The first method is to undertake a detailed sensitivity analysis of the projections resulting from the application of the model under conditions that differ from the Core Case. This approach has been undertaken in great detail in this case and it covered, as reported in Table 4 above, the most important elements that may influence results. The results are satisfactory and comprehensive.

A second approach is to provide, in detail, how the projected traffic results from a combination of different contributions, for example changes in route, mode and destination as well as the impact from land use. This approach was also followed by VLC as reported above and provides another way of understanding the impact of these elements of the model uncertainty. VLC has provided several "waterfall" figures showing how these components contribute to the final projections.

The third approach deal with uncertainty due to potential technology disruptions through scenario analysis. Despite its difficulty, this is in my view, the most appropriate approach to dealing with this type of uncertainty.

5.2. Scenario analysis

Following an exchange of views VLC decided to implement a Scenario Planning approach to consider the future disruption caused by two technological innovations: Mobility as a Service and Connected and Automated Vehicles (also known as Autonomous Vehicles when they reach automation levels 4 and 5). The concept of Mobility as a Service (MaaS) includes a wide range of on-demand services ranging from simple pay-as-you-go Uber-like service to complex multi-modal arrangements perhaps with a monthly subscription. Connected and Automated Vehicles (CAV) will have a number of impacts principally on safety, willingness to pay and freeway capacities[17].

[17] Willumsen, L. (2018) From When to What should happen to CAV and MaaS. Presented at the **European Transport Conference 2018**, Dublin.

Other technology disruptions like Electric Vehicles (EV), the Internet of Things (IoT), Distant Presence and Artificial Intelligence are less likely to affect the impact of NEL.

Infrastructure Victoria has undertaken a review of the potential impacts of EVs, CAVs and MaaS[18]. Zero Emission Vehicles are already providing benefits in Victoria and elsewhere. They are becoming cheaper to run and produce no emissions at the tailpipe thus reducing the impact on the environment. They will not have a major impact on traffic and therefore they are unlikely to generate environmental disbenefits.

The IoT will provide additional information on the performance and condition of major infrastructure, buildings and equipment thus reducing the need for regular inspection and will not affect travel significantly. Distant Presence is likely to improve but still most meetings and negotiations are likely to require physical presence to be effective.

Artificial Intelligence will certainly affect the world of work but its impact on travel is uncertain; I expect it to have a very low impact on travel, in particular the movement of commercial vehicles, a significant source of environmental benefits in the case of NEL. Therefore, the main concerns are MaaS and CAVs and the economy.

VLC therefore decided to develop and run three different scenarios applicable to the forecasting year of 2036. This is a sensible date to consider the impact of CAVs that by then will constitute a low but important fraction of the fleet.

5.3. Scenario 1 CAV

This considers the impact of CAVs on traffic and NEL. VLC restricted its analysis to Automation Level 4 but this is not critical at this stage. Vehicles with Level 4 automation will drive themselves without human intervention within their “operational domain”. Only when they venture outside their operational domain they will require human intervention. It is very likely that urban areas like Melbourne and freeways will be their natural operational domains. In any case, VLC has assumed that CAVs will have the following characteristics in the whole area of the model:

- They will constitute the 20% of the traffic (VLC states they will be 20% of the fleet but in practice treat them as 20% of the traffic as CAV will cover more kilometres per day than conventional vehicles). It is assumed that 20% of the car trips in the model will shift to CAV trips with new characteristics.
- Half of the CAVs will be privately owned and used as a better car. They will incur in additional Vehicle Kilometres Travelled (VKT) as they may be sent to park

[18] Infrastructure Victoria. Advice on Automated and Zero Emissions Vehicles Infrastructure. October 2018.

elsewhere, what VLC calls "dead running". They will serve 10% of the previous car trips.

- The other half will be part of a taxi like fleet and serve the remaining 10% of car trips.
- CAV users will be able to undertake other activities while travelling and therefore their Value of Time will be reduced by some 10%.
- When the CAV share of traffic is 20% they will increase the capacity of freeways by 10% as they can keep shorter headways safely. There will be no impact on other roads as junctions control their capacity and there CAV's advantage will be minimal at this share of traffic.
- VLC further assumes, following Infrastructure Victoria's advice, that 20% of the car fleet will be electric and this penetration was adopted for CAVs and conventional vehicles. In other words, 20% of the CAV fleet are EVs and 20% of the conventional vehicles are also EVs.
- VLC also assumes that CAVs will generate additional trips as those previously unable to drive will be able to use them. VLC allows a 10% increase in discretionary trips on this account. Although it could be argued that there will be some additional trips to work as well, I consider this a reasonable and valid approximation to the induction effect of CAVs.

These assumptions were then built into the model to estimate their impact on NEL in 2036.

5.4. Scenario 2 MaaS

This is the Mobility as a Service scenario and it focussed on the impact of ride-sharing services. This is a valid choice for a number of reasons. First of all, of all the possible MaaS services ride-sharing is the one with the greatest impact on traffic and congestion. Second, the single use, Uber-like services are likely to increase congestion (because of empty or dead running); therefore, policies will put in place to restrict their widespread growth and to internalise its externalities.

This scenario required some additional assumptions about the type of vehicle used and modal shifts. In discussion with VLC the decision was taken to base these on the project that the International Transport Forum (ITF, part of OECD) undertook for Auckland, New Zealand. The conditions are somewhat similar to Melbourne and certainly more appropriate than those of Lisbon, Dublin and Helsinki, the other cities studied by ITF.

The following assumptions were adopted:

- Ride-sharing will be adopted by 20% of the current car trips by 2036.
- Ride-sharing MaaS will reduce private vehicles trips as vehicle occupancy will be higher.

- 16% of these trips will be end-to-end in a MaaS vehicle and 4% will use MaaS as feeder to public transport, for example rail or BRT.
- Ride-sharing services will be provided by two types of vehicles, 16 seats minibuses and 8 seats taxis. The average occupancy turned out to be 6.7 person per vehicle and the average vehicle size is 1.3 passenger car units (pcu).
- There will be an increase in VKT due to the need to detour to pick up and drop passengers en route.

There is also an impact on waiting and walking times but these do not impact directly on the environmental impact of traffic and NEL.

5.5. Scenario 3 CAV + MaaS

In this scenario both the impact of ride-sharing Maas and CAVs are included. In this case the assumptions are in practice a suitable combination of those of Scenario 2 plus the idea that when MaaS services do not require drivers their operating costs, and therefore fares, will be significantly reduced. This will result in additional in demand for these services. This was handled with the assumption of a -0.02 elasticity in the changes of what is essentially a public transport service capturing car trips.

5.6. Results

The results from this exercise were generally as can be expected. Scenario 1 produces an increase in traffic that is not balanced by the increase in capacity on freeways. A summary of results is shown in the next Table:

Indicator (Daily)	Core Case	Scenario		
		CAV	MaaS	CAV+MaaS
Person trips	25,813,000	26,118,000	25,813,000	26,118,000
Difference	--	1%	0%	1%
Person car trips	19,086,000	19,453,000	15,501,000	15,604,000
Difference	--	2%	-19%	-18%
Person Public Transport trips	3,221,000	3,166,000	3,812,000	3,755,000
Difference	--	-2%	18%	17%
Vehicle Kilometres Travelled	223,072,000	235,073,000	208,271,000	218,310,000
Difference		5%	-7%	-2%
Vehicle Hours Travelled	5,005,000	5,365,000	4,427,000	4,671,000
Difference	--	7%	-12%	-7%
Change in NEL Traffic (2 way)		9,000	-13,000	-6,000
Percent change		7%	-10%	-5%

Table 5 Results from Scenario analysis

The impact of CAVs (Scenario 1) is positive in terms of traffic on NEL but negative in terms of the increase in Vehicle Kilometres and Hours travelled, plus 5% and +7% respectively. The increase in freeway capacity are not sufficient to compensate the additional number of vehicle trips, in particular empty ones.

Scenario 2, ride-sharing MaaS, in turn, reduces traffic in NEL by about 10% but has positive effects on the whole city with a 19% reduction in car trips and an 18% increase in public transport trips; this results in a 12% reduction in hours travelled and 7% reduction in vehicle kilometres travelled.

Scenario 3, the combination of CAV and MaaS, results in a 18% reduction in car trips, 17% increase in public transport trips and a 7% reduction in hours travelled. The reduction in NEL traffic is only 5%.

Overall, I am satisfied that the Scenario Planning Analysis undertaken by VLC in this case is sufficient to provide a better understanding of how these technology disruptions might affect traffic in NEL and its area of influence and satisfies the advice provided by Infrastructure Victoria.

6. Conclusions

Having undertaken a review of the model, assumptions, the calibration and validation tasks, its parameters, the sensitivity and reasonableness tests and convergence levels I conclude that the model is appropriate for use in the development of the Environmental Effects Statement.

I have been able to observe minor departures from my expectations in the model. However, in discussion with the modelling team these issues have been clarified and I am satisfied that they correspond to local conditions and that the model, overall, performs well.

The model produces reliable and consistent results that can serve as a solid base for the EES.

The treatment of uncertainty using different approaches, sensitivity analysis, disaggregation of contributors to traffic and Scenario Planning is sufficiently thorough and detailed to give confidence that these risks can be taken into account.