Appendix Q1
Economic Appraisal

February 2018

North East Link Economic Appraisal

24 May 2018

As included in the Business Case as provided to Transport for Victoria on 9 February 2018, the analysis has not been updated since 9 February 2018

Building a better working world

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Mr Duncan Elliott
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24 May 2018

As included in the Business Case
submitted to TFV on 9 February 2018

Economic Appraisal Report

Dear Duncan,

We refer to the contract between the Victorian State Government ("State") via the North East Link Authority ("NELA") (the "Contract"), through which EY has been engaged to provide economic and financial advisory services to NELA on the North East Link Project (NELP or the "Project").

As part of this engagement EY has produced this Economic Appraisal Report (the "Report"), attached to this letter. The analysis for the report is as included in the business case submitted to Transport for Victoria (TFV) and has not been updated since 9 February 2018.

Purpose of the Report and restrictions on its use

The Report may only be relied upon by the State of Victoria ("the State") pursuant to the terms of the Contract. Any commercial decisions taken by NELA are not within the scope of our duty of care and in making such decisions you should take into account the limitations of the scope of our work and other factors, commercial and otherwise, which you should be aware of from sources other than our work.

EY disclaims all liability to any party other than NELA for all costs, loss, damage and liability that the third party may suffer or incur arising from or relating to in any way connected with the provision of the deliverables to the third party without our prior written consent. If others choose to rely in any way on the Report they do so entirely at their own risk. If NELA wishes to provide a third party with copies of the Report, then our prior written consent must be obtained.

Our Role

EY performed the following scope of work:

- Developed an economic framework and economic models to accommodate the project assumptions;
- Coordinated collation of data and assumptions from NELA and its advisors;
- Prepared an Economic Appraisal Report

This Report was prepared on NELA's instructions, solely for the purpose of presenting economic appraisal for the Business Case and must not be relied upon for any other purpose. In carrying out our work and preparing this Report, we have worked solely on these instructions and for this purpose.

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The analysis contained in this report has been prepared by EY and informed by material provided by, and through discussions with NELA, Department of Treasury and Finance (DTF) and third parties including GHD, Advisian, VLC, Smedtech, Turner & Townsend and WT Partnerships. No verification or review of the information provided by these parties has been carried out by EY. EY has not altered the inputs or assumptions received from other parties for input into the financial analysis, except where identified in the relevant sections below.

If you would like to clarify any aspect of this Report or discuss other related matters, please do not hesitate to contact me.

Yours sincerely,

John Matthews
Partner

Table of contents

1. Introduction

1.1 Project overview

In 2016, Infrastructure Victoria released its 30 Year Infrastructure Strategy, identifying North East Link as the highest priority infrastructure project in Victoria. 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 five-year *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.

1.2 Purpose and scope of this report

This report presents the results of the economic appraisal undertaken by EY on behalf of NELA to evaluate the NEL project. The purpose of this report is to document the methodology and results of the economic appraisal, and should be read in conjunction with the business case prepared for the NEL project.

1.3 Structure of this document

The remainder of this document is structured as follows:

- Approach – provides an overview of the approach to the economic appraisal and outlines, in detail, the specific appraisal methods, assumptions and procedures
- Transport modelling results – provides a summary of the transport modelling framework and outlines some key findings regarding the transport impacts of the project
- Project costs – provides a description of the costs of the project and the economic cost adjustments applied for the purposes of the CBA
- Project benefits – provides a summary of the economic benefits provided by the project
- Cost-benefit analysis – presents a combined analysis of the project costs and benefits and provides a summary of the key findings of the economic evaluation

2. Approach

2.1 Economic appraisal framework

The objective of the economic appraisal is to assess the project's impact across economic, social, and environmental dimensions, and to provide information for Government and stakeholders upon which they can base their investment decision. This holistic approach is envisaged by the Transport Integration Act 2010, which explicitly requires transport system decision-making to adopt a 'triple bottom line' perspective.

The framework applied for the NEL project aims to ensure the economic appraisal of the NEL project is robust and aligns with the project objectives so that the likely project impacts, benefits and costs are fully captured by the analysis and can be presented in a way that demonstrates whether the project is expected to meet those objectives.

2.1.1 Investment logic and project objectives

As per the Investment Management Standard process, the NELP team undertook an Investment Logic Mapping (ILM) workshop for the business case in early 2017 to define the logic that underpins the investment. At that stage, the NEL project logic was defined to address the three problems listed below:

- Problem 1 - Melbourne's poor orbital connectivity is constraining the economic potential of Victoria
- Problem 2 - Inefficient freight movements between the North and South East of Melbourne is limiting supply chain competitiveness and hindering the growth of high-value industries
- Problem 3 - Congestion and heavy vehicles on neighbourhood roads in the North East is harming liveability and community wellbeing

By addressing these problems, the NEL Project is expected to deliver the following benefits.

- Benefit 1 - Economic growth
- Benefit 2 - Increased economic opportunity for households in the North, East and South-East
- Benefit 3 - Improved competitiveness of the State
- Benefit 4 - Improved liveability and thriving communities in the North East

In response to the problems and benefits identified in the ILM, the NELP team has derived the following project objectives that have been used throughout the assessment process to help guide the business case development:

- Improve business access and growth in Melbourne's north, east and south east;
- Improve household access and growth in Melbourne's north, east and south east;
- Improve freight and supply chain efficiency and industrial growth across the north, east and south east; and
- Improve access, amenity and safety for communities in the north east

2.1.2 Appraisal framework and tools

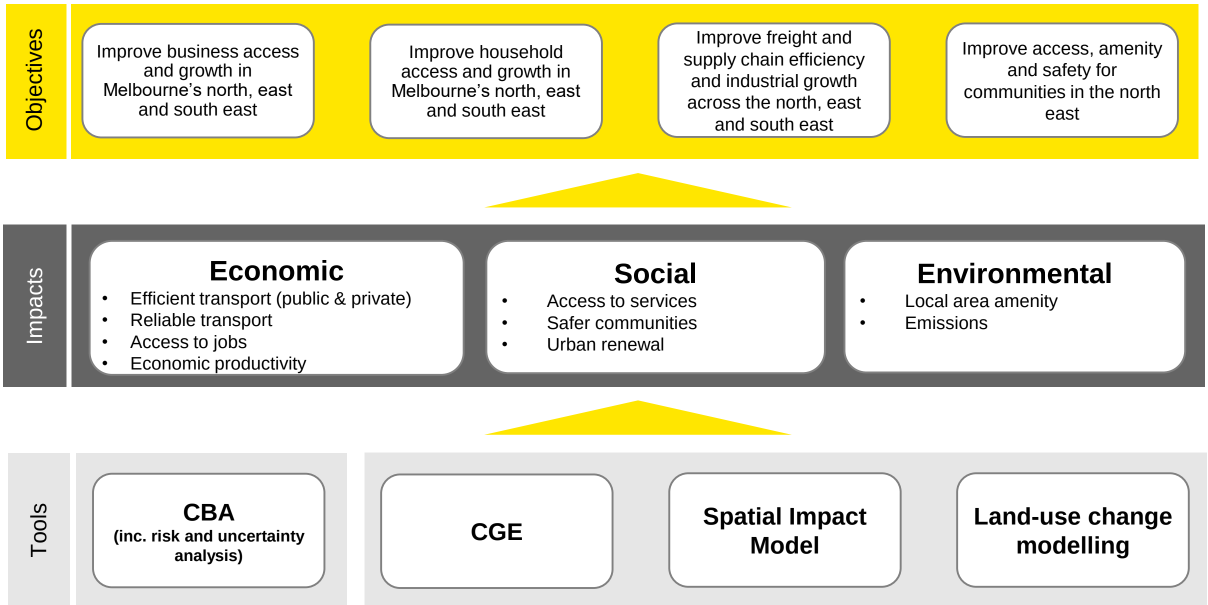
A high level representation of the appraisal framework developed for the evaluation of the NEL project is shown in Figure 1 below. This shows how the economic appraisal framework is driven by the project objectives outlined above. By achieving these objectives, the project will provide significant economic benefits through achieving different economic, social and environmental impacts in the parts of Melbourne that are important for the NEL project and for Victoria as a whole.

Various tools are available to evaluate and present these triple bottom line impacts. The main tool that has been used is Cost Benefit Analysis (CBA), which aims to identify and quantify, in monetary terms, all the costs and benefits of the project. CBA is a well-established and widely accepted methodology which is commonly used by governments to not only assess the economic feasibility of a project or initiative, but also to compare it with others.

Given that the North East Link is a large and complex project that will deliver road user and wider network and economic benefits over a long timeframe, there are a range of demand and other operational risks and uncertainties the project faces over the medium to longer term. To address this, and detailed assessment of risk and uncertainty (beyond standard sensitivity testing) has been included to add robustness to the CBA.

The economic appraisal has also been informed by Computable General Equilibrium (CGE) modelling and spatial impact analysis to understand the impacts on economic activity and employment, and the land use changes potentially brought about by the project.

Figure 1 Economic appraisal framework and tools



Source: EY

Note that the inclusion of land use modelling goes further than most conventional economic appraisal frameworks, but is considered a critical component of this appraisal as the project is expected to have a significant impact on Melbourne's city structure by encouraging households and businesses to locate in areas that will benefit from the significant accessibility improvements that the project will provide. These induced land use changes can create benefits and costs in addition to standard benefits that are usually included in transport cost-benefit analysis (CBA).

2.2 Alignment with relevant guidelines

The economic appraisal methodology has been developed in consideration of the following published Victorian and Australian government guidelines, noting that a number of issues were identified which necessitated some deviation from the recommended approach (see section 2.3):

- Department of Economic Development, Jobs, Transport and Resources (DEDJTR), Guidelines for Transport Modelling and Economic Appraisal v3.04 (May 2017)

- DTF's Investment Lifecycle and HV/HR Guidelines: Stage 2 (February 2015)
- DTF's Economic Evaluation for Business Cases Technical Guidelines (August 2013)
- The updated Australian Transport Assessment and Planning (ATAP 2016) Guidelines. Note, these have replaced the previous National Guidelines for Transport System Management in Australia
- Bureau of Infrastructure, Transport and Regional Economics (BITRE) Overview of Project Appraisal for Land Transport (November 2014)
- Infrastructure Australia's Assessment Framework Detailed Technical Guidance (June 2017).

To consider specific methodologies for land use benefits, wider economic benefits (WEBs) reliability benefits, and benefits associated with reducing the perceived costs of congestion, guidance has been considered from international literature and guidelines, such as:

- UK Department of Transport - Transport Appraisal Guidelines (WebTAG)
- NZTA Economic Evaluation Manual (2013)
- Transport for NSW (2016), Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives
- Warden, M and Ibanez, J.N (2012), The congestion multiplier: Variations in motorists' valuations of travel time with traffic conditions, Transportation Research Part A, Elsevier

In analysing the economic impacts of the Program, EY has also considered the following State and National guidance and recommendations:

- The ATC 2006 NGTSM (volume 3, p 37) states that secondary economic impacts – comprising economic activity flow-on expenditure effects in the rest of the economy – are generally presented separately from the standard net present value or benefit-cost ratio results to avoid double counting.
- The Victorian Department of Treasury and Finance 2013 HVHR recommends that CGE models only include market-based goods and services, not non-market goods (e.g. the environment). Due to their complexity and limitations, such models should only be used to complement a cost-benefit analysis, and only for significantly large investment projects that are likely to have economy-wide impacts.
- The Victorian Auditor General's office states that it prefers CGE modelling over input output analysis to measure economic impacts where expenditure exceeds $10 million.

2.3 Key methodological issues

While economic appraisal has been primarily informed by the guidance listed above, there are a number of key methodological issues that were identified where either the guidance was not clear as to the appropriate approach, or there was evidence to suggest that the current guidance was out of step with current condition and projected trends. Therefore additional analysis was required to determine the appropriate approach to be applied. The key issues that were identified include:

- The development of an appropriate annualisation factor
- The treatment of induced demand
- Selecting appropriate assumptions for growth in road vehicle operating costs

► Accounting for changes in the perceived costs of congestion.

► Estimation of wider economic benefits

These issues and the approach adopted in the economic appraisal to address them are discussed in further detail below.

2.3.1 Development of an appropriate annualisation factor

Strategic transport models used to simulate networks and travel demand typically model four separate time periods on an average weekday in each model year (i.e. an AM peak period, inter-peak period, PM peak period and overnight or off-peak period). The application of an annualisation factor is required to convert estimates of daily demand and economic benefits into annual values.

The choice of an appropriate annualisation factor depends on the nature of the project and the expected patterns of use across average weekdays, weekends, public holidays, and school holiday periods (i.e. when levels of demand may vary significantly).

Current DEDJTR guidance does not provide specific annualisation factors to be used in the economic evaluation of transport infrastructure project, but rather states that 'the specific characteristics of the network in which the project being assessed is located should be key considerations in the determination of daily and annual expansion factors.'

In a report prepared to inform the East West Link project, the Linking Melbourne Authority (LMA) undertook a detailed analysis of observed annualisation factors for EastLink and CityLink. Based on this analysis it was recommended that an annualisation factor of 330 be applied for all traffic, or individual annualisation factors of 340 for cars, 285 for LCV, and 265 for HCV.

A review of annualisation factors used for recent large-scale Victorian business cases shows that the majority of projects have utilised the same annualisation factor first developed for East West Link.

The recent West Gate Tunnel project refined this assumption based on observed annualisation factors for City Link and West Gate Freeway, which saw the annualisation factor for HCVs increase from 265 to 275.

Table 1 Annualisation factors adopted (by vehicle class)

Project	AF (Cars)	AF (LCVs)	AF (HCVs)
East West Link	340	285	265
West Gate Tunnel Project	340	285	275
Metro Tunnel Project	330	330	330
IV 30 year strategy	330	330	330
CityLink Tullamarine Widening	342	296	274
Level Crossing Removal Program	321	321	321
Suburban Roads Upgrade (SRU) Project	330	330	330

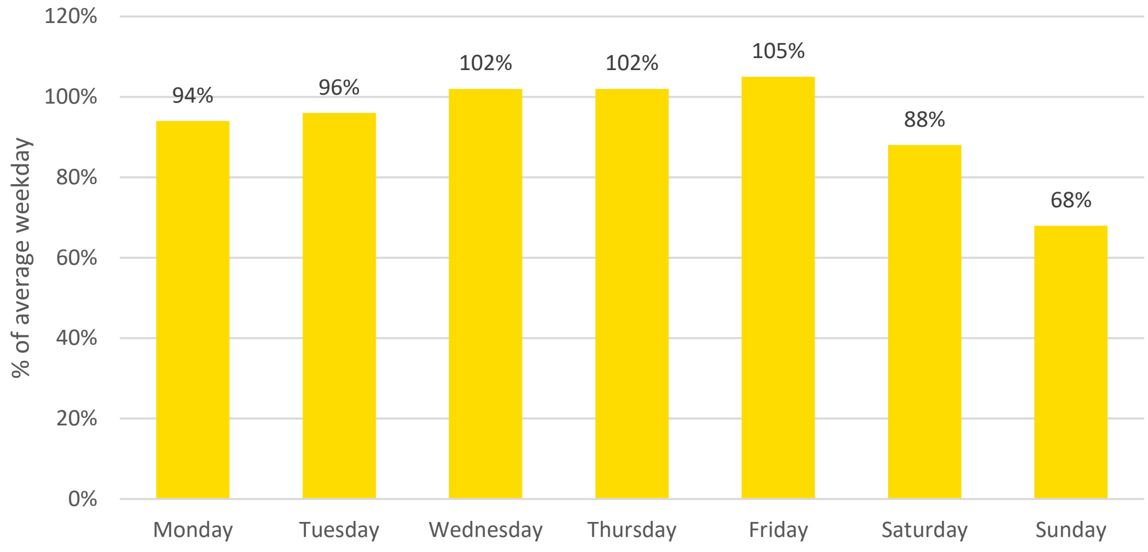
Source: EY analysis of previous projects

For the purposes of the economic appraisal, we sought to develop an appropriate project specific annualisation factor. In doing so it was noted that the project is expected to provide significant benefits to users across the network, and not just specific to the project. Therefore, it stands to reason that the annualisation factor should be derived from observed values from arterial roads or across the network, rather than from just freeways/toll roads.

Using recent data sourced from VicRoads[1] , it was found that weekend traffic volumes on Melbourne's road network are approximately 78% of that seen on an average weekday (Figure 3).

[1] VicRoads Traffic Monitor – As of 17 February 2017

Table 2 Traffic volumes by day of the week



Source: VicRoads Traffic Monitor – February 2017

Applying the weekday to weekend ratios calculated above provides us with an average weekday-to-year volume expansion factor of 339 across all vehicles.

Table 3 Volume expansion factors

	Number of days	% of weekday traffic	Volume expansion factor
Weekday	251	100%	250
Weekend/Public Holiday	114	78%	89
Total	365	n/a	339

Source: EY analysis of VicRoads data

However, it is noted that there is evidence to suggest that there exists a nonlinear relationship between demand and economic benefits, which is a feature of most transport infrastructure projects. Therefore using a volume expansion factor would overestimate travel costs (i.e. benefits). TfNSW guidance[2] suggests that the ratio of benefits to demand (i.e. volumes) is approximately 0.97. Applying this relationship to the volume annualisation factor calculated above results in a benefits annualisation factor of 330.

A further consideration is whether the annualisation factor of 330 should be applied equally to all vehicle types as was done for the Metro Tunnel, Level Crossing Removal Project and SRU, or whether separate factors reflecting different weekend travel rates should be calculated like the West Gate Tunnel and CityLink-Tullamarine Widening projects. For instance, if freight vehicles that benefit from the project are less likely to travel on weekends, then a lower factor could be applied to freight vehicles (noting that this would require an increase in the factor for cars to ensure the average value of 330 is maintained). This would have the impact of reducing benefits for freight users and increasing benefits for other users.

In the case of North East Link, it is considered that traffic volumes on the weekend will include a signification share of freight users. This reflects the important role the project will play in connecting key freight gateways, particularly as the intermodal freight network continues to evolve in serving manufacturing locations and the port. This suggests that a single factor of 330 provides a reasonable distribution of benefits between freight and other users.

[2] TfNSW guidance recommends a volume annualisation factor of 346 and a benefit annualisation factor of 336 for urban roads.

Furthermore, in recent years there has been an increase in weekend traffic relative to weekday traffic, which has supported the use of higher annualisation factors. Should that trend be considered likely to continue, there could be a case to use increasing annualisation factors over the appraisal period. This would provide further upside to the benefits profile.

In addition, sensitivity tests have shown that using an average annualisation factor across all vehicle types, does not produce a significantly different result overall than if vehicle specific annualisation factors are used. For example, applying factors of 340 for cars, 285 for light commercial vehicles, and 265 for heavy commercial vehicles has a minor impact on total benefits of around -1%.

Based on the analysis presented above a single annualisation factor of 330 has been applied in the calculation of benefits for the North East Link.

2.3.2 Treatment of induced demand

As the North East Link and complementary freeway and arterial upgrades will provide a significant increase in network capacity for the north, north-east and east of Melbourne, the project team has explicitly modelled multiple sources of induced demand including:

- Route, destination and mode choices as per the four-step modelling approach outlined in the Victorian guidelines, with route choice representing the lowest order choice and destination and mode choices representing mid-level demand responses
- Time shifting and land use changes as the additional demand responses that are identified in the national guidelines but not yet part of the Victorian framework.

Veitch Lister Consulting's Zenith model has been used to estimate route, destination and mode choices, with the model allowing the separate estimation of route choice (i.e. by assigning 'fixed trip' demand matrices) before being used to test for route, destination and mode choices in a combined modelling approach.

The estimation of potential land use changes due to the project has also formed part of the modelling for the economic appraisal, using EY's land use model and approach that was developed for previous projects (e.g. LXRP, SRU) with the results fed back into the Zenith model to test the impacts of land use changes on the network (i.e. using a land use – transport interaction (LUTI) approach).

2.3.2.1 Ramp up

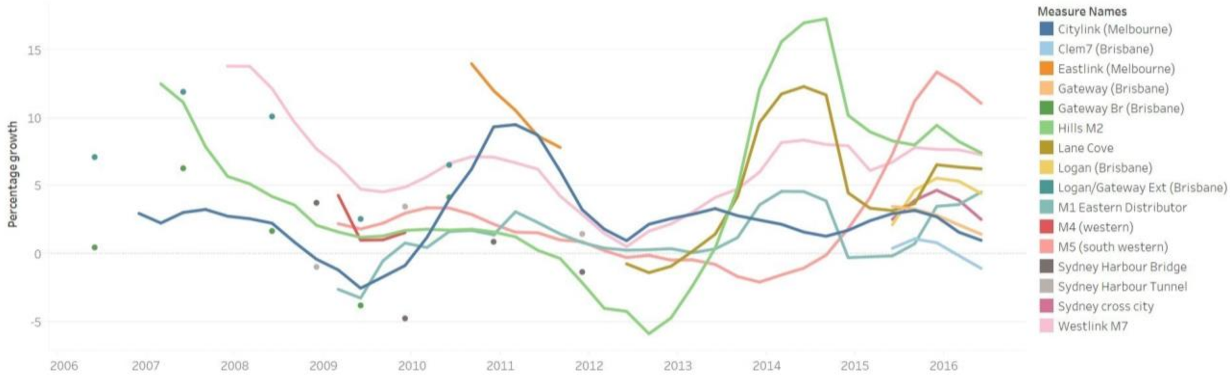
There is a significant degree of uncertainty about when a major toll road will reach its complete 'steady state' demand profile. This is the stage when all of the induced demand effects have occurred and the only factors changing demand growth include background population and employment growth, assumed changes in network capacity (and technology where relevant), and other behavioural changes not related to the project (e.g. changing work practices).

Previous guidelines in Australia (Australian Transport Council, 2006) identified the potential for a ramp-up period for urban transport projects, stating that this issue could be particularly relevant for public transport and toll roads.

Analysis of Australian toll roads

It is challenging to observe the path to complete steady state as there are so many factors at play and available data is very noisy including road works, volatility in fuel prices, economic trends and project/network upgrades that could compete with or complement use of toll roads (see Figure 2).

Figure 2 Year on year growth in traffic on Australian toll roads



Source: https://public.tableau.com/profile/chris.loader#!/vizhome/TollRoads/Austollroadyearonyeargrowth

While it might be possible to observe an initial ramp up phase for some toll roads where traffic appears to reach a stable growth path, this may in fact only represent the initial ramp-up for the route choice component of the induced demand hierarchy, where the additional responses could be playing out over a longer timeframe.

A paper presented to the Australian Transport Research Forum in 2010 has highlighted how more recent toll roads like EastLink in Melbourne and the WestLink (M7) project in Sydney have involved more gradual ramp-up profiles, which was considered to relate to the initial toll-free operating period as well as other factors.[3]

The figures below (Figure 3 and Figure 4) provide observed traffic build up profiles for a number of earlier toll roads and a notional "traditional" ramp-up profile for Australian toll roads. These show a rapid ramp-up period in the early years, which we consider relates to general acceptance of the project and the ramp-up of route choice decisions.

Figure 3 Observed traffic build up on recent toll roads

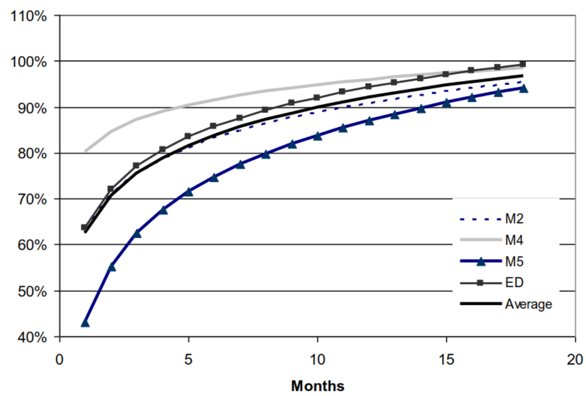
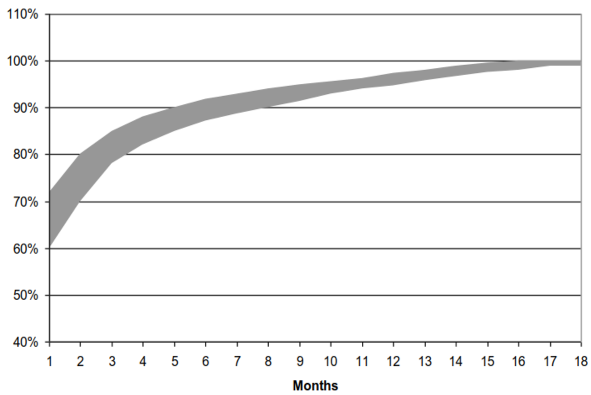


Figure 4 Traditional ramp-up profile



Source: Glen D'Este, Australasian Transport Research Forum 2010 Proceedings (http://atrf.info/papers/2010/1973_not_presented_Este.pdf)

Figure 5 presents a comparison of assumed and actual ramp-up for EastLink and WestLink, with the paper observing that this data suggests that ramp-up is likely to be more gradual and "straight-line" in comparison to the traditional ramp-up profile.

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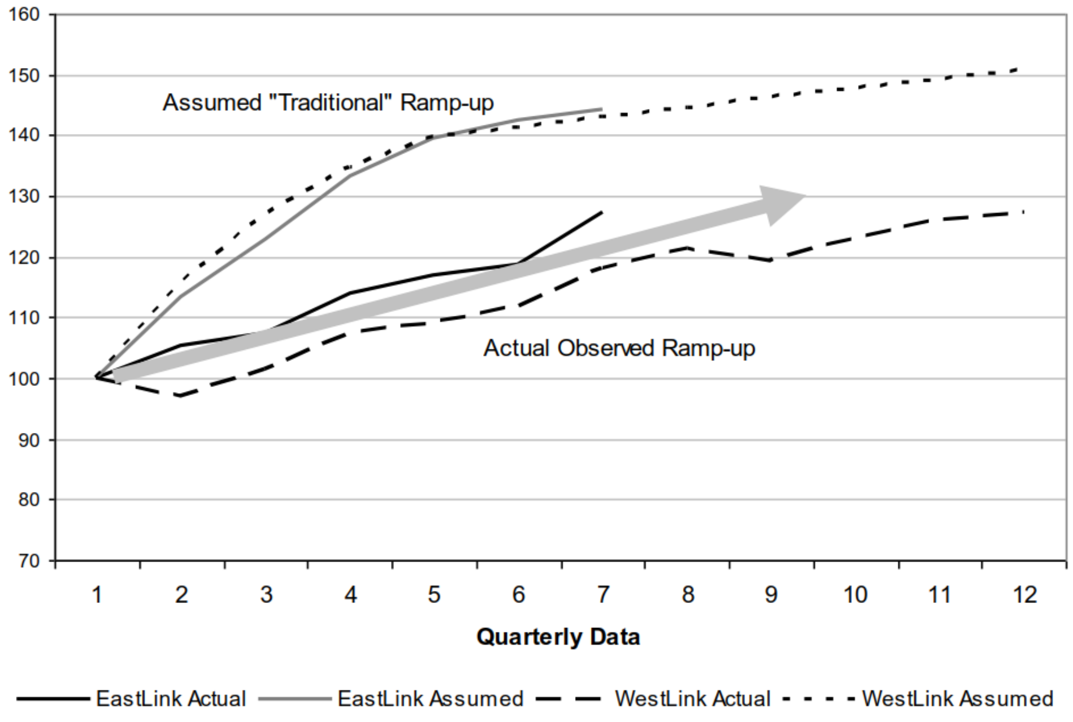
[3] Glen D'Este, What happens to toll road ramp-up profile when there is an initial toll-free period, and the broader implications for demand forecasting, Australasian Transport Research Forum 2010 Proceedings (http://atrf.info/papers/2010/1973_not_presented_Este.pdf)

Figure 5 Comparison of assumed and actual ramp-up for EastLink and WestLink M7 (Sydney)

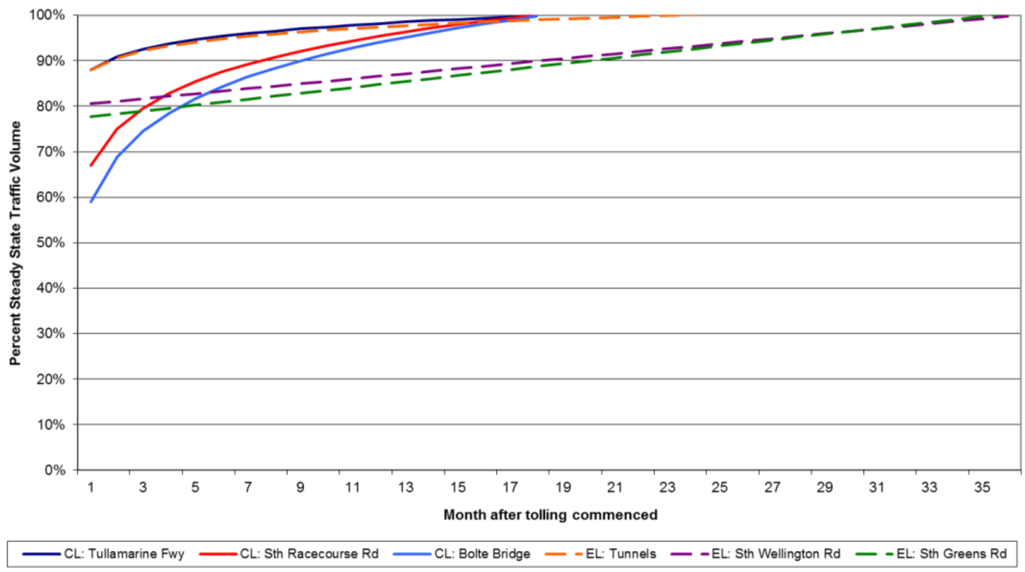


Source: Glen D'Este, Australasian Transport Research Forum 2010 Proceedings (http://atrf.info/papers/2010/1973_not_presented_Este.pdf)

Analysis of CityLink and EastLink

Observed demand profiles were provided for both EastLink and CityLink in a report prepared by the Linking Melbourne Authority for the East West Link business case. The report showed that it took up to three years for traffic along EastLink and CityLink to reach a stable growth path, with CityLink including a more rapid early period of user acceptance compared to EastLink (Figure 6).

Figure 6 Traffic build up for CityLink and EastLink



Source: Linking Melbourne Authority

As noted above, a key challenge with interpreting this data is in determining whether the stable growth path achieved in the first two to three years of operations represents the ultimate steady state or whether there are other induced demand effects playing out albeit through a relatively stable growth rate.

The project team has undertaken further analysis of traffic build up on the northern sections of EastLink compared to population growth for the project catchment. Based on analysis of EastLink traffic data, it was found that traffic growth rates were significantly higher than population growth in the early years and a gradual reduction to a level that is comparable with population growth over around eight years.

This issue was explored by SGS Economics and Planning when it prepared case studies for CityLink and the Western Ring Road to support the assessment of potential land use and wider economic impacts that occurred as a result of the projects.

For CityLink it was estimated that the associated land use changes and wider economic benefits of the project also took up to eight years to reach a steady state level. In the case of the Western Ring Road, land use changes and the resulting wider economic impacts were estimated to have taken between four and six years to materialise.[4]

2.3.2.2 Approach

There are significant challenges around traffic forecasting during the early years of operations, with the analysis of recent toll roads and BITRE's review of toll road forecasting performance highlighting the need to take ramp-up risks into account.

It is considered that the effect of NEL on long term decisions (e.g. home location, job location, school location, business location) might play out over a relatively longer timeframe compared to other trip purposes where the destination is more flexible (e.g. shopping). Mode choice is considered to be less of an issue in the context of NEL, although it is recognised that where alternative public transport services are available users will be able to change mode relatively quickly.

The analysis presented above supports this view and suggests that a gradual ramp-up profile would provide a realistic treatment of ramp-up risks for a toll road like the North East Link, with analysis completed for EastLink and CityLink suggesting that land use changes and associated induced demand effects could take up to eight years to reach a steady state growth profile.

The economic appraisal for the NEL is going a step further than previous toll road projects by assessing and modelling the impacts of possible land use changes. While this will provide an enhanced understanding of longer term induced demand effects, it heightens the need for caution with respect to ramp-up given the land use scenario will involve higher demand for the project.

A further consideration relates to the mechanism by which ramp-up assumptions are implemented. One approach involves blending the different demand scenarios based on a view about how the different sources of induced demand play out over time. The other approach involves simply discounting the demand and benefits generated from the scenario where all induced demand factors have been modelled. The blending approach provides a more intuitive evolution of demand and network impacts but is difficult to support with available evidence for the different sources of demand. However, the discounting approach is also difficult to validate and may be over simplistic in that it does not provide an intuitive profile of the wider network impacts of the project during the ramp-up period.

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[4] SGS Economics and Planning (2015): http://economicdevelopment.vic.gov.au/__data/assets/pdf_file/0004/1237279/Western-Distributor-Attachment-M-Land-Use-Report.pdf

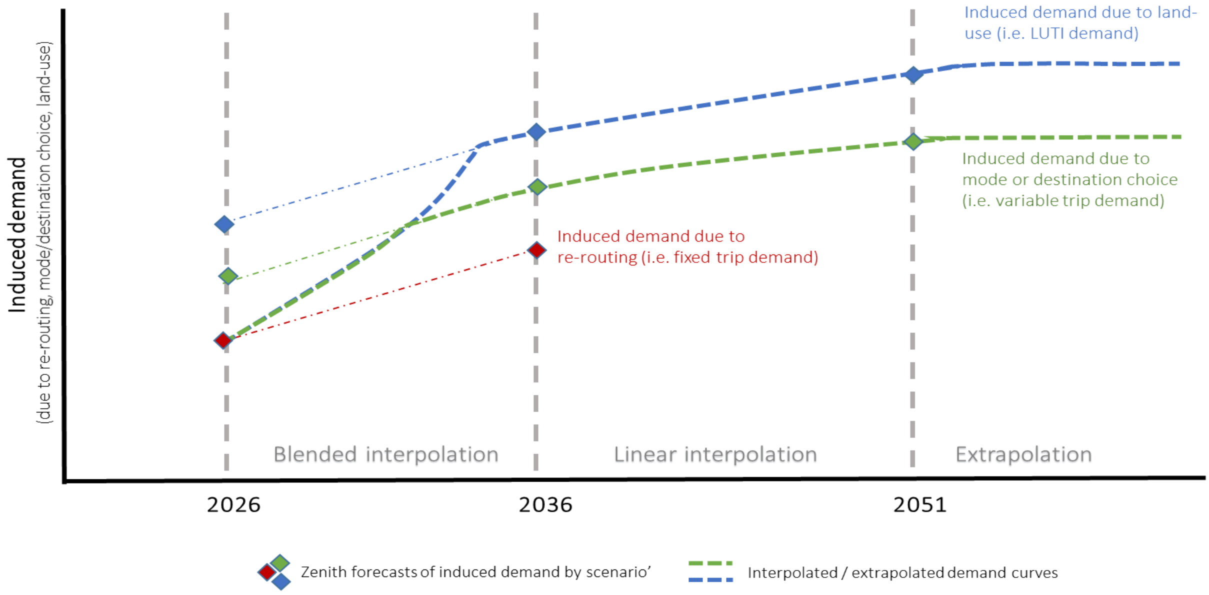
For the economic appraisal it has been assumed that it will take eight years for demand to reach a steady state level taking into account induced demand related to route choice, mode switching, destination choice and land use changes.

To implement this approach, a gradually blended revenue and benefits profiles will be estimated between 2026 and 2034 using the outputs of the Zenith Model for 2026, 2036 and 2051 based on three different demand scenarios as follows:

- A route choice scenario (using Victoria in future (VIF) land use inputs)
- combined route, mode and destination choice scenario (using VIF land use inputs)
- A combined route, mode and destination choice scenario (using 'with project' land use assumptions developed with the EY land use model).

This approach is illustrated conceptually in Figure 7. The core benefits and revenue profiles will be established using scenarios one and two, with scenario 3 providing the target level of demand in 2034 and the basis for calculating the ultimate revenue scenario and the impacts of land use changes on core benefits and (below the line) wider economic benefits in line with the land use benefits framework presented in the economic appraisal methodology.

Figure 7 Assumed ramp-up profile for the North East Link project (conceptual)



Source: EY analysis

This is considered to be a conservative approach to forecasting demand for the toll road (and hence wider network impacts), reflecting recent analysis of observed data for EastLink and WestLink, and the analysis of land use changes and wider economic benefits conducted for CityLink.

A benefit of this approach is that it is based on an assumption of how the different sources of induced demand might play out over time (i.e. instead of simply discounting the scenario three results). This provides more intuitive demand, revenue and benefits profiles that accord with user experiences of new toll road facilities and observed patterns of behavioural and land use changes.

Note that alternative ramp-up assumptions have also been tested as part of the sensitivity testing undertaken for the economic appraisal.

2.3.3 Assumptions for growth in road vehicle operating costs

The VOCs that motorists perceive, particularly fuel prices including any taxes and subsidies, play a key role in determining the level of demand for car trips on the network, with the evolution of fuel prices relative to the costs of public transport travel (i.e. fares) being a major contributor to car and public transport mode shares (along with relative travel times and other factors).

Strategic transport models (e.g. Zenith, VITM) are developed so that expectations about travel costs can be taken into account when predicting future travel patterns, including the demand for trips between trip origins and destinations, mode shares and route choices. Strategic transport models are highly sensitive to VOC parameters where, all other things being equal, increases (decreases) in assumed VOCs cause the model to predict significant reductions (increases) in car demand and a switch to (from) public transport.

These models are a crucial input to major transport infrastructure investment decisions like the NEL project (which is using the Zenith model developed by Veitch Lister Consulting), and are used to inform the engineering design, the economic benefits evaluation, the tolling strategy and the commercial evaluation. As such, it is important that the demand forecasts generated by the model represent the most likely forecast scenario that project planners can use with a reasonable level of confidence, particularly given the High Value – High Risk (HVHR) status of the project.

Transport modelling assumptions used for major projects in Victoria are informed by the Department of Economic Development, Jobs Transport and Resources' (DEDJTR's) Reference Case. The intention is for all major transport projects to use these assumptions in order to provide a consistent and comparable basis for project planning and evaluations across Victorian projects.

VOC assumptions developed prior to 2014 by the Department of Transport, Planning and Local Infrastructure (DTPLI, which was the precursor agency to DEDJTR, were based on expectations that oil and fuel prices would increase significantly above Consumer Price Index (CPI) over the forecast period, with increase of around 2 per cent (real) per annum predicted from 2011 to 2031, and of around 1.6-1.7 per cent per annum from 2031 to 2051. Under this approach, compared to 2011 levels, VOC factors were assumed to be around 48 per cent higher by 2031 and around 107 per cent higher by 2051. Once you include monetary inflation over the same period, this equates to a nominal price increase of around 435 per cent.

Given developments in energy markets and vehicle technologies over the last decade in particular, these forecasts were increasingly being questioned by transport planners. In order to increase the robustness and level of confidence around the Victorian Government's transport demand modelling, DTPLI engaged Frontier Economics in 2014 to provide an independent review of car parking costs and VOCs for Melbourne over the period to 2050. Frontier Economics was also required to review DTPLI's existing estimates, and to provide recommendations on new forecasts with the support of evidence.

Following the Frontier Economics review, the DEDJTR Reference Case assumptions were revised down, although the revision did not go as far as suggested by Frontier Economics, which reported a central case scenario with an average annual growth rate of around 0.2 per cent per annum compared to DEDJTR's 1.0 per cent (see below for further analysis).

The recent release of the DEDJTR Transport Modelling Reference Case v1.09 as of the 8th of September 2017 (the Reference Case)[5] has further revised VOC forecast growth, revising down growth estimates in all horizon years (except 2021-2031), resulting in an compound annual growth rate of 0.5 per cent between 2011 and 2051.

The current and past Reference Case growth assumptions for VOC are set out in Table 4.

[5] Revised Reference Case VOC assumptions received from the Department on the 8th September 2017.

Table 4 Reference Case VOC (real) growth assumptions

Period	DTPLI Reference Case		Reference Case v1.08a		Reference Case 1.09	
	VOC growth Compound Annual Growth Rate (%)	Total growth (%)	VOC growth Compound Annual Growth Rate (%)	Total growth (%)	VOC growth Compound Annual Growth Rate (%)	Total growth (%)
2011 - 2021	2.1	23.4	1.1	11.6	0.2	2.0
2021 - 2031	1.9	21.2	1.0	10.5	1.2	12.7
2031 - 2041	1.7	18.7	1.1	11.6	0.6	6.2
2041 - 2051	1.6	17.6	0.7	7.2	0.1	1.0
Cumulative 2011 - 2051	1.9	108.7	1.0	47.4	0.5	23.3

Source: DEDJTR (8 September2017), DEDJTR Transport Modelling Reference Case v1.08a

It is noteworthy that public transport fares in the current Reference Case are assumed to grow only marginally by 2.5 per cent in real terms between 2016 and 2018, in line with Government announcements for that franchising period, and then remain unchanged in real terms between 2018 and 2051. Conversely, car VOC are forecast to increase by 23.3 per cent between 2011 and 2051. Consequently, there is an inherent bias in future forecasts due to the divergence in the long term cost profile of car and public transport trips in comparison to car modes within the DEDJTR Reference Case. Therefore, the Reference Case assumption of higher growth in road costs would result in a shift towards public transport modes in the future, as the relative cost of road travel increases.

As VOCs are a function of both the price of fuel, and vehicle (i.e. fuel) efficiency, we have undertaken independent analysis and desktop research of the factors we have identified which are most likely to impact upon fuel prices and vehicle efficiency. While it is noted that fuel prices will also be impacted by changes in the level of excise, taxes or the implementation of a carbon tax, for the purposes of this analysis it has been assumed that the current tax arrangements will remain unchanged.

In addition to this, we have undertaken a review of approaches applied by other jurisdictions to understand how the current Victorian approach compares. Based on this analysis and review, we have estimated future VOC growth under a number of possible future scenarios. The scope of our work included analysis of:

- DEDJTR VOC assumptions and Frontier Economics report
- Market forecasts for fuel price
- Market trends for vehicle efficiency
- Forecasts for changing vehicle fleet mix over time
- Jurisdictional comparisons of VOC growth assumptions from NSW, UK and NZ
- Alternative scenarios for fuel prices and vehicle efficiency, culminating in a recommendation for the transport modelling and analysis supporting the NEL project.[6]

Based on our research and analysis it was found that:

Reference Case assumptions for VOC growth have been out of step with the findings of the Frontier Economics study, although the most recent update is close to the top-end of the range.

- Frontier Economics' review of DTPLI Reference Case parameters recommended that the Reference Case should use a forecast that sat within the lower bound and upper bound

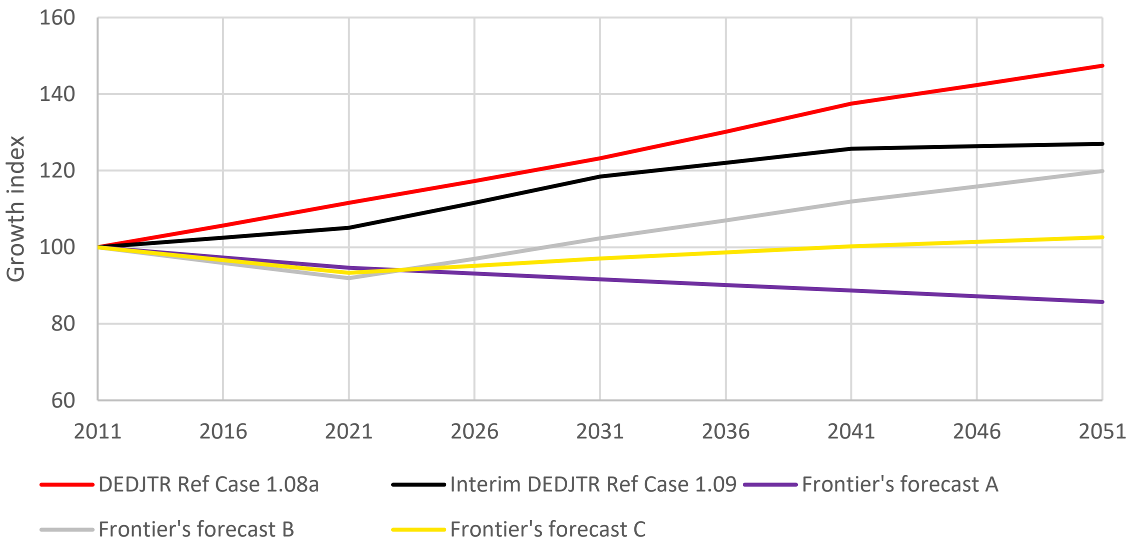
[6] NB: Scenario analysis assumes current tax arrangements for fuel excise and tax will not change markedly, such that perceived fuel costs will change at the same rate as resource fuel costs over time.

forecasts that they had developed, with the lower bound forecast (Forecast A) assuming zero real growth in fuel prices with ongoing improvements in average vehicle efficiency, and the upper bound forecast (Forecast B) assuming fuel price growth of around 0.9 per cent per annum over the period to 2040 based longer range forecasts for oil prices, small gains in vehicle efficiency and no real growth in GST or excise.

- Subsequent to the Frontier Economics review, VOC growth parameters have been revised multiple times. However, as can be seen in the figure below, the VOC growth parameters in the most recent revision of the Reference Case (v1.09) (as at 8th September 2017) still do not sit within the band of forecasts recommended by the review.

- Based on EY analysis, there appears to be an inconsistency in the forecasting methodology within the Reference Case VOC assumptions, with observed Australian pump prices being used between 2011 and 2016, and USD oil price forecasts used thereafter to forecast price change. This approach ignores factors other than oil price fluctuations that have driven recent changes in Australian pump price and appears to introduce an excessive rebound in oil prices between 2016 and 2021. In contrast, EY has ignored short term volatility and focussed on forecasting using broader relationship between pump price and oil price over the longer term from 2011 to 2021 and then beyond to 2051.

Figure 8 VOC Growth Parameter comparison



Source: Frontier Economics 2014, DEDJTR (8th September 2017)

Oil prices are the key driver of fuel prices and these have been trending down in recent years to stabilise at around $40-50 a barrel after reaching highs of around $100-110 over 2012 to 2014[7]. This is due to a mix of demand and supply factors, including the emergence of fracking and repeated unsuccessful efforts by OPEC to control supply and prices. These factors are assumed to persist in market forecasts for fuel prices.

- A recent study from the Bureau of Infrastructure, Transport and Regional Economics (BITRE) has shown that there is a strong link 'at the wharf' between world oil prices and Australian fuel prices. [8,9]

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[7] EIA 2017

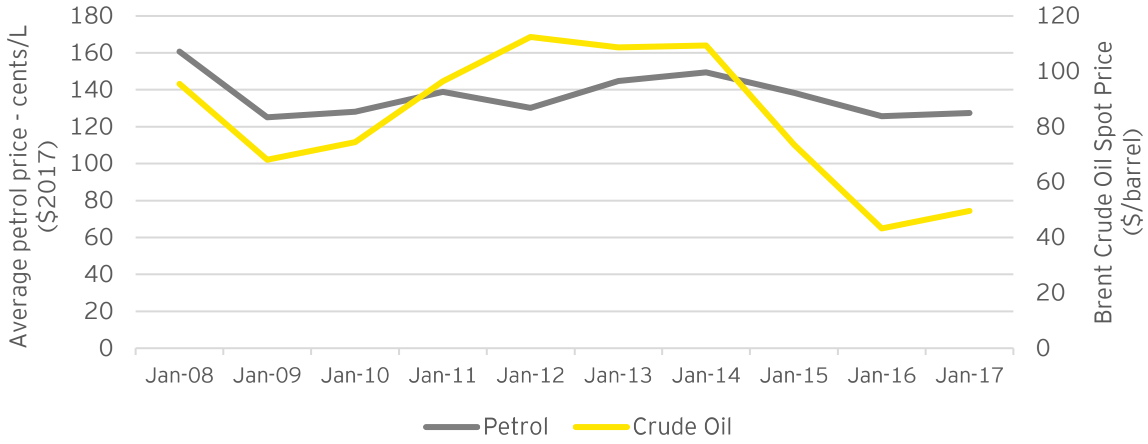
[8] Bureau of Infrastructure, Transport and Regional Economics (BITRE) 2016, Petrol Prices and Diesel Prices in Australia BITRE, Canberra

[9] Refers to the 'wharf' price of fuel, which is calculated based on the off-shore price of oil multiplied by the exchange rate. I.e. Price off-shore ($US/barrel) * exchange rate = wharf price ($AUD/barrel)

► Fuel prices have been trending downwards in recent years. Historical analysis shows that petrol prices have declined by 2.5 per cent per annum between 2008 and 2017 in line with a 7.0 per cent per annum drop in oil prices over that period.

► In the three years since the Frontier Economics report was completed (2014), the West Texas Intermediate (WTI) Crude oil spot price has fallen by 24.1 per cent per annum.[10][11]

Figure 9 Metropolitan Melbourne fuel price comparison with Crude Oil prices



Source: EIA (2017), Australian Automotive Association (2017)

► Our analysis suggests that while this price drop was initially due to the Global Financial Crisis, the continued decline was also due to ongoing increases to oil inventories, the rise of fracking and OPEC losing its control on setting prices.

► With the expected rise of electric cars as an alternative to petrol cars, a continuation of increased oil inventories and a weaker OPEC, the current World Bank forecasts suggest that oil prices will exhibit a brief period of recovery between 2016 and 2018, before falling back to a more subdued rate of growth of around 0.5 to 0.6 per cent per annum through to 2030. This is broadly in line with other market forecasts, such as the U.S Energy Information Administration (EIA) which predicts oil prices to gradually return to 2011 levels by 2051, and Deloitte who projects that international crude oil prices will remain constant beyond 2022. For the purposes of our analysis we have used the World Bank forecasts as a conservative proxy for growth in fuel prices in the future.

Fuel efficiency of vehicles continues to improve rapidly and the car fleet is expected to see an increase in the share of electric vehicles in the coming decades. Current expectations are that fuel efficiency could improve by almost 30 per cent between 2013 and 2030, and that electric vehicles could represent 13-18 per cent of the total car fleet[12].

► Fuel efficiency of vehicles is improving, primarily as a result of technological improvements. The average petrol consumption rates of new cars has decreased in recent times from approximately 9 L/100km in 2003 to 7 L/100km in 2013. Frontier Economics' analysis of Australian Bureau of Statistics (ABS) survey of motor vehicles suggests that fuel efficiency in Australia will continue to improve at a rate of 0.35 per cent per annum into the future, which is in line with recent trends.

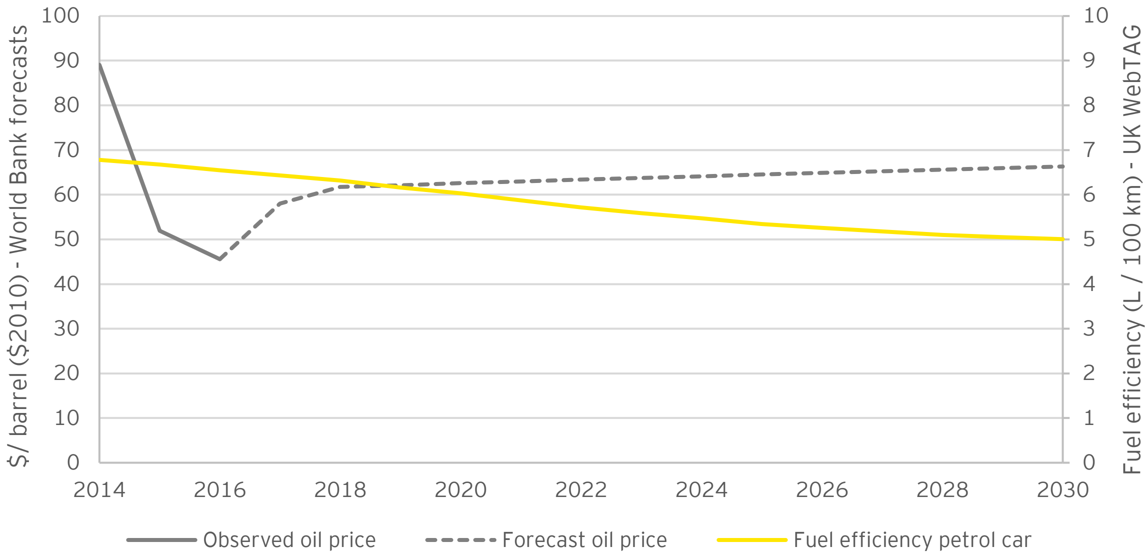
► A number of leading countries have begun putting measures in place to phase out the sale of petrol and diesel cars. France and Britain have announced that they will ban the sale of petrol

[10] Crude Oil Futures, Investing.com (2017)
[11] Crude Oil Futures, Investing.com (2017)
[12] WebTAG, 2017 and AEMO, 2017

and diesel cars by 2040.[13] More recently, China has also announced that a timetable is being developed for implementing a ban on the manufacture and sale of vehicles with combustion engines.[14] With China being the largest producer of cars, this policy and moves in Europe can be expected to significantly incentivise the use of electric and other non-petroleum fuel based alternatives globally. With these vehicles being cheaper to operate, this is expected to significantly reduce VOC in the future.

► The car fleet mix is set to change over the next 20 years. UK WebTAG predicts increases in the proportion of the road task performed by electric vehicles over time, from zero per cent of vehicle kilometres travelled in 2015 to 13 per cent in 2035.[15] Our research suggests that a similar forecast is suitable for the car market in Australia. For example, forecasts from the Australian Energy Market Operator (AEMO) suggest that electric vehicles will account for 17.8 per cent of the total fleet mix in Australia by 2036.

Figure 10 Fuel price forecasts vs Fuel efficiency



Source: WebTAG 2017, World Bank 2017

The approach applied in Victoria is out of step with approaches applied in other jurisdictions like the UK and NSW. The UK framework applies explicit assumptions about both fuel prices, vehicle efficiency and electric vehicle uptake, whereas in NSW it is assumed that VOCs and public transport fares are held constant in real terms.

► The UK's WebTAG guidance forecasts a reduction of 1.0 per cent per annum in real VOC between 2010 and 2050 to account for these trends in fuel prices and expectations about the car fleet mix and take-up of electric vehicles. Although, these forecasts have not been updated in light of recent government policy announcements to eliminate the sale of new petrol and diesel vehicles by 2040 as part of a plan for there to be zero emissions from vehicles by 2050.[16] [17]

► Other jurisdictions in Australia apply different approaches when considering VOC growth. For example, Transport for New South Wales (TfNSW) have assumed zero growth in VOC over time

[13] Opec and the oil barons face a slow death by electrification, Evans-Pritchard, The Age (July 27 2017)
[14] China formulates national smart car industry strategy, People's Daily (September 11, 2017)
[15] WebTAG (2017)
[16] Air quality plan for nitrogen dioxide (NO2) in UK (2017), Department for Transport (July 2017)
[17] UK government pledges bold ambition for electric cars (December 2015)

which is consistent with their assumption for public transport fares to ensure that the relativities remain constant over time.

It should be noted that both the Australian Transport Assessment and Planning (ATAP) guidelines and Infrastructure Australia's assessment framework do not provide guidance on the VOC growth or any other modelling parameter growth and therefore cannot be used as a guide to parameter growth assumptions in Victoria.

Our analysis suggests that the current VOC growth rate assumptions in the Reference Case do not reflect current market expectations about oil and petrol prices, newer car fleets and changing fleet mix over time.

In particular, it is noted that the Reference Case does not reflect the significant drop in petrol prices between 2011 and 2016. Therefore, it is likely that the Reference Case assumptions are overstating the future growth in VOCs.

Based on a comparison of alternative VOC profiles, we recommend that the DEDJTR Reference Case assumptions for growth in VOC should not be used to inform the base scenario for the NEL Project.

Therefore the growth parameters outlined in Table 5 have been used to inform the economic appraisal, which reflects the outlook of World Bank oil price forecasts and Frontier Economics' trend analysis of the ABS Survey of Motor Vehicle Use (SMVU).

We consider this to be a conservative approach in comparison to Scenario 6, which is the only scenario that considers increases in the uptake of EVs (arguably more likely than Scenario 2 given recent automotive manufacturing announcements by BMW, Volvo and Jaguar Land Rover and policy announcements in the UK, France and China).[18,19,20]

Table 5 – Proposed VOC growth rate assumption

Period	Reference Case 1.09		Proposed VOC growth rate assumption[21]	
	VOC growth Compound Annual Growth Rate (%)	Total growth (%)	VOC growth Compound Annual Growth Rate (%)	Total growth (%)
2011-2021	0.2	2.0	-2.9	-25.8
2021-2031	1.2	12.7	0.0	0.3
2031-2041	0.6	6.2	0.0	0.2
2041-2051	0.1	1.0	0.0	0.3
2011–2051	0.5	23.3	-0.7	-25.2

Source: EY analysis

While it is noted that, for comparison purposes, an economic appraisal should utilise a DEDJTR's Reference Case scenario, it is believed that doing so will not accurately represent future network conditions and may therefore have an impact on both the design of the project, as well as the economic benefits. Nevertheless, a sensitivity test has been undertaken to understand the relative impact of reference case assumptions.

2.3.4 Accounting for changes in the perceived costs of congestion

In recent years in Victoria, the economic appraisals of major transport projects have included time related benefits for road users in addition to general travel time savings that are valued using standard values of travel time. This includes benefits associated with more reliable/predictable

[18] BMW pledges to build new e-Mini at UK car plant, Topham, G. (25 July 2017), The Guardian

[19] All Volvo cars to be electric or hybrid from 2019, Vaughan, A. (5 July 2017), The Guardian

[20] Jaguar Land Rover to make only electric or hybrid cars from 2020, Vaughan, A. (8 September 2017), The Guardian

[21] Based on ABS fuel efficiency and World Bank oil price forecasts

travel conditions and benefits from avoiding levels of congestion that cause frustration, difficulty and stress associated with driving in stop-start traffic.

Including these benefits aims to ensure that the assessment of impacts on road users is comparable with the treatment of public transport users, where impacts on service punctuality and crowding represent a significant source of user benefits for some public transport projects.

The major projects that have included these additional benefits for road users include the West Gate Tunnel, Metro Tunnel (which is expected to create significant road decongestion benefits), the Level Crossings Removal Project and the Suburban Roads Upgrade (SRU) program.

Transport for Victoria's (TfV's) recently updated *Guidelines for Transport Modelling and Economic Appraisal in Victoria* (version 3.03, May 2017) has clarified the preferred treatment of benefits associated with changes in reliability and the perceived cost of congestion. The current guidance states the following:

- For **reliability** benefits, while the methodology for quantifying these impacts is currently being refined as part of the ATAP update, given this is a significant outcome for road transport investment, this is recommended to be presented as part of the core CBA results.

- For benefits due to changes in the **perceived cost of congestion**, while extensive international research shows that people's perceived value of time idling in congested conditions increases with the level of congestion, road congestion disutility impacts have only recently been explored as part of major project appraisal in Victoria. As such, work needs to be undertaken to understand the impact in Victoria and, for the interim, road congestion disutility benefits are to be presented outside of the core CBA results (i.e. as a separate additional benefit below the core CBA findings).

Based on discussions with TfV it is considered that this position may reflect a number of factors, including:

- The general framework for modelling instances of excessive congestion and the methodology for estimating benefits is based on an approach developed in New Zealand and is not test in Australia

- There is uncertainty whether the parameters for valuing the additional perceived costs have been derived in a way that accurately reflects these costs and/or whether there could be double counting with other benefits (i.e. general travel time and reliability benefits)

- Transport models have not been calibrated to reflect the additional perceived costs of congestion that are experienced when travelling on links with higher levels of congestion.

There is extensive evidence that road users' value relief from congested traffic conditions over and above their value of travel. Road users' higher willingness to pay to avoid time travelling on congested road links reflects the additional frustration, difficulty and stress associated with driving in stop-start traffic.

There is comprehensive evidence for including these effects when valuing travel time savings. Key references include:[22]

- The ATC 2006 NGTSM states that the general principle for the valuation of benefits should be based on the revealed willingness of users to pay to gain the benefits[23]

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[22] PWC, Western Distributor Economic Assessment Report, September 2015

[23] Australian Transport Council, 2006, National Guidelines for Transport. System Management in Australia, Part 4, Section 3.2.3, p. 21

- The NZTA 2013 EEM states that road users value improvements in traffic congestion over and above the benefits gained from travel time saving[24]
- TfNSW guidelines state that in economic appraisals, congestion costs can be evaluated by unit costs of vehicle kilometre travelled[25]
- The UK DfT TAG suggests that journey quality should be considered where specific revealed preference data is available[26]
- The Victorian Transport Policy Institute (Canada) note that travel time costs vary depending on travel conditions and traveller.[27]

The general approach for calculating benefits due to avoiding high congestion is adapted from the approach outlined in the New Zealand Transport Appraisal (NZTA) guidelines. The NZTA guidelines confirm that road user's value relief from congested traffic conditions over and above their standard value of travel time, defining the perceived cost of congestion as the difference between the observed travel time and the travel time when the road is operating at capacity.

Under the NZTA approach, operational capacity is defined as the "maximum sustainable flow" of a road, which is considered to occur when roads are operating with a volume-capacity (V/C) ratio of 0.7. Therefore, any time spent on roads with V/C ratios above 0.7 are assessed to incur a higher perceived cost, and the additional benefits for road projects arise when time spent on roads with V/C ratios above the 0.7 threshold is reduced compared to the base case scenario. [28]

The selection of 0.7 as the V/C ratio after which traffic conditions are assumed to create additional frustration compared to 'normal' traffic flow has been considered in the context of traffic engineering assessments of level of service, where different road types can exhibit different performance characteristics at similar levels of volume relative to capacity.

For example, the Transportation Research Board identifies different levels of service that can be achieved according to different V/C ratios for highways, arterials and intersections. In the case of arterials, traffic conditions when V/C ratios are in the 0.71-0.8 band are assessed to be stable but with restrictions in movement such that motorists start to experience "appreciable tension while driving". However, for intersections it is only above V/C ratios of 0.8 where significant congestion emerges on critical approaches, and where cars are required to wait for more than one cycle.[29]

It is recognised that network performance can vary significantly across road types and locations on the network. However, the approach applied in recent Victorian projects of gradually ramping-up the higher perceived costs of congestion so that the full incidence is only measured when roads operate with V/C ratios above 1 is a conservative approach that minimises the risks of over-estimating the potential for excessive congestion.

It is understood that TfV has expressed a concern that there may be some uncertainty as to whether the parameters for valuing the additional perceived costs have been derived in a way that accurately reflects these costs and/or whether there could be double counting with other benefits (i.e. general travel time and reliability benefits). In particular, TfV have expressed a view that parameters derived for the West Gate Tunnel project based on studies carried out by Hensher and Rose (2004, 2005, 2006 and 2008) may be an inappropriate use of the findings of those studies.

To address this issue a comprehensive review of available literature has been undertaken on the valuation of the perceived cost of congestion, with a key study by Wardman and Ibanez (2012)

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[24] NZ Transport Agency, 2013, Economic Evaluation Manual, p. 4-66

[25] Transport for NSW, 2016, Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives, Appendix 4, p. 255.

[26] The UK Department for Transport, 2014, Transport Analysis Guidance – TAG Unit A1.1 Cost Benefit Analysis, p. 2

[27] VTPI, Transportation Cost and Benefit Analysis II – Travel Time Costs (http://www.vtpi.org/tca/tca0502.pdf)

[28] NZ Transport Agency, 2013, Economic Evaluation Manual, p. 4-66

[29] Transportation Research Board, *Highway Capacity Manual*, Special Report 209 (Washington, D.C., 1994)

providing strong evidence on potential values and issues with double counting. After conducting surveys of a range of other studies examining the congestion multiplier, Wardman and Ibanez conclude that it is clear that the value of motorists' travel time depends on traffic conditions, and that a fine degree of gradation (beyond a simple two or three category decomposition, e.g. free-flow vs congested) in how time values relate to traffic conditions is both possible and preferable. [30]

Congested-time values proxy for the mental difficulty, stress, and frustration of driving in various conditions, not for variation in arrival times due to congestion. However it has been suggested that methods of determining the former might end up incorporating some of the latter if survey participants fail to distinguish between disutility of congested trips versus the associated unreliability in arrival times, which could lead to an element of double-counting congestion reduction benefits.

Wardman and Ibanez's study examines this point and finds no evidence that estimated multipliers are materially affected by the inclusion of reliability in questionnaires, giving confidence that estimated congestion disutility values can be added to reliability improvement benefits without risk of double-counting.

Wardman and Ibanez's survey also details a number of estimates of Australian congestion multipliers from past studies, most of which are in the range of around 1.3 to 1.7 (these represent the ratio of either 'congested', 'stop start', or 'slowed down' to free-flow time valuations). These suggest a time-value premium of between around $5 to $11 per in-vehicle hour spent driving on congested roads.

Based on this analysis, the benefits associated with changes in road users' perceived costs of congestion have been included in the economic appraisal, using the approach identified in the NZTA guidelines and applying a value of time uplift of 1.3, which is at the lower end of the range identified in the Wardman and Ibanez study.

As major road projects can have significant impacts on travel time in congested conditions (i.e. this is a significant outcome in the same vein as impacts on reliability), there is merit in including these benefits as part of the core appraisal. This same approach has been utilised on a number of major transport infrastructure projects in Victoria, and therefore utilising this approach will allow for consistency when comparing projects across the portfolio.

To increase transparency about the contribution of these benefits to total benefits and economic value-for-money, these benefits have been separately disclosed and the impact of removing them has been presented as a sensitivity test.

2.3.5 Estimating wider economic benefits

The assessment of WEBs has become an important feature of major transport project appraisals over the last 10 years, particularly the UK where the general framework that is currently applied to many projects in Australia was originally developed. This recognises that the assumptions underpinning conventional CBA fails to recognise the potential for transport projects to create externalities in relation to economic productivity, such as those related to market and knowledge spillovers and other market imperfections.

The methodologies for quantifying the different categories of WEBs has been a long established part of the UK's appraisal framework published in WebTAG, where the approach has been refined after initially developing and testing the framework on major projects like London's Crossrail and national high speed rail studies, among others. As can be seen in Table 6 below, the application of the current UK approach has produced estimates of WEBs between 5% and 56% of a project's conventional economic benefits (i.e. travel time and vehicle operating cost savings, emissions

[30] Warden, M and Ibanez, J.N (2012), The congestion multiplier: Variations in motorists' valuations of travel time with traffic conditions, Transportation Research Part A, Elsevier

reductions and other resource corrections) depending on the nature of the project. However, the majority of WEBs estimates are in the order of 10-30%.[31]

Table 6 Wider economic benefits project examples (percentage of conventional economic benefits)

Type of scheme	Location	Scheme	Agglom-eration	Imperfect competition	Labour market	Total additionality
Rail	Major city	Crossrail, London	24%	4%	28%	56%
HSR	Interurban	HSL London Birmingham	44%	8%	0%	52%
Road	Conurbation	Leeds to Bradford Improved Highways Connections	30%	6%	5%	41%
Road	Conurbation	Leeds Urban Area Highway Improvements	31%	5%	3%	39%
Mixed	Major city	Melbourne East West Road and Rail Package (Australia)	22%	2%	6%	30%
Rail	Major city	Airtrack, London - Heathrow	26%	2%	1%	29%
Road	Interurban	Leeds to Sheffield Highways Improvements	24%	6%	-2%	28%
HSR	Interurban	HSL Lisbon Porto (Portugal)	18%	8%	0%	26%
HSR	Interurban	HSL Y-Line London Manchester and Leeds	18%	7%	0%	25%
Bus	Conurbation	Leeds to Bradford PT Improvements	18%	3%	2%	23%
HSR	Interurban	HSL London - Scotland (West Coast)	14%	8%	0%	22%
Rail	Major city	Cross River Rail, Brisbane	16%	0%	5%	21%
Road	Interurban	A46 Interurban Road, East Midlands Region	13%	6%	1%	20%
Mixed	Conurbation	Victoria Transport Plan Package (Australia)	17%	1%	1%	19%
Bus	Urban	Intra Leeds Bus Fare Reduction and Frequency	13%	2%	2%	18%
Road	Interurban	M6 Shoulder, West Midlands Region	11%	5%	0%	17%
Rail	Major city	Melbourne East West Rail Package (Australia)	14%	1%	2%	16%
PT	Conurbation	Leeds Urban Area Major PT Investment	11%	3%	2%	16%
Bus	Area wide	West Yorkshire Bus Fares and Frequency	10%	2%	2%	15%
Bus	Area wide	South and West Yorkshire Bus Fares and Frequency	8%	3%	2%	12%
Bus	Area wide	South Yorkshire Bus Fares and Frequency	3%	3%	0%	5%

Source: Kernohan, D and L Rognlien (2011) Wider economic impacts of transport investments in New Zealand. NZ Transport Agency research report 448

The ATAP guidelines have recently been updated to provide project teams with advice on how to estimate WEBs for Australian projects using an interim methodology.[32]

The approach put forward by ATAP represents a significant departure from the UK approach in a number of respects, particularly in relation to the estimation of agglomeration benefits, which are typically the largest component of WEBs. Some of the key differences in the approach for estimating agglomeration benefits include:

- A focus on the effective density of firms as measured by business-to-business demand interactions in network models, as opposed to broader measures of the market that

[31] Kernohan, D and L Rognlien (2011) *Wider economic impacts of transport investments in New Zealand*. NZ Transport Agency research report 448.
[32] KPMG, *Measuring WEBs in Australian Cities*, Discussion Paper, Final Draft June 2017

encompasses other possibilities for externalities (e.g. including labour catchments as measured by commuter access to firms)

- Using inter-peak travel times as the relevant impedance measure instead of broader measures of generalised costs across the day including out-of-pocket expenses (e.g. tolls, fares, vehicle operating costs)
- Using a 'logsum' technique to estimate the relevant inter-peak travel times, which gives a very high weight to the lowest of car and public transport travel times are applied for each origin-destination pair
- The development to of a new decay function based on information in travel survey data, which produces a curve that gives greater weight to destinations which are further away
- Estimating agglomeration (productivity) elasticities using congestion-based measures.

EY has a number of questions about these departures from the UK methodology. For example:

- Is there a risk that focusing only on travel times could bias the results away from public transport given the additional out-of-pocket expenses associated with car travel?
- Does excluding commuting fail to acknowledge the significant role that deep labour markets play in driving agglomeration economies?
- Could estimating elasticities using congestion-based measures (like actual travel time) bias the results upwards? For instance, if a location twice the size has twice the infrastructure, the productivity differences will reflect both density and the 'time savings' from the additional infrastructure.

Notwithstanding these issues, EY and VLC have estimated WEBs for the NEL project using both ATAP and UK methodologies.

Preliminary estimates developed by the project team found that using the interim ATAP approach, it was found that agglomeration benefits were in the order of 10 to 15 times larger than those estimated using the UK WebTAG approach. Overall agglomeration benefits were found to be around 5% of conventional benefits using the UK approach, which is comparable with other major projects. Using the ATAP methodology, agglomeration benefits were estimated to be around 53% of conventional benefits, which is considered to be a significant overestimation of agglomeration benefits based on past experience.

Analysis undertaken by VLC identified two key factors that could be contributing to the differences. This includes:[33]

- The decay function, which leads to a high ratio of project to base effective density for the ATAP methodology compared to the UK methodology for around 95% of origin zones
- The industry elasticities, which cause the percentage change in productivity to be significantly higher for the vast majority of origin zones.

Given the issues outlined above and the level of agglomeration benefits estimated using the ATAP methodology, the appraisal of the NEL project has applied the UK methodology for the estimation of WEBs.

2.4 Cost benefit analysis

Cost-benefit analysis (CBA) is the key appraisal metric for evaluating the quantitative economic merit of the program.

The objective is to provide a single, dollar-value summary of the welfare benefits of the program, quantifying both market and non-market social and environmental benefits as fully as possible. As

[33] VLC memo to NELA, *Comparison of agglomeration methodologies*, 7 December 2017

noted, the CBA should not be considered in isolation but rather will support the overall project appraisal process and the broader value-for-money assessment.

2.4.1 Overview

CBA is a well-established and widely accepted methodology used to assess the economic feasibility of a project. Traditionally, transport CBA have tended to focus on the transport and wider economic benefits provided by a project.

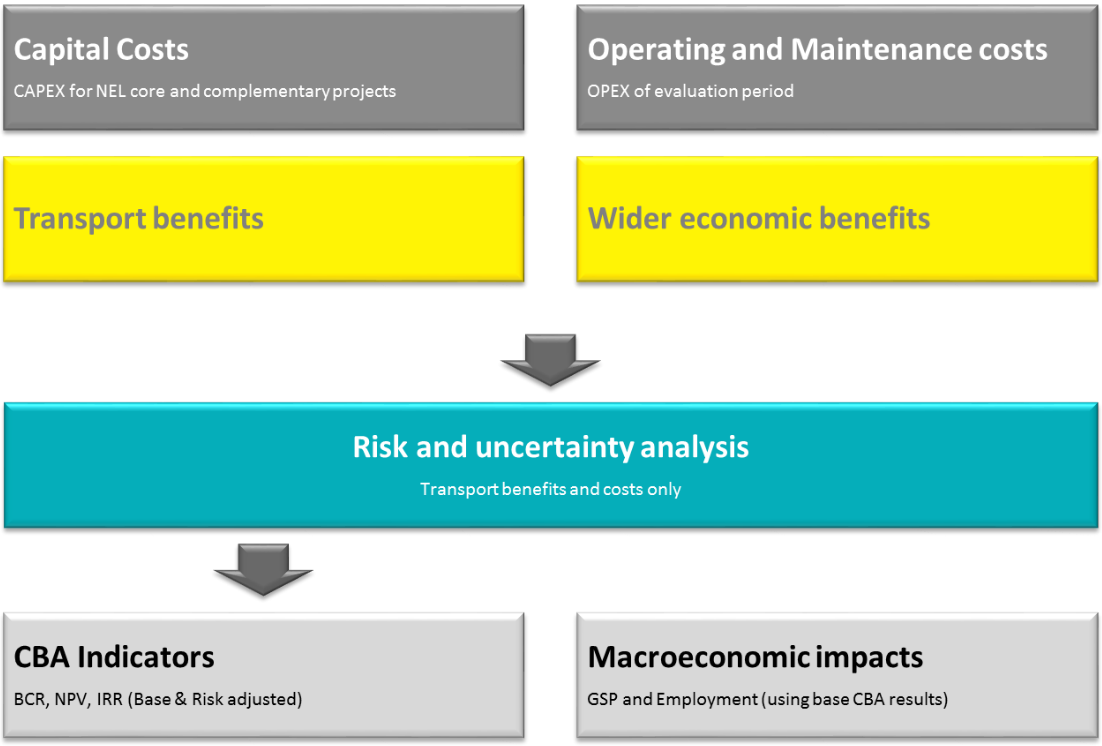
As illustrated in Figure 11, the project has adopted a comprehensive CBA framework that considers transport and wider economic benefits, and then applies a risk based adjustment based on the assessment of uncertainty around benefits. The approach reflects recent guidance from Infrastructure Australia on the inclusion of wider economic benefits and the impacts of land use changes on the transport system, and the treatment of risk and optimism bias.

In Victoria, CBAs typically present a single outcome based on a predicted future that has been defined by DEDJTR in the Reference Case. While the benefit of this approach is that it provides a simple and easy to understand measure to inform the government's investment decision, it fails to adequately recognise the significant upside and downside risks and uncertainties inherent to projections of future conditions and demand responses.

To address this the economic appraisal has included an integrated assessment of risk and uncertainty across the project costs, demand and benefits, using the results of probabilistic cost estimation and demand scenario modelling to test the risks around the Reference Case assumptions. The approach applied transparently addresses the key sources of risk and uncertainty, taking into account the potential for optimism bias and other demand and supply factors that could affect project value.

This analysis provides a 'risk-adjusted' outcome which provides a more fulsome assessment of the economic feasibility of the project, and is an important complementary measure that should be considered when making the decision to invest.

Figure 11 Cost benefit analysis framework



Source: EY 2017

The CBA methodology has been developed using DEDJTR's appraisal guidance (May 2017) and aligns with other Victorian and Australian government guidelines (as discussed in section 2.2). However, for specific methodologies regarding wider economic benefits, perceived costs of congestion and reliability benefits, international guidance and literature has been considered.

The guidance material recently published by Infrastructure Australia is the most relevant reference for the inclusion of benefits related to land use changes in a transport CBA. Infrastructure Australia recognises the increasing interest in considering the important city-shaping impacts that major transport projects can generate[34].

2.4.2 Benefits framework

The Project Objectives developed for North East Link highlight the key outcomes that are sought to be achieved by the project. These objectives have helped to shape the benefits framework used in the CBA. For example, improved access for businesses and households and improved freight and supply chain efficiency are likely to manifest through reduced congestion and an improvement in travel times. Similarly, improved access, amenity and safety for communities will result in less emissions and accidents in Melbourne's north east. Improving business access will also provide benefits to businesses by bringing firms closer together and providing access to a broader labour catchment, which will help to increase productivity.

These expected benefits suggest that a traditional benefits framework incorporating transport and wider economic benefits is justified for the project. However, the focus of the Project Objectives on providing benefits to areas in Melbourne's north, east and south east suggests that North East Link may induce a land use response as these areas become more attractive relative to the rest of the city. Therefore, the change in benefits due to induced land use changes has also been considered as part of the benefits framework adopted for the North East Link economic appraisal.

The benefits framework used to inform the CBA is summarised in Table 7 below.

Table 7 Economic benefits framework summary

Transport benefit	Description
Travel time savings	The change in travel times resulting from reduced levels of traffic and congestion due to the increased capacity that would be provided by the project.
Travel time reliability	The benefit provided to road users from more reliable and predictable journey times as a result of less traffic and congestion across the road network.
Reduced perceived cost of congestion	This is the benefit provided to road users for avoiding highly congested conditions. Road users typically value relief from highly congested traffic conditions over and above their value of travel time savings, due to more difficult driving conditions and a sense of frustration at delays.
Vehicle operating cost savings	The reduction in the operating costs of vehicles (e.g. fuel, tyres, general maintenance etc.), due to more efficient operating speeds and movements on the road network.
User tolls	User tolls are a perceived cost of road travel for users of toll roads, with North East Link estimated to increase the level of tolls incurred on the network. As tolls are not a resource cost (i.e. they are effectively a transfer payment), the impact of tolls is not taken into consideration when calculating user benefits for those who do not switch mode or destination. However, for the relatively small proportion of new car users that pay tolls this is taken into account in the calculation of user benefits. As the costs of the project are included in the CBA, there is a corresponding resource cost correction to account for this change in transfer payments (see below).
Public transport benefits	The benefits accruing to public transport users delivered primarily through less crowding, improved transfer and wait times, and reduced in-vehicle times. This includes benefits provided to users of rail, tram and buses.
Resource cost corrections (VOC, Tolls and PT Fares)	Resource cost corrections (RCCs) are applied to account for the difference between the overall social and user-perceived costs of travel. Travel decisions are made on the basis of a perceived cost of travel options, but this is not always equal to the full social resource cost. This is the case for vehicle operating costs, tolls and public transport fares, where taxes and subsidies can affect the prices perceived by transport users.

[34] Infrastructure Australia's Assessment Framework Detailed Technical Guidance (January 2016)

Transport benefit	Description
Emission savings	The change in greenhouse gas emissions as a result of more or less road users, and vehicle kilometres travelled along the road network as a result of the project.
Crash cost savings	Crash costs are a function of the number of vehicle kilometres travelled on a particular road type. While the project may result in some users switching from public transport to car, and increasing vehicle kilometres travelled on the network, the shift towards higher order roads (e.g. freeways and upgraded arterials) may result in safer conditions on the road network.
Other externalities	This includes other environmental externalities which have been quantified including air pollution and noise pollution.
Transport impacts due to induced land use change	This benefit account for the change in transport benefits due to induced changes in land use (i.e. 'second round' transport impacts).
Residual value	The infrastructure will have an economic life beyond the end of the 50-year project evaluation period. The residual value is an estimate of the economic benefit of the infrastructure from the end of the evaluation period to the end of the economic life of the asset.
Wider economic benefit	**Description**
Agglomeration	Agglomeration benefits arise when the transport system changes the 'effective proximity' of businesses and employees. That is, before any locations changes occur, making the transport system more efficient is effectively the same as bringing businesses and people closer together. Evidence shows that this can increase productivity beyond the benefits of direct time savings. These wider economic benefits are calculated based on changes in travel costs and demand only given a fixed land use pattern to avoid double counting with city-shaping benefits.
Labour Supply	Improved transport system efficiency can increase the time people spend at work by working longer in their current job or by becoming available for new employment. This increases overall economic activity and tax revenue for the community.
Output Change in Imperfect Markets	A reduction in transport costs allows firms in imperfectly competitive markets to profitably increase output of goods and services that require use of transport in their production. This will create a welfare gain as consumers' willingness to pay for the increased output will exceed the cost of producing it.

Source: EY

As outlined in section 2.1, the NELP team has derived the following project objectives that have been used throughout the assessment process to help guide the business case development. Table 8 below shows how the economic benefits captured by the CBA align with the project objectives that have been defined.

Table 8 Alignment of project objectives with economic benefits

Benefit category	Business	Household	Freight	Amenity	Other[35]
Transport benefits					
Travel time savings	✓	✓	✓		
Travel time reliability	✓	✓	✓		
Reduced perceived cost of congestion	✓	✓	✓		
Vehicle operating cost savings (including resource cost corrections)	✓	✓	✓		
User tolls (including resource cost corrections)	✓	✓	✓		
Public transport benefits (including resource cost corrections)	✓	✓	✓		
Emission savings				✓	

[35] Note that while not strictly aligned with any of the project objectives, 'other benefits' refer to benefits provided to Government through cost savings in the provision of public infrastructure, and the residual value of the asset at the end of the appraisal period.

Benefit category	Business	Household	Freight	Amenity	Other[35]
Crash cost savings				✓	
Transport impacts due to induced land use change	✓	✓	✓	✓	
Other externalities				✓	
Residual value					✓
Wider economic benefits					
Agglomeration	✓				
Labour supply	✓				
Imperfect competition	✓				

Source: EY

2.4.3 Key assumptions

The table below provides a summary of the key assumptions underpinning the cost benefit analysis.

Table 9 Key assumptions and parameters

Item	Assumption / Value	Source / rationale
Evaluation period	50 years, commencing from the start of the project's operations phase.	As per recent Victorian HVHR economic appraisals such as Metro Tunnel, WGT and LXRP
Prices and values	Prices and values expressed in FY17 dollars.	DTF, DEDJTR
Construction period	FY18 – FY27	Project assumption
Operation start date	FY27	Project assumption
Traffic model years	2026, 2036, 2051	Zenith
Interpolation between modelling years	Straight line, based on the average annual change between traffic model years	Project assumption
Extrapolation beyond the final modelling year	Straight line based on growth rate between 2036 and 2051	Project assumption
Discount rate	7% with sensitivity analysis using 4% and 10%	DEDJTR, ATAP (2016)
Annualisation factor (Public Transport)	AM peak and PM peak – 242 Inter-peak and Off-peak – 357	Based on PTV patronage data. Consistent with recent Victorian projects (e.g. LXRP, Metro Tunnel)
Annualisation factor (Road)	All vehicles: 330	Based on observed values and consistent with previous major road infrastructure projects
Values of time per person hour* (Car & PT)	Non-business trips: $16.22 Business trips : $52.61	DEDJTR, ATAP (2016) escalated to 2017 dollars using CPI
Business trips share of total VKT	18%	ABS Survey of Motor Vehicles (June 2016)
Value of time (freight)	LCV: $37.27 (including value of freight) HCV: $79.38 (including value of freight)	DEDJTR, ATAP (2016) - based on weighted average of LCV/HCV values as per ATAP to reflect Melbourne vehicle composition on West Gate Freeway.
Congested value of time per person hour	Car: $5.50 LCV/HCV: $4.19	Consistent with West Gate Tunnel and Metro Tunnel – Based on NZTA (2013), Hensher and Rose (2004, 2008, 2013)
Escalation of travel time savings, reliability and congestion benefits	1.50% - Business trips 0.75% - Non-business trips	2015 Intergenerational Report, ATAP (2016), DEDJTR
Escalation of project costs	4.0% - Capital expenditure and lifecycle costs 2.5% - Operating and maintenance expenditure	NELA (2017)

Item	Assumption / Value	Source / rationale
Escalation of VOC savings, Tolls, and emissions benefits	For benefits calculated by the Zenith economic module in monetary terms, benefits are inflated to present day values using CPI or PPI to account for parameter inflation. No further escalation of these benefits is assumed thereafter.	Zenith Economic module
Value of reliability (ratio relative to value of time)	Non-business trips: 0.8 Business trips : 1.2 LCV/HCV: 1.2	DEDJTR
PT Benefit Weighting	In vehicle Time: 1.0 Transfer and Access Penalty: 1.4 Waiting Time at Stop: 1.4 Walk Access/Egress: 1.4 Walk Transfer Time: 2.0 Park And Ride Access/Egress: 1.4 Kiss And Ride Access/Egress: 1.4 Crowding Disutility: 2.0	ATAP (2016)
Emission costs ($2010/tonne of emission)	Carbon dioxide equivalent: $52.40 Carbon monoxide: $3.30 Oxides of nitrogen: $2,089.20 Particulate matter: $332,505.90 Total hydrocarbons:$1,046.80	Austroads (2012), to be escalated to 2017 dollars using CPI
Asset life	86 years - Based on weighted average asset life of various cost capital components (e.g. road pavements, tunnels etc.)	DEDJTR, ATAP (2016), Austroads (2012)
Residual value	Straight-line depreciation	DTF, ATAP (2016)

2.4.4 Consumer surplus

User benefits are calculated by estimating the change in consumer surplus for all users, which is defined as 'the surplus of consumers' willingness-to-pay over and above what they actually pay for a given quantity of a good or service.'[36]

The CBA methodology adopted for this economic appraisal has followed the principles of the ATAP guidelines with respect to the treatment of continuing and switching users, and the application of the rule-of-half.

Box 1: Explanation of the "Rule of a half"

Economic theory suggests that when consumers change their travel in response to a financial incentive, the net consumer surplus averages half of their price change (called the "rule of a half"). This takes into account total changes in financial costs, travel time, convenience and mobility as perceived by consumers. For example, the first person to switch trips will do so when their willingness to pay is slightly below the generalised cost in the base case, and the user will only accrue a very minor benefit from making an additional trip. The last person to switch will only do so when they received the full benefit of the improvement and their willingness to pay is equal to the generalised cost in the project case.

Source: Adapted from Victoria Transport Policy Institute (2012), Transportation Cost and Benefit Analysis II – Evaluating Transportation Benefits

Zenith defines a continuing user as a user that has the same mode and destination in the base case and project case. Under this definition, continuing users may change route, although many will

[36] ATC National Guidelines for Transport System management in Australia, Volume 5

maintain their route in the project case. Switching users are those who are expected to change either their mode and/or their destination.

A graphical representation of the change in consumer surplus between the Base Case and Project Scenario is presented below (where it is assumed that perceived prices are generally higher than the average social cost of trips in the base and project cases). The shaded area represents the change in user and social benefit generated by the project. A description of the relevant segments under the demand curve is presented in the table below.

Figure 12 Change in user and social benefit generated by the project

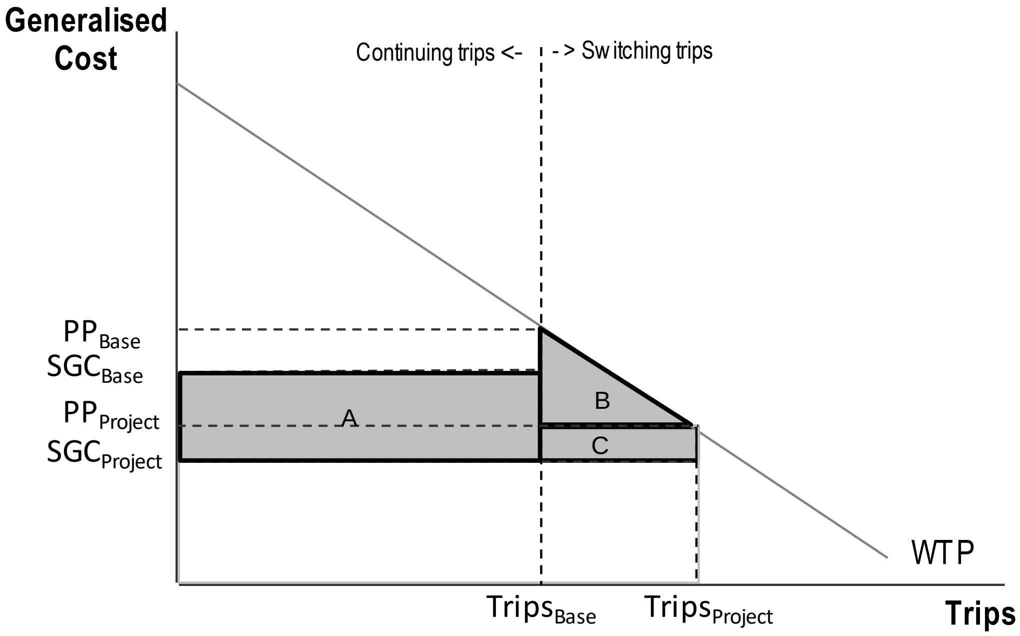


Table 10 Time saving benefits by trip type and vehicle type

Area	Trip type	Description
A	Continuing	Change in consumer surplus relative to the Base Case accrued by continuing/existing trip makers. The quantity of continuing trips is, by definition, the same under the Base Case and Project Scenario. Any difference between perceived and actual resource costs are treated as transfers.[37]
B	Switching	Perceived user benefit accruing to modified trip makers.
C	Switching	Additional net benefit to society generated by switching users.

The formulas applied to calculate the benefit associated with each of these areas are presented below.

A $= T_{Base}(SGC_{Base} - SGC_{Project})$

B $= \frac{1}{2}(PP_{Base} - PP_{Project})(T_{Project} - T_{Base})$

C $= PP_{Project}(T_{Project} - T_{Base}) - SGC_{Project}(T_{Project} - T_{Base})$

[37] ATC (2006) notes the following: "changes in money and perceived prices for existing road users are irrelevant. Any differences between the changes in money prices and social generalised costs represent transfers between transport users and others, not additional benefits and costs created. Any difference between the changes in perceived prices and social generalised costs are illusory."

where:

T_{Base}	Number of trips under the Base Case. The quantity of continuing/existing traffic is, by definition, the same in the Base Case and Project Scenario
$T_{Project}$	Number of trips under the Project Scenario
SGC_{Base}	The average generalised full cost to society valued at resource cost, including user costs and externality costs/benefits under the Base Case scenario
$SGC_{Project}$	The average generalised full cost to society valued at resource cost, including user costs and externality costs/benefits resulting from the Project Scenario
PP_{Base}	Average generalised price perceived by users as being required to complete a trip(s) under the Base Case
	Average generalised price perceived by users as being required to complete a trip(s) under the Project Scenario.

The rule of half is already applied via Zenith making the calculation of consumer surplus relatively straightforward for the capital projects. However, this information is not readily available for the maintenance component of the analysis. As such, the user benefits related to vehicle operating cost savings linked to the maintenance program are to be estimated on a resource cost basis.

2.4.5 CBA measures

The following economic performance measures are calculated to estimate the economic viability of the project:

- **Benefit Cost Ratio (BCR)** – a measure of the magnitude of net benefit to society derived from the capital investment in the project, as equal to the present value of benefits minus operating costs, divided by the present value of capital costs. A BCR greater than 1.0 indicates that quantified project benefits exceed project costs. However, projects with BCRs less than 1.0 may have net benefits if some of the benefits cannot be fully captured and monetised within a CBA framework. Such projects may still be considered on the basis that CBA is one of a number of considerations for decision makers.

- **Net Present Value (NPV)** – the difference between the present value of total incremental benefits and the present value of the total incremental costs, which allows comparison of options on the same basis and determination of the greatest net benefit to the community or the most efficient use of resources. A positive NPV indicates that the (discounted) incremental benefits of a scenario exceed the incremental costs over the evaluation period.

- **Internal Rate of Return (IRR)** – the discount rate at which the present value of costs equals the present value of benefits (i.e. the breakeven point)

Analysis of the results considers the above metrics using only the standard transport benefits in the CBA (without WEBs or land-use benefits) as the primary measures of economic viability. The same metrics calculated inclusive of transport benefits, WEBs and land-use benefits as a secondary measure of viability.

2.4.6 Accounting for risk and uncertainty

North East Link is a large and complex project that will deliver road user and wider network and economic benefits over a long timeframe.

In addition to construction and other delivery risks the project faces in the shorter term, there are a range of demand and other operational risks and uncertainties the project faces over the medium to longer term. In particular, with the emergence of new vehicle technologies and rapidly changing consumer behaviours, there is a sense that major infrastructure projects that are being delivered today face unprecedented sources and levels of risk and uncertainty.

To address this, an assessment of risk and uncertainty has been included to add robustness to the economic appraisal. A number of demand and benefit scenarios and sensitivity tests have been modelled to assess the potential impact of the key drivers of uncertainty to complement the risk modelling that has been applied to the project costs. These alternative scenarios have been modelled using Zenith in order to estimate the potential impacts on the base demand and benefits scenario for the project. The results were then subjected to a risk assessment to fit likelihood functions to the scenarios, and then combined with the risk-based cost estimates in an integrated Monte Carlo analysis to develop risk-adjusted economic indicators.

Note that the base demand and benefits scenario reflects the application of the DEDJTR Reference Case assumptions and alternative assumptions for VOC growth, public transport and road networks as outlined in Table 11.

The following table outlines the key areas of uncertainty that were identified for this analysis, as well as the alternative scenarios modelled. The steps undertaken as part of this assessment are outlined further below.

Table 11 Key areas of uncertainty

Area of uncertainty	Description
Population and employment change	The base scenario is based on the Victorian Government's demographic forecasts (Victoria in Future, VIF), which predict metropolitan Melbourne's population will grow from 4.4 million in 2016 to 7.4 million in 2051. It is possible that Victoria's population growth could decline to levels consistent with historic levels or continue to grow at the higher rates evident in recent trends. Historic population growth is highly variable and predicting long-term growth is challenging. The analysis has incorporated population growth uncertainty by applying historic variance to VIF forecasts using a stochastic process to predict alternative growth paths. Additionally, to understand the impact of population growth rate on project benefits, a high and low growth scenario have been modelled. The high scenario assumes that population and employment grow at the rate observed over the 10 years between 2006 and 2016. Furthermore, when compared to VIF estimates, the high growth scenario assumes a greater proportion of employment growth occurs outside of the Melbourne Local Government Area. The low growth scenario assumes that there is zero net migration in the future and the same distribution of growth outlined in VIF.
Autonomous vehicles	As discussed in Chapter 1, there is increasing momentum around the world to create cars capable of transporting commuters autonomously. Autonomous vehicle technology has the potential to significantly increase road capacities and speeds, as well as travel behaviour. Future uncertainty has been accounted for through modelling a scenario of 90% adoption of autonomous vehicle technology by 2046, which is consistent with a scenario cited in a background study published by Infrastructure Victoria as part of its 30-year strategy.[38] This scenario includes an increase of 60% capacity on freeway links and 15% on all other links. Going further, the scenario developed for the business case also includes an increase in recreation and shopping trip rates for dependents younger than 18 and older than 65.
Trip demand (behavioural change)	Innovative and disruptive technologies are changing the way in which consumers shop and businesses function. For example, recent years have seen an increase in flexible working arrangements and increased use of virtual office networks. Home shopping is increasingly popular and the arrival of Amazon in Australia is likely to reinforce this trend. These trends have the potential to reduce the number of trips made and have been reflected in the uncertainty analysis through modelling a scenario with 10% lower trip demand.
Induced demand profile (lag-effects)	There is a significant degree of uncertainty about when a major toll road will reach its complete 'steady state' demand profile. This is the stage when all the induced demand effects (changes of route, changes of destination, mode switching and land use changes) have occurred and the only factors changing demand growth are background population and employment growth, assumed changes in network capacity (and technology where relevant) and other behavioural changes not related to the project (such as changing work practices). The uncertainty analysis accounts for this by analysing alternative demand response timeframes (five years post opening) and a high demand response (10 years post opening) in addition to the base scenario (eight years post opening).
Real income levels	Personal incomes are assumed to grow in line with wages. However, the persistent low income growth that has occurred in recent years may affect long-term growth potential or there may be an increase in wage inflation similar to previous phases of high economic growth. The analysis has applied historic variance in real wages to the Reference Case assumptions to estimate the

[38] The Eno Center for Transportation, October 2013, Preparing a nation for autonomous vehicles, cited by KPMG, Arup, Jacobs in a study for Infrastructure Victoria (Preliminary Demand Modelling and Economic Appraisal, Final Report, September 2016)

Area of uncertainty	Description
	reflect uncertainty in wage growth. Furthermore, to understand the impact of incomes on project benefits, high (+3%) and low (0%) scenarios of wage growth have been modelled.
Cost of travel	Consumers are increasingly demanding fuel efficient vehicles to save on road travel costs and contribute to environmental outcomes. Rapid development in the electric vehicle market and automotive industry has led a number of governments around the world to consider banning the sale of petrol and diesel cars in the future. France and Britain have announced that they will ban the sale of petrol and diesel cars by 2040.[39,40] More recently, China has announced it is developing a timetable for banning the manufacture and sale of vehicles with combustion engines.[41] These actions and other trends and issues affecting the supply and demand of fuel prices could see reductions in fuel prices over the medium to longer term. However, there is also the possibility that current market trends affecting the oil industry will reverse and that real income growth in developing countries may provide more people with the opportunity to purchase cars and flights, thereby placing upwards pressure on oil prices. The uncertainty in road cost of travel has been reflected by modelling a high benefit scenario representing 50% adoption of electric vehicles by 2036 and a low scenario using the DEDJTR Reference Case assumptions for vehicle operating costs.
Practical road capacity	There are significant challenges in modelling future road capacities and network behaviour at demand levels implied by high population growth. A number of approaches are available to model practical road capacities using different speed-flow relationships, with the speed-flow relationships in the Zenith model being recognised as having more gradual functions than those applied in other models, which may lead to a more conservative estimation of project benefits. To complement the base and other scenarios developed using Zenith, the project team sought to model an additional scenario using Akçelik speed flow curves within the traffic model. While results using this relationship were not finalised, preliminary analysis showed significant upside potential to benefits. This area of uncertainty has been excluded from the analysis presented below.
Trip lengths	There is uncertainty about trends and preferences for the duration and length of trips, and how this could evolve in response to changing land use patterns (for example, greater urban sprawl) and congestion. This uncertainty has been assessed by incorporating project benefits under two alternative transport modelling methodologies that produce different average trip lengths with growing road congestion. Furthermore, the analysis has incorporated uncertainty by applying historic variance in vehicle kilometres travelled (VKT) per capita to forecasts using a stochastic process to predict alternative growth paths. The base scenario uses the approach applied in Zenith where the potential for trip shortening is constrained to broadly align with observed trends in trip patterns. The alternative scenario allows for greater trip shortening in the future.
Public transport constraints	As Melbourne's population grows, so will the demand for public transport. There is uncertainty surrounding the ability of the public transport system to service additional demand in the future, which is related to the future configurations of public transport vehicles and the willingness of people to accept growing levels of crowding. The base scenario assumes an unconstrained public transport system, which implies service levels will grow with demand and/or that transport users will be willing to accept increased levels of crowding. However, our uncertainty analysis also considers the likelihood that the future public transport network is constrained, which will increase the use of private vehicles.
Demand for business travel	There is significant uncertainty surrounding the number of business trips undertaken by Melbournians, with different travel surveys suggesting a wide range of demand. The base scenario applies assumptions based on the ABS Survey of Motor Vehicles, the uncertainty analysis also considers benefits estimated using trip purpose split defined by the Victorian Integrated Survey of Travel and Activity (VISTA).

1. Scenario development

For each of the uncertainties identified in step 1, alternative scenarios have been modelled to help to represent the full distribution of outcomes.

[39] Nicholas Hulot, French Environment Minister, July 6th 2017

[40] Department for Environment Food & Rural Affairs, Department for Transport, UK plan for tackling roadside nitrogen dioxide concentrations, July 2017

[41] Xin Guobin, Vice minister of industry and information technology, September 10th 2017

The table below provides a summary of the assumptions changed from the base scenario used to develop the high and low scenarios for each uncertainty.

Table 12 Risk and uncertainty scenarios

Uncertainty	Low benefit scenario	High benefit scenario
Land use	Zero net migration in the future. Population growth forecast at 1.0 per cent per annum for areas within Melbourne's UGB.	The rate of population growth for Melbourne's UGB between 2006 and 2016 (2.4% p.a.) continues into the future.
Autonomous vehicles	There is no scenario of a lower rate of adoption of autonomous vehicles than the reference case assumptions	90 per cent adoption of autonomous vehicles. Freeway capacities increase by 60 per cent, arterial capacities increase by 15 per cent. Greater trip rates amongst the young and the elderly.
Trip demand	10 per cent decrease in the number of trips.	There is no feasible independent trip demand scenario under which the number of trips would increase
Blending profile	Network transitions to with NEL state in 5 years	Network transitions to with NEL state in 10 years
Real income levels	Zero real wage growth	Real wage increase at 3.0 per cent per annum
Public transport services	Decrease by 10 per cent	Increase by 10 per cent
Cost of travel	Oil prices continue recovery and rise above 2008 price peak (18.4% increase in VOC by 2036).	Electric vehicles adoption decreases the cost of travel by car (50.1% decrease in VOC by 2036)
Trip lengths	Trip lengths decrease in the future	-
Public transport constraints	-	Constrained public transport services
Demand for business travel	VISTA trip purpose split	-

2. Fit likelihood functions

For each category of uncertainty there is a spectrum of possible outcomes, which can be represented by a distribution. While the low, core and high represent points on these distributions, the likelihood of each scenario materialising is unknown. Note, an alternative methodology using a random walk stochastic process has been used to develop distributions for land use and real income uncertainty. This methodology uses historic data to forecast future variance from the base scenario assumption.

To estimate the distribution of each category of uncertainty, a low, core and high scenario has been modelled using Zenith and/or the CBA model. The likelihood of each low, core and high scenario has been estimated through an internal workshop with the project team. This workshop involved rating each scenario as very pessimistic, pessimistic, neutral, optimistic and very optimistic with respect to the spectrum of possible benefit outcomes. These ratings are taken to correspond to a percentage of outcomes occurring below this point. For example at the very pessimistic point of the distribution, 10 per cent of outcomes are below this point and 90 per cent are above. Similarly, at the neutral point 50 per cent of outcomes are below this point and 50 per cent are above. The results of this workshop are presented in Table 13.

Table 13 Benefit risk workshop outcomes

Uncertainty	Method	Distribution	Low	Base Scenario	High
Land use	Random walk	Log-logistic		N/A	
Autonomous vehicles	Likelihood fitting	Log-normal	N/A	30%	90%
Trip demand	Likelihood fitting	Log-normal	30%	50%	N/A
Blending profile	Likelihood fitting	Log-normal	30%	50%	90%
Real income levels	Random walk	Minimum extreme value		N/A	
Public transport services	Likelihood fitting	Log-normal	30%	50%	70%

Uncertainty	Method	Distribution	Low	Base Scenario	High
Cost of travel	Likelihood fitting	Log-normal	10%	30%	70%
Trip lengths	Random walk	Weibull		N/A	
Public transport constraints	Likelihood fitting	Log-normal	N/A	10%	70%
Demand for business travel	Likelihood fitting	Log-normal	10%	70%	N/A

Source: EY

The ratings for each low, core and high scenarios have been fitted to a log-normal distribution to represent the possible outcomes due to each uncertainty category.

Note, in simplifying this analysis, it has been assumed that all uncertainty categories are independent of one another. Accordingly, no correlation has been modelled between distributions.

3. Integrate existing cost estimates

This analysis presents a risk adjusted scenario for benefit forecasts. It has long been common practice for project costs to reflect risks inherent in construction and operation. This is commonly presented as a P50 and P90 estimates for total project costs. The uncertainty analysis approach integrates the existing cost estimate distribution with the benefit distribution to calculate a risk adjusted benefit cost ratio for NEL.

4. Perform Monte Carlo simulation

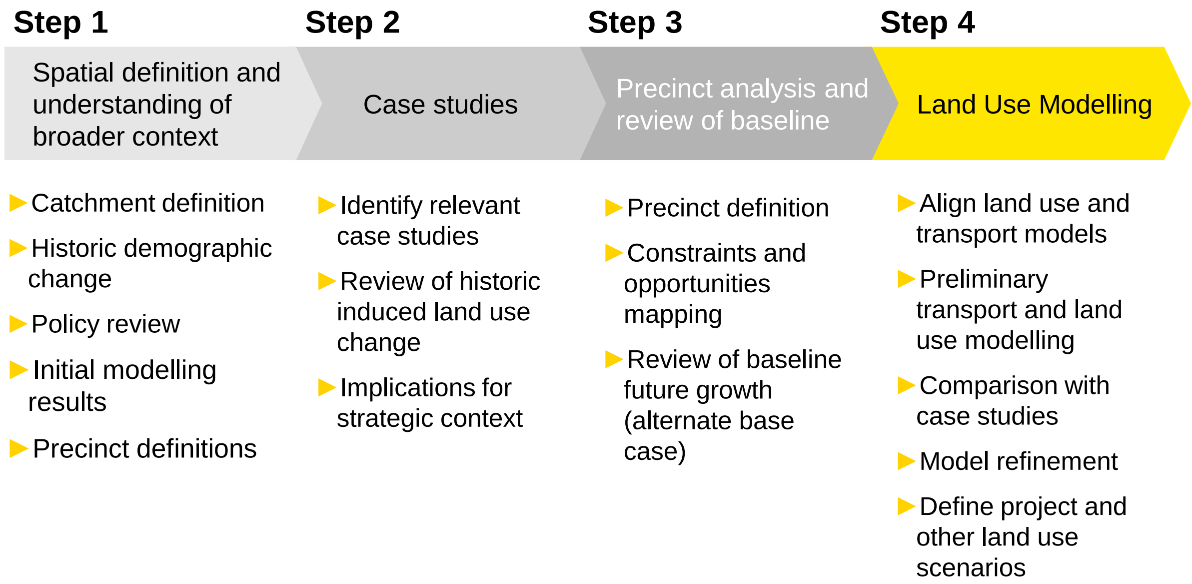
Our Monte Carlo simulation samples from our defined input distribution (created using Zenith, the CBA model and likelihood assumptions) many times, to create a distribution of possible outcomes for benefits, costs and the benefit cost ratio. Having created benefit distributions under multiple uncertainty categories, distributions are combined through a process of normalisation and multiplication. This process provides understanding to the confidence levels associated with different project outcomes for cost and benefits.

2.5 Land use assessment

In order to calculate the estimated land use impacts of the project in terms of its effect on the distribution of population and employment across Melbourne, a separate land use assessment has been undertaken by EY. The approach we have followed for assessing the impacts of NEL on urban land use is outlined in Figure 13 and described further below.

Note that the results of the land use modelling has been used to inform the calculation of land use benefits, using the methodologies described in Attachment C.

Figure 13 Approach to assessing the land use impacts of North East Link



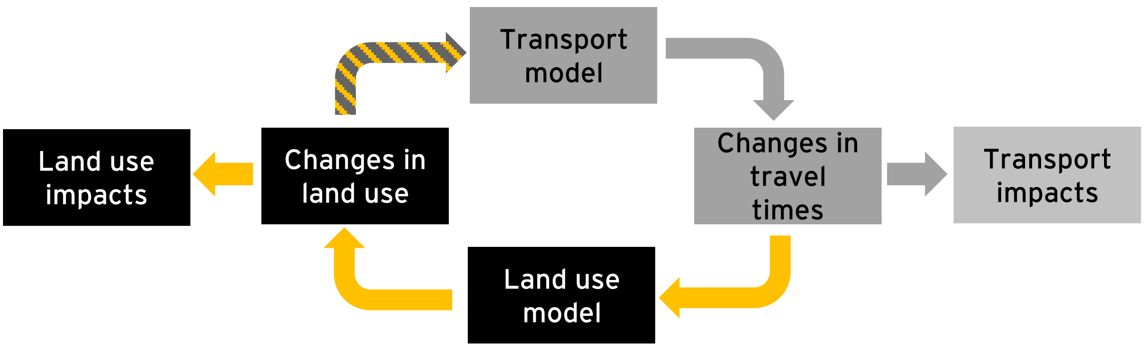
Source: EY

A key component of the land use assessment in terms of its impact on the CBA, is the use of land use modelling and the application of the Land Use Transport Interaction (LUTI) framework to quantify the benefits associated with land use change as a result of the project.

As summarised in Figure 14 below, the land use model interacts with the transport model to estimate dynamic (second/third round) impacts on the distribution of population and employment. For example, the project is expected to provide significant accessibility improvements to areas in the north east which can lead to land use changes as a result of shifting demand by encouraging:

- Residents to choose to locate in areas with greater accessibility to jobs.
- Businesses to choose to locate in areas with greater accessibility to potential employees and to other forms.

Figure 14 Summary of Land Use and Transport Interaction framework



Source: EY

There are a range of costs and benefits that may materialise through this interaction, which are not captured as part of conventional CBA approaches:

- Transport impacts – Shorter trips and lower car mode share as more individuals and jobs locate near the improved public transport infrastructure

► Land use impacts – Productivity gains and cost efficiency from a denser urban form.

There are also a range of other aspects driving location preferences that need to be controlled for within the analysis, and have been considered through case studies and precinct analysis.

2.6 Economic impact analysis

A significant investment like the NEL project will be a major contributor to economic activity and jobs (for example measured by changes to Gross State Product and employment). These economic impacts result from both the initial boost in construction sector activity over the construction period, and from ongoing improvements in business productivity due to lower transport costs and closer business-to-business linkages (i.e. agglomeration).

Modelling these impacts can provide a more tangible view of the potential benefits of the project, instead of focusing on just the typical welfare measures included in a CBA. However, it is important to note that positive economic impacts are not additions to the benefits included in the CBA. Aggregate economic should be seen as supplementary information about economic flows and broad sectoral changes, not as inputs to a CBA.

Economic impacts can be estimated at a high level using Input-Output (IO) analysis or by using detailed Computable General Equilibrium (CGE) models. While the use of these models is not encouraged by Infrastructure Australia for the purposes of project comparison, the results are useful in developing the strategic narrative for the project and building community support.

To provide high-level economic impact metrics - impacts on GSP, household incomes and productivity, for instance - EY engaged the Victoria University Centre of Policy Studies (CoPS) to prepare a state-wide analysis based on initial project costing and economic modelling. This provides an indication of the overall economic impact of the NEL project. The modelling task has been undertaken with CoPS multiregional model of the Australian economy, VURM[42].

The modelling considers the annual construction and operations impacts of the Program by drawing on capital, operating and maintenance costs and estimates of productivity improvements experienced by the road transport industry, which are provided from the CBA.

Using the results of the CBA as inputs into the CGE model ensures consistency and enables use of detailed traffic network wider economic benefits as 'shocks' (i.e. changes to the status quo) to the State and national economies. This includes capital costs and productivity improvements, such as travel time savings, vehicle operating cost savings and reduced crashes.

For more detail on the methodology used for the CGE and Spatial Impact modelling, please refer to Attachment D.

[42] VURM stands for Victoria University Regional Model. It was previously known as the MMRF model.

3. Transport modelling results

In general, the scale of a transport project dictates the requirement of the transport modelling task. High level, network based initiatives are generally modelled with 'strategic' models able to cover large areas in limited detail, while analysis of smaller areas is carried out with 'mesoscopic' or 'microsimulation' models.

Due to the strategic significance of the NEL project, impacts are likely to spread across a large area making it well suited to be analysed using a strategic transport model. However, microsimulation models can also be used in conjunction with a strategic model to give greater confidence to the results where greater detail is required to simulate complex demand and supply interactions at the local level.

3.1 Transport models

For the NEL project, strategic modelling was undertaken using the Zenith proprietary model developed by Veitch Lister Consulting (VLC). Zenith is a large scale multi-model (strategic) transport model of Victoria and projects movements and use of cars, public transport, active transport and freight.

The model uses a traditional four-step modelling approach:

- Trip generation – how many trips
- Trip distribution – origin and destination of trips
- Mode Choice – the mode of travel will be chosen
- Trip assignment – the chosen route.

Zenith's strong performance in the study area of influence, including forecasting for toll roads and its ability to estimate induced demand, provide a compelling basis for its use on the North East Link project.

The strategic transport model has broad scope of use on the NEL project (e.g. to help define current and future traffic conditions, to inform conceptual engineering designs and tolling strategies), but for the purposes of the economic appraisal, Zenith has been used for four key functions:

- To support the calculation of the economic benefits of the project
- To support the analysis of land use change resulting from the project
- To undertake sensitivity testing of various assumptions and parameters
- To undertake testing of alternative future scenarios

A microsimulation model was also developed using VISSIM. This model has assisted with the development of the interchanges with the existing freeways to optimise their layout to meet performance requirements. This will provide greater confidence in the production of cost estimates for the project. It has also been used to test the results of the strategic model.

3.2 Reference case

The DEDJTR 'Transport Modelling Reference Case' (Reference Case) defines key input parameters and network assumptions used in the transport model to inform economic evaluation of major transport projects in Victoria on a consistent basis.

3.2.1 Reference Case networks

Reference Case networks are defined by DEDJTR for each of the forecast model years typically used when modelling transport projects in Victoria.

Current DEDJTR guidelines state that 'Reference Case' network should be used to calculate core project benefits. Referred to as the 'Reference Case' approach, this approach is consistent with that adopted across the majority of recent major transport infrastructure projects in Victoria such as the Melbourne Metro Rail Project, the Level Crossing Removal Program, and the West Gate Tunnel Project (formerly Western Distributor). Accordingly, it has been used to inform the economic evaluation for NEL.

The 'Reference Case' network is defined as including committed projects plus those assumed to be built under a medium investment scenario. The year of assumed construction may be influenced by the staging of projects, forecast growth rates and/or political and financial commitment to the project.

A consistent evaluation approach across projects may not, however, capture in full the unique nature of investment and the existence of other benefits. Furthermore, the construction of a major project may represent a change in the level of commitment to different elements of the Reference Case. Because major projects are likely to alter the demand profile of other future network elements, the Reference Case sometimes needs to be amended in order to achieve a more accurate depiction of the future transport network relevant for the project.

Current DEDJTR guidelines also state that, in addition to the Reference Case approach above and any amendments that are required under that approach, modelling should also be undertaken using a 'Do-Minimum Network Reference Case' network.

The network under the 'Do-Minimum' case includes committed projects and "Business as Usual" upgrades to existing assets that supply the minimum capacity required to support future demand. The 'Do-Minimum' approach could, in some cases, provide a more realistic representation of the future transport network in the context of the project being assessed as part of an economic evaluation.

By including both 'Reference Case' and 'Do-Minimum' approaches as part of the modelling and evaluation framework, projects are able to address the uncertainties surrounding the definition of future networks and provide a range of outcomes that are consistent with best practice approaches.

In line with recommendations from TfV and DEDJTR, it is also proposed that that future network elements accommodating the same strategic movements as NEL be tested to determine their effect on road demand and alignment with the network development strategy. If scope elements are determined to be likely delayed as a result of NEL, their exclusion from all modelling cases may better reflect future networks, and therefore additional scenarios may be modelled for inclusion in the cost benefit analysis of the project.

3.2.2 Reference Case land use

The Reference Case also defines land use assumptions for future years, with these forecasts providing a critical input to demand forecasting for transport modelling and evaluation.

While land use assumptions in the Reference Case form a best practice view of the future, there is inherent uncertainty in future forecasts and land use supply constraints are variable. Forecasts often change to reflect new government policies or strategies. In addition, the forecasts effectively assume a 'business as usual' level of investment in transport system capacity across the network in the future, which may not reflect a realistic 'base case' situation aligned with a 'do minimum' investment scenario, and the delivery of specific major transport infrastructure projects is also likely to cause a redistribution from the Reference Case land use. Each of these factors are important to consider as part of the evaluation of a project.

Due to this uncertainty regarding the impact of various land use assumptions, the DEDJTR guidelines envisage that multiple land use scenarios may be developed to understand these impacts and to provide a range of benefits for possible future outcomes. This has been done for the economic evaluation using the LUTI framework as well as part of the risk analysis.

3.2.3 Reference Case parameters

The Reference Case also defines a set of parameters and growth assumptions to be used when transport modelling. This includes growth assumptions for:

- Fuel costs
- Parking charges
- Tolling prices
- Public transport fares
- Airport passengers (land side)
- Freight demand

Given that the strategic transport model results can be sensitive to these input assumptions, DEDJTR guidelines suggest the testing of alternative parameters to represent different future scenarios and a range of possible outcomes for the project. As described in section 2.3.3, alternative assumptions for the growth in road vehicle operating costs have been developed for this project.

3.2.4 Base and Project case definition

Making comparisons between transport network outcomes with and without the NEL project and drawing conclusions about the impact of the project requires precise definitions of a base case (the counterfactual scenario where the NEL project is not constructed) and a project case (where the NEL project proceeds).

While the base case will be defined in relation to DEDJTR's 'Reference Case', in order to define the most appropriate base case for the project, additional analysis is required to properly understand both the likelihood that certain projects will be included in future network scenarios, as well as the likely impact of these on the NEL project.

The scoping framework, required by DEDJTR guidelines, classifies future network elements as either *core*, *enabling*, *critically interdependent* or *complementary*. This classification defines the inclusion of scope elements in either the project or base case scenarios, with the difference between the two scenarios being used to evaluate project benefits. The scoping framework used to inform the transport modelling, as well as the projects defined in each category is summarised in Table 14 below.

Table 14 Scoping framework

Scope status	Scope category	Definition	Economic appraisal status	Projects
Out of scope	Current	Projects which are assumed to be delivered prior to or in parallel with the core project	Base case	► CityLink-Tulla Widening ► SRU ► M80 Upgrades ► West Gate Distributor (Stage 1a)

Scope status	Scope category	Definition	Economic appraisal status	Projects
				► Sunshine – Calder ► West Gate Tunnel (formerly Western Distributor) ► WGF – Western ► Chandler Hwy upgrade ► Sydney – Edgars ► Metro Tunnel (formally Melbourne Metro ► Plenty – Greensborough Hwy ► Mernda rail extension ► Hurstbridge Rail line upgrade(Phase 1) ► Yan Yean Road duplication ► Plenty Road widening
In scope	Core	Essential scope items for the project to achieve its objectives. Included in capital expenditure	Project case	► Freeway connection between Eastern Freeway / EastLink and M80 ► Eastern Fwy interchange (core) ► M80 widening C-Ds to Plenty Rd ► Eastern Fwy (enabling)
	Enabling	Scope items required for the project to fully achieve its objectives and mitigate unacceptable impacts on the wider network due to use of NEL. Included in capital expenditure		
Out of scope (delivered separately)	Critically interdependent	Equivalent to enabling scope elements, but delivered separately to the project		
Out of scope (future proof/make provision in project scope)	Complementary	Scope items or project which provide additional benefits by capitalising on the benefits of the core project but are not essential for the project to achieve its objectives	Base case	► Outer Metropolitan Ring Road incl. E6 ► Bridge Inn Rd duplication ► Craigieburn Road East widening & new overpass ► Boundary Rd widening ► Donnybrook Rd widening ► Grants Rd extension ► Main Rd widening (4 lanes) ► Templestowe Rd widening (4 lanes)
Out of scope	Delayed	These are scope items or projects which may be delayed as a result of the NEL	Not included in modelling	► Fitzsimons Lane / Williamsons Rd widening ► Greensborough Bypass (4 lane freeway) ► East West Link ► Hume Fwy Widening (M80 to Cooper St) (6 lanes) ► Diamond Creek Rd (6 lanes) ► Elgar Rd (6 lanes) ► Surrey Rd (4 lanes) ► Middleborough Rd (6 lanes) ► Eastlink (8 lanes) ► Hoddle / Punt Road widening

Source: VLC, EY

3.3 Transport impacts

Projections from Zenith of base case and project case traffic outcomes and the impact of the Project are discussed and contrasted below. Note that the results and outcomes presented here form the basis upon which the CBA has been undertaken, and focus on global (network wide) results.

3.3.1 Base case

Results from Zenith show that in the base case (do nothing) scenario, that daily vehicle kilometres travelled (VKT) for cars is predicted to increase by around 60% between 2016 and 2051. This expected to lead to a significant reduction in average speed throughout the day from 47.1km/h in 2016, to 41.4km/h by 2051. A similar trend is projected for freight vehicles.

Analysis of the base case also suggests that there will also be a significant increase in the number of public transport trips, with the daily share of public transport trips increasing from 8.4% in 2016 to 14.2% by 2051.

The base case projections from Zenith are summarised in the table below.

Table 15 Base case outcomes - daily

	2016	2026	2036	2051	% growth (2016 - 2051)
Car					
Number of Trips	14,243,944	16,672,913	19,077,614	22,739,469	59.6%
Vehicle Kilometres Travelled	140,217,397	173,517,362	201,633,086	244,262,623	74.2%
Vehicle Hours Travelled	2,974,472	3,810,899	4,617,177	5,898,538	98.3%
Mean Speed (Km/h)	47.1	45.5	43.7	41.4	-12.2%
Freight (LCV + HCVs)					
Number of Trips	698,774	852,162	986,485	1,231,895	76.3%
Vehicle Kilometres Travelled	13,475,107	16,977,294	20,045,022	25,386,672	88.4%
Vehicle Hours Travelled	245,867	326,006	406,275	554,496	125.5%
Mean Speed (Km/h)	55.8	53.0	50.2	46.6	-16.5%
Public transport					
Number of trips	1,532,474	2,447,078	3,216,253	4,485,324	192.7%
PT mode share (%)	8.4%	11.1%	12.5%	14.2%	5.8%

Source: VLC Zenith Model

Land use forecasts based on VIF 2015 projections in the base case expect high population growth in the outer south east, west and northern regions of Melbourne which will result in a significant increase in traffic on the surrounding arterial road and freeway networks, and the wider Melbourne road network.

The majority of traffic growth will be able to be accommodated by the additional freeway capacity delivered by major transport infrastructure upgrades on the M80, Tullamarine Freeway, West Gate Freeway (and the West Gate Tunnel) and the Monash Freeway. The estimated change in traffic volumes between the 2016 and 2036 scenarios are presented in Figure 15.

Figure 15 Change in daily traffic volumes between 2016 and 2036 base case scenarios

Source: VLC Zenith Model

3.3.2 Project case

With the introduction of the NEL in the project case, more users will be attracted to the road network, with over 22,000 extra car trips each day by 2051. As a result of the increased number of trips, total VKT on the network is projected to increase by approximately 1.6 million kilometres by 2051 due to the project. Although, improvements to the average speed across the network will result in an overall declined in vehicle hours travelled (VHT).

In terms of the project's impact on freight, the introduction of the NEL will allow freight vehicles in the North East to take more direct routes at improved speeds, reducing VKT and VHT for freight across the network.

By providing a significant improvement to the functionality of the road network, the project is expected to cause mode shift as users shift their method of transport from public transport to road to take advantage of the improvements. As a result, the overall number of public transport trips is projected to decline.

Table 16 below provides a summary of this project case analysis, and shows the changes in the project case as a result of the project relative to the base case.

Table 16 Project case outcomes (changes relative to base case) – daily

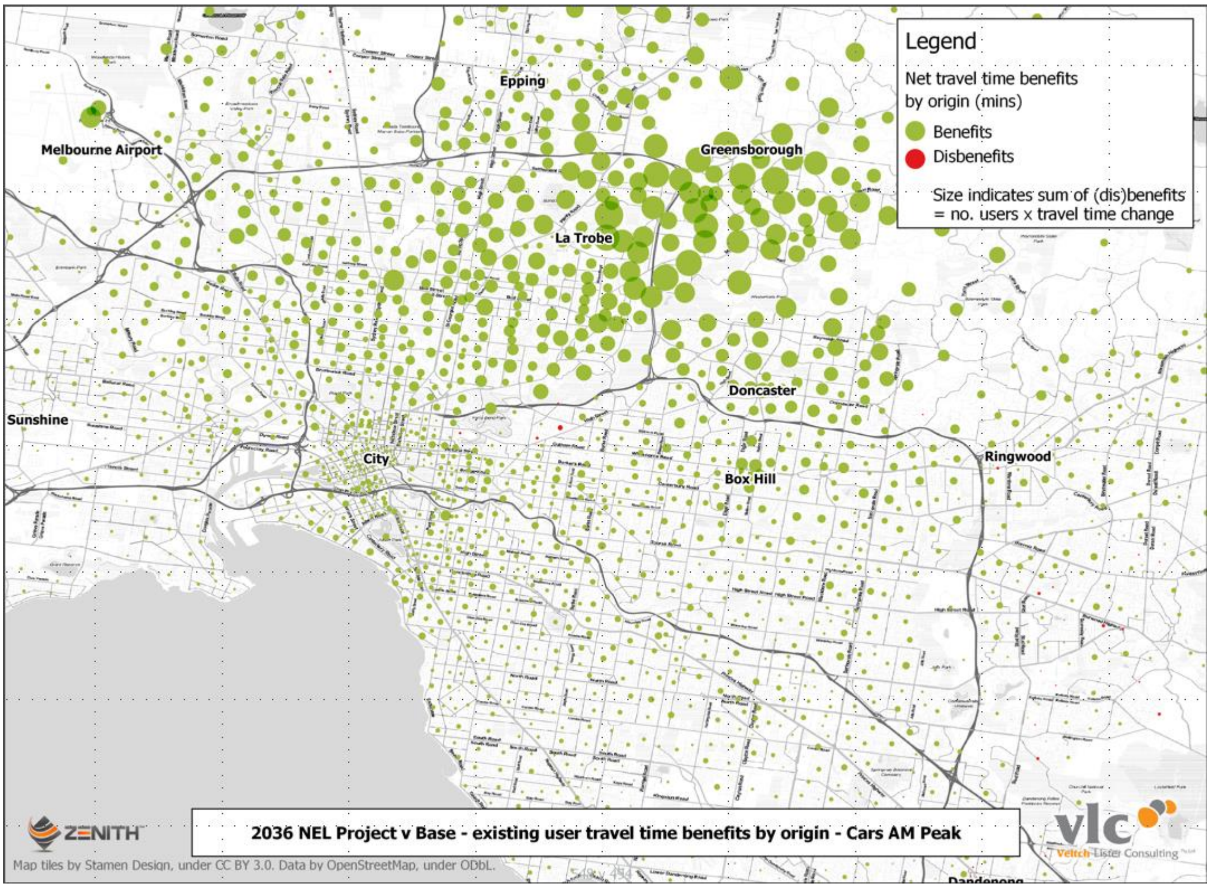
	2026	2036	2051
Car			
Number of Trips	12,929	13,412	22,070
Vehicle Kilometres Travelled	1,117,492	1,260,637	1,562,598

	2026	2036	2051
Vehicle Hours Travelled	-9,032	-12,295	-16,084
Mean Speed (Km/h)	0.40	0.39	0.38
Freight (LCV + HCVs)			
Number of Trips	0	0	0
Vehicle Kilometres Travelled	-28,833	-24,400	-13,103
Vehicle Hours Travelled	-4,764	-6,029	-7,970
Mean Speed (Km/h)	0.72	0.71	0.67
Public transport			
Number of trips	-3,626	-3,085	-7,960
PT mode share	-0.02%	-0.01%	-0.03%

Source: VLC Zenith Model

In terms of the distribution of benefits, Figure 16 below shows that a significant proportion of the net travel time benefits will be provided to users in the north east, particularly in areas such as Rosanna, Latrobe and Greensborough.

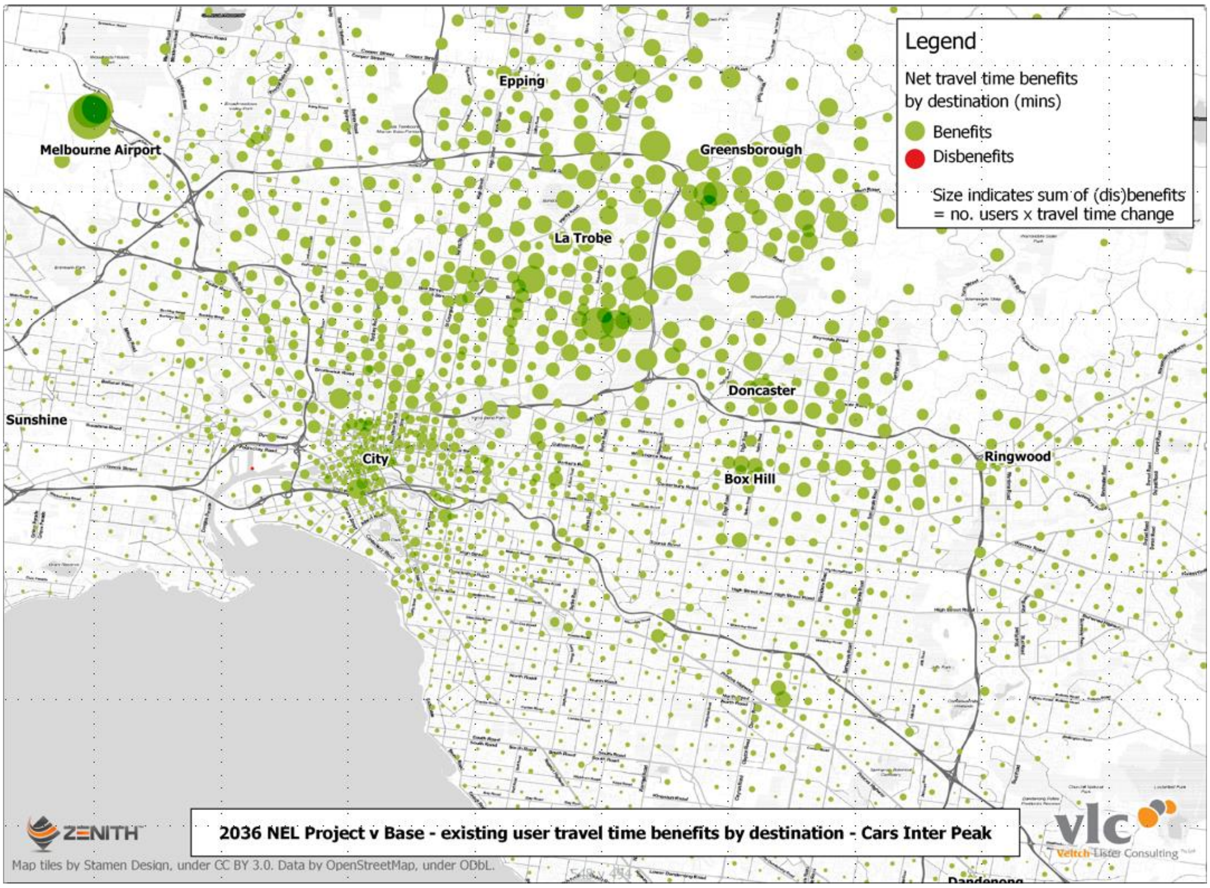
Figure 16 Net travel time benefits by origin (Car, AM Peak) - 2036 Project vs Base case



Source: VLC Zenith Model

Figure 17 shows that in the inter-peak period, the project is expected to provide significant travel time benefits to users travelling to key business locations, such as Heidelberg, Doncaster and Box Hill, as well as through the north east around Greensborough. The project is also expected to provide substantial improvements to users travelling to the city and Melbourne airport.

Figure 17 Net travel time benefits by origin (Car, Inter-peak) - 2036 Project vs Base case



Source: VLC Zenith Model

3.3.3 Induced demand from land use change

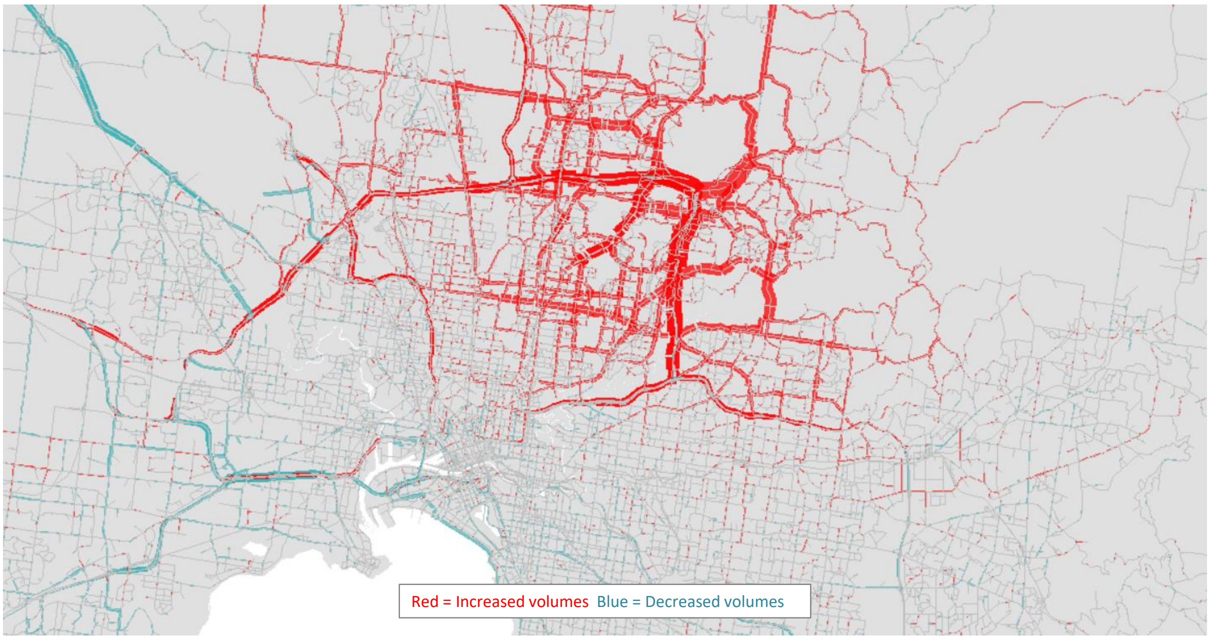
The North East Link is expected to have an impact on Melbourne's city structure by encouraging households and businesses to locate in areas that will benefit from the accessibility improvements provided by North East Link (see Chapter 8). These induced land use changes can create benefits and costs in addition to standard benefits that are usually included in transport CBAs.

By taking into account this additional source of induced demand that is often omitted from project assessments, this also helps project designers and decision makers understand the drivers of longer term demand for the project and the surrounding arterial network and their impacts. This approach addresses requirements of infrastructure bodies like Infrastructure Australia and criticisms of previous assessments by the Victorian Auditor General.

Using the Land Use Transport Interaction (LUTI) framework, the induced change in land use as a result of the project was estimated. The results of this analysis informed the project case land use scenario which was then reintroduced to the traffic model to understand how this induced change in land use will impact upon the transport network.

As can be seen in Figure 18 below, the analysis shows that the induced change in land use is likely to increase daily traffic volumes in the north east.

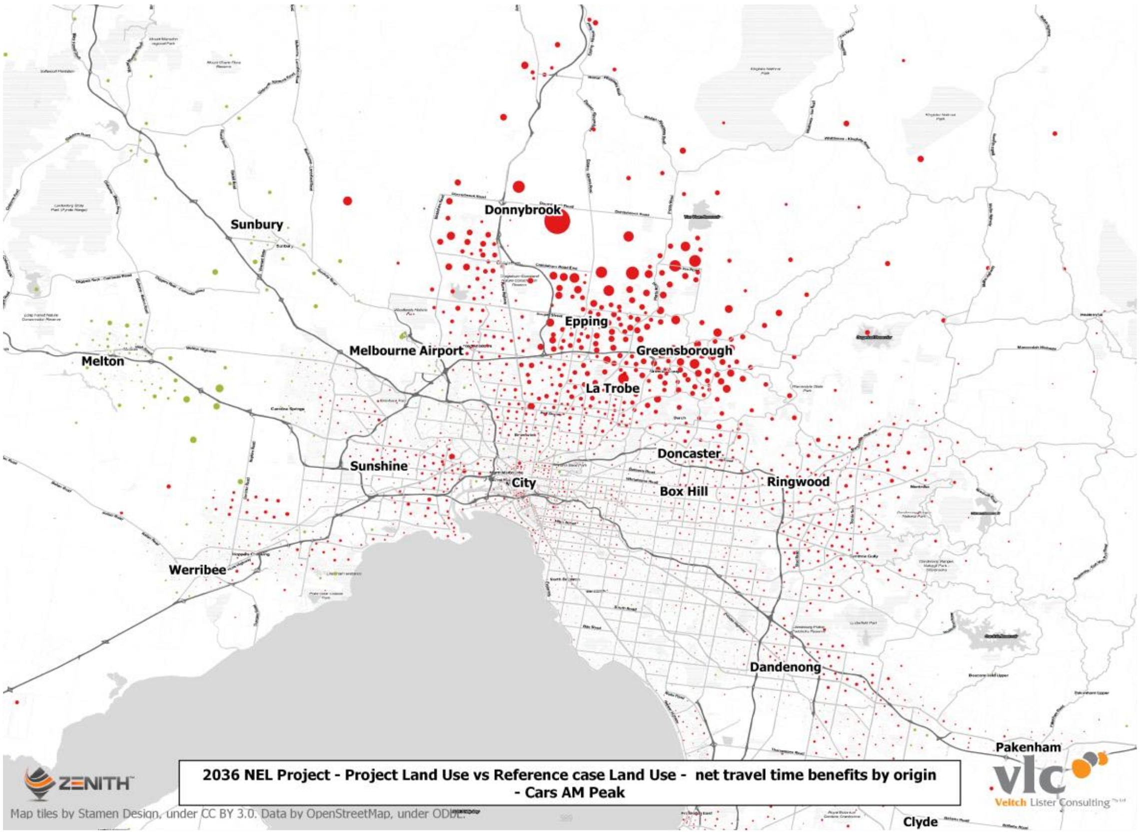
Figure 18 Change in daily traffic volumes (2036) – Project case land use vs Reference case land use



Source: VLC

As a result of this additional traffic in the north east, road users are likely to experience a reduction in project benefits particularly for those in the north around Epping and Craigieburn (as shown in Figure 19).

Figure 19 Net travel time benefits by origin (Car, AM Peak) - 2036 Project case land use vs Reference case land use



Source: VLC

It is important that these induced demand effects are taken into account in the assessment of major projects like North East Link, in order to give confidence that the benefits are not materially affected by increased congestion in the corridor, or to ascertain whether there are additional benefits and costs that could be included in the appraisal. The analysis of the impact of these effects on the benefits of the project is presented in section 5.3.

4. Project costs

4.1 Overview

This chapter outlines the economic costs used in the cost benefit analysis for the NEL project. It is important to note that while the costs used for purposes of the economic appraisal are based on the same costs presented as part of the financial assessment, the economic costs are presented as real values which have been adjusted from the nominal costs to remove the effects of inflation over time. Whereas the financial assessment presents the costs of the project as nominal values which retain the effects of inflation over time.

The CBA considers the following costs:

- **Capital costs** – all capital expenditure including planning, construction, land acquisition costs, inherent/contingent risk allowance and real escalation

- **Operating and maintenance costs** – relating to operating and lifecycle maintenance expenditure for the 50-year project evaluation period, including the costs for periodic and ongoing maintenance.

Detailed cost estimates for the project, inclusive of inherent risk have been provided by Advisian. As part of the financial assessment for the business case, EY has estimated the appropriate contingent risk allocation for P50 and P90 costs for capital delivery, lifecycle maintenance and the provision of ongoing maintenance services.

P50 costs are generally considered the appropriate level for inclusion in a CBA. This is because the P50 estimate, as the central value, should be the closest to the expected cost, just as the benefits estimate is a central, best estimate (the alternative, P90 value, is the estimate of the project cost based on a 90% probability that the cost will not be exceeded). The difference between a P50 and a P90 cost essentially relates to different levels of risk and escalation from the application of a full quantitative risk assessment.

It is important to note that while the costs used for purposes of the economic appraisal are based on the same costs presented as part of the financial assessment, the economic costs are presented as real values which have been adjusted from the nominal costs to remove the effects of inflation over time. Whereas the financial assessment presents the costs of the project as nominal values which retain the effects of inflation over time.

Therefore, the nominal cash flows as presented in the financial assessment of the project, have been adjusted to account for inflation (assumed to be 2.5% per annum) to calculate the real costs of the project, while also excluding profit margin (as it is perceived as a transfer) and any sunk costs that will have already been incurred prior to the investment decision being made (in accordance with ATAP guidelines).

The real costs of the project have then been discounted at 7% in order to obtain the present value cost used for the CBA.

4.2 Economic cost adjustments

As previously mentioned, the risk adjusted (P50 and P90) nominal cash flows presented in the financial assessment of the project, have been adjusted to account for inflation (assumed to be 2.5% per annum) to calculated the real costs of the project, and to also exclude any sunk costs that will have already been incurred prior to the investment decision being made (in accordance with ATAP guidelines). The real costs of the project have then been discounted at 7% real in order to obtain the present value cost used for the CBA.

Note that undertaking CBA requires the comparison of monetised economic costs and benefits that are realised over different timeframes. For the NEL project (like many transport projects) this involves comparing large upfront capital expenditures with a much larger total stream of economic benefits over the appraisal horizon (i.e. 50 years after opening). Discounting future cost and benefit profiles to their present values enables a like-for-like comparison of future costs and benefits in determining the net present value of a project and the calculation of the benefit-cost ratio.

There is considerable debate between different jurisdictions regarding the choice of an appropriate discount rate for use in the appraisal of public infrastructure projects.

DTF Guidelines for Victoria, recommend an approach that is based on the assumption that the choice of discount rate should broadly reflect a market-based cost of capital for similar investments (measured using historic returns in equity markets using the Capital Asset Pricing Model framework). This is similar to the approach applied in other states and adopted by Infrastructure Australia.

To simplify the application of discounting, DTF provides default discount rates and sensitivity tests, where different kinds of projects are categorised by risk to apply a relevant standard rate.

Like other transport projects, the NEL project is considered a 'Category 2' project under the DTF Economic Evaluation for Business Cases Technical guidelines (August 2013) given the risk profile of the project and the extent of monetised transport user benefits. As such, the standard real discount rate of 7% has been applied in this economic appraisal. In line with guidelines, sensitivity tests using real discount rates of 4% and 10% have also been included.

While recognising the importance of these adjustments for the purposes of the CBA, it is important to note that the actual (nominal) cost of delivering the project does not change.

Redacted – commercial-in-confidence

Note that nominal cost represents the actual cost of delivering the project. However for the purposes of the economic appraisal, these costs need to be discounted to a consistent base so that they can be compared on a like for like basis with the benefits of the project which is over $112 billion in real terms.

The table below summarises the economic cost adjustments made using P50 cost estimates.

Table 17 Economic cost adjustments for CBA – P50 costs

	Capital costs (P50)	Operating and Maintenance costs (P50)
*	*	*
* 43	*	*
* 44	*	*
Total Real Cost ($2017)	$12,241m	$3,276m
Present Value Cost ($2017, 7% discount rate)	$8,191m	$462m

Source: Advisian, EY analysis

The table below summarises the economic cost adjustments made using P90 cost estimates.

[43] *Redacted – commercial-in-confidence*
[44] *Redacted – commercial-in-confidence*

Table 18 Economic cost adjustments for CBA – P90 costs

	Capital costs (P90)	Operating and Maintenance costs (P90)
*	*	*
*	*	*
*	*	*
Total Real Cost ($2017)	$12,995m	$3,454m
Present Value Cost ($2017, 7% discount rate)	$8,688m	$488m

Source: Advisian, EY analysis

* *Redacted – commercial-in-confidence*

5. Project benefits

The North East Link project will deliver significant and tangible benefits to both businesses and households in the north eastern suburbs of Melbourne, as well as the northern growth corridor and the south east of Melbourne.

The project will provide efficiencies to the freight sector and drive increased productivity for businesses across broader Melbourne and Victorian economy. This section describes the benefits assessed for the preferred alignment identified in the North East Link Concept Design discussed in Chapter 6 of the business case.

Figure 20 summarises these benefits in terms of its alignment to NEL's overarching project objectives.

Figure 20 Overview of North East Link benefits

Source: VLC, VU-CoPS, EY analysis

As outlined in section 2.4.2, the appraisal has also been structured to isolate conventional transport CBA benefit categories, as aside from wider economic benefits (WEBs) and land-use benefits. As such, the benefits section is set out as per the following:

- Transport benefits- Section 5.1
- Wider Economic benefits (WEBs) - Section 5.2
- Land use benefits - Section **5.3**

The individual benefits that comprise each of these categories have been quantified and described in further detail in the sections below.

5.1 Transport benefits

Transport benefits include direct user benefits, externalities and other benefits that are common in CBA for the majority of transport projects. The estimation of these benefits is the foundation of a transport CBA, and should be calculated using base case population and employment projections (i.e. the patterns of population and employment that are expected to exist in the future without the project or program being assessed). In this way, it can be determined what benefits the underlying transport network changes will generate before any induced changes to population and employment patterns.

Note that a key feature of the NEL project is the induced mode switch that will occur as a result of the significant improvement to the road network. When users decide to switch mode, they base this decision on the perceived costs of the alternative modes. However, as the CBA is based on resource costs (i.e. the actual cost of travel), an adjustment (i.e. 'resource cost correction') is required to offset these differences. The benefit categories that are affected by this and thus require a resource cost correction include vehicle operating cost savings, user tolls and public transport benefits (i.e. public transport fares).

The table below summarises the total transport benefits that will be provided by the NEL project.

Table 19 Transport benefits

Benefit category	Value ($2017, Real)	Value ($2017, PV)
Travel time savings	$65,534m	$6,751m
Travel time reliability	$11,158m	$1,059m
Reduced perceived cost of congestion	$10,167m	$1,075m
VOC savings (including resource cost corrections)	$15,551m	$1,968m
User tolls	-$605m	-$64m
Public transport benefits	$1,187m	$148m
Resource cost corrections (Tolls and PT Fares)	$683m	$93m
Emission savings	$1,306m	$153m
Crash cost savings	$2,269m	$339m
Other externalities	-$650m	-$65m
Transport impacts due to induced land use change	-$8,232m	-$713m
Residual value	$5,163m	$95m
Total transport benefits	**$103,531m**	**$10,840m**

Source: EY analysis

5.1.1 Alignment of transport benefits to NEL objectives

In aligning the economic transport benefits provided by the project with the project objectives defined by the business case, the benefits detailed in Table 19 above can be disaggregated to demonstrate the value of benefits provided to businesses, household and freight, as well as amenity related benefits.

Table 20 below provides a breakdown of the annual transport benefits provided by the project in real terms, using 2036 as a representative model year. The results show that the project is expected to provide significant freight related benefits by providing a more direct and efficient route for freight and moving freight vehicles off local roads and onto the project which will provide substantial travel time savings and vehicle operating cost savings. In 2036, the value of freight related benefits is projected to be worth $427 million (real), with household and business related benefits expected to worth $342 million and $250 million respectively. Amenity benefits related to reduced emissions and accident savings is project to add a further $41 million in benefits.

Table 20 Alignment of transport benefits (2036) - $2017

Benefit category	Business	Household	Freight	Amenity
Travel time savings	$217m	$228m	$245m	n/a
Travel time reliability	$37m	$26m	$33m	n/a
Reduced perceived cost of congestion	$20m	$68m	$16m	n/a
Vehicle operating cost savings (including resource cost corrections)	$10m	$41m	$132m	n/a
User tolls (including resource cost corrections)	$3m	$10m	$2m	n/a
Public transport benefits (including resource cost corrections)	$0m	$12m	n/a	n/a
Emission savings	n/a	n/a	n/a	$14m
Crash cost savings	n/a	n/a	n/a	$39m
Other externalities	n/a	n/a	n/a	-$10m
Transport impacts from land use change	-$38m	-$42m	-$1m	-$2m
Total transport benefits	$250m	$342m	$427m	$41m

Source: EY analysis

Over the 50 year appraisal period, the project is expected to provide $4.1 billion (present value) in freight related transport benefits, accounting for 38% of the total transport benefits of the project. Benefits provided to households and businesses are expected to be worth around $3.6 billion and $2.7 billion (present value) respectively, with amenity benefits providing a further $409 million (present value).

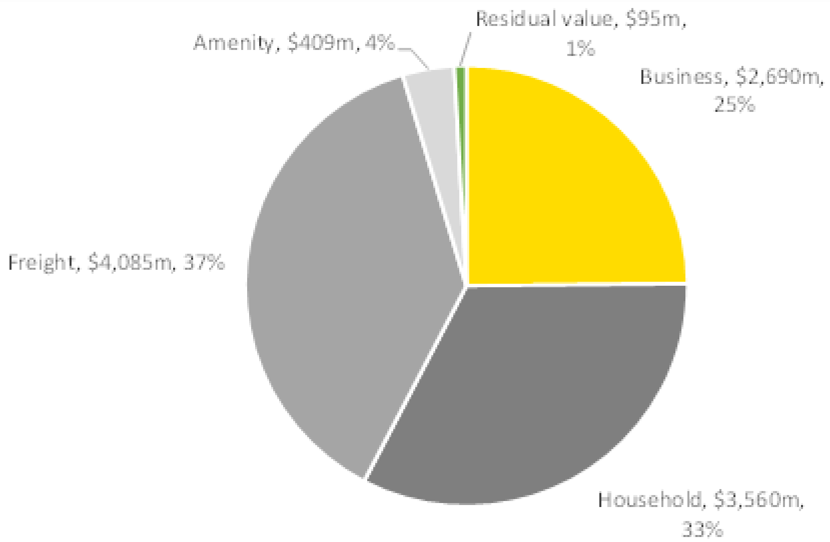
Table 21 Alignment of transport benefits over appraisal period - $2017. PV

Benefit category	Business	Household	Freight	Amenity	Other
Travel time savings	$2,170m	$2,155m	$2,427m	n/a	n/a
Travel time reliability	$419m	$275m	$365m	n/a	n/a
Reduced perceived cost of congestion	$214m	$688m	$173m	n/a	n/a
Vehicle operating cost savings (including resource cost corrections)	$156m	$613m	$1,199m	n/a	n/a
User tolls	$17m	$66m	$12m	n/a	n/a
Public transport benefits (including resource cost corrections)	$4m	$79m	n/a	n/a	n/a
Emission savings	n/a	n/a	n/a	$153m	n/a
Crash cost savings	n/a	n/a	n/a	$339m	n/a
Other externalities	n/a	n/a	n/a	-$65m	n/a
Transport impacts from land use change	-$289m	-$316m	-$91m	-$17m	n/a
Residual value	n/a	n/a	n/a	n/a	$95m
Total	$2,690m	$3,560m	$4,085m	$409m	$95m

Source: EY analysis

Figure 21 shows the spread of transport benefits in respect of alignment to NEL business case objectives. Overall, freight user benefits account for the greatest proportion of benefits (37%), followed by household (33%) and broader business user benefits (25%). Amenity values amount for a relatively minor share of benefits.

Figure 21 Alignment of transport benefits to NEL objectives



Source: EY analysis

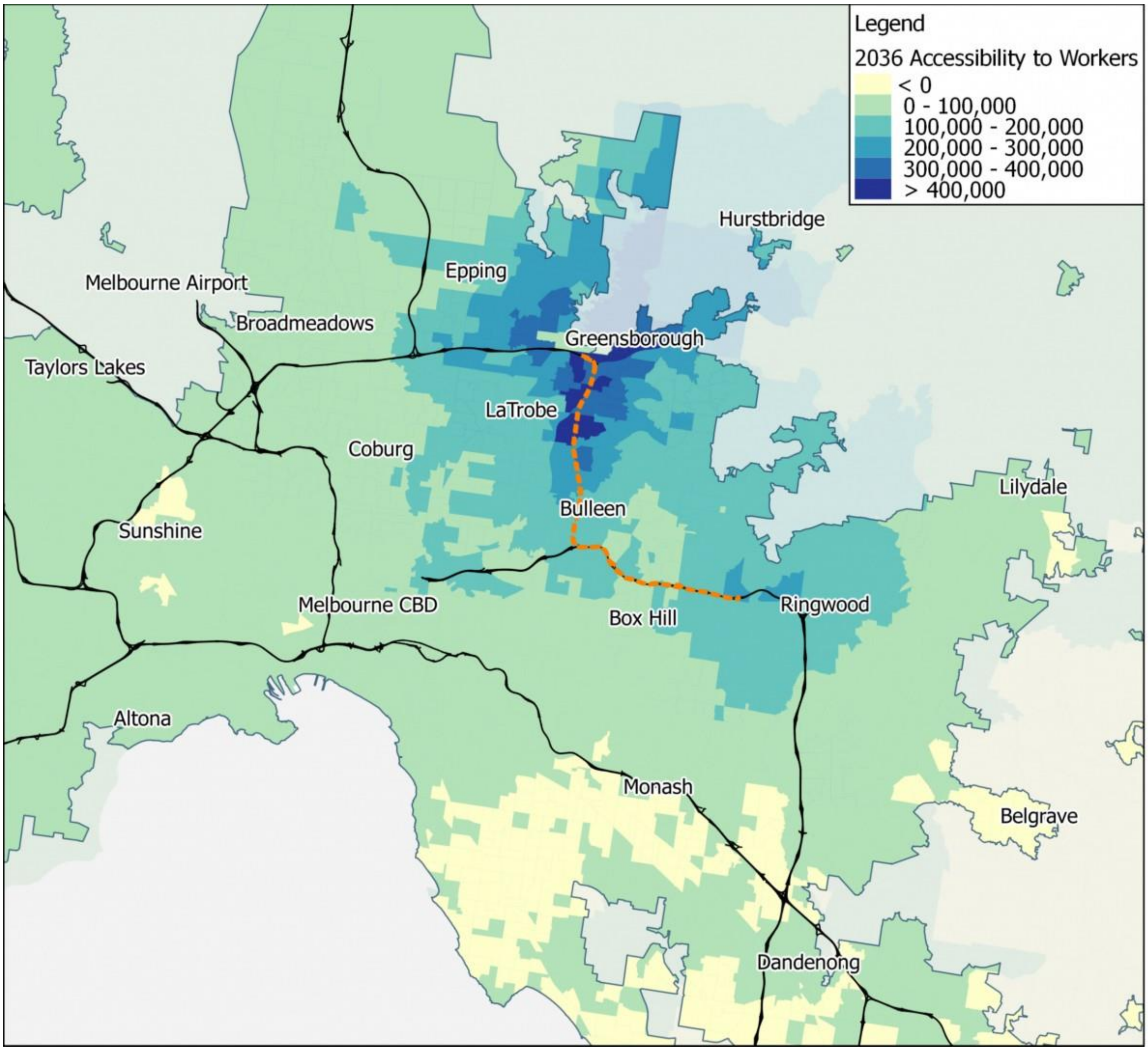
5.1.2 Accessibility metrics

Accessibility metrics have been used throughout the business case options assessment and final appraisal to determine the pattern of accessibility for businesses seeking access to workers, households seeking access to jobs opportunities.

The metrics are derivative of travel time benefits and therefore they have not been monetised. However, they do provide a useful means of understanding the improvements across the network, resulting from NEL, as they apply to common business and household trips, and they are reflective of the opportunities for economic productivity improvements that will result from NELs implementation.

Figure 22 shows the significant improvements in labour market accessibility that will occur as a result of North East Link across the city's north and north east. The figure shows that the spatial distribution of these changes is concentrated throughout the project corridor, along the Eastern Freeway and toward the northern growth corridor.

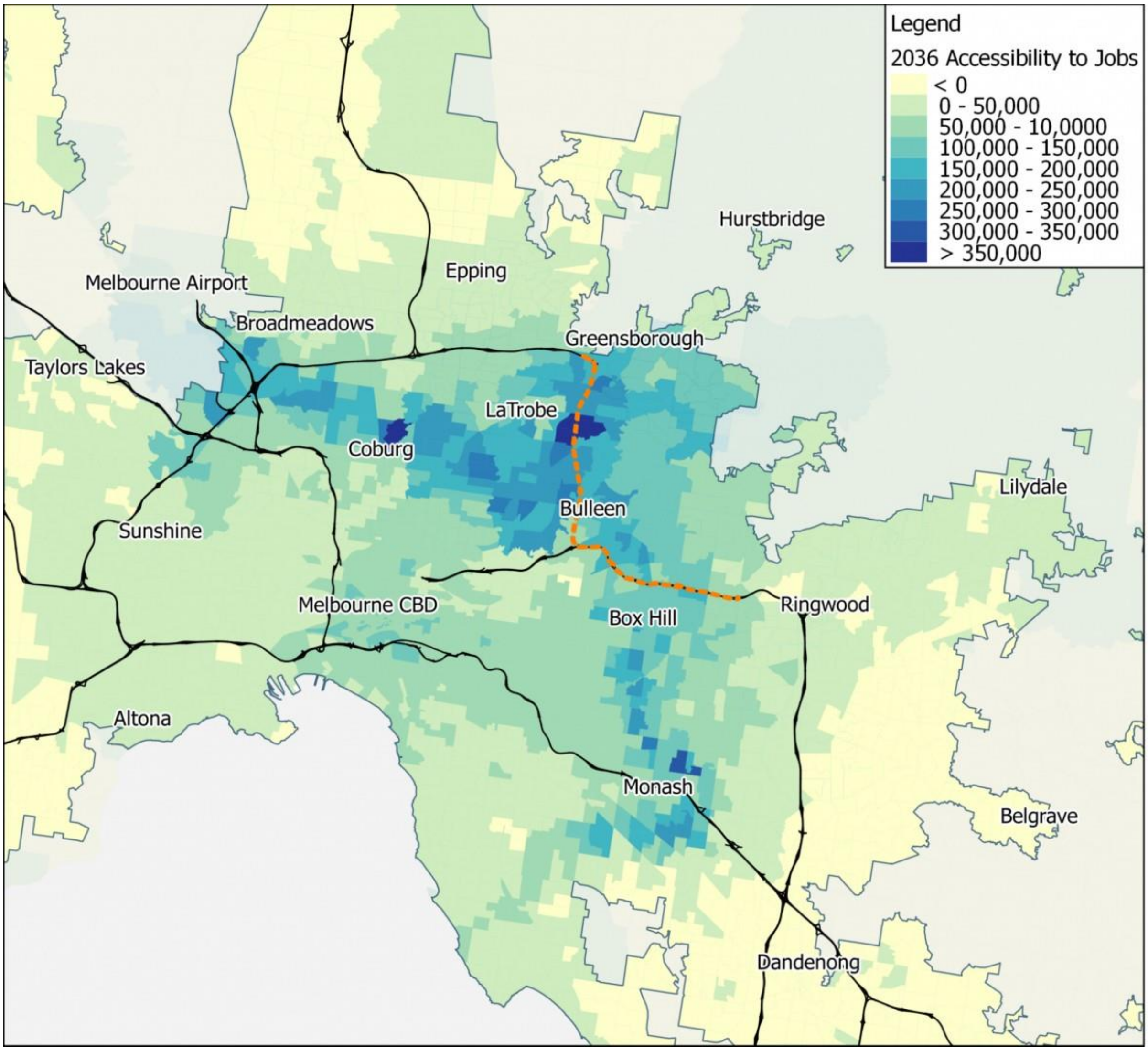
Figure 22 Number of workers accessible to firms within 45 minute car journey – improvement due to NEL



Source: VLC

Figure 23 shows that North East Link will improve accessibility to jobs for key residential locations along the corridor, with the largest improvements in Lower Plenty, Watsonia and Greensborough. Accessibility is also projected to improve modestly across the rest of the project catchment, including around the areas of Box Hill and Ringwood. On average, North East Link is projected to give people living in Melbourne's north east access to an additional 56,000 jobs.

Figure 23 Number of jobs accessible to households within 45 minute car journey – improvement due to NEL

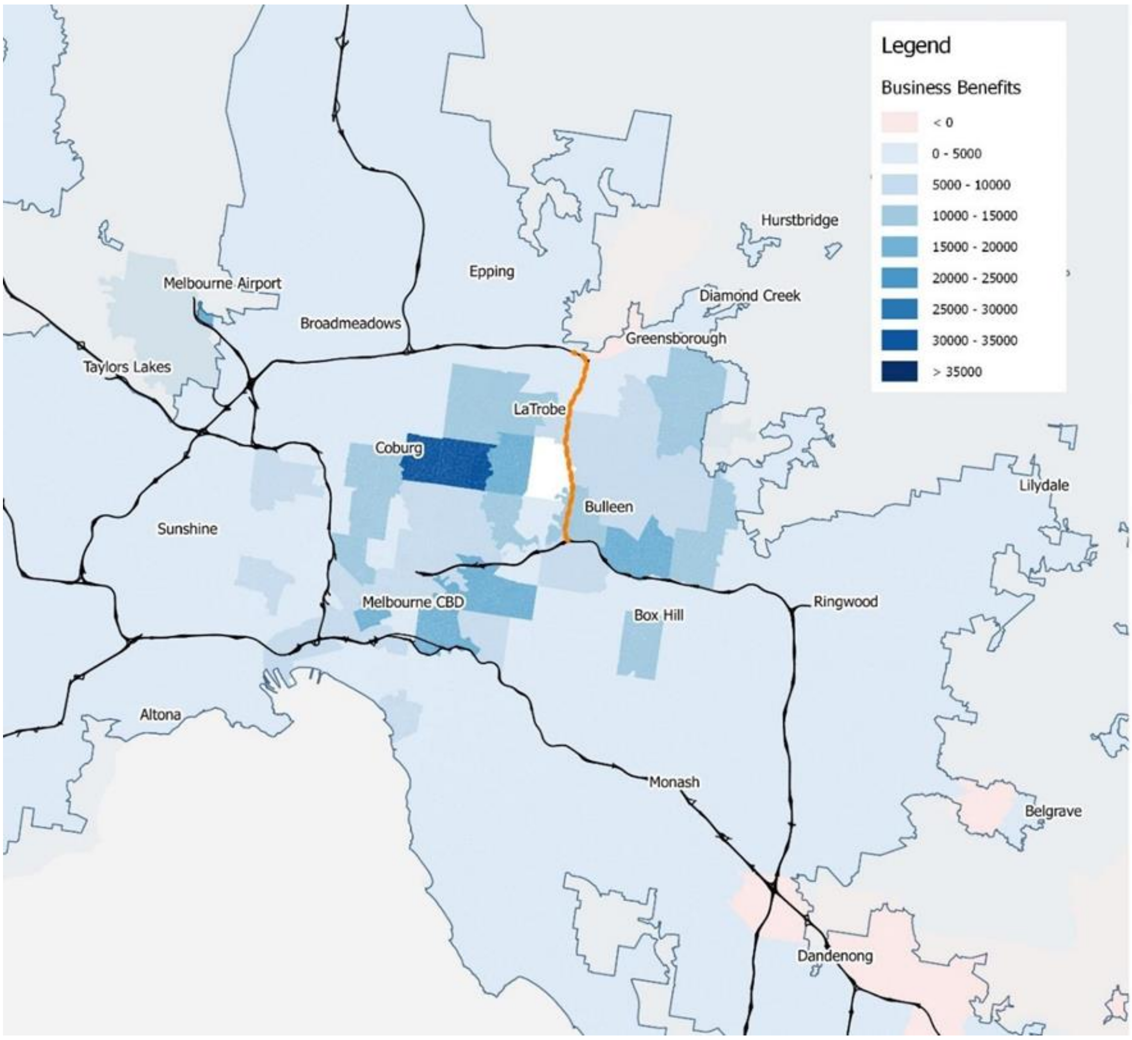


Source: VLC

5.1.3 Distribution of transport benefits

In terms of the geographic distribution of benefits, Figure 24 shows that the project will provide positive business related benefits across a broad area of metropolitan Melbourne, particularly in areas such as Preston, Doncaster, Bulleen, Box Hill, and Melbourne Airport, which are areas of high demand for business to business travel in future years. This geographic spread of business travel time savings is likely to apply similarly to VOC savings and reliability benefits as well.

Figure 24 Distribution of business travel time benefits by destination due to North East Link (change in consumer surplus hours – Car Inter-peak 2036)

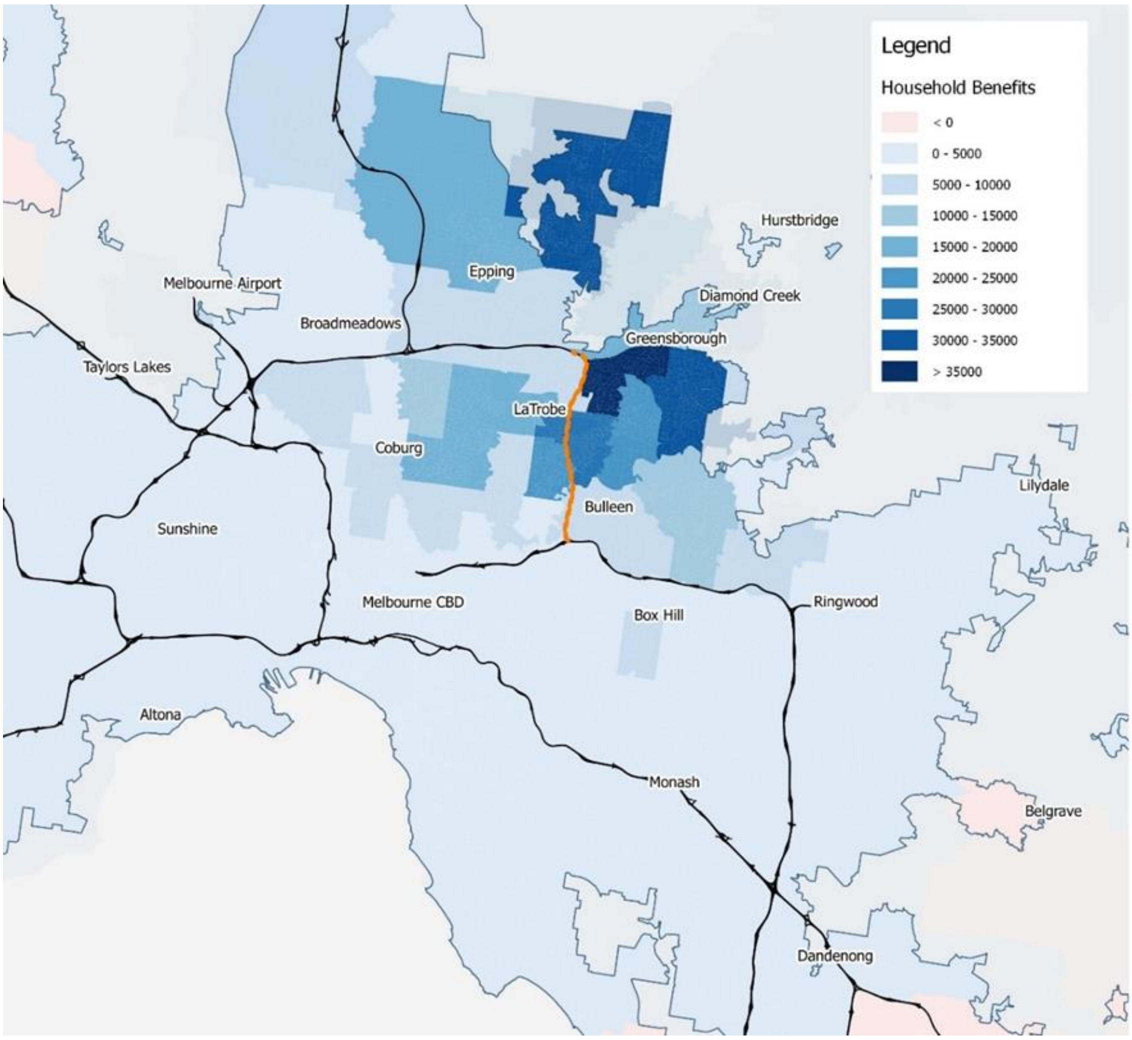


Source: VLC

Figure 25 shows the geographic distribution of household travel time benefits by origin across metropolitan Melbourne. The largest benefits will be experienced in areas along the project corridor including Rosanna and Greensborough, while households further north near Epping and further south near Box Hill are also expected to experience considerable travel time benefits. Overall, households are expected to save about 13.8 million hours each year due to North East Link.

Notably, suburbs in the far north, including Craigieburn and Wollert, are expected to experience net dis-benefits. This is due to considerable induced demand forecast for arterial roads connecting to North East Link, suggesting there is insufficient existing infrastructure in the far north for households to take full advantage of the new link.

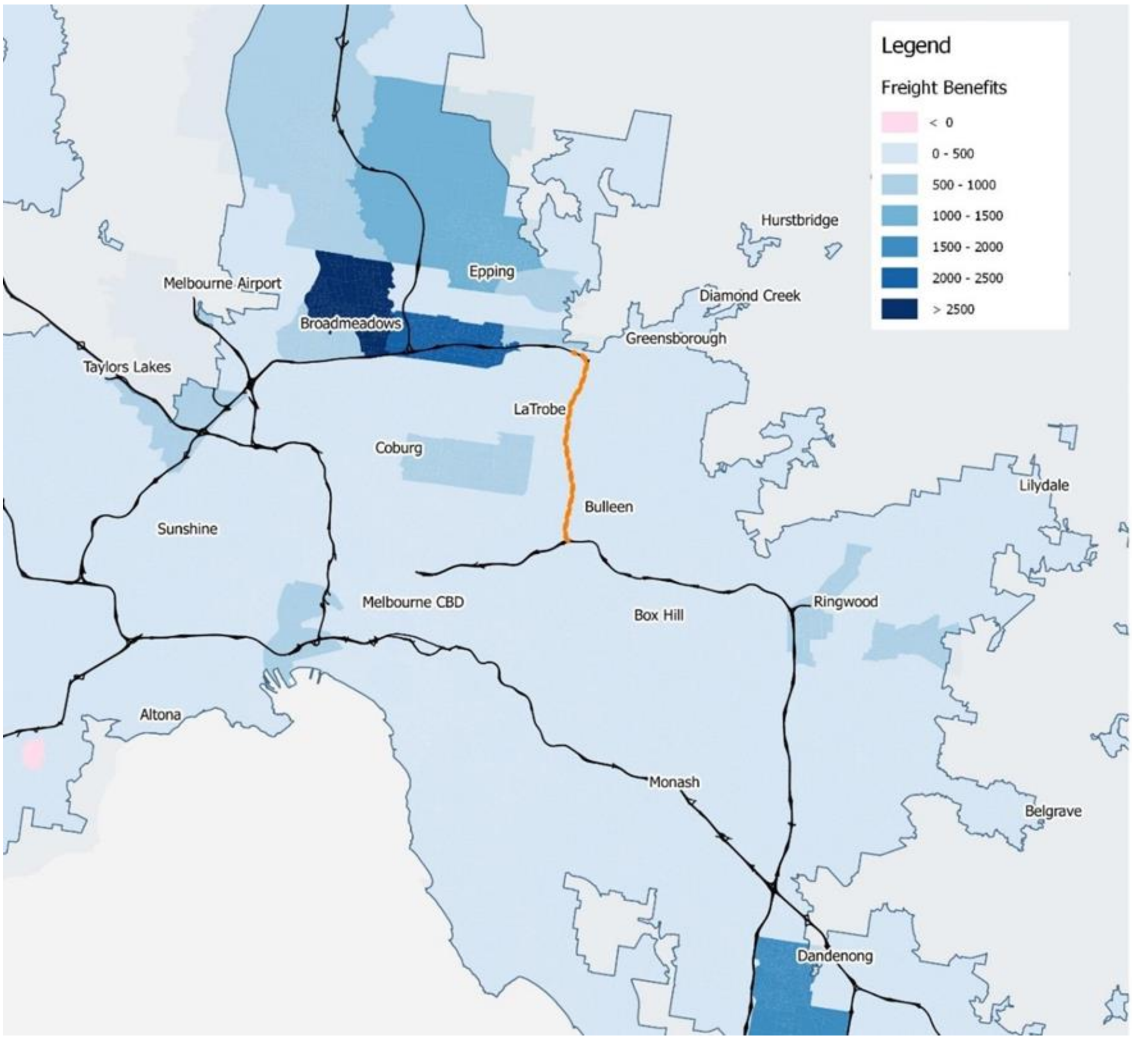
Figure 25 Distribution of household (commuter) travel time benefits by origin (change in consumer surplus hours – Car AM Peak 2036)



Source: VLC

Figure 27 shows the distribution of light and heavy commercial vehicle travel time net benefits by origin across metropolitan Melbourne. These benefits accrue to areas along the M80 corridor around Mill Park, Campbellfield, and Doncaster as well as in Dandenong, which is a major freight and logistics hub.

Figure 26 Distribution of HCV and LCV travel time benefits by origin – impact of North East Link (change in consumer surplus hours – HCV Inter-peak 2036)



Source: VLC

5.2 Wider economic benefits

Wider economic benefits refer to the wider economic benefits (WEBs) related to productivity gains that arise from changes in agglomeration, time spent at work and business output linked to transport system changes (i.e. in contrast to land use system changes that underpin the estimation of city-shaping benefits). These wider economic benefits are calculated based on changes in travel costs and demand only given a fixed land use pattern to avoid double counting with city-shaping benefits. The economic appraisal will include an assessment of these wider economic benefits attributable to the Program.

Table 22 Wider economic benefits

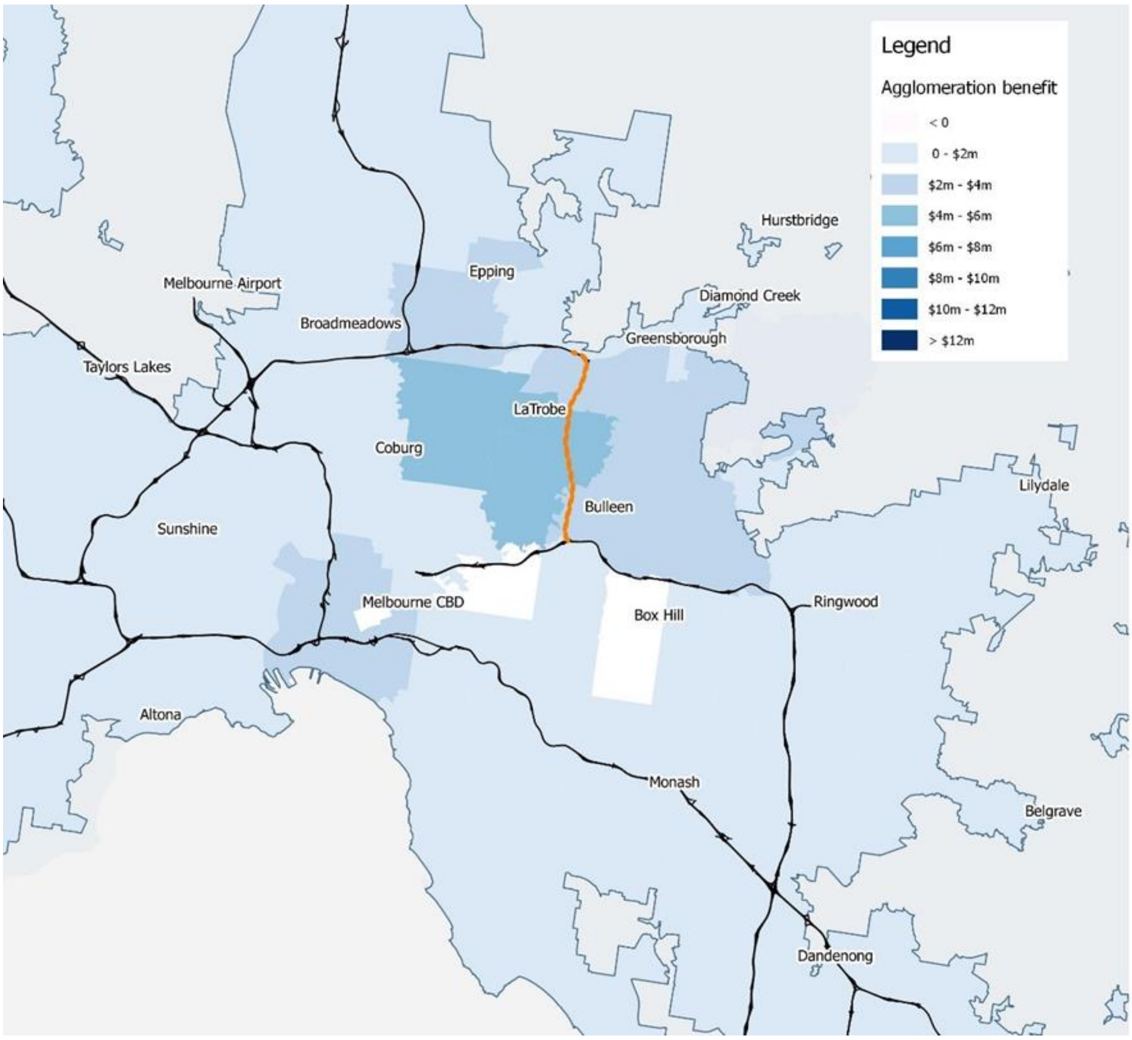
Benefit category	Value ($2017, Real)	Value ($2017, PV)
Agglomeration	$5,101m	$590m
Labour Supply	$689m	$89m
Output Change in Imperfect Markets	$1,704m	$211m
Total wider economic benefits	**$7,494m**	**$890m**

Source: EY analysis

5.2.1 Distribution of agglomeration benefits

The distribution of agglomeration benefits attributable to NEL are focused primarily in the northern and north eastern suburbs of Melbourne, as shown in Figure 27 below for 2036.

Figure 27 Agglomeration benefits due to North East Link (2036)



Source: VLC

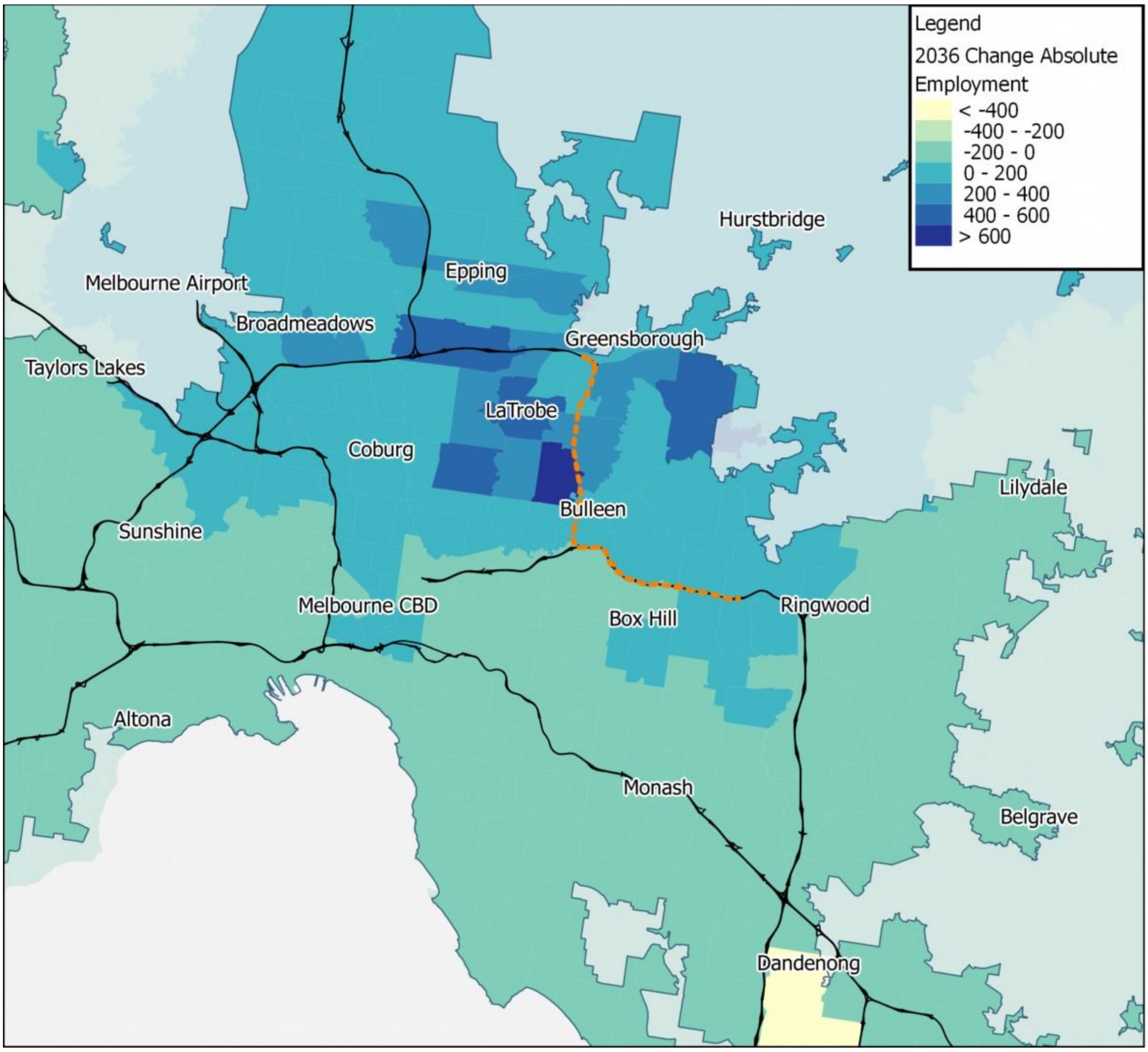
5.3 Land Use benefits

In addition to the transport impacts due to induced land use change, there are a number of other land use benefits that can arise when a transport project has the potential to significantly impact on the location decisions of household and businesses. This occurs when the changes in accessibility that underpin a project's demand projections and transport benefits change the patterns of population and employment as people and businesses seek to locate close to new transport infrastructure and services.

To identify areas likely to be impacted by changes in demand arising from improved accessibility, a land use and transport interaction (LUTI) modelling approach was used to estimate the potential redistribution of employment. The redistribution of employment is used as a proxy to represent the potential impacts of the project in attracting additional commercial or industrial activities due to improved accessibility.

Figure 28 below shows the projected change in employment location as a result of the North East Link. The results suggest that there will be in increase in demand for employment and development in key commercial and industrial precincts such as Epping, Campbellfield, Thomastown/Bundoora, La Trobe and Heidelberg.

Figure 28 Redistribution of employment due to North East Link



Source: VLC, EY analysis

The project is expected to redistribute approximately 7,700 jobs to key residential locations in Melbourne's north east.

At Additional provision of employment opportunities to areas of high growth (especially to regions like Whittlesea, where population growth is forecast to increase by over 140,000 between 2016 and 2036) is a beneficial and necessary phenomena that will help local workers in these regions to avoid having to travel long distances to employment opportunities.

Table 5 Additional employment growth redistributed using LUTI approach (Top 5 LGAs)

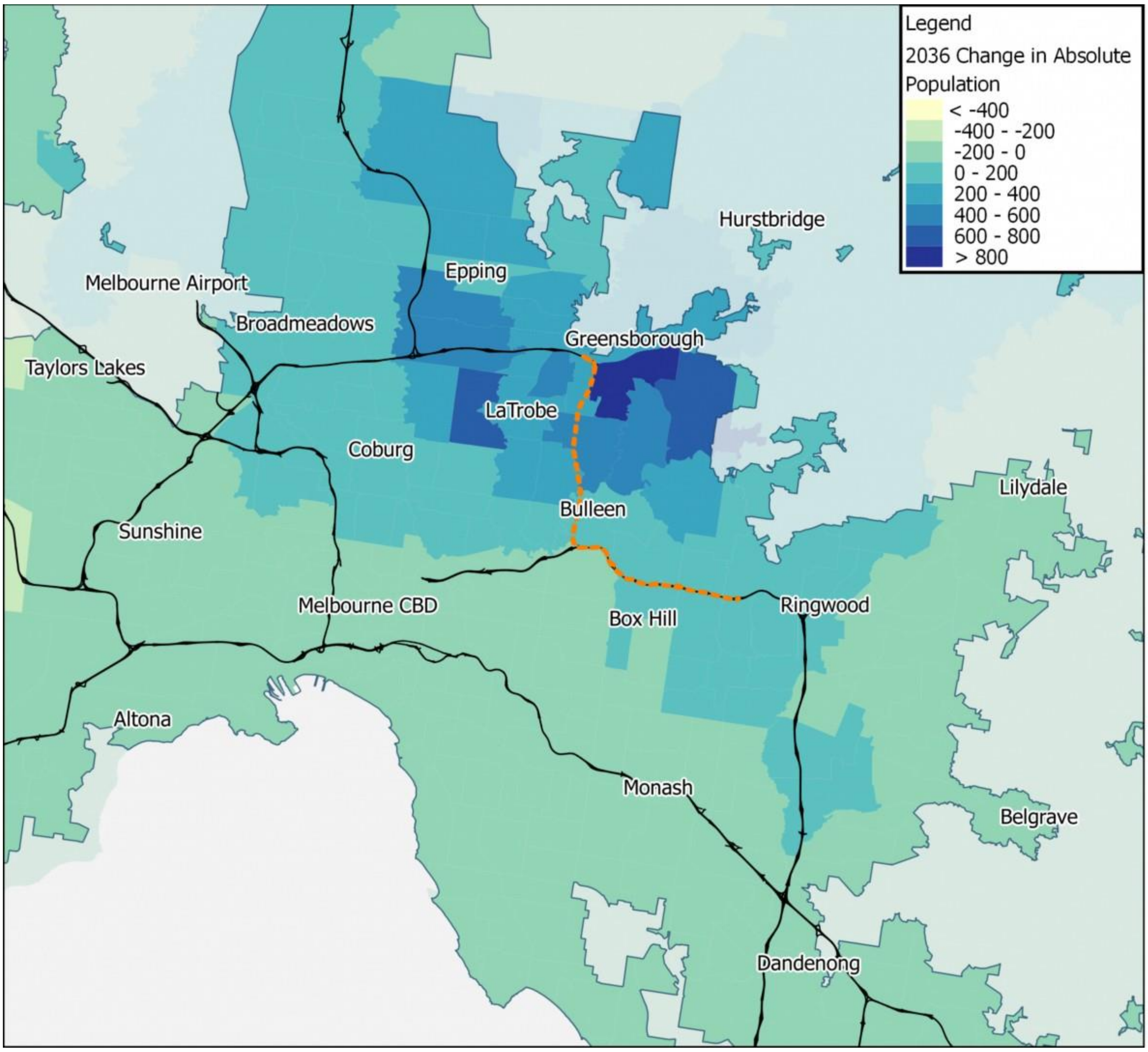
LGA	VIF forecast employment growth (2016 – 2036)	Additional employment growth redistributed using LUTI	LUTI employment growth uplift proportion
Banyule	22,530	3,720	17%
Whittlesea	144,420	3,580	2%
Darebin	49,290	2,050	4%
Manningham	4,960	1,510	30%
Nillumbik	24,010	1,090	5%

Source: VIF 2015, VLC, EY analysis

The project has been developed in anticipation of projected population increases in the city's urban growth corridors. The project's connectivity and accessibility improvements will also contribute to attracting more residents to these areas and to the north east, which has been experiencing relatively low growth.

Figure 29 outlines the projected redistribution of population as a result of the project. The project is expected to redistribute approximately 12,000 residents to Melbourne's north eastern Local Government Areas as outlined in the table below. This represents an additional 5% growth in addition to the existing forecast growth in population for these areas by Victoria In Future (VIF 2015).

Figure 29 Potential location of population change resulting from NEL



Source: VLC, EY analysis

The analysis suggests that the induced change in land use is likely to have a negative impact on productivity due to the added congestion that would arise as a result of more population and jobs being attracted to the area. However, disbenefits related to urban densification will be offset by a modest gain in the cost of providing infrastructure as the consolidation of homes will result in people moving from greenfield to middle and inner areas, which typically are more dense and thus have lower infrastructure cost requirements.

As can be seen in Table 23 below, these two land use benefits are relatively minor compared to other benefit categories and almost entirely offset each other. Given these issues, these benefit categories have not been included as part of the economic appraisal.

Table 23 Land use benefits

Benefit category	Value ($2017, Real)	Value ($2017, PV)
Urban Densification	-$2,714m	-$271m
Infrastructure Efficiency	$2,656m	$244m
Total wider economic benefits	**-$58m**	-$27m

6. Cost-benefit analysis results

6.1 Overview

As discussed previously in section 2.4.6, there are a number of key risks and uncertainties that have the potential to significantly impact upon the results of the cost benefit analysis. Traditional CBA approaches attempt to consider some of these uncertainties through sensitivity analysis, however produce a central estimate upon which the investment decision is typically based upon.

It is believed that using traditional CBA frameworks have the potential to significantly misrepresent the true costs and benefits of a project given that these approaches attempt to assign certainty to a highly uncertain future.

The approach that has been adopt for this economic appraisal utilises a risk based approach to analysing multiple possible futures, using the approach discussed in section 2.4.6.

6.2 Base CBA results

The CBA results for the base scenario suggest that the project will deliver significant economic value for the State of Victoria and the national economy, with total benefits that are around $3.1 billion greater than the capital and operating costs of the project.

The BCR of the base scenario when considering transport benefits only, is estimated to be 1.3, which means that for every dollar spent on the project, the Victorian economy will receive $1.30 of value in return. This is equivalent to an internal rate of return of around 8.3%, further demonstrating the positive economic value-for-money that the project can deliver. Once wider economic benefits are included, this value increases to $1.40 for every dollar of cost, further enhancing the economic return provided by the project.

These results for the base scenario are summarised in Table 24 below. Note this scenario has not undergone risk adjustment to reflect future uncertainty.

Table 24 Base scenario CBA results

	$Real	$PV
Capital expenditure costs (capex)	$12,241m	$8,191m
Operational expenditure (opex)	$3,276m	$462m
Total project costs	$15,517m	$8,653m
Transport benefits	$103,531m	$10,840m
Wider Economic Benefits (WEBs)	$7,494m	$890m
Total project benefits	$111,025m	$11,730m
Net present value (NPV) – Transport only	$2,187m	
Benefit Cost Ratio (BCR) – Transport only	1.3	
Net present value (NPV) - Transport + WEBs	$3,077m	
Benefit Cost Ratio (BCR) – Transport + WEBs	1.4	

Source: EY analysis

6.3 Risk and uncertainty analysis

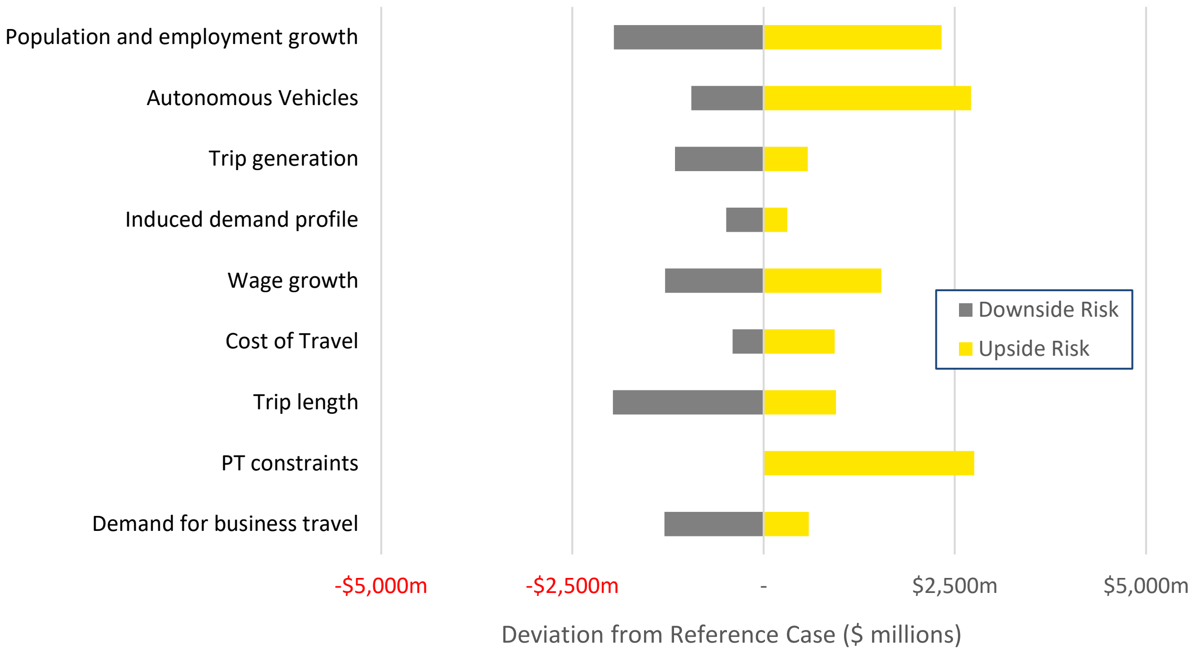
As discussed previously, the North East Link is a large and complex project that will deliver road user and wider network and economic benefits over a long timeframe. In addition to construction and other delivery risks and uncertainties the project faces in the shorter term, there are a range of demand and other operational risks and uncertainties the project faces over the medium to longer term.

Therefore, in order to understand the potential impact these risks and uncertainties may have on the results of the economic appraisal, a detailed risk and uncertainty assessment has been undertaken following the approach described in section 2.4.6. The following sections describe the findings of this analysis.

6.3.1 Benefit uncertainty

Our uncertainty analysis can be used to provide insight on the upsides and downsides of project benefits. Figure 30 compares the upside and downside risks of the benefit scenarios modelled, with the lower and upper ranges representing the P10/P90 ends of the distributions. This shows that project benefits are particularly sensitive to population and employment growth and autonomous vehicle uncertainty (with the potential for increased safety and capacity compared to current vehicle technology). While other key factors, such as future trip generation (user behaviour), cost of travel, and the induced demand profile can have an impact on the benefits realised due to the project, the scale of the potential impacts for these factors are relatively minor in comparison with the other factors identified above.

Figure 30 Upside and downside risk (P10/P90) of benefit uncertainty categories

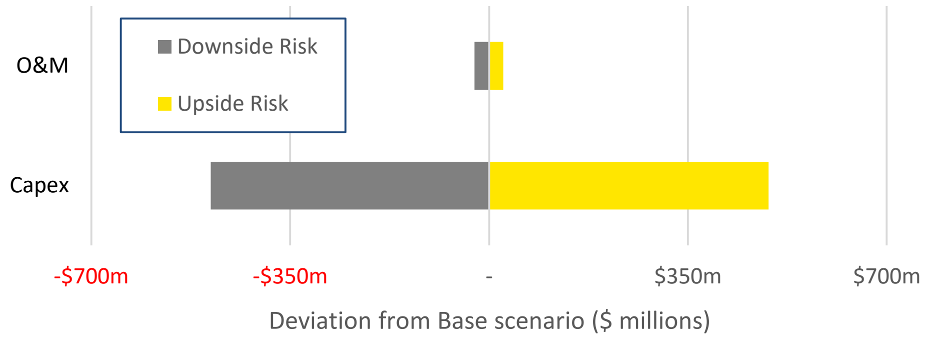


Source: EY analysis

6.3.2 Cost uncertainty

Figure 31 shows the upside and downside risks to project costs using the same method outlined in section 2.4.6. Note, the upside and downside cost risks are evenly distributed, indicating that the base scenario represents the expected outcome. Additionally, the figure shows that total project costs are most sensitive to capital expenditure.

Figure 31 Upside and downside risk of cost uncertainty categories



Source: EY analysis

By assigning a probability to each of the potential future scenarios modelled, a risk-adjusted BCR can be constructed which takes into account these key components of risk and uncertainty.

6.4 Risk adjusted result summary

The categories of benefit and cost uncertainties have been combined together to reflect their ability to impact project costs and benefits and calculate an overall distribution.

The diagram below plots the benefit and cost results of each simulation from the Monte Carlo analysis. The linear line running through the middle of the graph represents a scenario where the BCR is equal to 1.

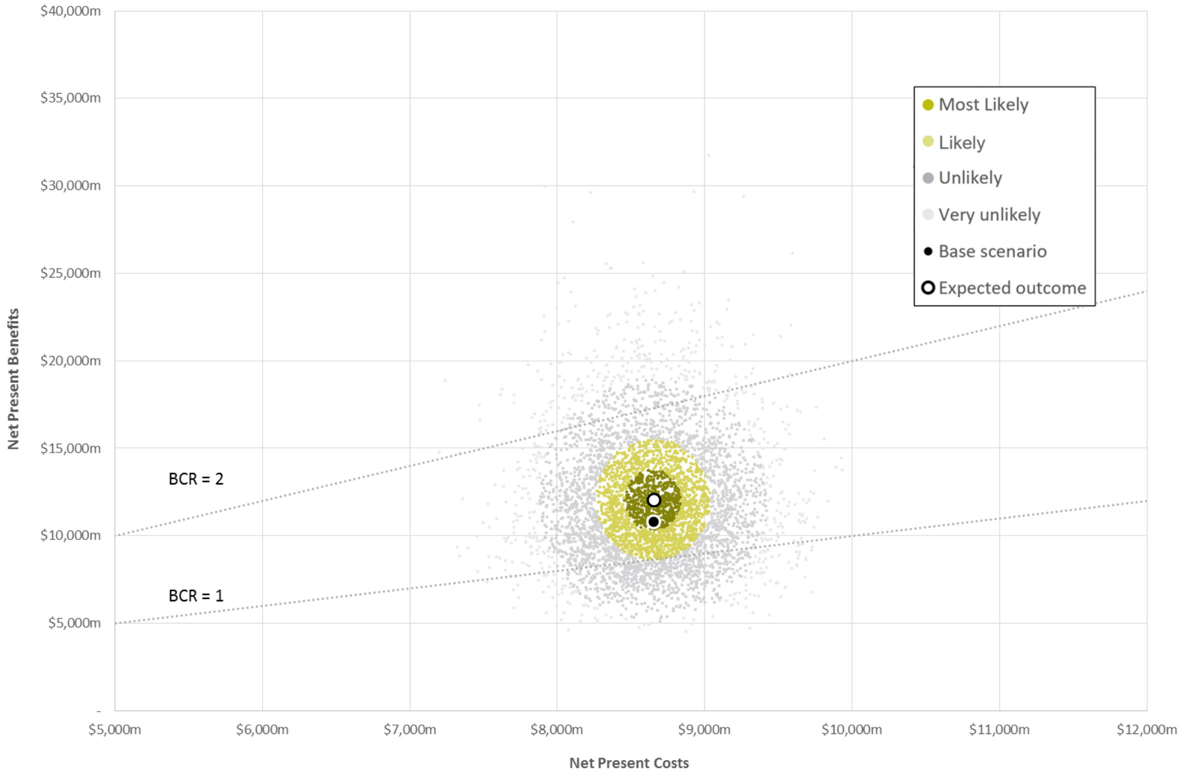
The contours of different colour represent the confidence level associated with the outcome of the simulation. Accordingly, it is known with 70% confidence that the costs and benefits of NEL will fall within the two inner most contours.

The dark dot on the chart represents the position of base scenario. As the base scenario sits below the middle of contour circles, this suggests that the upside potential for benefits is greater than the downside.

Accounting for uncertainty, the present value of benefits ranges from $7.2 billion (P5) to $18.5 billion (P95), with the likely and most likely benefit (BCR) ranges between $8.6 billion (1.0) and $15.5 billion (1.9). Accordingly, all outcomes within the likely and most likely range produce a BCR greater than one.

The costs range from $8.0 billion (P5) to $9.3 billion (P95), reflecting the risk scenarios developed by the cost estimators.

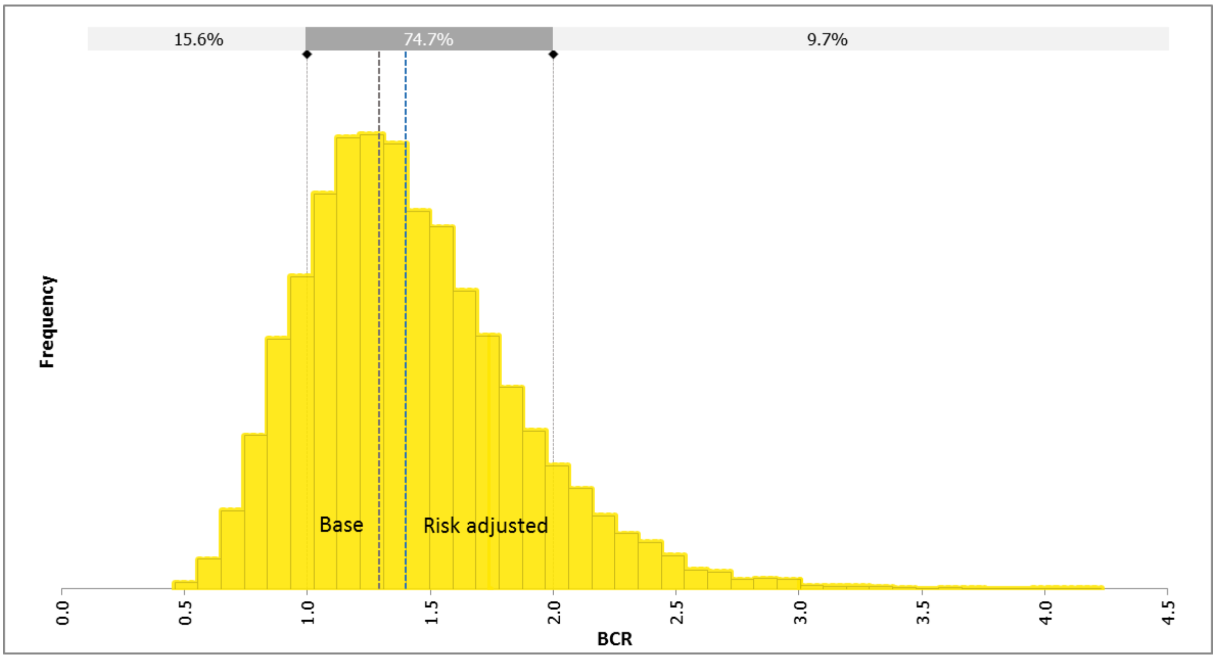
Figure 32 – Cost benefit risk and uncertainty



Source: EY analysis

This histogram plot below shows the distribution of the BCR and confidence levels associated with different outcomes. The distribution is slightly positively skewed (has a long tail of higher outcomes), highlighting how the upside potential for a number of benefit categories generates a high proportion of scenarios with BCRs greater than the base scenario.

Figure 33 North East Link risk adjusted BCR distribution



Source: EY analysis

Only a small proportion (15.6 percent) of possible combinations of cost and benefit outcomes would lead to a BCR less than one, while 9.7 percent of scenarios would lead to a BCR greater than two. These outcomes are associated with significant changes in circumstances that are possible, but unlikely, to occur given current economic, social and policy directions.

Table 25 below shows a comparison of the project costs and benefits for the base and the risk adjusted scenarios. The expected outcome for the risk adjusted scenario represents the average from all simulations from the Monte Carlo analysis. Notably, accounting for uncertainty, moves the BCR from 1.3 in the base scenario to 1.4 in the risk adjusted scenario. This movement reflects the greater overall upside potential to the uncertainty categories identified and assessed by the project team.

This result also suggests that the base scenario is relatively conservative in terms of some of its assumptions, and that based on our assessment of risk and future uncertainty, that the actual benefits of the project could be higher than initially forecast.

North East Link's risk adjusted NPV of $3.4 billion and BCR of 1.4 reinforces the potential for the project to deliver economic value-for-money, providing the state with $1.40 of value for every dollar spent on the project. This is equivalent to an IRR of 9.0 percent, further demonstrating the case for investing in the project to deliver substantial net benefits for the Victorian and national economies.

Table 25 Summary CBA results (risk adjusted)

	Base scenario	Risk-adjusted
Capital costs ($PV)	$8,191m	$8,191m
Operating and maintenance costs ($PV)	$462m	$462m
Total project costs ($PV)	$8,653m	$8,653m
Transport benefits ($PV)	$10,840m	$12,054m
Net present value (NPV) – Transport only	$2,187m	$3,401m
Benefit Cost Ratio (BCR) – Transport only	1.3	1.4

Source: EY analysis

6.5 Sensitivity testing

In addition to the risk and uncertainty analysis undertaken above, a number of other sensitivity tests were undertaken. These tests, most of which are commonly undertaken as part of most traditional CBAs, cover the following sources of uncertainty:

Table 26 Sensitivity test summary

Sensitivity test	Description
Scenario sensitivities	Using the drivers of risk and uncertainty outlined above, two additional scenarios were developed to represent an 'optimistic case' and a 'pessimistic case' scenario. The pessimistic case represents a scenario where benefits realised by the project are lower than expected, which has been modelled by giving a greater likelihood to the downside scenarios to a level that is significantly lower than the DEDTJR Reference Case. The optimistic case represents a scenario where the upside outcomes are given a greater likelihood than the base scenario.
Cost estimation	The economic appraisal currently includes capital cost estimates at the concept and detailed stages of development and therefore actual costs are likely to differ from those currently provided. In order to test the impact of cost savings or overruns on the robustness of the program, sensitivity tests were undertaken assuming over/under estimation of costs by 20%.
Demand analysis	Demand forecasting is an important element of estimating the benefit that will be provided by the project. While the scenario analysis undertaken effectively model varying degrees of demand response, a standard demand sensitivity tests (i.e. +/- 20% benefits) has been undertaken to provide a benchmark on which the project's sensitivity to demand can be measured.
Economic parameters	As with any economic appraisal, the outcomes are critically dependent on the economic parameters and assumptions used to inform the analysis. Therefore, a number of sensitivity tests have been undertaken to test the project's response certain key economic assumptions (e.g. discount rate, escalation rate, extrapolation etc.), as well as the impact of excluding

Sensitivity test	Description
	certain benefit streams from the analysis (e.g. perceived cost of congestion and travel time reliability)
Blending profile	The economic appraisal assumes that it will take the project eight years for demand to reach a steady state level taking into account induced demand related to route choice, mode switching, destination choice and land use changes. This has been modelling by assuming a gradual blended profile over eight years between fixed and variable trip matrix results produced by Zenith. To understand the impact this approach has on the overall outcomes of the project, sensitivity tests have been undertaken assuming a five year blending period, as well as a scenario that assumes no blending period (i.e. relying solely on variable trip matrix results).

The results of the sensitivity tests undertaken are summarised in the table below. The outcomes of the sensitivity testing shows that the NEL project will remain economically viable even when considering most ‘downside’ scenarios, except for the pessimistic scenario which has particularly pessimistic land use and real income assumptions. Note that all the sensitivity tests below consider transport benefits only, and have estimated relative to the base scenario.

Table 27 Sensitivity tests – summary results

Sensitivity test	NPV	BCR
Base Scenario	$2,187m	1.3
Risk-adjusted scenario	$3,401m	1.4
‘Pessimistic’ future scenario	-$4,191m	0.5
‘Optimistic’ future scenario	$20,629m	3.5
P90 costs	$1,665m	1.2
-20% costs	$3,918m	1.6
+20% costs	$456m	1.0
-20% benefits	$19m	1.0
+20% benefits	$4,355m	1.5
4% discount rate	$15,984m	2.7
10% discount rate	-$1,489m	0.8
5 year ramp-up period for induced demand	[*]	1.2
No ramp-up period for induced demand	[*]	1.1
Excluding 'perceived cost of congestion' benefits	$1,112m	1.1
Reference Case VOC growth assumption	$1,319m	1.2
Austroads VOC parameters	$1,044m	1.1
Benefits capped after 30 years	$1,764m	1.2
Benefits extrapolated in line with population growth	$1,705m	1.2
Vehicle specific annualisation factors	$2,027m	1.2
Increasing annualisation factor over time to allow for increased weekend travel	$2,838m	1.3

Source: EY analysis

In general it is considered that a suitable level of conservatism has been applied to the development of the CBA and that, on balance, the overall profile of benefits and costs presented in the business case is robust and defensible.

While there may be a tendency to focus on the potential downside risks to certain methodological approaches and assumptions, there are a number of areas where the project team could have incorporated new information and revised assumptions to increase the estimated benefits of the project. There are also some areas where potential downsides are acknowledged.

This is borne out in the risk and uncertainty analysis presented above to further demonstrate that a balanced approach has been applied.

[*] *Redacted – commercial-in-confidence*

6.5.1 Additional sensitivity tests

In addition to the sensitivity tests undertaken above, a number of additional scenarios were modelled by VLC to understand the impact of various projects and their inclusion/exclusion from the base and project cases.

Note that the sensitivity tests for these projects were undertaken for a single model year (2036), with the result focussed on changes in overall consumer surplus. Therefore, the results of this analysis have been presented as the changes in consumer surplus (i.e. increase or decrease) relative to the equivalent core run.

From this analysis, a number of key findings were identified:

- Tolling of the North East Link is extremely important to preserve the benefits provided by the project, with modelling suggesting that benefits would be almost 50% lower if the project was to be toll-free.
- Widening of the Eastern Freeway is critical for the project to meets its objectives, and to avoid disbenefits along the freeway. Benefits are estimated to reduce by around 30% without the widening and bus upgrades.
- Modelling scenarios that assume that future public transport network is constrained suggest there is significant upside for the North East Link project (17%).
- While a freeway management system (FMS) is to be implemented on the Eastern Freeway as part of North East Link, there is a view that FMS would be provided in the short to medium term without North East Link and therefore should form part of the base case definition. Despite uncertainty around the inclusion of FMS on the Eastern Freeway as part of the base case, modelling suggests that benefits would reduce by around 10% if it were to be included. While significant, this would not undermine the economic value of the project.
- Other major projects that are part of the Reference Case, such as Melbourne Metro 2, are not expected to have a material impact on the benefits of North East Link.

The outcomes of the additional sensitivities are summarised in the table below.

Table 28 Additional sensitivity tests – indicative results

Sensitivity test	Impact on benefits
Hume Freeway widening added to base case	+3%
EastLink widening added to base case	0%
North East Link without tolls	-47%
Excluding Eastern Freeway widening and BRT from project case	-31%
Excluding BRT from project case	-1%
Excluding FMS	-24%
Constrained PT network	+17%
Melbourne Metro 2 added to base case (2051)	-1%
FMS removed between Hoddle St and Chandler Hwy	-2%
Exclude SRU North package from base and project case	+2%
Addition of FMS to Eastern Freeway only	-11%

6.5.2 E6 transport corridor

One of the key complementary projects that was considered in the context of the NEL project is the E6 transport corridor, which is part of the broader Outer Metropolitan Ring (OMR), a reservation intended to accommodate a 100 kilometre long high-speed transport link for people and freight in Melbourne's north and west.

The E6 component is planned as a new freeway connection from the Hume Freeway, near Kalkallo to the M80 at Thomastown. The E6 has been reserved through a Public Acquisition Overlay in the planning scheme as part of the OMR.

The proposed E6 has strong alignment with North East Link's project objectives, particularly around improving access and growth in Melbourne's north for businesses, households and freight. The delivery of the E6 is expected to provide significant benefit to Melbourne's rapidly growing population in the outer north, through improved accessibility and network operation.

In order to understand the potential impact of the E6 in the context of the NEL, a rapid CBA was undertaken to compare the costs and benefits of the NEL project both with and without the proposed E6 transport corridor, with the benefits provided by the E6 corridor assumed to be the difference between those two scenarios.

Note that this analysis undertaken is based on high level cost estimates, and preliminary transport modelling, and therefore should only be interpreted as indicative. However, as can be seen in the table below, the results of the rapid CBA suggest that the E6 transport corridor provides a strong economic return *Redacted – commercial-in-confidence*.

Table 29 E6 transport corridor – Rapid CBA summary results

Redacted – commercial-in-confidence

6.6 Supporting impact analysis

Monetising figures in dollar terms via cost-benefit analysis (CBA) is often not the clearest way to articulate real-world outcomes of investment decision-makers. For this reason the CBA should be seen as just one element of a broader assessment approach that aims to fairly represent the full impacts of the program in terms which are meaningful to stakeholders and decision-makers.

The supporting analyses described below have been used to both inform and support the overall economic evaluation of the project.

6.6.1 Economic impact analysis

A significant investment like the North East Link will be a major contributor to economic activity and jobs (for example measured by changes to Gross State Product and employment). These macroeconomic impacts result from both the initial boost in construction sector activity over the life of the project, and from ongoing improvements in business productivity due to lower transport costs and closer business-to-business linkages (i.e. agglomeration).

Modelling these impacts using a Computable General Equilibrium (CGE) model provides a more tangible view of the potential benefits of the project, instead of focusing on just the typical welfare measures included in a CBA. However, it is important to note that positive macroeconomic impacts are not additions to the benefits included in the CBA. What the CGE model does is to translate the CBA outputs into economy-wide outcomes. The main difference of CGE modelling is that it yields results for the whole economy rather than just for a narrow part of the economy as is the case with CBA. Thus CGE gives a more complete picture, including identifying winners and losers across the economy.

The economic impact of the project has been modelled by Victoria University Centre of Policy Studies (CoPS), who was commissioned to undertake macroeconomic simulations using their dynamic CGE model, VU-TERM, which is the model endorsed by current DEDJTR guidelines.

Table 30 below provides a summary of the economic impacts of the project over the CGE modelling period (2018-2046).

Table 30 CGE modelling results summary (2018-2046)

Indicator	Value
Real GDP ($millions)	$12,544m
Jobs supported per year - Construction period (2018 - 2026)	10,300
Jobs supported per year - Operating period (2027-2046)	3,800

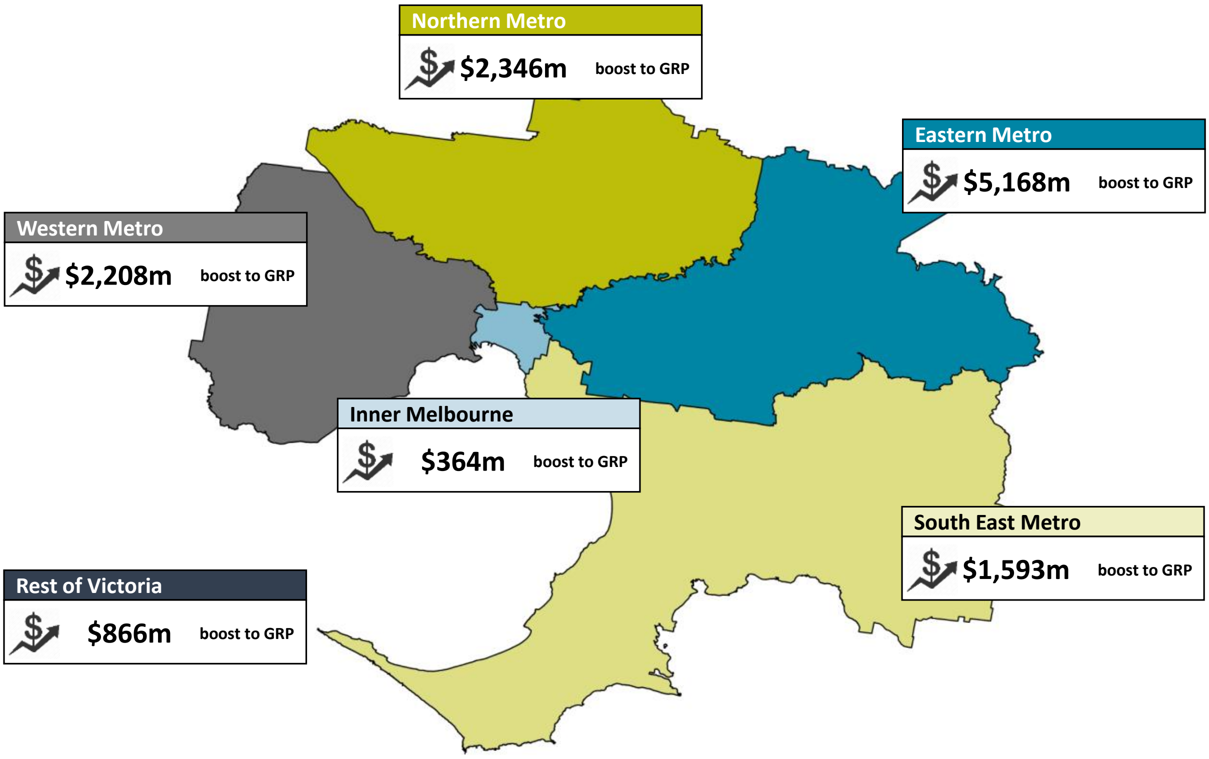
Source: VU-CoPS

In terms of the impact of the project on employment, the CGE modelling suggests that the project will support an average of 10,300 additional (net) jobs across Victoria during the construction period, while over the operating period, the project will support 3,800 additional (net) jobs across Victoria.

6.6.2 Spatial impact analysis

In terms of the spatial distribution of the economic impacts estimated above, it is estimated that the majority of the economic impacts will be concentrated in the Eastern Metro region, with the project providing an economic boost of over $5.1 billion to the region. The project is also expected to provide significant benefits to the rest of the state as summarised in Figure 34 below.

Figure 34 Spatial impact analysis results



Source: VU-CoPS, EY analysis

Attachment A Transport benefit calculations

Travel time savings

The strategic transport modelling undertaken by Zenith estimates the extent to which the project can be expected to alleviate delays and congestion along Melbourne's road network. Additional capacity provided by the project will create more time-efficient journeys overall, generating or hours worked in productive activity or additional leisure time.

Estimation approach and assumptions

Savings in base travel times for the Project Case were estimated relative to Base Case for continuing users and switchers based on a typical weekday, with trip purposes disaggregated.

For continuing users (i.e. those whose choice of travel mode or destination does not change in response to the project) the benefits of the project are simply the changes in perceived cost of their journeys. For users switching models (i.e. those whose choice of mode of travel or destination does change in response to the project), the calculation is more complicated. This is because individuals who change mode will tend to have a different preferences and values of time to the average continuing user.

The CBA resolves this issue by assigning half of the change in generalised costs on the old mode and half of the change on the new mode for the switching users. This approach, referred to as the "rule of a half", was previously discussed in section 2.4.3. Continuing users receive the full change in travel time and are not subject to the rule of a half.

The Zenith model uses three vehicle modes of travel to classify private travel, these are Car, Light Commercial Vehicle (LCV) and Heavy Commercial Vehicle (HCV). The proportion of car trips made by trip purpose have been calculated based on results from the ABS Survey of Motor Vehicle Use (ABS Cat. 9208.0) noting that courier van trips are classified as car trips within Zenith. The proportions used to inform the CBA are summarised in Table 31 below.

Table 31 Proportion of car trips by trip purpose

Trip purpose	% of car trips
Non-business trips	70.5%
Business trips	18.0%
Van (courier) trips	11.6%

Source: ABS Survey of Motor Vehicle Use (ABS Cat. 9208.0)

Following the estimation of travel time savings by trip purpose and vehicle and user type for the Base Case and Project Case, monetisation of this benefit involves applying the relevant value of travel time for each of the user types. These values are listed in the table below and have been escalated to the valuation year (2017) and are in accordance with ATAP guidelines.

Note that while the calculation of commercial vehicle benefits in the core analysis does not consider the benefits that will be provided by high productivity freight vehicles (HPFV) on the North East Link, these benefits have been assessed as part of a sensitivity test.

Table 32 Values of time by road user type

Parameter	Value ($2017)
Non-business trips	16.22
Business trips	52.61
Van trips	27.49
Commercial vehicles – LCV (including value of freight)	37.27
Commercial vehicles – HCV (including value of freight)	79.38
Commercial vehicles – HPFV (including value of freight)	159.54

Parameter	Value ($2017)
VOT escalation – Non-business	0.75%
VOT escalation – Business/freight	1.50%
Annualisation factor (all vehicles)	330

Source: ATAP (2016) values escalated to $2017.

Travel time savings for high productivity freight vehicles

Commercial vehicle movements are summarised within Zenith by LCVs and HCVs. However, as the project will provide a new, high productivity freight vehicle (HPFV) compliant freeway link from the M80 to the Eastern Freeway and through to EastLink, it is projected that the project will support more HPFV movements and help to improve freight efficiency along the link.

The conversion of HCVs (e.g. articulated trucks and B-Doubles) to HPFVs (e.g. A B Combination, A-Triple and D-Double) have been estimated, reflecting that HPFVs have higher load capacity and can therefore transport a greater volume of freight assuming that the total number of freight trips remains constant. Based on surveys and analysis undertaken by XAct Solutions[45], it is estimated that HPFV account for between 5% to 8% of the current HCV fleet mix, with this proportion predicted to double by 2036. For the purposes of sensitivity testing for the economic appraisal, it has been conservatively assumed that HPFVs account for 5% of HCV vehicles across the life of the appraisal.

Perceived cost of congestion

There is evidence that road users' value relief from congested traffic conditions over and above their value of travel[46]. Road users' higher willingness to pay to avoid an hour of travel time on congested road links reflects the additional frustration, difficulty and stress associated with driving in stop-start traffic.

In principle, since the social value of time saved is higher, the valuation of travel time savings in CBA should be sensitive to the disutility of time spent in congested traffic and should apply higher values to time saved on heavily congested links.

Estimation approach and assumptions

While not traditionally applied to transport appraisals in Australia, the practice of implementing 'congestion multipliers' to reflect more difficult driving conditions is applied in other jurisdictions, and has been gaining traction among recent projects.

The NZ Transport Agency's CBA guidelines provide a formula to generated composite values of time savings and congestion using standard transport model outputs which specify the volume/capacity ratio of each link.[47] The guidelines apply a travel time premium for users of urban roads with V/C ratios above 0.7, with the premium rising from zero for ratios of 0.7 up to a maximum level when the V/C ratio reaches 1.0.

A similar approach is to be applied for the CBA, using Zenith model outputs of traffic volumes, travel time, and volume to capacity (V/C) ratios for each modelled link in the road network. The calculation involved:

[45] XAct Solutions, North East Link Phase 2 Assessment, 10 November 2017

[46] NZ transport Agency, Economic Evaluation Manual, p4-66, 2013

[47] NZTA Economic Evaluation Manual (2013), Appendix A4.3. The NZ multipliers are around 1.2-1.3 depending on road type and time.

- Calculating the proportion of total travel time spent along each link by V/C ratio
- Weighting travel time savings for users on links with V/C ratios above 0.7, with the congested-time premium rising linearly from 0 for road links with V/C=0.7 up to the maximum for road links with VC=1.0 or more
- A conservative maximum congested-time premium of $5.50 per hour for cars, and $4.19 per hour for freight vehicles.[48]

Analysis is undertaken on the extent to which the project reduces average VCRs in the range above 0.7. Depending on the extent of change, benefits related to reductions in the perceived cost of congestion are to be estimated using the methodology outlined below and reported separately from the other benefits, including in the NPV/BCR results.

Travel time reliability

Unpredictable or random variation in journey times can impose additional travel costs in the form of delays and higher vehicle operating costs. This includes variability in congestion levels during the same period each day (e.g. random variability) as well as variability arising from incidents (such as breakdowns, road accidents and bad weather). These variations from the average can form a significant proportion of journeys undertaken by road users.

Unpredictable trip durations cause frustration and inconvenience for drivers experiencing unexpected delays, as well as creating additional personal and business costs as road users build in precautionary time to their journeys. While some degree of unpredictability is inherent in every journey, the project is expected to provide reliability benefits particularly for those travelling in the north east.

Estimation approach and assumptions

Approaches for estimating monetisable impacts of changes in levels of reliability are currently followed in New Zealand and the United Kingdom, although it is only the former that recommends its use in formal CBA calculations

For the purposes of the economic appraisal, the UK approach will be applied, which relates the benefits of journey time reliability to changes in travel time variability based on measures of standard deviations and other factors.

In the UK framework, the major source of disutility associated with travel time variability is scheduling costs, and they present two scheduling cost models to support the analysis and demonstrate the close relationship between departure times and the standard deviation of travel times (i.e. under the assumption of optimised and continuous travel choices, which is feasible for the car mode, but requires extending the models to account for the constraints associated with public transport scheduling and operations).

The UK Department for Transport (DfT) present a model developed by Hyder Consulting, Ian Black and John Fearon. The model estimates the Coefficient of Variation (CV) from Distance (d) and Congestion Index (ci) terms for each origin to destination flow in the urban area. The Coefficient of Variation (CV) is the ratio of the standard deviation of travel time to the mean travel time:[49]

$$\mathrm{CV} = 0.161 * ci^{1.02} * d^{-0.39}$$

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[48] Based on analysis of studies from Hensher and Rose from 2004 to 2008. This value represents the difference in the value of time in stop-start traffic compared to overall travel time.

[49] UK Department for Transport, TAG unit A1.3: user and provider impacts (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/603254/webtag-tag-unit-a1-3-user-and-provider-impacts-march-2017.pdf)

The Congestion Index (ci) is defined as the ratio of mean travel time to free flow travel time, so that the model can be rearranged to forecast the standard deviation of journey time.

WebTAG also presents an alternative standardised model for forecasting changes in standard deviation for travel on urban roads linked to changes in journey times and distances, which can be used if it is assumed that average free flow speeds and distances do not change:[50]

$$\Delta\sigma_{ij} = 0.0018\left({t_{ij2}}^{2.02} - {t_{ij1}}^{2.02}\right){d_{ij}}^{-1.41}$$

Where:

$\Delta\sigma_{ij}$	is the change in standard deviation of journey time from i to j (seconds)
t_{ij1} and t_{ij2}	are the journey times from i to j before and after the change (seconds)
d_{ij}	is the journey distance from i to j (km)

For the appraisal of North East Link, VLC has undertaken the calculation of changes in standard deviation using the first CV formula presented above. In applying that approach, VLC has not assumed single average free flow speeds, but instead have introduced the 'actual' free flow speeds from the model.

A reliability ratio is used to convert changes in variability in travel time to a monetary value, which is expressed as follows:

Reliability ratio = [value of standard deviation of travel time] / [value of travel time]

The appropriate equation for calculating the benefit of improved journey time reliability under the UK framework is provided below:

$$Benefit = -\frac{1}{2}\sum_{ij}\Delta\sigma_{ij}.\left(T_{ij}^{0} + T_{ij}^{1}\right).VOR$$

Where:

Value of reliability (VOR) = [value of time] x [reliability ratio]

T_{ij}^{0} and T_{ij}^{1} are the number of trips before and after the change

The value of the reliability ratio that has been recommended by DEDJTR and applied to recent projects like Melbourne Metro is 0.8, and this value is applied in the CBA for North East Link. This value was the previous value recommended in WebTAG based on research undertaken in the Netherlands, although more recent research has provided the basis for WebTAG reducing the value to 0.4. In contrast, TfNSW recommends a value of 1.0 for the reliability ratio.[51]

Vehicle operating cost savings

Lower per kilometre vehicle operating costs (VOC) for road users are associated with improvements in average length of a journey, traffic volumes and vehicle speeds arising from the project. Total VOCs include all running costs of the vehicle: depreciation, fuel, repairs and maintenance (but not taxes and duties which are transfers from a social perspective); however, road users base their

[50] UK Department for Transport, TAG unit A1.3: user and provider impacts (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/603254/webtag-tag-unit-a1-3-user-and-provider-impacts-march-2017.pdf)

[51] https://www.transport.nsw.gov.au/sites/default/files/media/documents/2017/principles-and-guidelines-for-economic-appraisal-of-transport-investment.pdf

travel decisions on 'perceived' costs, which represent only a portion of total costs. Therefore, an appropriate 'resource cost correction' must be made so all costs are captured by the CBA.

Estimation approach and assumptions

The resource cost value of VOCs is calculated using an interrupted flow model in accordance with the methodology found in Section 5.4.2 of the ATAP Road Parameter Values Guidelines.

Using this methodology, vehicle operating costs (cents / km) are modelled as a function average link speeds:

Stop-start model - $VOC = A + \frac{B}{V}$

Free -flow model - $VOC = C_0 + C_1 \times V + C_2 \times V^2$

Where:

- The stop-start model is used for calculating VOCs for road links < 60 km/hr
- The free-flow model is used to calculating VOCs for road links > 60 km/hr
- VOC is the rate at which vehicle operating costs are incurred (cents / km)
- A, B, C_0, C_1 and C_2 are model parameters
- V is the average link speed (in km / hr)

The five VOC model parameters (A, B, C_0, C_1 and C_2) are defined across 20 vehicle classifications, which have been averaged to the three Zenith modelled vehicle classes. These parameters, drawn from Table 35 of the ATAP 2016 guidance are contained in Table 33. The vehicle operating cost calculated by the above methodology and parameters are expressed in 2013 dollars and have been escalated using CPI to $2017.

Table 33 VOC parameter values ($2013)

Vehicle Type	A	B	C0	C1	C2
Cars	15.3178	1335.6416	37.2137	0.1721	0.0013
LCV	34.886	1901.7297	57.0943	-0.2742	0.0026
HCV	129.8532	4954.7104	163.5236	-0.7852	0.0072

Source: ATAP (2016), Table 35

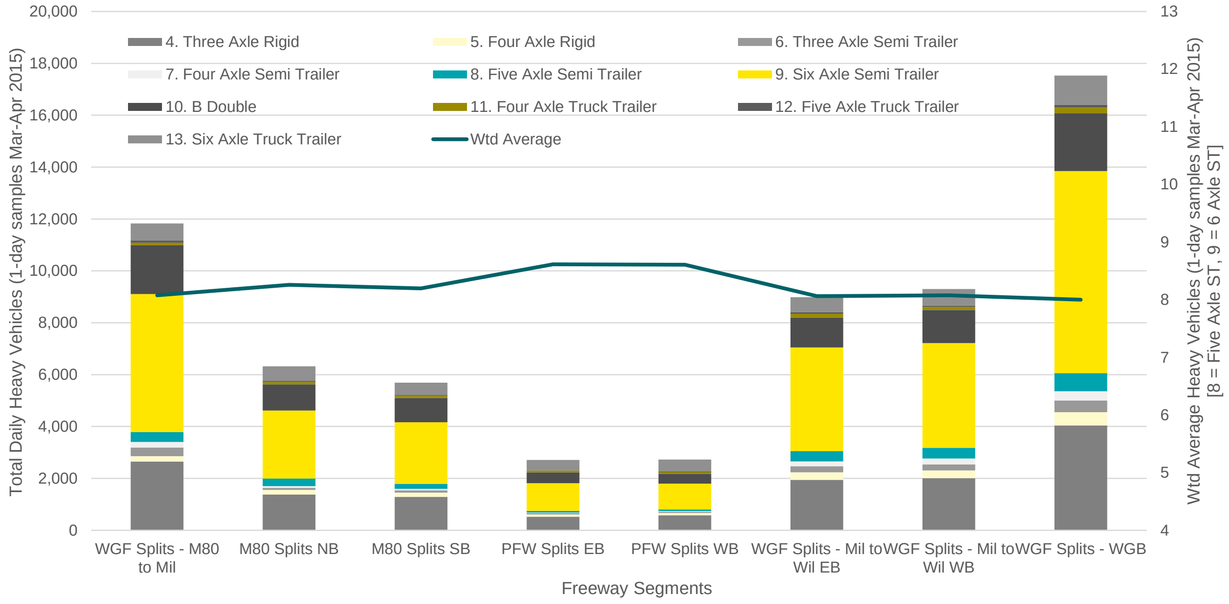
To validate the values derived for HCVs we analysed heavy vehicle counts from a sample of arterials in the north-east and freeway links including the West Gate Freeway. This analysis shows that there is a significant proportion of larger heavy vehicles on motorway links, with the 2015 samples showing that over two thirds of heavy vehicles are six-axle semi-trailers or larger, including B-doubles and other large vehicles. The weighted average for each segment is in the range of five- and six-axle semi-trailers, which is comparable with the values used in the CBA.

A further consideration for the CBA relates to determining appropriate values over the appraisal horizon (50 years) where there is data that shows that average vehicle sizes have been increasing in recent years. For example, data cited by GHD estimates that between 2007 and 2016 rigid trucks have increased by 20% and larger articulated trucks have increased by 29%.[52]

[52] GHD advice to Smedtech. Sent by Smedtech to EY via email on 5 Octber 2017.

Given the trend of increasing vehicle sizes, including a growing use of HPFVs, this further supports the use of average parameter values for heavy vehicles.

Figure 35 Heavy vehicle counts on freeways in Melbourne's west (March 2017)



Source: Smedtech heavy vehicle counts, EY analysis

It is noted that while the above methodology is the recommended approach according to current ATAP guidelines, there is an alternative view that the resource cost of VOCs should be calculated using the methodology found in Chapter 6 of the Austroads Guide to Project Evaluation, Part 4 – Project Evaluation Data (Austroads, 2008), which provides more conservative estimates of VOC savings.

Using the previous Austroads methodology, vehicle operating costs (cents / km) are modelled as a function average link speeds:

$$VOC = A + BV + C \times V + D \times V2$$

Where:

- VOC is the rate at which vehicle operating costs are incurred (cents / km)
- A, B, C, D are model parameters
- V is the average link speed (in km / hr)

Different parameter sets (A, B, C, D) are defined for each combination of road type (freeway /non-freeway), and vehicle type (Car, Light Commercial Vehicle, Heavy Commercial Vehicle).

The parameters, drawn from Tables 6.1 and 6.2 of Austroads (2008), are contained in Table 4.1 and Table 4.2.

Table 34 Vehicle operating cost parameter values on freeways

Vehicle Type	A	B	C	D
Cars	-16.26	1553.78	0.23531	0.0000501
LCV	-30.00	3396.74	0.25629	0.001262
HCV	-30.00	8544.38	0.01850	0.006029

Source: Austroads (2008), Table 6.1

Table 35 Vehicle operating cost parameter values on non-freeways

Vehicle Type	A	B	C	D
Cars	2.185	976.21	0.05711	0.0005795
LCV	-3.096	2092.48	0.19609	0.0005658
HCV	5.885	5471.53	0.58625	0.0002108

Source: Austroads (2008), Table 6.2

Sensitivity tests were undertaken using the Austroads (2008) approach, and it was found that VOC savings estimated using this approach were approximately 30% to 40% lower than the current ATAP approach. Nevertheless, based on advice from DEDJTR, VOC savings in the CBA have been estimated in accordance with the current ATAP guidance.

Vehicle operating cost savings for high productivity freight vehicles

As the Zenith model does not distinguish between HCVs and High productivity freight vehicles (HPFV), the vehicle operating cost savings calculated using the method above will underestimate benefits as the VOC for HPFVs are much more sensitive to changes to speeds than equivalent HCVs.

Based on analysis of Zenith outputs of the change in speeds for HCV volumes across the network, VOC savings have been calculated using ATAP parameters both with and without the inclusion of HPFVs, assuming that HPFVs account for 5% of the current HCV fleet mix[53],

Based on this analysis, it was found that the inclusion of HFPVs increases total VOC savings by 4.9%. This relative uplift has therefore been applied to the VOC savings for HCVs calculated using the methodology described above to account for the presence of HPFVs across the network.

User tolls

Transport users perceive road tolls based on the amount they actually pay, inclusive of GST. The project will provide improved service levels on the arterial road network by reducing removing significant freight volumes, helping to ease congestion and improving travel times and reliability on key routes. Some road users are likely to benefit from these improved service levels, by taking advantage of improved journey times on routes that avoid tolled roads, thereby reducing tolling costs.

Toll cost savings are calculated by Zenith as the perceived cost of tolls and presented in $2008, which have then been escalated using CPI to $2017.

[53] XAct Solutions, North East Link Phase 2 Assessment, 10 November 2017

Public transport benefits

Public transport benefits refer to the time savings provided to public transport users over their entire journey. It is noted that each public transport trip typically consists of a number of discrete parts, and therefore for the purposes of the economic appraisal, overall public transport benefits have been calculated in terms of the generalised time savings which have been measured for each of the individual components using the appropriate weightings (as per ATAP guidelines) as described below. The components of public transport benefits include:

- In vehicle time – the change in in-vehicle travel times due to the project. The change in in-vehicle time is calculated by Zenith and multiplied by the appropriate VOT to quantify the benefit

- Waiting time at stop –reflects the reduction in time spent waiting at a stop due to improved service frequency. In order to monetise the benefits, the wait time is multiplied by the VOT and a weighting of 1.4 is applied as passengers value out-of-vehicle time greater than the time spent within the vehicle

- Transfer and access penalty - transfer penalties represent user preferences which are not explicitly measured by variables in the patronage model. Transfer penalties are included to reflect the disutility that most users associate with interchanging, over and above the measured travel time. The transfer and access penalties are calculated by Zenith and multiplied by the VOT, with a weighting of 1.4 applied as passengers value out-of-vehicle time greater than the time spent within the vehicle

- Walk access and egress time – the change in time spent walking to (access) or from (egress) public transport. In order to monetise the benefits, the walk time is multiplied by the VOT and a weighting of 1.4 is applied as passengers value out-of-vehicle time greater than the time spent within the vehicle

- Park & Ride access and egress time – the change in time spent in a car on the way to (access) or from (egress) public transport. In order to monetise the benefits, the walk time is multiplied by the VOT and a weighting of 1.4 is applied as passengers value out-of-vehicle time greater than the time spent within the vehicle

- Walk transfer time reflects the change in transfer time (within or between modes) due to service changes. The change in transfer time is calculated within Zenith and multiplied by the VOT. A weighting of 2.0 times the value of IVT as passengers value time spent transferring between services at twice that of time spent in vehicle

- Crowding disutility - Crowding disbenefits reflects the discomfort that passengers feel from travelling in varying levels of crowded conditions. As crowding levels increase towards crush capacity, the valuation of passengers' in vehicle time also increases. The time users spend in crowded conditions is calculated within Zenith and multiplied by the VOT with a weighting 2.0 times the value of IVT as passengers value time spent in crowded conditions at twice that of time spent in vehicle

Resource cost corrections (PT Fares and Tolls)

Resource cost corrections (RCCs) represent the difference between the overall social and user-perceived costs of travel. Travel decisions are made on the basis of a perceived (generalised) cost of travel options, but this is not always equal to the full social resource cost.

For example, the increase in revenues from public transport fares and toll payments are typically considered as a transfer payment between users and the operator to reflect the resources required to provide the transport services and, as a result, are excluded from the CBA. However, users base their decision to travel on the perceived generalised travel costs when choosing between modes and destinations, which includes both tolls and fares. Therefore, as the perceived resources are already accounted for, there is a need to reflect this additional revenue as a resource correction for the mode and destination switchers.

Estimation approach and assumptions

RCCs need to be added or subtracted to/from total benefits to correct user benefits for the above four cost components where there is a difference between perceived costs and resource costs. The total resource cost correction amounts for each of these are then reported as a separate category of project benefits (or disbenefits).

The process to calculate RCCs for each of the above four cost components consists of:

1. Calculating total costs based on resource costs for base case.

2. Calculating total costs based on perceived costs for base case.

3. Subtracting 2 from 1 – i.e. subtract total costs in perceived costs from total costs in resource costs. This gives the total amount by which resource costs are misperceived in the base case.

4. Repeating steps 1 and 2 for the project case.

5. Subtracting total costs in perceived costs from total costs in resource costs for the project case. This gives the total amount by which resource costs are misperceived in the project case.

6. Subtracting 5 from 3 – i.e. subtract the project case resource cost misperception from the base case resource cost misperception. The resulting difference is the resource cost correction.

The rule of a half does not apply to RCCs. All users are assumed to misperceive resource costs to the same extent. Therefore when a person changes travel behaviour in response to a project the full amounts of the resource cost misperceptions apply for the former and new trips.

Externalities

All transport modes cause environmental externalities, which should be accounted for in a CBA. Since different transport modes result in different production of environmental emissions, such as greenhouse gas emissions, air pollution and noise pollution, changes in travel patterns will cause changes in network-wide emissions.

Estimation approach and assumptions

The ATAP Guidelines provide monetary estimates for a number of environmental externalities including greenhouse gas emissions, local air pollution, noise, and water pollution.

These monetary estimates are usually given as costs per vehicle-kilometre or per tonne (in the case of carbon emissions). Zenith modelling outputs include network statistics such as vehicle kilometres travelled by different vehicle types. The difference in these estimates between base case and project case multiplied by the relevant unit rates will give the benefit or disbenefit for each externality.

Externality impacts have been measured using changes in vehicle kilometres travelled by vehicle type (from Zenith) together with evidence on emissions per vehicle kilometre and damage cost per unit of emission (from ATAP guidelines). Other externality benefits include reduction in noise and road wear and tear. These are also estimated using evidence on such externality costs per vehicle kilometre.

The measurement of environmental externalities reflects the need to consider the impact of road use on parties other than road users. Vehicle use produces externalities, including air pollution and greenhouse gas emissions.

The table below shows the parameters used to quantify the externality impacts. Note that these values have been inflated 2010 to 2016 values. Total externality cost of trucks were calculated based on an assumed average load of 5.4 tonnes per trip for rigid trucks, and 25.3 tonnes per trip for articulated trucks as is specified by Austroads 2012.

Table 36 Externality parameters ($2016)

Externality	Car ($/VKT)	Truck ($/1000 tonne-km)	Truck ($/VKT)
Greenhouse gas emissions	0.02	5.84	0.08
Air pollution	3.15	26.24	0.40
Noise pollution	1.03	4.38	0.07

Source: ATAP (2016)

Crashes

Crash costs are a function of the number of vehicle kilometres travelled on a particular road type. In general, limited access roads such as freeways and divided arterial roads have lower crash rates per VKT than roads in residential areas.

Reduced accident benefits have been calculated using the Zenith EAM, with the results expressed in $2013, which have then been escalated to $2017 for the purposes of the CBA.

Accident benefits have been calculated by:

- ► Calculating absolute accident casualties using accident rates sourced from Table 3.1 of the VicRoads, "Accident Analysis by Road Profile Study, Operational Report", January 1996 (Updated by T Boyd 2010)

- ► Converting casualties into dollars using Austroads' accident costs from Table 4.8 (p26) of the 2015 revision of the National Guidelines for Transport Systems Management (NGTSM) Road Parameter Values (PV2) report.

VicRoads outlines eight road types and their corresponding accident rates in units of accident casualties per 100 million VKT (Table 37 below).

Table 37 Default urban accident rates (VicRoads)

Road Type	Road Category	Description	Estimated urban casualty rates (acc/10^8 veh-km)
1	Old Freeways	Inner City 4 lanes	10.6
2	South Eastern Art	Toorak to Warrigal	9.4
3	High Standard Fwys		5.7
4	All Freeways		6.9
5	Primary Arterials	Divided with trams	25.8
6	Primary Arterials	Undivided with trams	34.0
7	Primary Arterials	Divided without trams	16.8
8	Primary Arterials	Undivided without trams	20.8
9	All Primary Arterials		19.4
10	Secondary Arterials	Divided with trams	43.0
11	Secondary Arterials	Undivided with trams	45.0
12	Secondary Arterials	Divided without trams	24.1
13	Secondary Arterials	Undivided without trams	28.9
14	All Secondary Arterials		30.8
15	Primary Arterial/Service Roads		14.9
16	All Melbourne Arterials		23.2

Source: VicRoads, 'Accident analysis by road profile study operational report', January 1996 Table 3.1 (Updated by T Boyd 2010)

The table below outlines the accident costs used to monetise the value of crash cost savings, as specified by Austroads for Victoria. Note that it has been assumed that the rate of accidents is the same for both cars and commercial vehicles due to a lack of class-refined source data.

Table 38 Estimation of crash costs by injury severity (Victoria), inclusive WTP values

Injury severity	Urban ($2013)	Rural ($2013)
Fatal crash	$8,409,584	$8,611,365
Serious injury crash	$594,663	$499,138
Other injury crash	$39,848	$48,429

Source: ATAP 2016, PV2 Road Parameter Values

Attachment B Wider economic benefit calculations

Agglomeration

Agglomeration economies are the wider economic benefits firms derive from being located in close proximity to each other and to workers. Research demonstrates these agglomeration economies are greater the closer firms are located to other firms with which they interact. Improvements to transport infrastructure that reduce travel times for workers and freight have the potential to increase the density of economic activity by effectively bringing existing firms and workers closer to each other (e.g. increasing the number of jobs and workers within a 30 minute journey time).[54]

A transport project can also encourage new workers into the labour force, either by reducing travel times or by physically causing jobs and workers to locate closer together. Conventional analyses of transport initiatives typically estimate the extent to which these travel time savings increase the welfare of the community by measuring the willingness of workers to pay for those travel time savings. That is, they typically only consider the extent to which transport initiatives increase the welfare of the workers who enjoy the travel time savings.

However the willingness of these workers to pay for time savings will underestimate the overall welfare gains that the community as a whole receives from those savings due to the imposition of taxes (e.g. income tax and Medicare contributions) on additional labour income those individuals derive. That is, the private return (the increase in net wages as a result of the extra work effort) will be less than the gross value of the community derives from that additional work effort. The second WEBs component values this difference.

Estimation approach and assumptions

Agglomeration benefits have been calculated using the methodology described in Transport Analysis Guidance (TAG) provided by the UK Department of Transport. This methodology characterises agglomeration benefits by originating travel zone using the following process:

- ► Select appropriate measure of travel cost (generalised cost is specified for TAG).
- ► Calculate the effective density of employment in the base and project cases, from which the percentage change in effective density is calculated. For TAG, the percentage change is a different value by zone and by industry, as the decay parameter is industry specific. An inverse function is used for the decay rate.
- ► Estimate the change in productivity between the base and project cases. This is industry-specific, as the agglomeration elasticity is industry-specific.
- ► Estimate change in gross value added (GVA) between the base and project cases. This requires the GVA by industry, and in the current implementation a single GVA by industry is applied across all travel zones. Note that GVA by industry is calculated for each industry as GVA per worker x employment (i.e. number of workers). GVA per worker is part of the change in productivity calculation in step 3.

The formulation for agglomeration benefits, as adapted from UK DfT (2014) is as follows:

$$A_o = \sum_i (P_{EJD,o} * GDP_i * E_{o,i,base})$$

Where:

[54] This improvement in the 'effective' density of the city is in addition to any agglomeration benefits from actual urban densification, which can be expected to generate equivalent productivity gains. Note these patterns of land use change have been quantified and captured as part of the land use benefit analysis in this CBA

- A_o = agglomeration benefit for originating zone *o*
- ρ_i = productivity elasticity for industry category *i*
- GDP_i= GDP output per worker for industry category *i*
- $E_{o,i,base}$= base case employment for industry category *i* for originating zone *o*
- $P_{EJD,o}$= percentage change in effective job density for originating zone *o* between the project case and base case, which is calculated by:

$$P_{EJD,o} = (\frac{EJD_{o,project}}{EJD_{o,base}})^{\rho_i} - 1 = (\frac{\sum_d \frac{E_{d,project}}{g_{o,d,project}}}{\sum_d \frac{E_{d,base}}{g_{o,d,base}}})^{\rho_i} - 1$$

Where:

- $EJD_{o,project}$ = effective job density for originating travel zone *o* in the project case
- $EJD_{o,base}$= effective job density for originating travel zone *o* in the base case
- $E_{d,project}$ = total employment in destination zone *d* in the project case
- $E_{d,base}$ = total employment in destination zone *d* in the base case
- $g_{o,d,project}$ = generalised cost of travelling to zone *d* (from originating zone *o*) in the project case by car in the inter-peak
- $g_{o,d,base}$ = generalised cost of travelling to zone *d* (from originating zone *o*) in the project case by car in the inter-peak

The elasticities and decay parameters specified by TAG can be found in Table 39.

Table 39 Agglomeration Elasticities and Decay Factors.

Employment Category	Productivity Elasticity	Decay Factor
Agriculture	n/a	n/a
Mining	n/a	n/a
Manufacturing	0.021	1.097
Electricity, Gas & Water	n/a	n/a
Construction	0.034	1.562
Wholesale	0.024	1.818
Retail	0.024	1.818
Recreation and Personal services	n/a	n/a
Transport & Storage	0.024	1.818
Communication	0.024	1.818
Financial & Business	0.083	1.746
Public Administration	n/a	n/a
Community services	n/a	n/a

Source: UK DfT TAG (2012), Agglomeration Table 1, grouped into ANZSIC1993 categories by EY (2017)

Labour supply

The calculation of the labour supply impact estimates the impact a transport improvement has on the attraction of more labour into the market. This calculation in done using the following method:

$$LS = -\varepsilon^{LS} \frac{\mu}{(1-\tau)} \sum_{i} \left[\sum_{j} W_{i,j} (G_{i,j}^{A,c} - G_{i,j}^{B,c}) \right]$$

Where:

LS = Labour supply benefit

ε^{LS} = the elasticity of labour supply with respect to effective wages

μ = the parameter that captures the lower productivity (compared to the average) of workers on the margin of the labour force. Assumed to be 0.69 of the average wage

τ = the average tax rate on earnings

$W_{i,j}$ = the number of workers living in transport zone i and working in transport zone j

$G_{i,j}^{A,c}$, $G_{i,j}^{B,c}$ = round trip commuting average generalised costs of travel between zone i and zone j

Imperfect competition

Imperfect competition benefits are the result of reduction in prices and increased productivity. The benefits of which, due to competition, are passed on from the firm to buyers of its products. Increased transit amenity effectively increases the ability of firms to compete against each other making the economy more efficient.

The output change in imperfectly competitive markets is estimated by multiplying an imperfect competition factor of 10% to total business user benefits.

Attachment C Land use benefit calculations

The calculation of land use benefits will be informed detailed land use modelling will utilise the EY LUTI model to understand the interaction between the results of the transport model and resulting land use impacts.

The following sections describe how the land use benefits that are provided by the project will be quantified, while a detailed description of the land use model is provided in Appendix Q2 – Assessment of potential land use impacts of North East Link.

Urban densification

As agglomeration benefits with relation to transport improvement have also been calculated as part of the traditional WEBs analysis, care needs to be taken in order to avoid the possibility of double counting. In order to do this, transport costs will be held fixed, and agglomeration benefits will be calculated solely from the changing land use patterns in accordance with the methodology described in Transport Analysis Guidance (TAG) provided by the UK Department of Transport. This methodology characterises agglomeration benefits by originating travel zone using the following method:

1. Estimate the effective job density for the base case using B2B generalised cost and trip numbers in the revised base case

2. Holding the generalised cost of travel constant, the expected change in productivity can be calculated by applying an elasticity of productivity for each industry with respect to the change in employment in each respective travel zone

3. Estimate the absolute change in productivity using GDP per worker and employment levels for each sector in the trip origin area being assessed

4. Total agglomeration impact is the sum of all the changes across all origin areas and sectors

The agglomeration elasticities and decay factors used are described in the table below.

Table 40 Agglomeration elasticities

WebTAG Agglomeration elasticities	Elasticity	Decay parameter
Manufacturing	0.021	1.097
Construction	0.034	1.562
Consumer services	0.024	1.818
Producer services	0.083	1.746

Source: WebTAG

Another major component of the estimation of land use benefits is the estimate of the 'move to more productive jobs' (M2MPJ) facilitated by the projects. The change in land use from the base case to the project case results in a number of jobs moving between locations with differing levels of productivity. These changes in the location of employment therefore impact the overall productivity of the workforce.

In the absence of clear guidance from National or State guidelines, a number of different options to calculate the benefits associated with M2MPJ have been explored. Upon investigating these different options, it was determined that the idea approach would be to adopt the UK WebTAG methodology in which the additional wider economic benefits have been estimated using the formula below:

$$GSP\ Impact = GSPW * \sum_i (E_i^{PC} - E_i^{BC}) * PI_i$$

Where:

$GSPW$ GSP per worker

E_i^{PC}, E_i^{BC} Employment in travel zone i in the Project Case (PC) and Base Case (BC)

PI_i Productivity index per worker in travel zone i

As there is no generally accepted set of productivity indices for Melbourne, the productivity index for each region (SA2) has been calculated based on their relative difference in effective density.

It is noted that this is a simplified approach to calculating the PI as it does not control for other factors that impact upon productivity such as education, occupation etc. which it does in the UK. However, for the purposes of this evaluation it is believed to be a reasonable proxy for the relatively differences in income between regions.

Infrastructure cost savings

Changing the dispersion of people and households can have an impact on the total direct costs of providing public infrastructure, such as connection to water, storm water, sewerage, gas, electricity, roads and information and communication technology and more. Furthermore, public infrastructure exhibits significant economies of scale. In dense developments, less wires, pipes and roads are required to serve a given population. Encouraging more urban developments, at the expense of lower density developments at the urban fringe, therefore reduces the overall infrastructure costs (and vice versa), including government expenditure given the tendency for public subsidies of certain infrastructure costs, particularly in greenfield areas.

A number of sources and evidence suggests that, on average, the cost per dwelling to provide public infrastructure to greenfield locations is much higher than to the already well serviced infill and established locations[55]. While a share of these costs is recovered from developers through developer contributions, a significant proportion falls on the public sector.

The approach that will be used to estimate these benefits is to:

- Calculate the change in dwellings between the project case and base case by locations.

- Estimate the average cost of infrastructure provision by location. Sourced from a literature review of a range of sources, including previous literature studies, as well as government and other reports and data to document the public infrastructure cost associated to the provision of essential infrastructure. The table below shows the average public sector cost assumptions results of this analysis.

- Calculate the cost savings in infrastructure provision by applying average cost of infrastructure provision by location to the expected change in the number of dwellings by location.

The table below includes the assumed public infrastructure costs associated with additional dwellings in infill, middle and greenfield areas of Melbourne.

[55] Empirical Analysis of Benefits of Urban Renewal, EY report to UrbanGrowth NSW, 2016

Table 41 Infrastructure cost assumptions

Location	Cost per dwelling ($2016)
Infill	$60,995
Middle	$85,673
Greenfield	$110,351

Source: "Empirical Analysis of Benefits of Urban Renewal", EY report to UrbanGrowth NSW, 2016

Sustainability benefits

Recent studies have provided evidence that medium and higher density dwellings in and around transit oriented development have a lower average consumption profile of electricity, gas and water than lower density dwellings elsewhere[56]. As such, households that choose to move to medium/high density development along north east corridor due to the project are likely to result in lower the consumption of energy and water. The forgone use of energy and water has a corresponding decrease in in greenhouse gas emissions.

The following provides an overview of the approach and key inputs and parameters that will be used to quantify the benefit associated with the savings in greenhouse gas emissions due to the propensity for households to choose higher density living includes due to improved accessibility:

- Calculate the change in the number of dwellings between the project case and base case by locations;
- Calculate the share of dwellings that are high, medium, low density dwellings.
- Estimate the weighted average cost of household greenhouse gas emissions per dwelling by density type based on the analysis below:
- Apply the emission cost per dwelling profiles above to the change in the number of dwellings (high, medium and low) between the project case and base case.

The numbers of dwellings by type will be obtained from the ABS Census of Population and Household – Dwelling Structure statistics. The assumptions used to calculate the share of dwellings by density type are listed in the table below.

Table 42 Dwelling density classifications

Dwelling Type	Density Type
Separate House	Low
Semi-detached, row or terrace house, townhouse	Medium
Apartment - a one/two/three storey block; attached to a house	Medium
Apartment in a four or more storey block	High
Other - Caravan, cabin, houseboat; Improvised home tent	Low
Other - House/flat attached to shop/office	Medium

Source ABS Census; EY analysis

[56] Residential energy and water use in Sydney, the Blue Mountains and Illawarra, PART, 2010

The table below shows the emission cost per dwelling that will be applied to calculate total emission costs.

Table 43 Emission cost assumptions

Greenhouse gas emissions ($/dwelling)	Low	Medium	High
Electricity	101	64	52
Gas	15	12	9
Total	115	75	62

Source: PART (2010), Residential energy and water use in Sydney, the Blue Mountains and Illawarra. Emission factor sourced Australian Government (2014), National Greenhouse Accounts Factors, and monetisation factor sourced from www.eex.com. CPI of 2.5% applied to escalate values to 2016.

Health benefits

Residents in dense urban areas tend to walk and cycle more than residents at the urban fringe. Active travel has significant health benefits that are not fully perceived by the individuals themselves. Some of these benefits are already captured within the CBA through changes in walk and cycle access to public transport. The same effect should also be included for changes in active trips arising from land use changes.

Facilitating urban living near job opportunities and good infrastructure can encourage more active travel (i.e. walking and cycling – including assess to public transport), which has health benefits. Aside from the positive impact on individuals themselves, there are important cost savings to government from lower health care costs.

The following provides an overview of the approach that will be used to quantify the benefit associated with health cost savings relating to extra walking and cycling trips:

- Calculate the change in the number of residents between the project case and base case by location.
- Estimate the average number of trips per day per person and the average number of kilometres per trip by location for walking and cycling. Sourced from Victorian Integrated Survey of Travel and Activity (2009-10) - areas defined in Statistical Local Area.
- Apply the monetized benefit of increased walking and cycling
- Apply an annualisation factor

Attachment D CGE modelling

The economic effects on Victoria of the North East Link Roads Program

December, 2017

Centre of Policy Studies, Victoria University

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1 Introduction

Ernst & Young (EY) has sub-contracted the Centre of Policy Studies (CoPS) at Victoria University to undertake modelling of the economic impact of the North East Link (NEL) Program. The modelling task has been undertaken with the CoPS multiregional model of the Australian economy, VURM[1]. The features of this model are outlined in section 2.1 below. This is followed by an outline of the approach taken to the study in Section 2.2. The input data is described in Sections 2.3 and 2.4, and the modelling assumptions are discussed in section 3. The simulation results are presented in section 4.

The specific implementation of VURM used for the present study is the same as that which was used in earlier reports for the overall effects of the Outer Suburban Arterial Roads (OSAR) program. In this report we present results for a new scenario; the completion of the North East Link (NEL) program. The NEL program as reflected in this report consists of a 10 year construction phase over the period 2018-2027 followed by a 20 year operation phase over the period 2027-2046.

2 Study method

2.1 The Economic Model: VURM

In the version of VURM used for the study, there are 58 industry sectors (see Table A1 in Appendix A) in two regions, Victoria and the Rest of Australia (RoA).[2] All but two of the industries produce a single commodity[3]. Investment is allocated across industries to maximise rates of returns to investors (households, firms). Capital creators assemble, in a cost-minimizing manner, units of industry-specific capital for each industry. Each state has a single representative household and a state government. There is also a federal government. Finally, there are foreigners, whose behaviour is summarised by export demand curves for the products of each state and by supply curves for international imports to each state.

As is standard in CGE models, VURM determines the supply and demand for each regionally-produced commodity as the outcome of optimising behaviour of economic agents. Regional industries are assumed to choose labour, capital and land so as to maximize their profits while operating in a competitive market. In each region a representative household purchases a particular bundle of goods in accordance with the household's preferences, relative prices and its amount of disposable income. Regions are linked via interregional trade, interregional migration and capital movements and governments operate within a fiscal federal framework.

[1] VURM stands for Victoria University Regional Model. It was previously known as the MMRF model.
[2] RoA is an aggregation of the other five Australian states and the two territories.
[3] The exceptions are Grains and Petroleum Products. The bulk of Grain's production is grains for animal and human consumption, but it also produces a small amount of biofuels for feedstock into Petroleum Products. Petroleum Products produces five commodities – gasoline, diesel, LPG, aviation fuel, and other refinery products (mainly heating oil).

VURM provides results for economic variables on a year-on-year basis. The results for a particular year are used to update the database for the commencement of the next year. In particular the model contains a series of equations that connect capital stocks to past-year capital stocks and net investment. Similarly debt is linked to past and present borrowing/saving and regional population is related to natural growth and international and interstate migration.

For a detailed description of the theoretical structure of the VURM model, see Adams, *et al.* (2011). For a diagrammatic illustration of the detailed industry/commodity multiregional input-output information used by the VURM model, see Figure 7.1 of Giesecke and Madden (2013).

2.2 Approach to modelling the NEL Program

We first conduct a VURM simulation to produce a baseline forecast for each year up to 2046, under the assumption that the NEL program did not proceed. We then repeat our forecast under the same assumptions as for the baseline forecast, except that for this new forecast (which for convenience we shall call the policy forecast) we incorporate additional economic shocks designed to represent the direct effects of implementing the NEL scenario. The new forecasts are then compared with the baseline forecast. Results are reported as deviation of the policy forecast from the baseline forecast for each year from the start of the NEL program in 2018 to 2046. These years can be viewed as two virtually distinct phases: a 10-year construction phase from 2018 to 2027, and a 20-year operating phase from 2027 to 2046. The program also involves additional expenditure on maintenance (operating expenditures) for each year from 2027 to 2046.

Estimates for the annual direct costs and benefits of the NEL program were provided by EY. These figures consist of the construction and operating expenditures and the net benefits flowing from the program in terms of improvements in travel time and road congestion, reduced vehicle operating costs and environmental and safety benefits.

2.3 Construction and maintenance

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For the VURM simulations, both capital expenditure and road maintenance costs are assumed to consist entirely of expenditure on the VURM commodity Construction.

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Redacted - commercial-in-confidence

2.4 *Direct benefits from NEL program*

Travel Time Savings:

EY provided a time-series for each of the benefits flowing from the NEL package. The first of these related to travel-time savings. Travel time savings for the NEL package are decomposed into 5 types of road users: "Non-business trips", "Business trips", "Van trips", "Freight LCV" and "Freight HCV". Benefits to four of these five users were modelled, while travel-time savings for "Non-business trips" (which accounted for about 30 per cent of travel-time saving) were considered to be consumed entirely as leisure or other non-work activities. This is a conservative approach, since it is likely that a certain portion of non-business travel, particularly by commuters, would add to labour supply. In considering the simulation results, it should be borne in mind that the benefits of increased leisure time should be added to the welfare gains flowing from the NEL package. Similarly, the EY figures showed gains from increased travel-time reliability. The time-savings (including travel-time reliability) were modelled as increased labour productivity. For business travelers these benefits were spread across all industries, while for road transport the productivity savings occurred in the single VURM industry Road Freight.

Vehicle Operating Costs:

The NEL package estimated to lower vehicle operating costs (VOC), in terms of lower fuel use and reduced vehicle maintenance costs. These benefits were modelled for the 4 classes of road users: "Business trips", "Van trips", "Freight - LCV" and "Freight - HCV". VOC savings to "Business trips" were apportioned as (fuel- and material-saving[6]) productivity gains across selected transport-using industries. Under instructions from EY, "Van trips" were modelled as fuel- and material-saving productivity improvements in the VURM industry, "Road Transport". For the two types of road transport "Freight - LCV" and "Freight – HCV" ("freight – Rigid" and "freight – Articulated" in the previous study), these productivity improvements were imposed on Road Transport. In all cases, fuel- and material-saving productivity improvements were apportioned between the 4 classes of road users based upon each transport-using-industry's shares of commodities "Gasoline", "Diesel", "Motor Vehicle Parts" and "Trade".

[5] Repayments are computed using a real interest rate of 7 per cent per annum. Note that road maintenance costs are treated as a current expenditure and are assumed to be paid out of the Victorian government's budget in the year they are incurred.

[6] Fuel-saving productivity gains were imposed as productivity improvements in use of the VURM commodities Gasoline and Diesel in line with the fuel input patterns of the respective industries. Material-saving productivity gains were imposed as productivity improvements in use of the VURM commodities Motor Vehicle Parts, Other Manufactures and Trade line with the material input patterns of the respective industries. Note that unlike the previous work on the OSARs program, no separate vector of maintenance-saving productivity improvements were provided for the NEL program.

All other savings were treated as either transfers (impacts on tolls, fares) or as welfare gains to be considered separately from the economic modelling. Only around two-thirds of the value of net benefits as provided by EY was included in the economic modelling.

3 Simulation Assumptions

3.1 Labour markets

At the national level, we assume that the deviation in the national real wage rate from its base case level increases in proportion to the deviation in economy-wide employment from its base case level. Eventually, the real wage adjustment eliminates any deviation in national employment caused by a particular year's set of shocks.

At the regional level, labour is assumed to be mobile between state economies. Labour moves between regions so as to maintain inter-state wage and unemployment-rate differentials at their levels in the base case projection.

3.2 Private consumption and investment

Consumption expenditure of the regional household is determined by Household Disposable Income (HDI). HDI is the sum of payments to domestic labour and capital (wages and profit dividends) and government transfer payments net of direct taxation.

Since budget constraints are not imposed on the business sector, regional economies will run trade deficits/surpluses to the extent that aggregate regional expenditure levels are greater than/less than aggregate regional incomes. The deficits or surpluses can be held with other agents in other regions, with foreigners or with both regional agents and foreigners.

Investment in all but a few industries is allowed to deviate from values in the base case scenario in line with deviations in expected rates of return. Investors are assumed to be myopic, implying that expected rates of return move with contemporaneously observed rates of return.

3.3 Rates of return on capital

VURM allows for short-run divergences in rates of return on industry capital stocks from their levels in the base case. Such divergences cause divergences in investment and hence capital stocks. The divergences in capital stocks gradually erode the initial divergences in rates of return, so that, provided there are no further shocks to the system, in the long run rates of return revert to their base case levels.

3.4 Production technologies and household tastes

VURM contains many types of technical change variables. As outlined in Section 2.4, the net benefits of the NEL program are modelled as improvements in labour and material-saving productivity. These are implemented as calibrated shocks to the corresponding technological variables. It is assumed that all other technology and taste variables are unaffected by the NEL shocks.

3.5 Government spending and government budget balances

Original closure:

It is assumed that the net present values of government borrowing requirements are unaffected by the NEL program. Government budget balances are fixed via model-determined changes in cash payments to local households. The Victorian Government is assumed to have an increase in its budget deficit compared to baseline for each year during the Construction phase to accommodate the costs of NEL capital costs.

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Alternative closure:

An alternative closure was specified under which government budget balances were not held fixed. As in the initial closure, over the Construction phase, the Victorian Government's budget deficit increases to accommodate the costs of the NEL capital costs. But upon completion of the Construction phase in 2027, the Victorian Government does not pay off the NEL borrowing. Rather, Victorian Government spending simply returns to baseline, the budget balance is allowed to adjust endogenously, and there are no changes to cash payments to local households (the mechanism in the previous closure by which the Victorian Government paid off the NEL borrowing).

3.6 Top-down regional model

Finally, we use a top-down regional disaggregation of the model to show how the NEL program would affect Gross Regional Product and Employment in different regions in Victoria. The regional aggregation used in this study for the NEL program is illustrated in the map in Figure 3 at the end of this report.

4 Simulation results

The net present values of the economic effects of the NEL package on Victoria are shown in Table 1. The middle column labelled "Original Closure" presents results when government budget balances are fixed, with adjustments to household cash payments during the Operation phase to pay off the first 40 per cent of the NEL borrowing for the capital costs of the NEL. The right-most column labelled "Alternative Closure" presents results under the alternative closure when the government budget balances are allowed to vary and the Victorian government does not pay off the NEL borrowing.

The time-paths of the effects on Victorian macroeconomic variables are shown in Figure 1 for the Original Closure and in Figure 2 for the Alternative Closure.

Table 1: Effects of NEL program on Victorian macroeconomic variables

	Original Closure Net Present Value ($ million)	Alternative Closure Net Present Value ($ million)
Real private consumption	-1946.6	1401.1
NEL capital works	8048.6	8048.6
Real private investment	4385.1	5874.5
Real government consumption*	-130.0	-136.2
Net international exports	2558.7	1621.6
Net interstate exports	-371.4	-1926.5
Real GDP	12544.4	14883.1

* Includes NEL road maintenance

In considering the results for real consumption, it should be borne in mind that only two-thirds of the benefits of the NEL program were modelled. In particular it should be recalled that we do not model any benefits of time-savings by non-business travelers, under the assumption that all of the time saved is consumed as leisure. Such benefits needed to be added to real consumption benefits in considering the overall benefits on Victoria.

The program has a positive effect on Victorian employment, with an increase over the baseline of just under 6,900 jobs in an average year of the simulation period 2018-2046. As can be seen from Figure 1, the increase in employment is strongest in the Construction phase, where the increase in jobs on average is just over 10,300 per year. There is a small negative effect on employment in the first two years of the Operating phase as the economy adjusts to the end of the Construction phase, but the employment effect soon returns to positive as real wages adjust. Rather than returning to baseline after the end of the Construction phase, employment continues to increase during the whole of the Operating phase, ultimately reaching 0.13 per cent above baseline by 2046. This is due to the increasing strength of the productivity improvements arising from the increasing travel time savings and travel time reliability.

The NEL program has a negative effect on welfare in Victoria, as evidenced by the decrease in the net present value of consumption over the simulation period of -$1,947m. This is due to a large extent to the cost of paying off the 40 per cent of the capital costs of the NEL construction by 2046. This is clear when comparing the effects of the NEL program on real private consumption in Table 1 above under the Original Closure to those under the Alternative Closure. Under the Alternative Closure, the Victorian government budget deficit is allowed to adjust over the length of the simulation period, so households are not burdened with the negative cash transfer to pay off the 40 per cent share of the NEL construction costs. As a result, instead of falling by $1,947m, real private consumption rises by $1,401m. Since the external balance is fixed in this modelling simulation, the borrowing costs are effectively borne by the rest of Australia region. The national change in the net present value of real consumption and real GDP (ie: results for Victoria and the rest of Australia combined) are virtually identical under either the Original Closure or the Alternative Closure: -$2870m and $7,481m for real consumption and real GDP, respectively. Recall also that the travel time savings to non-business travelers are not included in the simulation – these would contribute positively to welfare through increases in leisure.

Finally, Table 2 shows how the results of the NEL program should affect Gross Regional Product and Employment in different regions within Victoria, using the top-down regional disaggregation noted in Section 3.6.

Table 2: Effects of NEL program on Victorian macroeconomic variables

	Fixed Budget Balance		**Variable Budget Balance**	
	GRP ($m)	Employment	GRP ($m)	Employment
Inner Melbourne	363.8	199	431.6	307
Western Metro	2,207.8	1210	2619.4	1861
Northern Metro	2,345.8	1286	2783.1	1978
Eastern Metro	5,168.3	2832	6131.8	4357
South East Metro	1,593.1	873	1890.2	1343
Rest of Victoria	865.6	474	1026.9	730

The effects of the NEL program in terms of gross regional product and employment are felt most in the Eastern Metro region. But while most of the construction will take place in the Eastern Metro region, there are employment gains in all regions, as labour markets adjust to draw workers from other regions into the Eastern Metro region where the bulk of the construction work is expected to take place during the Construction phase.

Figure 1: Effects of NEL program on Victorian economy – Original Closure (percentage deviation from baseline)

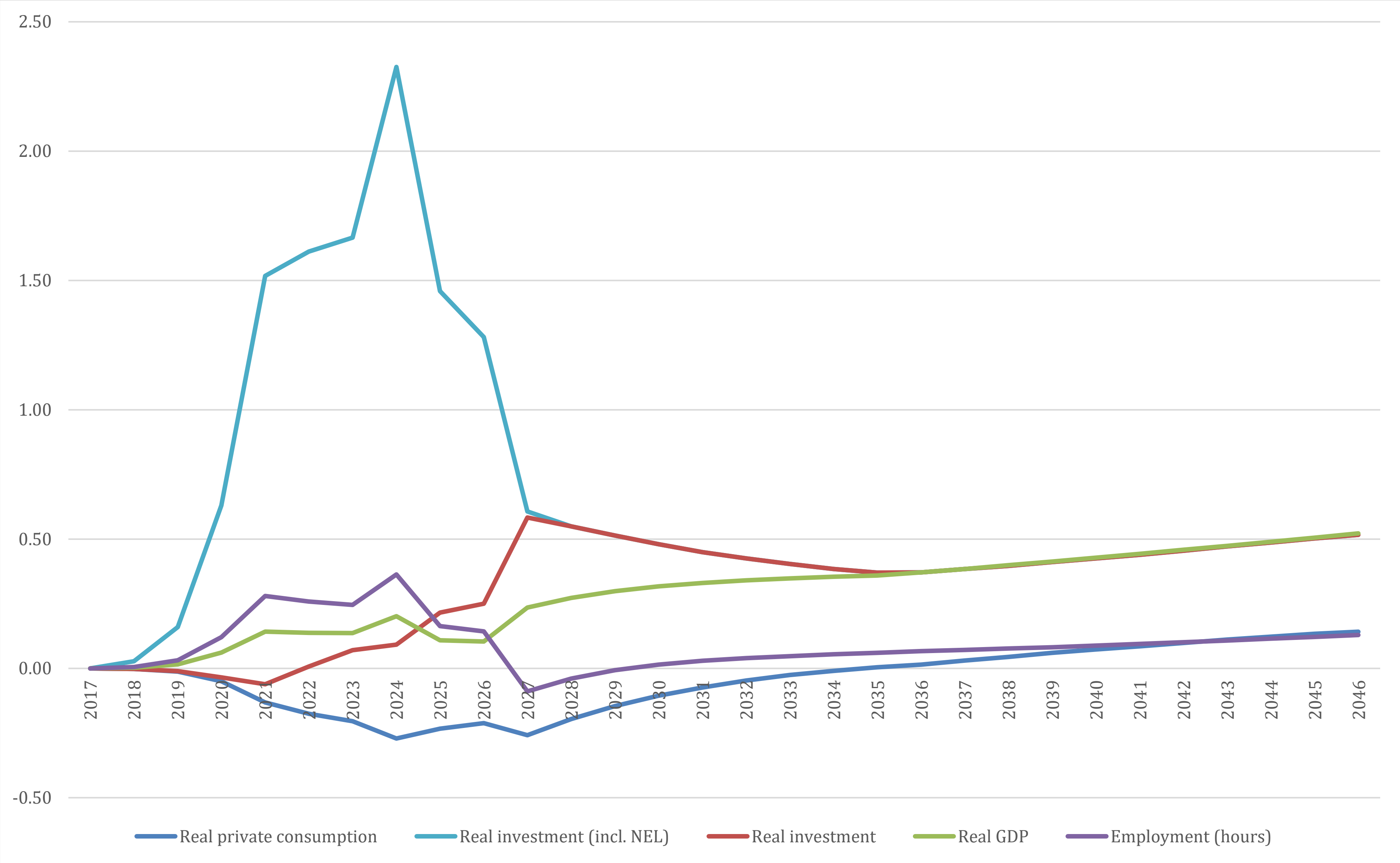
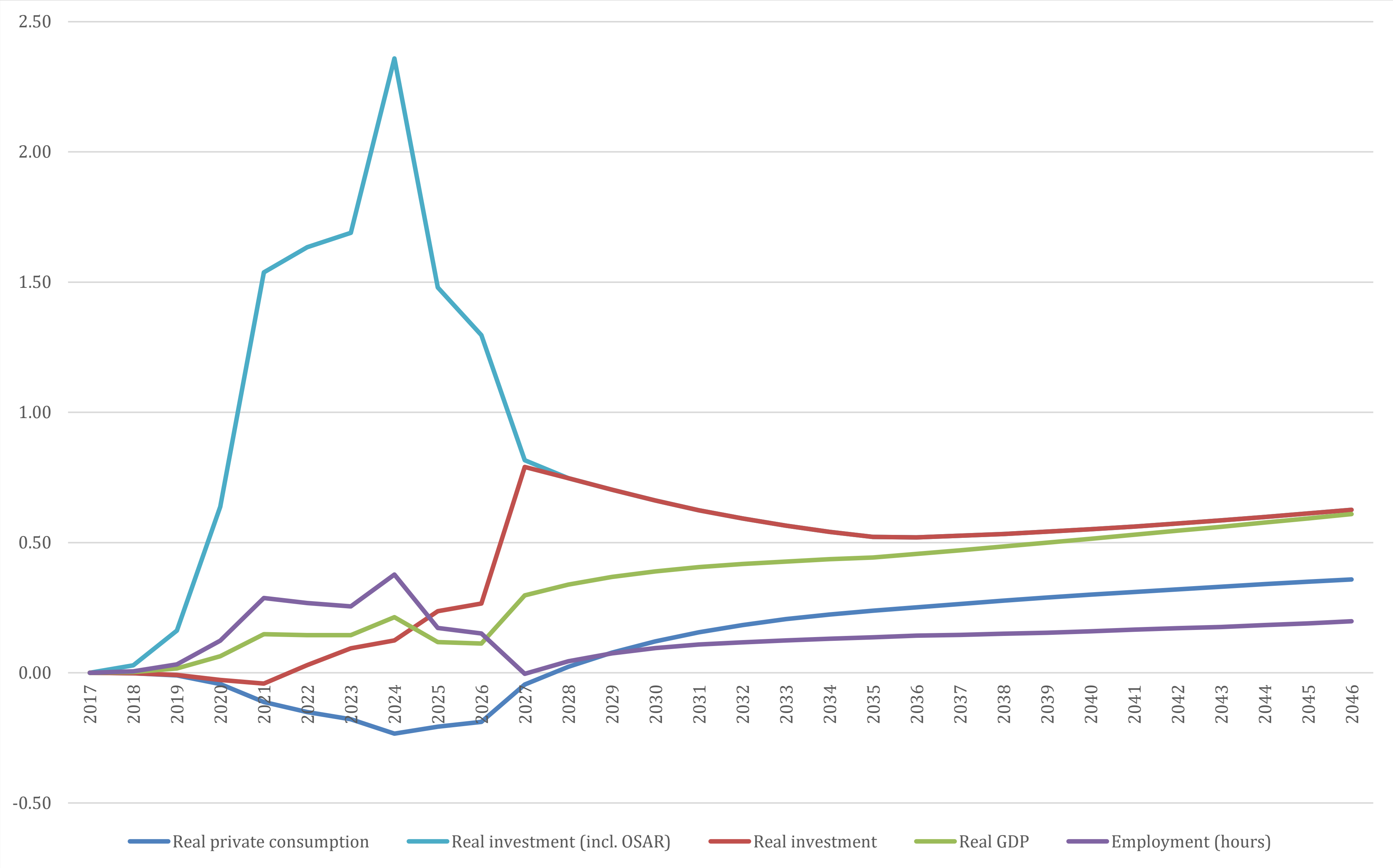


Figure 2: Effects of NEL program on Victorian economy – Alternative Closure (percentage deviation from baseline)



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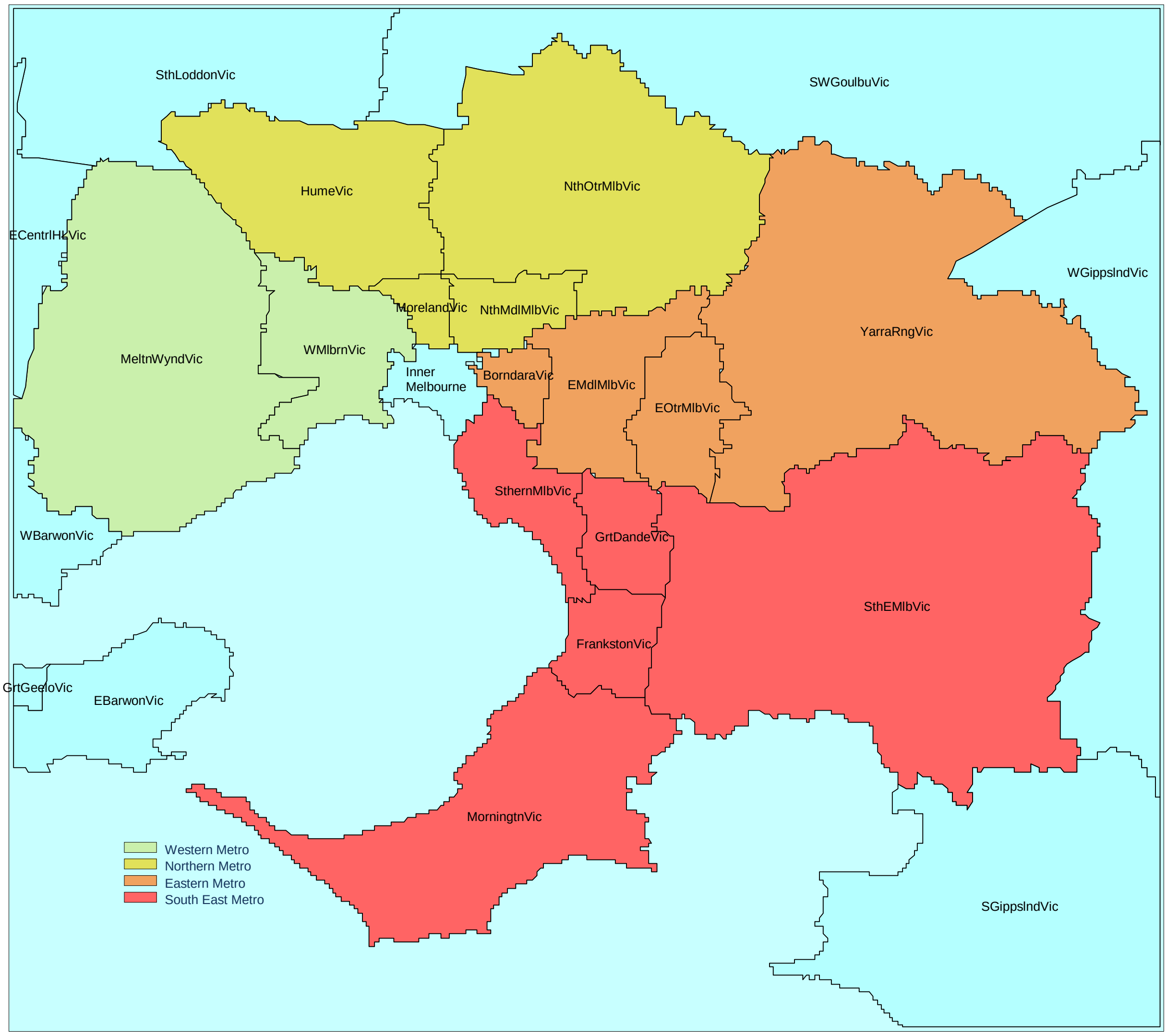
APPENDIX - Descriptions of Industries

Table A1: Industries in VURM

Name	Description of major activity
1. Sheep & beef cattle	Primary agricultural activities related to sheep and cattle production
2. Dairy cattle	Primary agricultural activities associated with dairy cattle
3. Other livestock	Primary agricultural activities associated with other animals
4. Grains	Grains production
5. Other agriculture	Other primary agricultural production
6. Agricultural services, fishing and hunting	Provision of agricultural services, fishing and hunting
7. Forestry	Logging and forestry services
8. Coal mining	Mining of coal
9. Oil mining	Mining of oil
10. Gas mining	Production of natural gas at well
11. Iron ore mining	Mining of iron ore
12. Non-ferrous ore mining	Mining of ore other than iron
13. Other mining	Other mining activity
14. Meat & meat products	Processed food related to animal
15. Other food, beverages & tobacco	Other food and drink products
16. Textiles, clothing & footwear	Textiles, clothing and footwear
17. Wood products	Manufacture of wood (including pulp) products
18. Paper products	Manufacture of paper products
19. Printing and publishing	Printing and publishing
20. Petroleum products	Manufacture of petroleum (refinery) products
21. Basic chemicals	Manufacture of basic chemicals and paints
22. Rubber & plastic products	Manufacture of plastic and rubber products
23. Non-metal construction products	Manufacture of non-metallic building products excl. cement
24. Cement	Manufacture of cement
25. Iron & steel	Manufacture of primary iron and steel.
26. Alumina	Manufacture of alumina
27. Aluminum	Manufacture of aluminium
28. Other non-ferrous metals	Manufacture of other non-ferrous metals
29. Metal products	Manufacture of metal products
30. Motor vehicles and parts	Manufacture of motor vehicles and parts
31. Other manufacturing	Manufacturing non elsewhere classified
32. Electricity generation - coal	Electricity generation from coal (black and brown) thermal plants
33. Electricity generation - gas	Electricity generation from natural gas thermal plants
34. Electricity generation – oil products	Electricity generation from oil products thermal plants
35. Electricity generation - nuclear	Electricity generation from nuclear plants
36. Electricity generation – hydro	Electricity generation from renewable sources – hydro
37. Electricity generation – other	Electricity generation from all other renewable sources
38. Electricity supply	Distribution of electricity from generator to user
39. Gas supply	Urban distribution of natural gas
40. Water supply	Provision of water and sewerage services
41. Construction services	Residential building and other construction services
42. Trade services	Provision of wholesale and retail trade services
43. Accommodation, hotels & cafes	Provisions of services relating to accommodation, meals and drinks
44. Road passenger transport	Provision of road transport services – passenger
45. Road freight transport	Provision of road transport services - freight
46. Rail passenger transport	Provision of rail transport services – passenger
47. Rail freight transport	Provision of rail transport services - freight
48. Water, pipeline & transport services	Provision of water transport services
49. Air transport	Provision of air transport services
50. Communication services	Provision of communication services
51. Financial services	Provision of financial services
52. Business services	Provision of business services
53. Dwelling services	Provision of dwelling services
54. Public services	Provision of government and community services
55. Other services	Provision of services not elsewhere classified
56. Private transport services	Provision of services to households from the stock of motor vehicles
57. Private electricity equipment services	Provision of services to households from the stock of electrical equipment
58. Private heating services	Provision of services to households from the stock of heating equipment

* For most of the industries identified in this table there is an obvious correspondence to one or more standard categories in the Australian and New Zealand Standard Industrial Classification (ANZSIC), 2006 version. The exceptions are: industries 32 to 38, which together comprise ANZSIC 26 *Electricity Supply*; industry 53, which is equivalent to the *Ownership of dwellings* industry in the industrial classification of the official Input/output statistics; and industries 56 to 58 which relate to the provision of services from the private stocks of motor vehicles, electrical equipment (not heating) and heating equipment.

Figure 3: Regional Aggregation for NEL Program



Attachment E VLC Economic Model Technical Report

Prepared for

North East Link Authority

Transport Modelling for North East Link

Zenith Economic Assessment Model - Technical Note

October 2017

Transport Modelling for North East Link

Zenith Economic Assessment Model - Technical Note

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Contents

List of Tables

1 Introduction

This Technical Note describes the Economic Assessment Model (EAM) which is used within the Zenith Transport Model to calculate the economic and social benefits associated with transportation projects.

1.1 Background

The Zenith EAM is a procedure implemented by Veitch Lister Consulting (VLC) within the OmniTRANS software package, which calculates the economic and social benefits associated with transportation projects. The Zenith EAM is designed to interface with outputs produced by the Zenith Model.

The output of the Zenith EAM is stored within a specially designed Microsoft Excel spreadsheet, which can house the results of multiple modelled transport scenarios. This spreadsheet will be referred to as the "*Zenith EAM Spreadsheet*".

The scope of the Zenith EAM includes the calculation of:

- User benefits (consumer surplus);
- Resource costs (i.e. vehicle operating costs);
- Externalities (i.e. vehicle emissions and road accidents); and
- Agglomeration benefits.

The Zenith EAM can be applied to estimate the economic and social benefits of a wide variety of transportation projects, including:

- New road infrastructure and road upgrades;
- Toll roads;
- New public transport infrastructure / services and service upgrades; and
- Changes in public transport fares, parking prices, etc.

The Zenith EAM can be applied to "variable demand" scenarios, where the modelled trip matrices are predicted to change in response to the particular infrastructure / service improvement (so as to reflect "induced travel").

The scope of the Zenith EAM does not extend to estimating the cost of constructing, operating and maintaining new infrastructure / services.

The methodologies used by the Zenith EAM are consistent with the guidelines provided by the Australian Transport Council and Austroads, though in some cases it has been necessary to expand upon these guidelines.

1.2 Report Structure

The balance of this document is structured as follows:

- **Section 2** describes the overall economic assessment framework;
- **Section 3** describes the calculation of benefits associated with travel time savings, improvements in reliability and reductions in transit overcrowding;
- **Section 4** describes the calculation of benefits associated with reductions in the vehicle operating costs;
- **Section 5** describes the treatment of tolls and public transport fares;
- **Section 6** describes the calculation of benefits associated with reduced traffic accidents (crashes);
- **Section 7** describes the calculation of environmental benefits; and
- **Section 8** describes the calculation of wider economic benefits.

2 Economic Evaluation Framework

2.1 Scenarios

The economic and social benefits of a transportation project are generally calculated by comparing the outputs generated by two modelled scenarios:

- The “Base Scenario” (sometimes referred to as the “Reference Case Scenario”). This scenario does not include the particular transportation project which is of interest; and
- The “Project Scenario”. This scenario does include the transportation project of interest.

Generally, a series of Base and Project Scenarios are generated for a range of forecast years (i.e. 2026, 2036, 2051, etc.), allowing the benefits of the Project Scenario to be forecast and appropriately discounted.

2.2 Calculation of Benefits

This section details the calculation of benefits resulting from a transportation project.

In order to accurately calculate the benefits of a transportation project it is necessary to distinguish between the following two types of trips:

- *Continuing trips* – these are trips which continue to have the same origin, destination, mode of travel and time of travel (ODMT) in the Project Scenario (compared to the Base Scenario);
- *Modified trips* – these are trips which have a modified origin, destination, mode of travel or time of travel (ODMT) in the Project Scenario (compared to the Base Scenario).

Modified trips occur when the Project Scenario transportation project causes some travellers to alter their travel choices. For example, the implementation of a rail upgrade may cause some trip makers to switch from car (in the Base Scenario) to public transport (in the Project Scenario), or even to change the destination of their travel.

Note that a change of *route* does not constitute a modification under the above definition, and therefore trips which modify their route only are classed as continuing trips.

For the purpose of defining continuing and modified trips, the following modes are considered by the Zenith EAM:

- Car;
- Walking;
- Cycling;
- Public transport (walk access and egress);
- Public transport (park and ride); and
- Public transport (kiss and ride).

Under this definition, a change in route from one public transport sub-mode to another (e.g. bus to train) would be considered to be a route choice change and would not constitute a modification to the trip.

The following two sub-sections detail the methodology used calculate benefits for continuing trips and modified trips. The notation and many of the concepts used build upon the work of Godinho & Dias (2012), which specifically considered the case of *newly generated trips*. In this note, their framework is generalised to incorporate modified trips.

The subscript "*B"* is used to mean "*Base Scenario*"; the subscript "*P*" is used to mean "*Project Scenario*".

2.2.1 Continuing Trips

For continuing trips which have the same ODMT in both the Base Scenario and the Project Scenario, benefits are derived from changes in resource costs between the two scenarios.

The benefit *S* is calculated as follows:

$$S = N_B - N_P + P_B - P_P + U_B - U_P + E_B - E_P$$

where:

- N_x – untraded resources used to make the trip in scenario *x* (e.g. time);
- P_x - traded resource costs (resources which must be purchased) which are paid for by the trip maker, and which are perceived by the trip maker in scenario *x* (e.g. fuel);
- U_x – traded resource costs which are paid for by the trip maker, but which are not perceived by the trip maker in scenario *x* (e.g. tyres, vehicle depreciation);
- E_x – external costs resulting from making the trip in scenario *x* (e.g. accidents, environmental costs).

Taxes, tolls and subsidies do not feature in this calculation (being a transfer payment they do not lead to the consumption of resources and their net effect is zero).

$E(S) = (N_B - N_P) +$	*Change in untraded resources (e.g. time)*
$(P_B - P_P) + (U_B - U_P) +$	*Change in consumption of traded resources*
$(E_B - E_P)$	*Change in externalities*

2.2.2 Modified Trips

Our notation must be extended to cater for the case of trip makers who modify their trip, either by changing their origin, destination, mode of travel or time of travel.

As with the previous sub-section, the subscript is used to refer to scenarios (either "B" for Base Scenario or "P" for Project Scenario).

In this sub-section a superscript is also introduced to differentiate between the ODMT which was chosen in the Base Scenario (t1) and the ODMT which was chosen in the Project Scenario (t2). By varying the subscript and superscript, it is possible to differentiate between the following four definitions of cost:

- C_B^{t1} – the cost (C) of making trip t1 (the ODMT chosen in the Base Scenario) in the Base Scenario
- C_P^{t1} – the cost (C) of making trip t1 (the ODMT chosen in the Base Scenario) in the Project Scenario
- C_B^{t2} – the cost (C) of making trip t2 (the ODMT chosen in the Project Scenario) in the Base Scenario
- C_P^{t2} – the cost (C) of making trip t2 (the ODMT chosen in the Project Scenario) in the Project Scenario

Utilising both subscript and superscript we now have the following extended notation:

- N_c^t – untraded resources (e.g. time) used in making trip *t* (t1 or t2) in scenario *c* (B or P);
- P_c^t - traded resource costs (resources which must be purchased such as fuel) which are paid for by the trip maker, and which are perceived as costs of making trip *t* (t1 or t2) in scenario *c* (B or P);
- U_c^t – traded resource costs which are paid for by the trip maker, but which are not perceived by the trip maker when making trip *t* (t1 or t2) in scenario *c* (B or P). Examples include tyres, vehicle depreciation, etc.
- TP_c^t - tolls, fares, taxes, subsidies which are paid by the trip maker, and which are also perceived by the trip maker when making trip *t* (t1 or t2) in scenario *c* (B or P);
- TU_c^t – tolls, fares, taxes, subsidies which are paid for by the trip maker, but which are not perceived by the trip maker when making trip *t* (t1 or t2) in scenario *c* (B or P);
- E_c^t – external costs resulting from the making of trip *t* (t1 or t2), in scenario *c* (B or P). Examples include road accidents, environmental costs, etc.
- V^t - the gross value derived by the trip maker from the activities enabled by making trip *t* (t1 or t2), but excluding value (or cost) associated with the trip itself. Examples include the ability to undertake activities at the trip destination, such as work, shopping, etc. This value is assumed to vary by ODMT, and is assumed to be the same in the Base and Project scenarios (for each ODMT).

Now, the net perceived benefit (B) of making trip *t* in scenario *c* is calculated by subtracting the perceived costs (*N* and *P* and *TP*) of making the trip from the gross value of the activities enabled by the trip (V). So,

$$B_c^t = V^t - N_c^t - P_c^t - TP_c^t$$

In the base scenario, the trip maker chooses to make trip *t1*. Therefore, we can conclude that in the Base Scenario the perceived net benefit of making trip *t1* is greater than the perceived net benefit of making trip *t2*. Therefore:

$$V^{t1} - N_B^{t1} - P_B^{t1} - TP_B^{t1} \geq V^{t2} - N_B^{t2} - P_B^{t2} - TP_B^{t2}$$

which can be arranged to give:

$$V^{t2} - V^{t1} \leq N_B^{t2} + P_B^{t2} + TP_B^{t2} - N_B^{t1} - P_B^{t1} - TP_B^{t1}$$

Following similar logic, in the Project Scenario, the trip maker chooses to make trip *t2*. Therefore, we can conclude that in the Project Scenario the perceived net benefit of trip *t2* is greater than that of *t1*.

$$V^{t2} - N_P^{t2} - P_P^{t2} - TP_P^{t2} \geq V^{t1} - N_P^{t1} - P_P^{t1} - TP_P^{t1}$$

which gives:

$$V^{t2} - V^{t1} \leq N_P^{t2} + P_P^{t2} + TP_P^{t2} - N_P^{t1} - P_P^{t1} - TP_P^{t1}$$

We have thus established an upper and lower bound for the expression $V^{t2} - V^{t1}$.

Assuming that the expected value of this expression is given by the mid-point between the upper and lower bounds (i.e. the rule of a half), we have:

$$E(V^{t2} - V^{t1}) = \frac{(N_B^{t2} + P_B^{t2} + TP_B^{t2} - N_B^{t1} - P_B^{t1} - TP_B^{t1}) + (N_P^{t2} + P_P^{t2} + TP_P^{t2} - N_P^{t1} - P_P^{t1} - TP_P^{t1})}{2}$$

This assumption holds exactly in the case of linear demand functions, but is only an approximation in the case of non-linear demand functions. Zenith uses a non-linear demand function (using Logit Models), and so the above expression is only an approximation.

Now, given that the trip maker is predicted to choose trip t1 in the Base Scenario and t2 in the Project Scenario, we have the following expression for the change in net perceived benefit, ΔB:

$$\Delta B = B_P^{t2} - B_B^{t1}$$

$$\Delta B = V^{t2} - N_P^{t2} - P_P^{t2} - TP_P^{t2} - V^{t1} + N_B^{t1} + P_B^{t1} + TP_B^{t1}$$

Substituting for $E(V^{t2} - V^{t1})$, as was derived earlier, we can calculate the expected value of ΔB:

$$E(\Delta B) = -N_P^{t2} - P_P^{t2} - TP_P^{t2} + N_B^{t1} + P_B^{t1} + TP_B^{t1} + \frac{(N_B^{t2} + P_B^{t2} + TP_B^{t2} - N_B^{t1} - P_B^{t1} - TP_B^{t1}) + (N_P^{t2} + P_P^{t2} + TP_P^{t2} - N_P^{t1} - P_P^{t1} - TP_P^{t1})}{2}$$

$$E(\Delta B) = \frac{(N_B^{t2} + P_B^{t2} + TP_B^{t2} + N_B^{t1} + P_B^{t1} + TP_B^{t1}) + (-N_P^{t2} - P_P^{t2} - TP_P^{t2} - N_P^{t1} - P_P^{t1} - TP_P^{t1})}{2}$$

$$E(\Delta B) = \frac{(N_B^{t2} - N_P^{t2}) + (P_B^{t2} - P_P^{t2}) + (TP_B^{t2} - TP_P^{t2}) + (N_B^{t1} - N_P^{t1}) + (P_B^{t1} - P_P^{t1}) + (TP_B^{t1} - TP_P^{t1})}{2}$$

This result provides an estimate of the expected value of the perceived benefit attained by the trip maker. However, in the calculation of total benefit, we must also include the unperceived benefits / costs to the user (measured in terms of resource costs), externalities, and the positive effect of taxation, subsidies and tolls (as perceived by the collector of those payments).

Therefore, we can compute the expected value of total benefit as:

$$E(S) = E(\Delta B) + (U_B^{t1} - U_P^{t2}) + (TU_B^{t1} - TU_P^{t2}) + (TP_P^{t2} - TP_B^{t1}) + (TU_P^{t2} - TU_B^{t1}) + (E_B^{t1} - E_P^{t2})$$

$$E(S) = E(\Delta B) + (U_B^{t1} - U_P^{t2}) + (TP_P^{t2} - TP_B^{t1}) + (E_B^{t1} - E_P^{t2})$$

Now, if we simultaneously add $(P_B^{t1} - P_P^{t2})$ and $(P_P^{t2} - P_B^{t1})$ to this expression (which has no net impact), then we arrive at the following expression:

$E(S) = E(\Delta B) +$	*Change in perceived benefit*
$(P_B^{t1} - P_P^{t2}) + (U_B^{t1} - U_P^{t2}) +$	*Change in consumption of traded resources*
$(P_P^{t2} - P_B^{t1}) + (TP_P^{t2} - TP_B^{t1}) +$	*Resource cost and transfer payment corrections*
$(E_B^{t1} - E_P^{t2})$	*Change in externalities*

The Zenith Economic Evaluation Model has been implemented in accordance with the above expression.

2.3 Types of Benefit

The following types of benefit are included in the Zenith EAM:

Table 2.1 – Types of economic benefits considered within the Zenith EAM

Type of Benefit	Classification	Further information
Travel time savings	Untraded resource (N)	Chapter 3
Improvements in travel time reliability	Untraded resource (N)	Chapter 3
Reductions in crowding levels on public transport	Untraded resource (N)	Chapter 3
Vehicle operating costs	Traded resource, with perceived component P, and unperceived component U. Taxes on vehicle operating costs (i.e. fuel tax) are included with perceived component TP and unperceived component TU.	Chapter 4
Tolls	Treated as a tax, with perceived component TP and unperceived component TU.	Chapter 5
Fares	Treated as a tax, with perceived component TP and unperceived component TU.	Chapter 5
Road accidents (crashes)	Treated as an externality (E)	Chapter 6
Environmental costs	Treated as an externality (E)	Chapter 7
Wider economic benefits	Treated as an externality (E)	Chapter 8

3 Travel Time Savings, Reliability and Transit Overcrowding

This Chapter describes the treatment of Travel Time Savings, Travel Time Reliability and Public Transport Overcrowding within the Zenith EAM.

3.1 Travel Time

Travel time is treated as *untraded resource* in the Zenith EAM.

As discussed in Section 2, the inclusion of untraded resources in the benefit calculation differs for *continuing* trips versus *modified* trips.

In the case of *continuing* trips (trips which do not alter their origin, destination, mode or time of travel (ODMT) in the Project Scenario), the full change in the consumption of untraded resources is included in the benefit calculation (i.e. $N_B - N_P$). Therefore, for continuing trips, the full change in travel time, travel time reliability, or public transport overcrowding is included in the benefit calculation.

In the case of *modified* trips (trips which do alter their ODMT in the Project Scenario), changes in the consumption of untraded resources form an important part of the expected value of perceived user benefit, given by:

$$E(\Delta B) = \frac{(\boldsymbol{N_B^{t2}} - \boldsymbol{N_P^{t2}}) + (P_B^{t2} - P_P^{t2}) + (TP_B^{t2} - TP_P^{t2}) + (\boldsymbol{N_B^{t1}} - \boldsymbol{N_P^{t1}}) + (P_B^{t1} - P_P^{t1}) + (TP_B^{t1} - TP_P^{t1})}{2}$$

Referring the formula above, the components of perceived user benefit related to untraded resources are

$\frac{\boldsymbol{N_B^{t2}} - \boldsymbol{N_P^{t2}}}{2}$ and $\frac{\boldsymbol{N_B^{t1}} - \boldsymbol{N_P^{t1}}}{2}$.

The first quantity represents half of the change in the untraded resource cost of trip *t2* (the trip predicted to be made in the Project Scenario).

The second quantity represents half of the change in the untraded resource cost of trip *t1* (the trip predicted to be made in the Base Scenario).

Therefore, for modified trips, if the travel time of the newly chosen trip is decreased in the Project Scenario (compared to the Base Scenario), then half of that travel time saving will be recorded as a benefit. Likewise, for the trip which was previously chosen (in the Base Scenario), half of any decrease in travel time in the Project Scenario (compared to the Base Scenario) will also be recorded as a saving.

These formulae are based on "*the rule of half*".

The Zenith EAM includes numerous types of travel time. For public transport trips, travel time savings are separately reported in the following categories:

- **In-vehicle Time:** time spent travelling inside cabin in hours;
- **Waiting Time at Stop:** time spent at stop awaiting service in hours;

- **Transfer and Access Penalty:** time penalties associated with first access to public transport stop (i.e. walking or driving to station) and transferring between services in hours;
- **Walk Access Time from Origin to First Stop:** time spent walking from origin to first stop (i.e. first public transport access) in hours;
- **Walk Transfer Time Between Stops:** time spent walking while transferring between two stops, expressed in hours;
- **Walk Egress Time from Final Stop to Destination:** time spent walking from final stop (i.e. last alighting from public transport) to destination in hours;
- **Car Access Time from Origin to First Stop:** time spent driving from origin to first stop (i.e. first public transport access) in hours; and
- **Car Egress Time:** time spent driving from final stop (i.e. last alighting from public transport) to destination in hours

For car and commercial vehicle travel, there is only a single form of travel time. However, it is worth noting that in the case of car travel, the travel time savings of both drivers and passengers are calculated and aggregated in the output produced by the Zenith EAM. For commercial vehicles, the travel time savings produced by the Zenith EAM are expressed in vehicle hours (effectively assuming a vehicle occupancy of 1).

In the Zenith EAM, travel time benefits / dis-benefits are generally summarised by mode, time of day, and in some cases by trip purpose (e.g. commuting, business, airport, other).

Benefits can also be summarised by origin / destination, though this is generally performed within a GIS package (such as OmniTRANS) rather than in the Zenith EAM spreadsheet.

3.2 Travel Time Reliability

Improvements in travel time reliability are treated as an untraded resource (N) in the Zenith EAM.

Therefore, for continuing trips, the full amount of any improvement in travel time reliability is included in the benefit calculation ($N_B - N_P$).

For modified trips, only half of any improvement in travel time reliability is included: $\frac{N_B^{t2} - N_P^{t2}}{2}$ and $\frac{N_B^{t1} - N_P^{t1}}{2}$.

In the Zenith EAM, travel time reliability is quantified as an estimate of the standard deviation of travel time (for each origin / destination). The output produced by the Zenith EAM does not convert this quantity to a dollar value, but leaves it in units of standard deviation of travel time.

The standard deviation of travel time is calculated in accordance with the methodology set out in section 9.1.1 of The Department for Transport's (UK) Transport Analysis Guide Unit 3.5.7 (see References).

3.3 Perceived Cost of Congestion

Improvements in the perceived cost of congestion are treated as an untraded resource (N) in the Zenith EAM.

Therefore, for continuing trips, the full amount of any improvement in travel time reliability is included in the benefit calculation ($N_B - N_P$). For modified trips, only half of any improvement in travel time reliability is included: $\frac{N_B^{t2} - N_P^{t2}}{2}$ and $\frac{N_B^{t1} - N_P^{t1}}{2}$.

In the Zenith EAM, the perceived cost of congestion is quantified according to the methodology laid out in the 2013 New Zealand Traffic Authority Economic Evaluation Manual (NZTA EEM). In Appendix A4 (p. 5-207) they define the perceived change in travel time (caused by congestion) on urban roads, multi-lane rural highways and motorways as

$$\Delta \mathrm{T}_{\mathrm{l}}^{C} = \max\left(0.0, min\left(1.0, \frac{V_l - 0.7C_l}{0.3C_l}\right)\right)T_l$$

where:

- $\Delta \mathrm{T}_{\mathrm{l}}^{C}$ – perceived incremental travel time caused by congestion
- T_l – Congested Travel Time on link l
- V_{l} – Traffic Volume on link l
- C_{l} – Capacity on link l

The Zenith EAM calculates the perceived cost of congestion in units of hours for each individual link in the network. This link based metric is then converted to an OD based metric via the process laid out in Appendix B such that it can be combined with demand matrices to generate the overall benefits.

3.4 Transit Overcrowding

The perceived cost of transit overcrowding is treated as an untraded resource (N) in the Zenith EAM. Therefore, for continuing trips, the full amount of any reduction in the perceived cost of transit overcrowding is included in the benefit calculation ($N_B - N_P$).

For modified trips, only half of any reduction in the perceived cost of transit overcrowding is included: $\frac{N_B^{t2} - N_P^{t2}}{2}$ and $\frac{N_B^{t1} - N_P^{t1}}{2}$.

The Zenith Model employs a crowding cost function which calculates the perceived cost of overcrowding (to public transport passengers), based on:

- The load of the public transport service (per link);
- The number of seats on the public transport vehicle;
- The crush capacity of the public transport vehicle; and
- Whether each passenger is seated or standing.

The crowding benefits output by the Zenith EAM are expressed in 2008 AUD and can be included directly in the benefit calculation.

4 Vehicle Operating Costs

This Chapter describes the treatment of Vehicle Operating Costs (VOCs) within the Zenith EAM.

Chapter 2 of Austroads (2008) describes the various costs which comprise overall VOC. In summary, VOCs include the resource costs of:

- Fuel;
- Lubricating oil;
- Tyres;
- Vehicles (i.e. depreciation); and
- Vehicle repairs and maintenance costs.

In the case of freight, Austroads also include "freight time" as part of the vehicle operating cost.

4.1 Vehicle Operating Costs as a Traded Resource

VOCs are treated as a *traded resource* in the Zenith EAM.

In the case of *continuing* trips (trips which do not alter their origin, destination, mode or time of travel (ODMT) in the Project Scenario), the full change in the consumption of both perceived and unperceived traded resources is included in the benefit calculation (i.e. $(P_B - P_P) + (U_B - U_P)$). These quantities are resource costs, and do not include taxes. The methodology used to calculate the resource cost of VOCs is described in the following section.

In the case of *modified* trips (trips which do alter their ODMT in the Project Scenario), changes in the consumption of traded resources feature separately in three parts of the overall benefit calculation.

- Firstly, the full reduction in the consumption of both perceived and unperceived traded resources is included as a benefit: $(P_B^{t1} - P_P^{t2}) + (U_B^{t1} - U_P^{t2})$. This is consistent with the treatment of continuing trips.
- Secondly, the full reduction in the perceived cost of traded resources (including taxes) is included as a dis-benefit (conversely increases are included as a benefit): $(P_P^{t2} - P_B^{t1}) + (TP_o^{t2} - TP_b^{t1})$. This term acts as a "*resource cost correction*".
- Thirdly, changes in the <u>*perceived*</u> consumption of traded resources, plus the perceived cost of taxes on traded resources, form part of the expected value of perceived user benefit, given by:

$$E(\Delta B) = \frac{(N_B^{t2} - N_P^{t2}) + (\boldsymbol{P_B^{t2}} - \boldsymbol{P_P^{t2}}) + (\boldsymbol{TP_B^{t2}} - \boldsymbol{TP_P^{t2}}) + (N_B^{t1} - N_P^{t1}) + (\boldsymbol{P_B^{t1}} - \boldsymbol{P_P^{t1}}) + (\boldsymbol{TP_B^{t1}} - \boldsymbol{TP_P^{t1}})}{2}$$

Referring the formula above, the components of perceived user benefit related to traded resources are

$\frac{(\boldsymbol{P_B^{t2}} - \boldsymbol{P_P^{t2}}) + (\boldsymbol{TP_B^{t2}} - \boldsymbol{TP_P^{t2}})}{2}$ and $\frac{(\boldsymbol{P_B^{t1}} - \boldsymbol{P_P^{t1}}) + (\boldsymbol{TP_B^{t1}} - \boldsymbol{TP_P^{t1}})}{2}$.

The first quantity represents half of the change in the *perceived* cost of traded resources (including both resource costs and taxes) for trip *t2* (the trip predicted to be made in the Project Scenario).

The second quantity represents half of the change in the *perceived* cost of traded resources (including both resource costs and taxes) for trip *t1* (the trip predicted to be made in the Base Scenario).

These formulae are based on "*the rule of half*".

In the Zenith Model, the only type of Vehicle Operating Cost which is assumed to be *perceived* by trip makers when making destination and mode choice decisions is the cost of fuel. In other words, it is assumed that drivers do not perceive (and take account of) the other types of VOC such as the marginal cost of tyres, oil, vehicle depreciation and repairs when choosing a mode or destination.

Furthermore, research conducted by VLC using Australian household travel surveys has suggested that drivers do not perceive the full cost of fuel (the cost here including resource costs and taxes) when making mode and destination choices. In Victoria, for example, it was found that drivers perceive approximately 74% of the fuel cost.

Therefore, in the Zenith Model, $\boldsymbol{P_x^t} + \boldsymbol{TP_x^t}$ is given by:

$$\beta \times fuel\ price \times fuel\ consumption_x^t$$

where

β is the proportion of the total cost of fuel which is perceived by drivers when making travel choices (in the case of Victoria, this is 0.74);

$fuel\ price$ is the price of fuel paid by consumers (including taxes); and

$fuel\ consumption_x^t$ is the amount of fuel consumed to make trip *t* in scenario *x*.

Therefore, we can rearrange the formula used to calculate the perceived benefit in relation to trip t2:

$$\frac{(\boldsymbol{P_B^{t2}} - \boldsymbol{P_P^{t2}}) + (\boldsymbol{TP_B^{t2}} - \boldsymbol{TP_P^{t2}})}{2}$$

$$= \frac{(\boldsymbol{P_B^{t2}} + \boldsymbol{TP_B^{t2}}) - (\boldsymbol{P_P^{t2}} + \boldsymbol{TP_P^{t2}})}{2}$$

$$= \frac{\beta \times fuel\ price \times (fuel\ consumption_B^{t2} - fuel\ consumption_P^{t2})}{2}$$

Likewise for trip t1 we have:

$$\frac{\beta \times fuel\ price \times (fuel\ consumption_B^{t1} - fuel\ consumption_P^{t1})}{2}$$

4.2 The Resource Costs of Vehicle Operating Costs

The resource cost value of VOCs is calculated in accordance with the methodology found in Section 5.4.2 of the ATAP Road Parameter Values Guidelines.

Using the Austroads methodology, vehicle operating costs (cents / km) are modelled as a function average link speeds:

Stop-start model - $VOC = A + \frac{B}{V}$

Free -flow model - $VOC = C_0 + C_1 \times V + C_2 \times V^2$

Where:

- The stop-start model is used for calculating VOCs for road links < 60 km/hr
- The free-flow model is used to calculating VOCs for road links > 60 km/hr
- VOC is the rate at which vehicle operating costs are incurred (cents / km)
- A, B, C_0, C_1 and C_2 are model parameters
- V is the average link speed (in km / hr)

The five VOC model parameters (A, B, C_0, C_1 and C_2) are defined across 20 vehicle classifications, which have been averaged to the three Zenith modelled vehicle classes. These parameters, drawn from Table 35 of the ATAP 2016 guidance are contained in Table 4.1.

Table 4.1 – Vehicle operating cost parameter values on freeways. Source: ATAP (2016), Table 35

Vehicle Type	A	B	C_0	C_1	C_2
Cars	15.3178	1335.6416	37.2137	0.1721	0.0013
LCV	34.886	1901.7297	57.0943	-0.2742	0.0026
HCV	129.8532	4954.7104	163.5236	-0.7852	0.0072

The vehicle operating cost calculated by the above methodology and parameters are expressed in 2013 dollars.

5 Tolls and Public Transport Fares

This Chapter describes the treatment of tolls and public transport fares within the Zenith EAM.

The payment of tolls and public transport is treated as a tax in the Zenith EAM.

In the case of continuing trips (trips which do not alter their origin, destination, mode or time of travel (ODMT) in the Project Scenario), tolls and public transport fares do not feature in the calculation, having been treated as a transfer payment.

However, in the case of modified trips (trips which do alter their ODMT in the Project Scenario), tolls and public transport fares do enter into the calculation of economic benefit as a tax.

The perceived cost of taxes (TP) enters into the calculation of the expected value of perceived user benefit, given by:

$$E(\Delta B) = \frac{(N_B^{t2} - N_P^{t2}) + (P_B^{t2} - P_P^{t2}) + (\boldsymbol{TP_B^{t2}} - \boldsymbol{TP_P^{t2}}) + (N_B^{t1} - N_P^{t1}) + (P_B^{t1} - P_P^{t1}) + (\boldsymbol{TP_B^{t1}} - \boldsymbol{TP_P^{t1}})}{2}$$

The components of the above calculation related to taxes are:

$\frac{\boldsymbol{TP_B^{t2}} - \boldsymbol{TP_P^{t2}}}{2}$ and $\frac{\boldsymbol{TP_B^{t1}} - \boldsymbol{TP_P^{t1}}}{2}$

Taxes also enter into the overall benefit calculation via the resource cost and transfer payment correction:

$$(P_P^{t2} - P_B^{t1}) + (\boldsymbol{TP_P^{t2}} - \boldsymbol{TP_B^{t1}})$$

6 Accident Costs

Benefits associated with a reduction in road accidents can be readily calculated and analysed using the Zenith Economic Assessment Model. Resultant outputs are presented in the Zenith EAM Spreadsheet (tab name "report_Accidents") expressed in dollars ($AUD2013).

The Zenith EAM calculates road accident benefits by:

1. Calculating absolute accident casualties using accident rates sourced from Table 3.1 of the VicRoads, "Accident Analysis by Road Profile Study, Operational Report", January 1996 (Updated by T Boyd 2010)
2. Converting casualties into dollars using Austroads' accident costs from Table 4.8 (p26) of the 2015 revision of the National Guidelines for Transport Systems Management (NGTSM) Road Parameter Values (PV2) report.

VicRoads outlines eight road types and their corresponding accident rates in units of accident casualties per 100 million VKT. Accident costs specified by Austroads' are defined by state and are expressed in dollars ($AUD2013). These sources have been listed in Table A.1 and Table A.2 respectively of Appendix A – Source Accident Rate & Cost Parameters.

In order to integrate the different sets of road definitions used by VicRoads and Austroads in their accident rate and cost specifications, VLC has defined the four categories as shown in Table 6.1 below to underpin its accident benefit calculations (namely 'Local', 'Undivided Major', 'Other Divided' and 'Freeway'). The rates and costs for these categories have been interpolated from the source data provided by VicRoads and Austroads.

Table 6.1 – Accident rates and costs by VLC road category

Link Description	Casualty Accident Rate (accidents/10^8 VKT)	Accident Costs ($AUDJun2013)
Local	30.8	$329,800
Undivided Major	27.4	$369,954
Other Divided	21.3	$416,565
Freeway	6.9	$586,125

Using the above parameters in Table 6-1, the Zenith EAM outputs accident benefits by the four listed road types, time period and vehicle type (Car, Light Commercial Vehicle, Heavy Commercial Vehicle). The EAM assumes identical accident rates and costs for cars and commercial vehicles, due to a lack of class-refined source data.

7 Environmental Costs

The emission of greenhouse and other gasses cause impacts that are detrimental to both health and the environment. Emissions related to vehicular traffic (both cars and trucks) are captured within the Zenith Economic Assignment Model, both in terms of tonnages and costs ($). These outputs are stored within the “report_Emissions” and “report_TonnesEmissions” tabs of the Zenith EAM Spreadsheet.

The calculation of emissions takes a three step process:

1. Calculate fuel consumption on each road link,
2. Convert fuel consumption to tonnes of emissions,
3. Value the cost of the emissions, by converting tonnes to dollars

Each step is now described.

7.1 Calculating Fuel Consumption

Austroads (2005) provides the following model of fuel consumption as a function of average link speed:

$$F = A + \frac{B}{V} + C \times V + D \times V^2$$

Where:

F is the rate of fuel consumption (L / 100km)

A, B, C, D are model parameters

V is the average link speed (in km / hr)

Different parameter sets (A, B, C, D) are defined for each combination of road type (freeway / non-freeway), and vehicle type (Car, Light Commercial Vehicle, Heavy Commercial Vehicle). The parameters, drawn from Tables 4.3 and 4.4 of Austroads (2005) are:

Table 7.1 – Fuel consumption parameter values on freeways. Source: Austroads (2005), Table 4.3

Vehicle Type	A	B	C	D
Cars	7.149	268.1	0.0	0.0003
LCV	11.365	423.0	0.0	0.0005
HCV	26.932	1276.4	0.0	0.0008

Table 7.2 – Fuel consumption parameter values on non-freeways. Source: Austroads (2005), Table 4.4

Vehicle Type	A	B	C	D
Cars	0.361	528.0	0.0	0.000785
LCV	-3.129	1017.0	0.0	0.001481
HCV	-10.495	2915.7	0.0	0.00315

7.2 Calculating Tonnes of Emissions

Emissions are calculated as a linear function of fuel consumption. In other words, each litre of fuel consumed results in a fixed amount of emissions.

DOT (2001) defined a set of emission rates, as set out in Table 7.3 below. Emission rates were defined by vehicle type (cars, light trucks, heavy trucks and bus), for 2001 and a forecast year of 2021.

Table 7.3 – Emission Rates (grams of emissions / litres of fuel consumed). Source: DOT (2002), Table 3-15

Vehicle Type	NO_X	NMVOC	SO_X	CO_2	CH_4	N_2O	CO	Total
Year 2001								
Cars	11.10	6.75	0.34	2211.41	0.88	0.18	92.68	2323.33
Light Trucks	12.02	11.71	0.93	2225.71	0.76	0.09	132.38	2383.59
Heavy Trucks	20.43	6.55	2.91	2606.98	0.18	0.08	34.38	2671.50
Buses	15.91	5.99	2.95	2598.24	0.16	0.08	27.13	2650.45
Year 2021								
Cars	10.71	5.01	0.32	2166.97	0.80	0.20	72.87	2256.87
Light Trucks	12.00	11.60	0.88	2177.53	0.74	0.09	132.22	2335.07
Heavy Trucks	20.02	6.17	2.90	2577.39	0.17	0.08	27.20	2633.91
Buses	14.97	6.98	2.32	2350.09	0.24	0.07	44.74	2419.40

7.3 Valuing the Cost of Emissions

Emission costs by tonne are specified by Austroads (2012) and are shown in Table 7.4 in units of dollars ($AUD2010) per tonne of emission.

Table 7.4 – Emission Costs ($AUD2010 dollars / tonne of emission). Source: Austroads (2012), Table 5.4

Carbon dioxide equivalent (CO2-e)	52.4
Carbon monoxide (CO)	3.3
Oxides of nitrogen (Nox)	2 089.2
Particulate matter (PM10)	332 505.9
Total hydrocarbons (THC)	1 046.8

8 Wider Economic Benefits

8.1 Agglomeration

Agglomeration benefits are accrued where an increase in effective job density (and therefore productivity) is introduced. Three methodologies are available in the Zenith EAM to evaluate agglomeration benefits, which are discussed in the following sections.

Note each methodology assumes the following Gross State Product (GSP) added per worker, (as sourced from ABS) to calculate annualised agglomeration benefits.

Table 8.1 – GSP output per worker by ANZSIC 1993 industry category. Source: ABS (May 2014), grouped into ANZSIC categories

Employment Category	GSP output per worker ($AUD2014) GSP_i
Agriculture	95,115
Mining	445,243
Manufacturing	92,539
Electricity, Gas & Water	247,053
Construction	90,572
Wholesale	135,888
Retail	59,920
Recreation & Personal Services	46,196
Transport & Storage	104,607
Communication	221,362
Financial & Business	162,810
Public Administration	102,155
Community Services	70,890

8.1.1 ATAP Discussion Paper

In the ATAP discussion paper "*Estimating WEBs of Transport Projects*" (27 July 2015), KPMG suggests that an appropriate measure of 'Business to Business' (B2B) accessibility for the purposes of estimating agglomeration is B2B effective density, as defined below (from page 14):

$$B2BEd_{i,y,m} = \sum_{j} Decay\ i,j,m * Employment\ j,y$$

Where:

- i = journey origin zone
- j = journey destination zone
- m = transport mode
- y = year
- $Decay\ i,j,m$ = decay curve for generalised journey costs for business travellers between zones i and j in year y by mode m
- Please note that the above formula has been altered from the original documentation such that the summation sigma is applied across all journey destination zones j rather than origin zones i

On pages 25 and 26 of their document, KPMG outlines a piecewise decay function incorporating an exponential curve as estimated from VISTA07/09. The decay function is described as 'mode-blind', and uses 'generalised time' (a log-sum measure of travel times across modelled modes) as its primary input. The function is described below:

$$Decay_{TT} = \begin{cases} 1\ if\ TT < 10 \\ e^{(-0.05*(TT-10))}\ if\ 10 \le TT < 120 \\ 0\ if\ TT \ge 120 \end{cases}$$

Where:

- TT = generalised travel time (minutes)

KPMG also separately specify productivity elasticities calibrated especially for the Zenith model, which are shown in Table 8.2 below.

Table 8.2 – Productivity elasticity by ANZSIC 2006 industry category. Source: KPMG Agglomeration Elasticities (2017), grouped into ANZSIC 2006 categories by EY (2017)

Employment Category	Productivity Elasticity* ρ_i
Agriculture, Forestry and Fishing	0.08
Mining	0.00
Manufacturing	0.05
Electricity, Gas & Water	0.00
Construction	0.10
Wholesale Trade	0.10
Retail Trade	0.04
Accommodation and Food Services	0.00
Transport, Postal and Warehousing	0.16
Information Media and Telecommunications	0.13
Financial and Insurance Services	0.17
Rental, Hiring and Real Estate Services	0.08
Professional, Scientific and Technical Services	0.12
Administrative and Support Services	0.14
Public Administration and Safety	0.00
Education and Training	0.13
Health Care and Social Assistance	0.09
Arts and Recreation Services	0.09
Other services	0.02

8.1.2 TAG

The TAG methodology was developed by the UK DfT. The general process as implemented in the Zenith EAM is:

1. Select appropriate measure of travel cost (generalised cost is specified for TAG).
2. Calculate the effective density of employment in the base and project cases, from which the percentage change in effective density is calculated. For TAG, the percentage change is a different value by zone and by industry, as the decay parameter is industry specific. An inverse function is used for the decay rate.
3. Estimate the change in productivity between the base and project cases. This is industry-specific, as the agglomeration elasticity is industry-specific.
4. Estimate change in gross value added (GVA) between the base and project cases. This requires the GVA by industry, and in the current implementation a single GVA by industry is applied across all travel zones. Note that GVA by industry is calculated for each industry as GVA per worker x employment (i.e. number of workers). GVA per worker is part of the change in productivity calculation in step 3.

The formulation for agglomeration benefits, as adapted from UK DfT (2014) is as follows:

$$A_o = \sum_i (P_{EJD,o} * GDP_i * E_{o,i,base})$$

Where:

- A_o = agglomeration benefit for originating zone *o*
- ρ_i = productivity elasticity for industry category *i*
- GDP_i= GDP output per worker for industry category *i*
- $E_{o,i,base}$= base case employment for industry category *i* for originating zone *o*
- $P_{EJD,o}$= percentage change in effective job density for originating zone *o* between the project case and base case, which is calculated by:

$$P_{EJD,o} = \left(\frac{EJD_{o,project}}{EJD_{o,base}}\right)^{\rho_i} - 1 = \left(\frac{\sum_d \frac{E_{d,project}}{g_{o,d,project}}}{\sum_d \frac{E_{d,base}}{g_{o,d,base}}}\right)^{\rho_i} - 1$$

Where:

- $EJD_{o,project}$ = effective job density for originating travel zone *o* in the project case
- $EJD_{o,base}$= effective job density for originating travel zone *o* in the base case
- $E_{d,project}$ = total employment in destination zone *d* in the project case
- $E_{d,base}$ = total employment in destination zone *d* in the base case
- $g_{o,d,project}$ = generalised cost of travelling to zone *d* (from originating zone *o*) in the project case by car in the inter-peak
- $g_{o,d,base}$ = generalised cost of travelling to zone *d* (from originating zone *o*) in the project case by car in the inter-peak

The elasticities and decay parameters specified by TAG can be found in Table 8.3 below.

Table 8.3 – Agglomeration Elasticities and Decay Factors. Source: UK DfT TAG (2012), Agglomeration Table 1, grouped into ANZSIC1993 categories by EY (2017)

Employment Category	Productivity Elasticity* ρ_i	Decay Factor
Agriculture	n/a	n/a
Mining	n/a	n/a
Manufacturing	0.021	1.097
Electricity, Gas & Water	n/a	n/a
Construction	0.034	1.562
Wholesale	0.024	1.818
Retail	0.024	1.818
Recreation and Personal services	n/a	n/a
Transport & Storage	0.024	1.818
Communication	0.024	1.818
Financial & Business	0.083	1.746
Public Administration	n/a	n/a
Community services	n/a	n/a

Note that TAG specifies the use of demand weighted-average car and public transport generalised costs, for a daily (24-hour) travel time. The implementation in Zenith uses the car inter-peak generalised cost.

8.1.3 East West Link Business Case

The following methodology was developed during the East West Link Business Case. This method accrues agglomeration benefits where an increase in effective job density (and therefore productivity) is introduced, using the following formulation:

$$A_o = \sum_i (P_{EJD,o} * \rho_i * GDP_i * E_{o,i,base})$$

Where:

- A_o = agglomeration benefit for originating zone *o*
- ρ_i = productivity elasticity for industry category *i*
- GDP_i= GDP output per worker for industry category *i*
- $E_{o,i,base}$= base case employment for industry category *i* for originating zone *o*
- $P_{EJD,o}$= percentage change in effective job density for originating zone *o* between the project case and base case, which is calculated by:

$$P_{EJD,o} = \left(\frac{EJD_{o,project}}{EJD_{o,base}}\right) - 1 = \left(\frac{\sum_d \frac{E_{d,project}}{g_{o,d,project}}}{\sum_d \frac{E_{d,base}}{g_{o,d,base}}}\right) - 1$$

Where:

- $EJD_{o,project}$ = effective job density for originating travel zone *o* in the project case
- $EJD_{o,base}$= effective job density for originating travel zone *o* in the base case
- $E_{d,project}$ = total employment in destination zone *d* in the project case
- $E_{d,base}$ = total employment in destination zone *d* in the base case
- $g_{o,d,project}$ = generalised cost of travelling to zone *d* (from originating zone *o*) in the project case by car in the inter-peak
- $g_{o,d,base}$ = generalised cost of travelling to zone *d* (from originating zone *o*) in the project case by car in the inter-peak

The methodology employed by the Zenith EAM utilises the percentage change in effective job density (EJD) as the key driver of agglomeration benefits. The calculation of EJD in turn employs a decay function defined as an inverse relationship with respect to generalised cost for cars in the inter peak period ($g_{o,d,project}$ and $g_{o,d,base}$). In Zenith, the 'generalised cost' for cars incorporates a weighted summation of travel time, toll costs and fuel costs, which means that the resultant EJD (and hence, agglomeration benefit) is dependent on all three components of travel.

This methodology uses productivity elasticities obtained from SGS, which are listed in Table 8.4 below.

Table 8.4 – Productivity elasticity by ANZSIC 1993 industry category. Source: SGS Economics & Planning (2012) where available, otherwise NZTA (2010)

Employment Category	Productivity Elasticity* ρ_i
Agriculture	0.03
Mining	0.03
Manufacturing	-0.11
Electricity, Gas & Water	0.03
Construction	0.13
Wholesale	0.02
Retail	0.06
Recreation & Personal Services	0.28
Transport & Storage	-0.05
Communication	0.09
Financial & Business	0.11
Public Administration	0.20
Community Services	0.09

8.2 Labour Supply

The Zenith EAM provides a means to calculate labour supply benefits by determining the change in generalised travel costs for home-based work (commuter) trips. These are presented in the "*report_LabourSupply*" tab of the Zenith EAM Spreadsheet, grouped by a nominated spatial sector system (e.g. SLA) in terms of generalised transport costs (2008 AUD). This provides a flexible platform for users of the EAM to apply their own methodologies to calculate the corresponding labour supply tax wedge.

The following approach is used to calculate the commuter generalised cost savings:

$$L_n = \sum_{h,w,t} N_{h,w,t}(G_{h,w,t,project} - G_{h,w,t,base}) + \sum_{w,h,t} N_{w,h,t}(G_{w,h,t,project} - G_{w,h,t,base})$$

Where:

- $N_{h,w,t}$ = number of home-based work person car trips (including both drivers and passengers) which travel from home zone *h* to work zone *w* during time period *t*;
- $N_{w,h,t}$ = number of home-based work person car trips (including both drivers and passengers) which travel from work zone *w* to home zone *h* during time period *t*;
- $G_{h,w,t,scenario}$ = generalised travel cost associated with travelling from home zone *h* to work zone *w* by car in the given *scenario* (either *base* or *project* case) during time period *t.*
- $G_{w.h,t,scenario}$ = generalised travel cost associated with travelling from work zone *w* to home zone *h* by car in the given *scenario* (either *base* or *project* case) during time period *t.*

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Appendix A – Source Accident Rate & Cost Parameters

Table A.1 – Default Urban Accident Rates. Source: VicRoads, "Accident Analysis by Road Profile Study Operational Report", January 1996 Table 3.1 (Updated by T Boyd 2010)

Road Type			**2010 Estimated Urban Casualty Rates (acc/10^8 veh-km)**
1	Old Freeways	Inner City 4 lanes	**10.60**
2	South Eastern Art	Toorak to Warrigal	**9.44**
3	High Standard Fwys		**5.65**
4	All Freeways		**6.94**
5	Primary Arterials	Divided with Trams	**25.79**
6	Primary Arterials	Undivided Trams	**33.98**
7	Primary Arterials	Divided No Trams	**16.83**
8	Primary Arterials	Undivided No Trams	**20.83**
9	All Primary Arterials		**19.43**
10	Secondary Arterials	Divided Trams	**43.03**
11	Secondary Arterials	Undivided Trams	**44.99**
12	Secondary Arterials	Divided No Trams	**24.09**
13	Secondary Arterials	Undivided No Trams	**28.91**
14	All Secondary Arterials		**30.78**
15	Primary Arterial/Service Roads		**14.86**
16	All Melbourne Arterials		**23.16**

Table A.2 – Estimated accident costs by state and injury severity (June $AUD2013) (source: NGTSM 2015, Table 4.8)

Table 4.8: Estimation of crash costs by injury severity, Inclusive WTP values[9], June $2013

State	Rural			Urban		
	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)	Fatal crash ($)	Serious injury crash ($)	Other injury crash ($)
New South Wales[10]	7,848,085	216,675		6,476,155	136,505	
New South Wales[11]	8,947,869	543,335		8,298,633	659,881	
Victoria	8,611,365	499,138	48,429	8,409,584	594,663	39,848
Queensland	8,331,930	507,261	47,699	7,955,196	633,652	38,566
South Australia	8,905,039	504,427	48,175	7,780,230	611,175	38,110
Western Australia	8,820,027	507,601	53,513	8,001,286	617,588	43,661
Tasmania	8,302,092	460,750	52,429	7,720,934	563,748	42,488
Northern Territory	8,343,480	522,627	44,779	8,780,310	655,048	37,888
Australian Capital Territory				9,233,736	567,583	

Source: ARRB Group Ltd.

Appendix B – Aggregation of Link based Attributes to OD Attributes

Often the methodologies laid out in the above document require the calculation of metrics at the link level (for example congested time, fuel consumption, vehicle operating costs etc.) but the final application of the economic evaluation requires that these metrics be available at the Origin-Destination level so that they can be realistically combined with demand matrices.

The methodology used within the Zenith EAM to convert link based metrics to a suitable form is as follows

1. Determine the given metric for each link in the network, disaggregated by modelled time period.
2. For each Origin-Destination zone pair within each modelled time period
    a. selecting the path through the network which minimises the route choice cost function (typically this is chosen as the shortest cumulative travel time)
    b. calculate the summation of the relevant metric across this path and store this in the appropriate cell within the output matrix

This process is obviously only applicable to metrics which can be additively aggregated.

As a practical example let us consider the congested time metric. This metric is calculated by converting the volume on capacity ratio (VCR) to a cost (expressed in minutes) using a piece-wise linear conversion function. As a first step the VCR on each link is calculated, and then converted to units of time (which can be additively aggregated). The above process is then applied to calculate the overall perceived congested time that is incurred for each OD pair.

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