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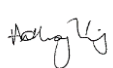
ECONOMIC OUTCOMES REPORT - MAJOR TRANSPORT INFRASTRUCTURE

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Title	**Economic outcomes report - major transport infrastructure**
Client	Infrastructure Victoria ABN: 83 184 746 995
Prepared by	**AECOM Australia Pty Ltd** | Level 10, Tower Two, 727 Collins Street, Melbourne VIC 3008, Australia T +61 3 9653 1234 F +61 3 9654 7117 www.aecom.com ABN 20 093 846 925
In Association with	
Reviewed by	**Anthony King, Michael Byrne, Bruce Johnson**
Ref	
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			Name/Position	**Signature**
1	26-Feb-2021		Anthony King, Technical Director	
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4	7 Jul-2021		Anthony King, Technical Director	

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EXECUTIVE SUMMARY

Project Scope

To support the development of *Victoria's infrastructure strategy 2021 –2051* (Victoria's infrastructure strategy), AECOM and Arup were engaged to provide high level preliminary cost estimation, demand modelling and economic analysis of several transport projects and scenarios as selected and specified by Infrastructure Victoria (IV).

IV has identified the selected projects taking into consideration their potential benefits to address future key challenges. This includes future population growth in areas expected to come under pressure; improving access to jobs and services between the city, key precincts, and outer suburban and growth areas; and to support *Plan Melbourne's* direction 1.1, that being to create a city structure that strengthens Melbourne's competitiveness for jobs and investment. The selected projects also have the potential to encourage better use of existing assets through improved road network operation systems and to complement other major transport projects already under construction.

The projects are described below:

- **City Loop reconfiguration and northern rail corridor upgrade (CLR)** – a broad group of interrelated changes to the rail network facilitating increased service provision along the Craigieburn, Frankston and Glen Waverley corridors. Also includes new stations and the extension of metropolitan rail services towards Wallan.

- **Cross city motorway (CCM)** – the widening of the Eastern Freeway from Chandler Highway inbound and a new road tunnel that forms an east-west connection connecting the Eastern Freeway and CityLink to West Gate Tunnel.

- **Melbourne Metro Two and direct Geelong rail line (MM2)** – the construction of a new rail tunnel connecting Newport to Clifton Hill, to support additional train services on Hurstbridge, Mernda, and Werribee / Williamstown services and support direct electrified train services to Geelong.

- **Outer Metropolitan Ring Road (OMR)** – a new tolled ring road across Melbourne's outer western and northern suburbs, facilitating 100 km/h travel for private vehicles and freight. While the corridor will ultimately be used for rail freight also, no rail freight has been considered as part of this scope.

- **Road management systems (RMS)** – a combination of network-wide operational improvements, such as improved traffic signal timings, for arterial roads in metropolitan Melbourne as well as lane configuration changes on select corridors to assist with traffic flows and public transport reliability and punctuality, assumed to drive an increase in efficiency across the network.

- **Western rail corridor upgrade (WRU)** – upgrades to the Melton rail corridor to support extension of the metropolitan rail services from Sunshine to a new station at Mount Atkinson. This would also enable increased capacity to the Pakenham/Cranbourne corridors in Melbourne's south-east.

Approach

AECOM and Arup have supported IV to develop cost estimation, demand modelling and economic analysis to support an overarching project appraisal presented in the IV Major Transport Program Strategic Assessment Report, which has been used to inform recommendations in *Victoria's infrastructure strategy*, as shown below:

Figure 1   The role of Arup / AECOM work in informing the Recommendations for Victoria's infrastructure strategy
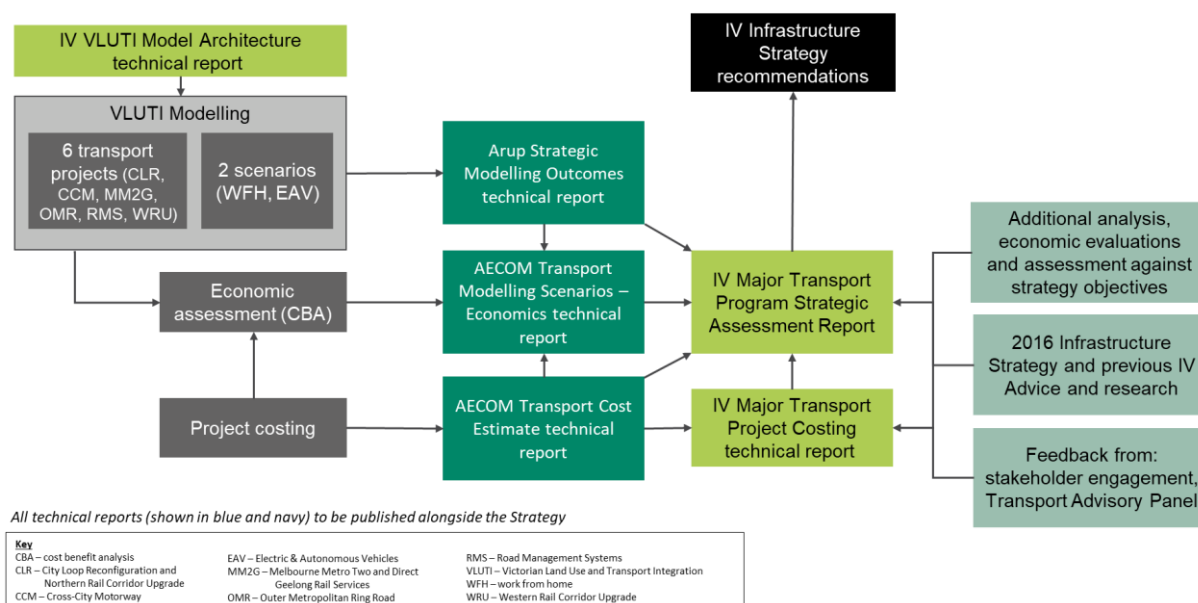
The core of the economic assessment was a Cost Benefit Analysis (CBA) undertaken on each project. The CBA took into account the capital and operational costs of each project and 50 years of operational benefits. The construction periods and opening years of each project differed, and the MM2 and OMR assessments considered two project stages with distinct construction periods.

The costs of the CBA comprised project capital costs, maintenance and operational costs, and asset replacement costs (where applicable). These were presented in Present Value (PV) terms.

Benefits were also presented in PV terms. Benefits were derived from Victorian Land Use and Transport Integration model (VLUTI), and considered the following elements:

- Static land use benefits ('static benefits') – these are the benefits that accrue as a result of each project where there are no changes in land use. This measure provides an understanding of the transport benefits only accruing from a project, and its impact on travel patterns.

- Benefits when land use change is taken into account ('dynamic benefits') – these are the benefits which accrue as a result of a project when land use changes are taken into account. Land use changes are derived from the VLUTI Model. This analysis estimates benefits which reflect not just changing travel habits, but also changes in the distribution of population and jobs as a result of a project.

- Wider Economic Benefits (WEBs) – these represent the improvements in economic welfare acknowledged but not generally quantified in a traditional CBA. They have been calculated for: agglomeration economies (WEB1), output change in imperfectly competitive markets (WEB2) and tax revenues from labour markets (WEB3).

A traditional CBA for a transport project typically captures only static benefits and does not consider the benefits associated with land use changes or WEBs. This means that a traditional CBA does not capture a range of impacts that result from a project and may consequently understate project benefits. In particular, a CBA which includes only static benefits does not account for productivity changes as a

result of induced land use changes over time, or the benefits to the wider economy of changes in employment and population redistribution.

The inclusion of both dynamic benefits (resulting from land use changes) and WEBs in this analysis therefore represents a break from the 'standard' CBA and has sought to build on the conventional transport CBA methodology with a more innovative approach.

An overview of the different elements of the CBA is illustrated in Figure 2.

Figure 2   CBA framework
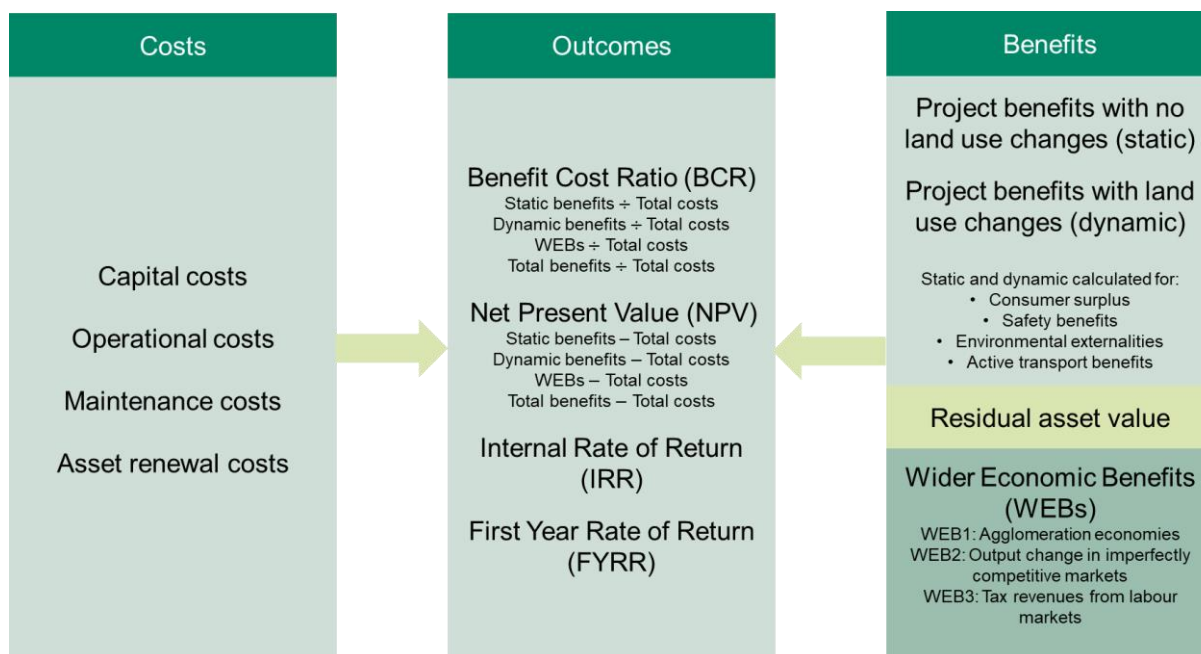
While the CBA for these six projects provides a more holistic review of benefits compared to the standard approach, there are other benefits, such as local amenity, that are not able to be monetised. That said, changes in residential and employment patterns may reflect changes in amenity at a local level.

Presentation of results

Economic results are contained in six Sections, one for each of the projects. Results have been presented in a range, using two different discount rates. The rationale for this approach is that each of the projects has elements of both economic and social infrastructure, and they are planned for a long way in the future with a long appraisal period. Given the uncertainty about the network and the demands on it many decades from now, a range provides a more conservative approach to the estimation of possible outcomes. It is therefore appropriate to adopt a range as part of the core assessment rather than results represented by a single discount rate.

Two core discount rates have been used. A discount rate of seven percent has been used as the upper end of the range, on the basis that it is the recommended discount rate for investments in traditional core service delivery areas of government. A discount rate of four percent has been used as the lower end of the range, as this is the recommended rate where projects carry a high level of uncertainty. Given that all the projects have a low level of design development and a high level of cost contingency, four percent represents an appropriate low end for a range of results. These major projects have long lives, large impacts and a strategic focus which will benefit society more in the future, therefore, it may be prudent to place more emphasis on the four per cent discount rate values and BCR.

The following results have been presented for each project using four and seven percent discount rates:

- Benefit Cost Ratio (BCR) – the ratio of Present Value Benefits divided by Present Value Costs.

- Net Present Value (NPV) – the net value of Present Value Benefits minus Present Value Costs. NPV values are those accrued over time and subject to discounting to account for opportunity costs.

- Internal Rate of Return (IRR) – this is the rate of return that equalises the present value of benefits to the present value of costs, i.e., the discount rate, which gives an NPV of zero.

- First Year Rate of Return (FYRR) – this measures the benefits received in the first full year of a project's operation per dollar of capital cost.

- In addition, BCR and NPV results were presented for static only benefits, dynamic and static benefits, and total benefits (including WEBs).

In addition to the 'core' results, sensitivity analysis has also been undertaken. Sensitivity analysis is used as a risk assessment and mitigation tool to understand the impacts on project outcomes when certain project parameters change. Sensitivity tests used are:

- Differential discount rates (three and 10 percent).

- Changes in capital expenditure (20 percent decrease in capital costs, 20 percent increase in capital costs and 40 percent increase in capital costs).

- Changes in total benefits (40 percent decrease in total benefits, 20 percent decrease in total benefits and 20 percent increase in total benefits.

- Changes in timing of delivery (delay by 5 and 10 years).

- Changes in the value of travel time.

For the CLR and CCM projects, a further set of sensitivity tests were undertaken using the results of the conventional VITM model. Data from this model has previously been used to estimate benefits for these projects, and this test was useful to ensure that the BCRs from this study were comparable with previous analyses. The conventional VITM model was used to estimate the static benefits and WEBs for CLR and CCM in 2036 and 2051. This approach also enabled a comparison between the core modelling outcomes and when land use change was not taken into account.

Spatial analysis

A high-level spatial analysis on the distributional and equity impacts of each project was undertaken, using the outputs from the VLUTI model. This assessment seeks to complement the economic analysis, by examining in more detail the spatial impacts of each project on population and employment, and the distribution of benefits across the modelling area.

The assessment has been presented using maps, which demonstrate the spatial outcomes of different indicators, compared to the base case. The spatial analysis focuses on:

- Changes in population distribution compared to the transport base case in 2036 and 2051.

- Changes in employment distribution compared to the transport base case in 2036 and 2051.

- Changes in consumer surplus compared to the transport base case in 2036 and 2051. Consumer surplus is defined as the benefits resulting from a reduction of generalised transport costs in a project case compared to a project base case.

1. Economic report scope and purpose

Infrastructure Victoria (IV) provides independent and expert advice about Victoria's current and future infrastructure needs and priorities to support improved social, economic and environmental outcomes for the State. A key function of IV is to prepare and publish a 30-Year Infrastructure Strategy ('the Strategy'), the first of which was released in 2016. IV is required to update the Strategy every three to five years.

IV is now preparing an updated infrastructure strategy, which will be released in 2021. *Victoria's infrastructure strategy 2021-2051* will consider infrastructure needs and priorities from across the State and include a comprehensive mix of social and economic infrastructure.

As part of the consideration of optimal prioritisation and timing of planned large transport infrastructure projects, IV commissioned Arup and AECOM to model and assess six large transport infrastructure projects and a number of different 'future state' scenarios. In particular, the project had four inter-related, workstreams, these being:

- Workstream 1: Potential future scenarios (economic, policy and technological shock scenarios).
- Workstream 2: Transport modelling and assessment against a 'no project' base case (transport base case) undertaken using the Victorian Land Use and Transport Integration model (VLUTI).
- Workstream 3: Transport infrastructure costing.
- Workstream 4: Cost Benefit Analysis (Economics).

This report addresses the fourth workstream.

The economic report focuses on assessing the economic and social impacts of the six transport projects. These are:

- City Loop reconfiguration and northern rail corridor upgrade (CLR).
- Cross city motorway (CCM).
- Melbourne Metro Two and direct Geelong rail line (MM2).
- Outer Metropolitan Ring Road (OMR).
- Road management systems (RMS).
- Western rail corridor upgrade (WRU).

These six projects are described in Sections 3-8 of this report.

AECOM and Arup have supported IV to develop cost estimation, demand modelling and economic analysis to support an overarching project appraisal presented in the IV Major Transport Program Strategic Assessment Report, which has been used to inform recommendations in Victoria's infrastructure strategy, as shown below.

Figure 3   The role of Arup / AECOM work in informing the Recommendations for Victoria's infrastructure strategy
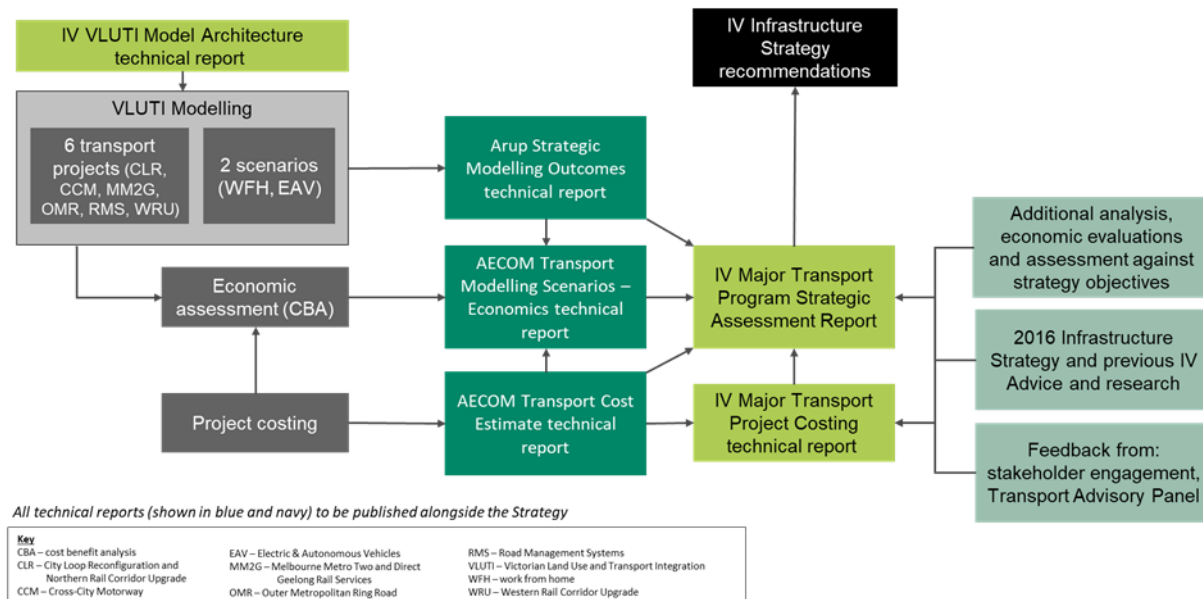
The economic assessment comprised several elements. These were:

- Cost Benefit Analysis (CBA) for the six projects, comparing the 'project case' to the transport base case for each.
- Benefits were derived from two broad sources:
  - Static and dynamic benefits, these being transport productivity benefits associated with the project. These are captured through changes in Vehicle Kilometres Travelled (VKT), Vehicle Hours Travelled (VHT) and consumer surplus. The benefits for each project have been captured under both static land use (assuming no land use changes) and dynamic land use (assuming land use changes over time) scenarios. The dynamic component recognises that major transport changes can induce land use change in their own right, and that benefits can be provided through these land use changes. Most transport CBAs focus on the benefits associated with static land use only. While important, this misses substantial quantifiable benefits as a result of changes in the distribution of people and jobs as the direct result of a project.
  - Wider Economic Benefits (WEBs) are the improvements in economic welfare acknowledged but not generally captured in traditional CBA. Consistent with Australian Transport Assessment and Planning (ATAP) guidelines, WEBs were calculated for: agglomeration economies (WEB1), output change in imperfectly competitive markets (WEB2) and tax revenues from labour markets (WEB3).
- Assessment of spatial impacts. Using some of the VLUTI model outputs, a high level assessment of equity and distributional effects resulting from the six projects was undertaken.

The economic assessment report will assist IV in understanding the impacts, benefits and opportunities of the six key projects assessed. The inputs will inform the timing for select major transport infrastructure programs and will be used to inform long term investment priorities and key transport program prioritisation for IV. In particular, the work undertaken provides insight into:

- The impacts that the development of major transport projects and technological changes could have on land use and travel patterns.
- The impact of long term work place and technology trends on patterns of land use and travel within metropolitan Melbourne and the implications for the benefits achieved through the major transport projects.

- The spatial distributions of benefits accruing from the development of major projects.

The following appendices have been provided in the report:

- Appendix A – Economic assessment framework.
- Appendix B – Project Benefit Estimation.
- Appendix C – Land use change benefit correction.
- Appendix D – Methodology to estimate WEB1 using VITM.
- Appendix E – SIRCV inputs to VLUTI.

2. Assessment framework and assumptions

A separate Economic Assessment Framework was developed for this project. This section of the report provides an outline of the framework; for more detail, please refer to the Economic Assessment Framework in Appendix A.

2.1 Cost Benefit Assessment framework

The main focus of the economic assessment was the CBA, that is, assessment of the costs and benefits respectively of each of the six projects. As noted in Section 1, the CBA comprised the following elements:

- Costs, including capital costs, maintenance and operational costs, and asset replacement costs (where applicable).

- Static and dynamic benefits, derived from the VLUTI Model. Static benefits are those that accrue from a project with no changes to land use; dynamic benefits are those which accrue from a project once land use changes have been considered.

- WEBs.

An overview of the different elements of the CBA is illustrated in Figure 4.

Figure 4   Cost Benefit Analysis framework diagram
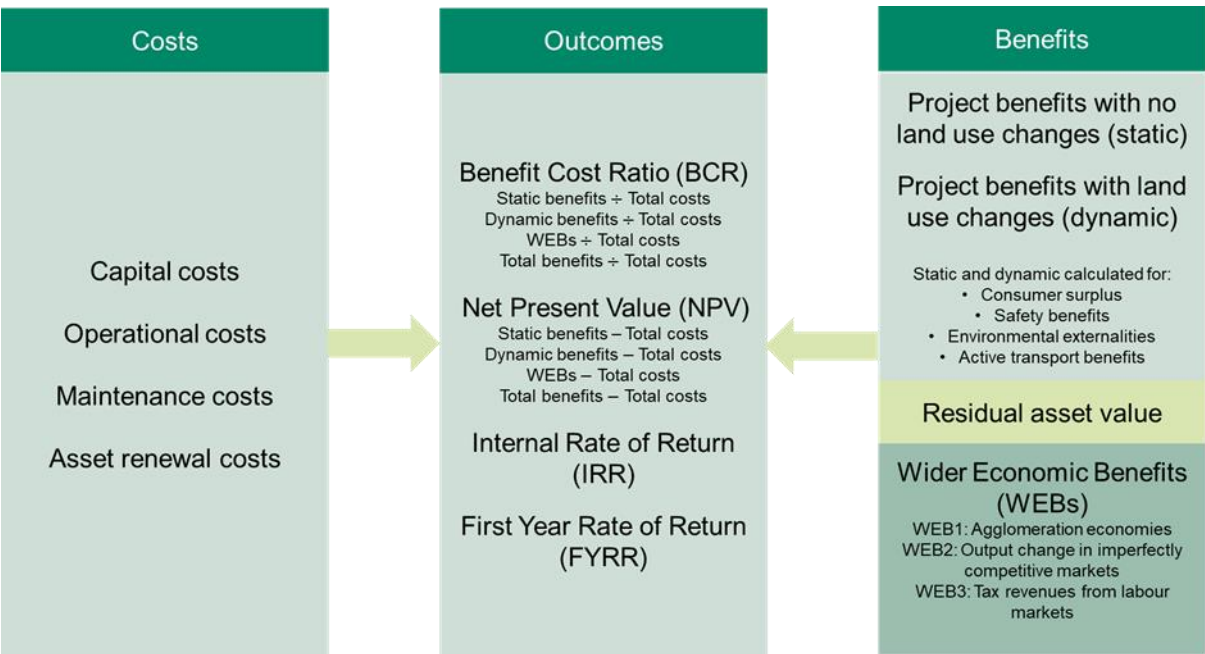
In addition to the CBA component, another part of the report considers the equity and distributional impacts associated with land use changes. This is a qualitative assessment, which considers the equity and distributional impacts of each project separately.

CBA assessments of transport projects typically capture only static benefits, and do not consider either the benefits of land use change or WEBs. This is reflected in the 'standard' advice provided by ATAP and other transport economic assessment guidelines. This assessment recognises that a standard CBA

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has significant limitations, namely that they do not capture productivity changes as a result of induced land use changes over time, and nor do they recognise the benefits that may accrue to the wider economy as a result of land use changes involving work and residential redistribution (generally involving densification of jobs and housing, often around transport nodes). The result is that a standard CBA understate the economic benefits of transport projects, particularly large scale projects which can have significant impacts on the geographic distribution of where people live and work. Further discussion of the CBA limitations is contained in Section 2.12.

This assessment, therefore, represents a break from the 'standard' CBA, and has sought to build on the conventional transport CBA methodology with a more innovative approach. While the CBA of the six projects provides a more holistic view of benefits compared to the standard approach, there are other benefits, such as local amenity, that are not able to be monetised. That said, changes in residential and employment patterns may reflect changes in amenity at a local level.

In addition to reflecting changes in land use, the difference between static and dynamic benefit calculations are also derived by the 'pool' of beneficiaries. Static modelling only takes account of new, lost and 'staying' transport network users. All users are assumed to remain *in situ*; users can, however, switch from one mode of transport to another or change their destination.

Dynamic modelling captures a more diverse group of beneficiaries. This is enabled by consideration of land use changes as part of the model. These groups are:

- New users.

- Existing users who remain at their current location and maintain existing travel patterns and mode.

- Existing users who remain at their current location but change modes or travel patterns, due to job changes or trip redistribution.

- Existing users who change residential location, and as a consequence change their travel patterns.

- Lost users.

The benefits associated with existing users who relocate are called land use correction benefits (see Appendix B for further details).

The different elements in the framework are described in Table 1.

Table 1   CBA framework – key elements

Element	Description
Costs	Costs are comprised of three elements, these being the capital cost (capex) of construction, the operating and maintenance cost (opex, which is an annual expense), and asset renewal costs. The latter is assumed to occur at the end of the asset life (or periodically during the asset life); it has been calculated by main capital components for each project (e.g. Bulk Earthworks, Retaining Walls, Drainage, Road bridge). The details of these costs are included in the AECOM report, *IV 118 Transport Cost Estimate to support Cost Benefit Analysis*, dated 2 June 2021. Note that the opex includes annual maintenance costs, asset upgrade and asset replacement costs.
Consumer surplus (changes in generalised costs)	These are the benefits of a project largely derived from changes in Vehicle Kilometres Travelled (VKT) and Vehicle Hours Travelled (VHT) under both the static and dynamic scenarios. Generalised costs comprise the following: • Changes in travel times (private vehicles, freight vehicles and public transport). • Public transport overcrowding relief on public transport services.

	• Resource corrections for vehicle operating costs including car parking costs, road tolls, vehicle maintenance and operating costs for private vehicles.
	• Changes in public transport fares.
Safety benefits	Accidents occur on the transport network for numerous reasons, including road surface quality and geometry, speed limit, congestion and other factors. Each crash may cause property damage, injury and/or loss of life; these aspects can be attributed with an economic value. Savings in crash costs are estimated via the willingness to pay method and may also consider changes to transport network safety associated with infrastructure changes. Changes in safety outcomes are derived from changes in VHT and VKT.
Environmental externalities	The transport network is a significant contributor to net greenhouse gas emissions. It also impacts the urban and natural environments in which we live through noise, visual and other pollutants. These impacts have a detrimental economic impact and are calculated using changes in vehicle composition and VKT.
Active transport benefits	Under both static and dynamic scenarios, changes in active transport travel (cycling and walking) are measured as a component of public transport travel. Examples of this change include walking to and from a train station or bus stop. Active transport impacts are measured by the community health benefits associated with cycling and walking. Note that modelling only captures active transport benefits associated with public transport travel, and does not recognise all active transport trips.
Residual asset value	The residual asset value (RAV) recognises that there is typically some value remaining in infrastructure at the end of the appraisal period. That is, while assets will be appraised over a 50-year operating period within the CBA model, the asset will endure beyond this time and continue to provide transport benefits. Residual asset value is calculated by reducing the capex value by annual depreciation amounts.
Wider Economic Benefits	WEBs capture the improvements in economic welfare acknowledged but not generally quantified in a traditional CBA. They have been calculated for: agglomeration economies (WEB1), output change in imperfectly competitive markets (WEB2) and tax revenues from labour markets (WEB3).

•

2.2 Transport and land use modelling

Derivation of CBA results including WEBs relied on the outputs of VLUTI. The VLUTI is an integration of the rapid Victorian Integrated Transport Model (VITM) and the Spatial Computable General Equilibrium (SCGE) model of Victoria developed by the Centre of Policy Studies at Victoria University. The VLUTI is able to simulate the redistribution of land use in response to changes in the transport network and has been used to estimate the land use patterns associated with each infrastructure project. Further detail on the VLUTI model can be found in Infrastructure Victoria's *2021 VLUTI Model Architecture Report.*

2.3 Overall modelling parameters

Key modelling parameters are outlined in Table 2.

Table 2   Key modelling parameters

Parameter	Assumption / value
Modelling period	50 years of operations, in addition to a construction period for each.
	Construction and operating modelling periods for each project are outlined in Section 2.6.
Discount rate	The core discount rates are sourced from the Department of Treasury and Finance (DTF), as per *Economic Evaluation for Business Cases Technical Guidelines*, August 2013.
	Two core discount rates have been selected for the analysis. The 'core' refers to the discount rates used for the standard present values and BCRs. This means that each of the NPV and BCRs (and other monetised results) are in effect presented as a range. The rationale for this approach is as follows:
	• The projects are planned a long way in the future, and with operating periods of 50 years being captured in the analysis, this means that there is a high level of uncertainty about future demands on the network.
	• The low level of design certainty means that a high level of contingency is used. As project design progresses and site conditions and risks are better understood, these contingencies would be expected to reduce.
	Seven percent is the recommended discount rate for investments in traditional core service delivery areas of government for which benefits attributed to the project can be translated to monetary terms (e.g. public transport and roads). This is a real discount rate, based on the long-term average government bond rates.
	While the seven percent discount rate has been applied as part of the core analysis, a discount rate of four percent has also been used. This is consistent with DTF's guidelines, and is generally applied for investments which can be difficult to translate into monetary terms. In this instance, the high level of uncertainty about future demand scenarios is addressed through the use of the four percent discount rate.
	Discount rates of three and ten percent have been applied as part of the sensitivity analysis.
Modelling base case	The base case for the transport modelling of the six projects (and consequently, the CBA) is derived from the Network Development Scenario (NDS) minus all of the six projects (referred to as the Transport Base Case). Project cases have been developed using the Transport Base Case plus the addition of the project being modelled.
Transport modelling – deriving annual benefits	Benefits have been derived from VLUTI based on two years only, these being 2036 and 2051. VLUTI produces land use and traffic results for an average non-school holiday weekday and that the results adopt an annualisation factor (see Section 2.5). Benefits for the years between 2036 and 2051 have been estimated based on a 'straight line' derivation.
	Benefits growth after 2051 is assumed to be the same as estimated population growth by region. These estimates have been sourced from *Victoria in Future 2019,*

Population Projections 2016 to 2056 (July 2019), Department of Environment, Land, Water and Planning.

This approach is described in more detail in Section 2.5.

2.4   Approach to sensitivity analysis

Sensitivity analysis is used as a risk assessment and mitigation tool to understand the impacts on project outcomes when certain project parameters change. In this report, a range of different sensitivity tests have been applied, these being:

- Changes in discount rates.

- Changes in capital expenditure.

- Changes in total benefits.

- Changes in timing of delivery (delay by 5 and 10 years). These tests were selected as a realistic way of testing modest delays in the commencement of projects.

- Changes in the value of travel time.

- Use of the conventional VITM as static scenario tests for CCM and CLR.

All of the sensitivity tests except the changes in behaviour/technology are consistent with those recommended in *Economic Evaluation for Business Cases Technical guidelines, August 2013*, from the Victorian Department of Treasury and Finance.

The approach for each of these tests is described below.

Differential discount rates

Discount rates of three percent, typically applied for social infrastructure, and ten percent, which may be applied to commercial investments, have been adopted.

The discount rate is a critical parameter in cost-benefit analysis whenever costs and benefits differ in their distribution over time, especially when they occur over a long time period. Discounting is based on the concept of time preference. Time preference is reflected in positive market interest rates, which show that a future dollar is worth less than a current dollar. This occurs for several reasons: impatience, the expectation that wealth will grow over time, opportunities for productive investment, and uncertainty. Discounting acknowledges the opportunity costs of investing in a particular project by asking what return it would have produced in an alternative use. Ultimately, no single discount rate can precisely meet the characteristics of every public sector project. It is therefore important to sensitivity test results. The values of three and ten per cent represent a meaningful range to test whether the outcome of a CBA is very sensitive to the choice of discount rate. These major projects have long lives, large impacts and a strategic focus which will benefit society more in the future, therefore it may be prudent to place more emphasis on the four per cent discount rate values and BCR.

Changes in capital expenditure

This refers to the test which assumes changes in the capital cost compared to the central case. The sensitivity tests have been undertaken for the following capital expenditure (capex) scenarios:

- Capex which is 20 percent less than the central case cost

- Capex which is 20 percent above the central case cost

- Capex which is 40 percent above the central case cost.

Changes in benefits

Benefits sensitivity has been undertaken by testing the BCR and present value (PV) of each project by changing the total monetised benefits to:

- 60 percent of total benefits
- 80 percent of total benefits
- 120 percent of total benefits.

Changes in timing of project delivery

Sensitivity testing has been done for the following changes in the construction program, (and consequently the timing of the commencement of operations for each project):

- Delay construction by five years
- Delay construction by ten years.

Note that for each of these tests, 50 years of operating impacts has been captured.

Changes in the value of travel time

The value of each hour of travel time is expected to increase over time. This recognises that, over time, productivity and real incomes tend to increase, so that an additional hour spent travelling has a larger 'loss' associated with it.

For this sensitivity test, it is assumed that the real value of time will increase by one percent per annum. This estimate has been sourced from the Australian Transport Council.

2.5 Traffic assumptions

Daily traffic modelling inputs and benefits were provided by the VLUTI model for the years 2036 and 2051. To convert these into annual values, expansion factors shown in Table 3 were used.

Table 3   Volume expansion factors (source, DoT for train, tram and bus; TfNSW for private vehicle and freight)

Volume expansion factor	Volume expansion factor	Source
Daily urban road to annual urban road	345	Transport for NSW
Daily public transport to annual public transport (multi-mode)	291	Department of Transport
Daily Rail to annual Rail	291	Department of Transport
Daily Tram to annual Tram	306	Department of Transport
Daily Bus to annual Bus	275	Department of Transport

The 2036 and 2051 annual values were interpolated to get the values for the years in between 2036 to 2051. Population growth rates shown in Table 4 were used to extrapolate annual traffic volumes and benefits pre and post 2036 and 2051. The Melbourne population growth rate post 2051 was used to extrapolate traffic after 2051 for all projects. The Melbourne population growth rate pre 2036 was used to extrapolate traffic pre 2036 for CCM, CLR, MM2 and RMS.

Different population growth assumptions were applied for the OMR and WRU projects, on the basis that the projects are located in regions experiencing above average growth. This assumption has only been made for the period 2021-36. This means that:

- The estimated population growth rate of Northern Metropolitan Region LGAs 2018-2036 was used to extrapolate traffic pre 2036 for the OMR project.[1]

- The estimated population growth rate of Melton LGA 2018-2036 was used to extrapolate traffic pre 2036 for the WRU project.

Table 4   Growth rates

Description	Growth rate	Source
Melbourne population growth rate pre 2036	1.75%	*Victoria in Future 2019, Population Projections 2016 to 2056* (July 2019), Department of Environment, Land, Water and Planning.
Melbourne population growth rate post 2051	1.24%	
OMR population growth rate pre 2036	2.7%	
WRU population growth rate pre 2036	4.2%	

2.6   Costs

Costs were developed to provide an Order of Magnitude (OoM) cost for each of the six projects. The costs comprise capital costs (capex), and maintenance and operational costs (opex). Maintenance and operational costs have been estimated for 50 years of operation (post-construction). Detailed cost information is provided in the *IV 118 Transport Cost Estimate to support Cost Benefit Analysis*, prepared by AECOM and dated 2 June 2021.

The construction and operating period assumptions are outlined in Table 5. Note that for the purposes of this assessment, the MM2 and OMR have been divided into two construction stages. Timing and scope for each stage has been agreed with IV.

Table 5   Construction and operating periods for modelling

Project	Capital		Operating	
	Opening year	Final year	Opening year	Final year
CLR	1/07/2031	30/06/2035	1/07/2035	30/06/2085
CCM	1/07/2029	30/06/2035	1/07/2035	30/06/2085
MM2 Stage 1	1/07/2029	30/06/2040	1/07/2040	30/06/2090
MM2 Stage 2	1/07/2035	30/06/2043	1/07/2043	30/06/2090
OMR Stage 1	1/07/2030	30/06/2035	1/07/2035	30/06/2085
OMR Stage 2	1/07/2044	30/06/2050	1/07/2050	30/06/2085
RMS	1/07/2021	30/06/2035	1/07/2026	30/06/2075
WRU	1/07/2029	30/06/2035	1/07/2035	30/06/2085

Project construction timing varies between 14 years (RMS) and four years (CLR). Note that RMS is anticipated to comprise ongoing network improvements during its construction period, but sufficient infrastructure would be put in place to commence operations by 2026. For projects which are staged, the operating period modelled begins at the end of the first construction and continues for 50 years. This means that, for second stages of construction, less than 50 years of operating impacts are captured.

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[1] These are the Cities of Banyule, Darebin, Hume, Moreland, Nillumbik and Whittlesea

For instance, while the OMR Stage 1 operating period is modelled for 50 years (2035-85), only 25 operating years are captured for OMR Stage 2 (2050-85).

Real percentage growth rates were adopted in order to escalate capital costs. Table 6 summaries the real per annum percentage growth rates used for escalation in the different projects.

Table 6   Real per annum percentage rates for escalation

Project Type	2019-2020	2020-21	2021-22	2022-23	2023-51
Rail	4.7%	3.0%	2.5%	2.2%	1.6%
Road	4.7%	3.1%	2.5%	2.2%	1.7%
Tunnel (Road)	3.8%	2.5%	2.1%	1.9%	1.4%

Capital and operating cost totals, by project, are outlined in Table 7. The Present Value (PV) totals have been used to derive the BCR. Values have been calculated, and are presented, in 2021 dollars.

Table 7   Capex and opex cost profile (nominal with escalation and PV, four and seven percent discount rates)

Project	Nominal capex ($m)	PV capex ($m)	Nominal opex ($m)	PV opex ($m)	Nominal asset renewal ($m)	PV asset renewal ($m)
CCM	$16,383	$6,990 - $9,993	$975	$104 - $242	$452	$13 - $53
CLR	$8,932	$3,790 - $5,430	$3,440	$368 - $853	$3,644	$223 - $657
CLR (including Beveridge to Wallan)	$9,615	$4,069 - $5,837	$3,440	$368 - $853	$3,644	$223 - $657
MM2 total (staged)	$54,004	$17,207 - $27,663	$7,271	$515 - $1,433	$4,798	$196 - $689
OMR total	$49,396	$16,758 - $25,770	$1,666	$154 - $379	$6,438	$245 - $892
RMS	$5,471	$3,537 - $4,210	$962	$87 - $216	$0	$0 - $0
WRU	$2,784	$1,210 - $1,716	$2,358	$252 - $585	$816	$40 - $129

Table 8   Total costs (nominal with escalation and PV, four and seven percent discount rates)

Project	Nominal cost ($m)	PV cost ($m)
CCM	$17,811	$7,107 - $9,892
CLR	$16,016	$4,381 - $6,674
CLR - dynamic	$16,699	$4,660 - $7,064
MM2 (total, Staged)	$66,073	$17,918 - $28,640
OMR (total)	$57,500	$17,157 - $26,001
RMS	$6,433	$3,624 - $4,256
WRU	$5,958	$1,502 - $2,337

2.7   Conventional benefits

As noted earlier, conventional or standard benefits are those that are typically estimated for transport projects and comprise:

- Generalised cost savings or consumer surplus, including travel time, overcrowding on public transport, vehicle operating costs, and fares and tolls.

- Environmental externalities (such as greenhouse gases, other emissions and noise).

- Safety benefits (i.e. reduction in crash costs).

- Active transport benefits (health and other benefits associated with increases in walking and cycling).

- Residual asset value (which has been calculated for all assets).

These are usually estimated using *static* transport models only, i.e. they generally do not account for changes in land use. Estimation of these benefits using static land use is reflected in key transport economics guidelines, including ATAP and those of Transport for NSW.

Because the VLUTI model has been used, this means that these benefits have been calculated to account for changes in land use, specifically changes in the location of jobs and where people live. For this reason, this economic assessment has been able to capture *dynamic* benefits, i.e. those conventional benefits that accrue as a result of both the transport project in question *and* the associated land use changes as a result of that project. Static (no change in land use) benefits derivation can therefore be considered a sub-set of dynamic conventional benefits.

Compared to using a static transport model which does not account for land use changes, such as VITM, this approach provides a more holistic approach to identifying project benefits. As noted in Section 2.2, VITM is one component of the overall VLUTI model.

Throughout the report, there are references to static and dynamic benefits. The dynamic benefits have been calculated considering the change in land use as a result of the project, as calculated by the VLUTI model. Static benefits have been estimated assuming no change in land use between the case and project case.

VLUTI provided the following outputs which provide the demand information for the CBA model:

- VKT – changes in total number of kilometres travelled on the network between the base case and project case. These were calculated for 2036 and 2051.

- VHT – changes in total hours spent travelling between the base case and the project case. These were calculated for 2036 and 2051.

- Consumer surplus – this captures changes in costs associated with time and convenience, such as travel time changes, inconvenience, overcrowding on public transport, public transport fares and tolling, between the transport base case and the project case. This was calculated for 2036 and 2051.

Appendix B provides in detail the methodology and results of conventional benefits for CCM, CLR, MM2, OMR, RMS and WRU for both static and dynamic scenarios in 2036 and 2051. Appendix C presents a methodology to estimate a correction of land use change benefits applicable to dynamic land use scenarios. This approach also enabled a comparison between the core modelling outcomes and when land use change is not taken into account.

2.8   Wider Economic Benefits

WEBs represent improvements in economic welfare that are not usually captured in a conventional CBA. In addition to the estimation of dynamic conventional benefits, the inclusion of WEBs in the CBAs for

the six projects represents an advance in the breadth of benefits typically captured in transport projects in Victoria.

Three WEBs have been estimated for each project. These are described in Table 9.

Table 9   Description of WEBs

WEB name	Description
WEB1: Agglomeration benefits	Agglomeration benefits are productivity advantages generated when connectivity is improved between firms and workers. Firms derive productivity benefits from being close to one another (e.g. supply chain, knowledge sharing etc.) and from being efficiently connected to labour markets. SIRCV was used to calculate WEB1 dynamic benefits.
	WEB1 is calculated by:
	{elasticity of productivity x the percentage change in worker effective density due to the scheme} x the GDP/worker of each industry sector x employment.
WEB2: Output change in imperfectly competitive markets	This WEB reflects the ability of companies to profitably increase their output based on a reduction in transport costs.
	WEB2 = the imperfect competition uprate factor (0.1) x the conventional business (in-work) user cost savings.
WEB3: Tax revenues from labour markets	Tax revenues collected by government may increase if, as a result of transport infrastructure, more people decide to work, increase the hours they work and/or are able to change to a higher paying or more productive job.
	The Spatial Interactions Within and Between Regions and Cities in Victoria (SIRCV) model estimates utility and disutility for different categories of commuters associated with change. For VLUTI outcomes, SIRCV has been used to estimate expected utility associated with a change in place of residence by occupation. Please note that SIRCV has been used to estimate WEB3.
	This WEB could be estimated as a tax component of the following outcomes:
	• More people choosing to work as a result of commuting time savings
	• Some people choosing to work longer hours because of reduced commuting times
	• Workers changing jobs to a more distant but higher productivity (higher wage) area because of reduced travel times (estimated through SIRCV).

Appendix B provides in detail the methodology for and results of the estimation of WEBs. Appendix D presents the methodology to estimate WEB1 independently using the VITM. Appendix E provides a detailed description of the SCGE modelling as well as the methodology to estimate WEB1 and WEB3 by comparing the gross state products between a project and the base, which were used as the inputs to the CBA. The WEB1 estimated by VITM was used to crosscheck the SCGE results. As noted earlier, details of the VLUTI model are contained in Infrastructure Victoria's *VLUTI Model Architecture Report*.

2.9   CBA calculations

The following CBA outcomes have been presented in this report:

• Benefit Cost Ratio (BCR) – the ratio of Present Value Benefits divided by Present Value Costs. A project or set of projects with a ratio greater than 1 is considered to have a positive economic return.

- Net Present Value (NPV) – the net value of Present Value Benefits minus Present Value Costs. NPV values are those accrued over time and subject to discounting to account for opportunity costs. An NPV greater than $0 provides a positive economic return.

- Internal Rate of Return (IRR) – this is the rate of return that equalises the present value of benefits to the present value of costs, i.e., the discount rate, which gives an NPV of zero.

- First Year Rate of Return (FYRR) – this measures the benefits received in the first full year of a project's operation per dollar of capital cost. It is used to indicate the best start date for a project's implementation. FYRR is calculated by dividing the present value of first year benefits by the present value of capital costs (those used to initially complete the project). The timing of a project with an FYRR greater than the specified discount rate is considered economically appropriate. Implementing a project with an FYRR less than the specified discount rate should be deferred until the FYRR exceeds the discount rate.

BCR and NPV results are presented for:

- Benefits under a static land use scenario.

- Benefits under a dynamic land use scenario.

- Benefits for static and dynamic scenarios, as well as WEBs.

2.10   Conventional VITM modelling – CLR and CCM

The Small Area Land Use Projections (SALUP) are forecasts for the distribution of people, households and jobs. They were estimated for the Network Development Scenario and have been used as the static land use input to the conventional VITM for the assessment of the major transport projects. To ensure the BCRs from this study can be comparable with other previous projects, the SALUP data were used to estimate the static benefits for CCM and CLR in 2036 and 2051 as an additional sensitivity analysis. This approach also enabled a comparison between the core modelling outcomes and when land use change is not taken into account.

2.11   Spatial analysis

A high level spatial analysis on the distributional and equity impacts of each project was undertaken, using the outputs from the VLUTI model.

The assessment has been undertaken using maps, which demonstrate the spatial outcomes of different indicators, compared to the transport base case. Spatial analysis has been undertaken for the following outputs:

- Change in population distribution compared to the transport base case in 2036 and 2051.

- Change in employment distribution compared to the transport base case in 2036 and 2051.

- Change in consumer surplus in 2036 and 2051. Public transport consumer surplus is shown for public transport projects, highway consumer surplus is shown for road transport projects.

- For maps representing population and employment changes, each dot represents a change of five residents or jobs (either positive or negative). For the consumer surplus maps, which are for changes in consumer surplus for existing, new and lost users, each dot represents a change in benefit/disbenefit equating to 120 minutes of value.

2.12   Limitations

The economic assessment relied on outputs from two related, but separate, analytical exercises, these being:

- The development of cost estimates for each project

- Strategic transport modelling using VLUTI.

Each of these outputs has its own limitations, which are outlined in detail in the respective deliverables.

With this in mind, the key limitations for this report include the following CBA limitations:

- Distribution of benefits – economic analysis seeks to identify impacts on economic efficiency. The CBA, however, does not enable us to identify different groups of beneficiaries, and is therefore not able to provide insight into income distribution effects of each project. The spatial analysis in each section of the report, however, aims to provide a high level commentary on the broader geographic impacts of each project. Note that the VLUTI model provides an insight into the distribution of benefits to the community, although does not quantify benefits to different groups.

- Some benefits are not able to be monetised – certain benefits, such as increased community amenity as a result of changed travel patterns, or impacts on socio-economic equity, are not able to be monetised in this CBA project. Social and community impacts, which are less tangible than changes in travel patterns, may still be significant, but are difficult to estimate in a CBA. While not a part of the CBA, the spatial analysis at the end of each project chapter seeks to discuss the potential equity impact associated with each project.

- Discount rate and intergenerational equity – typically, CBA gives little weight to costs that occur far in the future, and this may have the outcome of overemphasising short term impacts. High discount rates tend to give a lower value to benefits that accrue after longer periods. It does the same for the negative effects that may arise in the distant future.

- Taking into account long term economic and societal changes – all CBA models rely on extrapolations about future demand and supply behaviours, such as transport modelling results. All future demand scenarios, however, are estimates and it should be recognised that their accuracy may be impacted by long term changes in the economy and society that are not yet recognised or sufficiently understood to account for in a model.

- The costing was prepared as Order of Magnitude (OoM), reflecting the limited scope definition of each project. The cost estimate was based on desktop studies, without site visits or site investigations being carried out. Consequently, risk adjusted cost, based on detailed design and a deep understanding of site conditions, has not been undertaken.

3. Project 1: City Loop reconfiguration and northern rail corridor upgrade (CLR)

3.1   Project background

The CLR project involves reconfiguring the City Loop through constructing new single tunnel links between Flagstaff (Caufield Loop) and North Melbourne platform two (one kilometre in length), and Parliament (Northern Loop) to Richmond platform three (1.3 kilometres in length). This upgrade will enable additional services to run through the rail network's central city core, delivering a capacity uplift on the Upfield, Craigieburn and south-east rail lines, and to enable an extension of the metropolitan train network towards Beveridge and Wallan.

The rail tunnel works include the construction and formation of the tunnel and associated works such as cross-tunnels, access shaft, portal works and construction of the concrete lining, and allowance for the commissioning and de-commissioning of tunnel boring machines.

The works also encompass a provision to improve stations to allow for more passenger interchanges that would occur most likely at Richmond, but South Yarra and Burnley are also options. To allow for this, three new pedestrian bridges, two at South Yarra and one at Burnley, were put in as a provisional cost. Given the complexity at Richmond, it is assumed that these works would occur at these stations if a solution at Richmond was to cost more than this option. With Sunbury trains to deviate into the Melbourne Metro Tunnel, it is assumed that North Melbourne Station will be able to accommodate the additional interchange activity associated with this project.

Figure 5 illustrates the alignment for the City Loop's reconfiguration showing the increase and decrease in public transport capacity. The overall rail capacity in inner Melbourne is expected to increase, as illustrated below.

Figure 5   CLR Alignment

3.2   Cost and timing

The total costs estimates, inclusive of contingencies, 50 years of renewal costs and operations and O&M are shown in Table 10.

Key dates that have been assumed for the purposes of this assessment for the CLR project are as follows:

- Construction is assumed to occur over the period 2032-35 (financial years)
- Operations assessment has been undertaken for the period 2036-85 (financial years).

The CLR project has been costed on the basis of a number of separate components, these being

- City Loop Reconfiguration.
- Upfield rail corridor upgrade - Upfield to North Melbourne.
- Upfield to Craigieburn rail corridor upgrade.
- Craigieburn to Beveridge upgrade.
- Craigieburn rail corridor upgrade - Craigieburn to North Melbourne (via Broadmeadows and Essendon).
- Glen Waverley rail corridor upgrade - Glen Waverley to Richmond.

Please note that any level crossing removals are not captured under this cost, and are assumed to be a part of the Level Crossings Removal Program.

The costs for the CLR project are contained in Table 10.

PV capital expenditure for CLR is estimated is in the range $4.1-$5.8 billion, with the first year of operational benefits being realised in 2035-36.

Table 10 CLR capex and opex cost profile (nominal with escalation, 2021 dollars, discounted at four percent and seven percent)

Project	Nominal capex ($m)	PV capex ($m)	Nominal opex ($m)	PV opex ($m)	Nominal asset renewal ($m)	PV asset renewal ($m)
CLR - Costs	$9,615	$4,069 - $5,837	$3,337	$347 - $813	$3,644	$223 - $657

3.3 Benefits

Table 11 summarises the value of benefits for CLR using four and seven percent discount rates over a 50 year appraisal period.

Table 11 CLR summary of project benefits (PV, $ million, 2021 dollars, discounted at four percent and seven percent)

Benefits	Static only	Dynamic only	WEBs only	Total
Safety benefits	$68 - $151	$41 - $127		$109 - $278
Environmental benefits	$45 - $111	$102 - $291		$147 - $402
Active transport benefits	$240 - $596	-$34 - -$100		$206 - $496
Consumer surplus benefits	$3,748 - $9,408	$1,084 - $3,135		$4,832 - $12,543
Residual values	$23 - $139	$0 - $0		$23 - $139
WEBS			-$226 - -$892	-$226 - -$892
Total benefits	**$4,124 - $10,404**	**$1,193 - $3,453**	**-$226 - -$892**	**$5,091 - $12,965**

The project is expected to deliver between $5.1-$13 billion of benefits over the appraisal period, with the bulk being derived from static benefits.

The majority of the benefits are derived from consumer surplus ($4.8-$12.5 billion), derived largely as a result of public transport composite time benefits and reduced travel times, parking and vehicle operating costs for road users, and private vehicle users switching to public transit. Additional consumer surplus is realised under the dynamic scenario. This is typical of rail projects as land use around the new public transport infrastructure changes (with denser residential and employment patterns), increasing demand and therefore benefits.

By contrast, WEBs are expected to be slightly negative, mainly reflecting reductions in tax revenues from labour markets. As employment and population is redistributed to the north of Melbourne along the corridor, this may suggest that these jobs may have lower pay compared to employment in central Melbourne.

3.4 CBA outcomes

Table 12 summarises the results of the CBA conducted for CLR using four and seven percent discount rates.

Table 12   CLR CBA results (PV, $ million, 2021 dollars, discounted at four percent and seven percent)

Economic outcomes	Static	Static and Dynamic	Total (incl WEBs)
NPV	-$529 - $3,004	$664 - $4,743	$438 - $5,564
BCR	0.89 - 1.41	1.14 - 1.88	1.09 - 1.76
IRR	6.16%	7.90%	7.64%
FYRR	9.6% - 13.8%	9.1% - 13%	10.9% - 16%

Under the static scenario, the NPV ranges between -$529 million to $3 billion, with a positive BCR at the upper end of the range, and has a BCR of 1.76. BCR and NPV results are positive for the dynamic scenario. Even with a slight reduction because of WEBs, the CLR project returns a positive BCR and NPV using both the four and seven percent discount rates.

The cumulative present value of benefits and costs over the project's life year is shown in Figure 6. The green area represents the difference between costs and benefits.

Figure 6   CLR cumulative costs and benefits (PV)
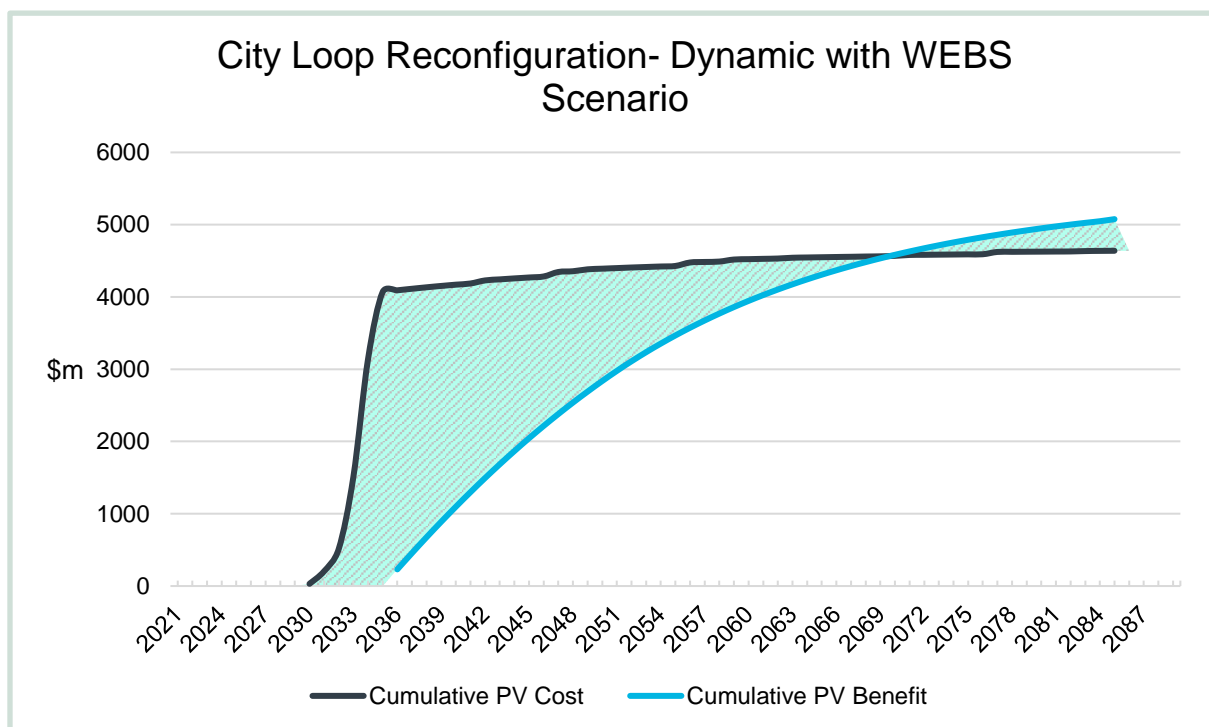
3.5 Sensitivity tests

Sensitivity tests were undertaken to understand how the viability of the project varies with changes to key variables. The results of the sensitivity analysis carried out for discount rates of three and ten percent are shown in Table 13 and Table 14. Under the three percent sensitivity test, the CLR project generates a stronger BCR (1.69) and NPV ($6 billion). By contrast, using a ten percent discount rate results in a BCR below one and a negative NPV.

Table 13   CLR sensitivity analysis - discount rates (BCR)

CLR sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
4% discount rate (central case)	*1.41*	*1.88*	*1.76*
7% discount rate (central case)	*0.89*	*1.14*	*1.09*
3% discount rate	1.69	2.28	2.12
10% discount rate	0.60	0.75	0.74

Table 14   CLR sensitivity analysis - discount rates (NPV)

CLR sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
4% discount rate (central case)	*$3,004*	*$6,456*	*$5,564*
7% discount rate (central case)	*-$529*	*$664*	*$438*
3% discount rate	$5,966	$11,051	$9,645
10% discount rate	-$1,234	-$766	-$813

Table 15 and Table 16 show the results of the sensitivity analysis for changes in capital costs. A 20 percent decrease in capital cost further strengthens economically viability with a higher BCR and NPV.

Where capital costs are decreased, the BCR and NPV is positive at both ends of the range; BCR is less than one and NPV is negative at the bottom end of the range where capital costs are increased.

Table 15   CLR sensitivity analysis - capex (BCR, discounted at four and seven percent)

CLR sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*0.89 - 1.41*	*1.14 - 1.88*	*1.09 - 1.76*
20% decrease in capital costs	1.07 - 1.68	1.39 - 2.24	1.33 - 2.10
20% increase in capital costs	0.75 - 1.22	0.97 - 1.62	0.93 - 1.52
40% increase in capital costs	0.66 - 1.07	0.85 - 1.43	0.81 - 1.33

Table 16   CLR sensitivity analysis - capex (NPV, discounted at four and seven percent)

CLR sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*-$529 - $3,004*	*$664 - $6,456*	*$438 - $5,564*
20% decrease in capital costs	$284 - $4,171	$1,478 - $7,623	$1,252 - $6,732
20% increase in capital costs	-$1,343 - $1,836	-$149 - $5,289	-$376 - $4,397
40% increase in capital costs	-$2,157 - $669	-$963 - $669	-$1,190 - $3,230

Table 17 and Table 18 show the results of the sensitivity analysis for changes in total benefits.

Where benefits are decreased, the BCR becomes less positive, although it remains above one at the top end of the range for a 40 percent reduction in benefits and for a 20 percent decrease in benefits. Where benefits are increased, the BCR and NPV remain positive and are strengthened.

Table 17   CLR sensitivity analysis - benefits (BCR, discounted at four and seven percent)

CLR sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*0.89 - 1.41*	*1.14 - 1.88*	*1.09 - 1.76*
40% decrease in total benefits	0.53 - 0.85	0.69 - 1.13	0.66 - 1.06
20% decrease in total benefits	0.71 - 1.13	0.91 - 1.51	0.88 - 1.41
20% increase in total benefits	1.06 - 1.69	1.37 - 2.26	1.31 - 2.11

Table 18   CLR sensitivity analysis - benefits (NPV, discounted at four and seven percent)

CLR sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*-$529 - $3,004*	*$664 - $6,456*	*$438 - $5,564*
40% decrease in total benefits	-$2,173 - -$1,121	-$1,457 - $951	-$1,593 - $416
20% decrease in total benefits	-$1,351 - $941	-$396 - $3,704	-$577 - $2,990
20% increase in total benefits	$293 - $5,066	$1,725 - $9,209	$1,453 - $8,139

Table 19 and Table 20 show the results of the sensitivity analysis for the delay in opening year. For the static, static and dynamic and total scenarios, the delay improves the BCR (above one at both ends of the range) and ensures that the range of NPV is positive. This suggests that a delay will improve the economic feasibility of the project.

Table 19   CLR sensitivity analysis - delay (BCR, discounted at four and seven percent)

CLR sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*0.89 - 1.41*	*1.14 - 1.88*	*1.09 - 1.76*
Delay in opening traffic by five years	0.98 - 1.54	1.34 - 2.14	1.23 - 1.95
Delay in opening traffic by 10 years	1.06 - 1.54	1.5 - 2.36	1.35 - 2.12

Table 20   CLR sensitivity analysis - delay (NPV, discounted at four and seven percent)

CLR sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*-$529 - $3,004*	*$664 - $6,456*	*$438 - $5,564*
Delay in opening traffic by five years	-$77 - $3,237	$1,115 - $6,840	$760 - $5,688
Delay in opening traffic by 10 years	$145 - $3,262	$1,188 - $6,721	$830 - $5,514

Table 21 and Table 22 show the results of the sensitivity analysis for the value of travel time sensitivity test. In this test the value of travel time was increased at the rate of one percent per year. In the static,

static and dynamic and total scenarios, the NPV improves significantly, and the BCR is positive at both ends of the range.

Table 21 CLR sensitivity analysis - value of travel time (BCR, discounted at four and seven percent)

CLR sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*0.89 - 1.41*	*1.14 - 1.88*	*1.09 - 1.76*
Value of travel time	1.69 - 2.92	1.17 - 2.08	1.13 - 1.96

Table 22 CLR sensitivity analysis - value of travel time (NPV, discounted at four and seven percent)

CLR sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*-$529 - $3,004*	*$664 - $6,456*	*$438 - $5,564*
Value of travel time	$3,764 - $14,056	$1,191 - $7,895	$964 - $7,004

3.6   Conventional VITM modelling

Table 23 summarises the value of benefits for each project for the CLR Conventional VITM run using a four percent and seven percent discount rate over a 50-year appraisal period.

Table 23 CLR SALUP summary of project benefits (PV, $ million, 2021 dollars, discounted at four percent and seven percent)

Benefits (PV $mil)	Conventional VITM	Conventional VITM with WEBs
Safety benefits	$85 - $212	
Environmental benefits	$92 - $226	
Active transport benefits	$274 - $687	
Consumer surplus benefits	$5,114 - $13,326	
Residual values	$7 - $45	
WEBS		$6,075 - $15,734
Total benefits	$5,572 - $14,496	$6,075 - $15,734

The project is expected to deliver between $5.6-$14.5 billion of benefits under the Conventional VITM (without WEBs) scenario and $6.1-$15.7 billion of benefits when WEBs are included.

The small difference in benefits between the VLUTI-based and conventional tests is difficult to attribute to any single factor. It likely stems from the fact that under the VLUTI tests, the base case land use is adapted to the base case network assumptions whilst the CLR scenario land use reacts to the presence of the project. In the case of the conventional tests, both the base and project cases use the same distribution of land use.

The majority of the benefits are derived from consumer surplus ($5.1-$13.3 billion) and active transport ($274 - $687 million). The underlying transport modelling data shows that most of the consumer surplus benefit is as a result of travel time savings and associated reductions in vehicle operating costs for private and freight vehicles, as well as public transport composite time benefits and reduced parking costs. These gains are slightly offset by increases in road tolls.

The majority of the WEBs benefits are derived from agglomeration benefits (96 percent), with output changes in imperfectly competitive markets being four percent. This indicates that the project has resulted in increasing productivity as a result of greater business density.

Table 24   CLR Conventional VITM CBA results (PV, $ million, 2021 dollars, discounted at four percent and seven percent)

Economic outcomes	Conventional VITM	Conventional VITM with WEBs
NPV	$1,085 - $7,311	$1,588 - $8,550
BCR	1.24 - 2.02	1.35 - 2.19
IRR	8.53%	9.21%
FYRR	9.6% - 12.2%	10.9% - 13.9%

The VLUTI model run for CLR was assessed including the cost to extend the metropolitan rail line from Beveridge to Wallan. Analysis of these results found that Seymour V/Line services will have sufficient capacity to accommodate demand at the existing Wallan Station beyond 2051, so the extension of the metro line would not be required at that time. As such, the Conventional VITM run was modelled without this extension to Wallan, so the capital costs for this scenario do not include the extension.

Under the Conventional VITM scenario, the NPV ranges between $1.1 to -$7.3 billion, with a BCR above one. The BCR and NPV both indicate that the project is economically viable at a discount rate of four and seven percent under this scenario.

The IRR for this project, at 8.7 percent, is higher than the discount rates (four and seven percent), which confirms that the project is economically feasible. Similarly, the FYRR is greater than the project discount rates, indicating deferral of the project is not warranted as it is unlikely to improve the BCR.

The inclusion of WEBs outcomes results in better outcome to the BCR and NPV. The inclusion of WEBs in the CBA results in an NPV range of $1.6 - $8.5 billion and a BCR range of 1.35 - 2.19, indicating that the project does have economic merit. Additionally, the Conventional VITM with WEBs scenario produces a FYRR higher than the project discount rates at 10.9 - 13.9 percent, indicating deferral of the project is not warranted. The IRR for both scenarios is higher than the discount rates, indicating the project is economically feasible at its current proposed timing.

Sensitivity analysis using three and ten percent discount rates is contained in Table 25 and

Table 26. Under the three percent sensitivity test, both scenarios generate stronger BCRs (2.41 for Conventional VITM and 2.61 for Conventional VITM with WEBs) and NPV ($12.1 billion for Conventional VITM and $13.7 billion for Conventional VITM with WEBs). By contrast, using a ten percent discount rate results in a BCR below one and a negative NPV for both scenarios.

Table 25   CLR Conventional VITM sensitivity analysis - discount rates (BCR)

CLR sensitivities	Conventional VITM	Conventional VITM with WEBs
	BCR	BCR
4% discount rate (central case)	*2.02*	*2.19*
7% discount rate (central case)	*1.24*	*1.35*
3% discount rate	2.41	2.61
10% discount rate	0.83	0.91

Table 26   CLR Conventional VITM sensitivity analysis - discount rates ($ NPV)

CLR sensitivities	Conventional VITM	Conventional VITM with WEBs
	NPV	NPV
4% discount rate (central case)	*$7,311*	*$8,550*
7% discount rate (central case)	$1,085	$1,588
3% discount rate	12,113	13,852
10% discount rate	-$517	-$282

Table 27 and

Table 28 show the results of the sensitivity analysis for changes in capital costs. A 20 percent decrease in capital cost strengthens economically viability with a higher BCR and NPV.

At a 20 percent increase in capital, the project remains economically viable with BCRs above one and a positive NPV for both scenarios. A 40 percent increase in capital cost makes the project unfeasible at the lower end of the range.

Table 27   CLR Conventional VITM sensitivity analysis - capex (BCR, discounted at four and seven percent)

CLR sensitivities	Conventional VITM	Conventional VITM with WEBs
	BCR	BCR
Core (central case)	*1.24 - 2.02*	*1.35 - 2.19*
20% decrease in capital costs	1.5 - 2.4	1.64 - 2.6
20% increase in capital costs	1.06 - 1.74	1.15 - 1.89
40% increase in capital costs	0.92 - 1.53	1 - 1.53

Table 28   CLR Conventional VITM sensitivity analysis - capex (NPV, discounted at four and seven percent)

CLR sensitivities	Conventional VITM	Conventional VITM with WEBs
	NPV	NPV
Core (central case)	*$1,085 - $7,311*	*$1,588 - $8,550*
20% decrease in capital costs	$1,868 - $1,868	$2,371 - $9,693
20% increase in capital costs	$302 - $302	$805 - $7,407
40% increase in capital costs	-$482 - $5,025	$21 - $6,264

Table 29 and Table 30 show the results of the sensitivity analysis for total benefits The project remains economically viable under all tests except for the low end of the range for the 40 percent decrease in total benefits.

Table 29   CLR Conventional VITM sensitivity analysis - benefits (BCR, discounted at four and seven percent)

CLR sensitivities	Conventional VITM	Conventional VITM with WEBs
	BCR	BCR
Core (central case)	*1.24 - 2.02*	*1.35 - 2.19*
40% decrease in total benefits	0.75 - 1.21	0.81 - 1.31
20% decrease in total benefits	0.99 - 1.61	1.08 - 1.75
20% increase in total benefits	1.49 - 2.42	1.62 - 2.63

Table 30   CLR Conventional VITM sensitivity analysis - benefits (NPV, discounted at four and seven percent)

CLR sensitivities	Conventional VITM	Conventional VITM with WEBs
	NPV	NPV
Core (central case)	*$1,085 - $7,311*	*$1,588 - $8,550*
40% decrease in total benefits	-$1,144 - $1,513	-$842 - $2,256
20% decrease in total benefits	-$29 - $4,412	$373 - $5,403
20% increase in total benefits	-$29 - $4,412	-$4,487 - -$7,185

Table 31 and

Table 32 show the results from the sensitivity analysis for when the opening year of operation is delayed by five and ten years respectively. When undertaking sensitivity analysis by delaying the timing of the project, the results show an NPV higher than the central case under Conventional VITM, and Conventional VITM with WEBs scenarios. This is largely as a result of a lower discount factor as costs are incurred in a later time period, and thus have lower present values. Benefits also increase as there is higher demand in the future. The BCR increases in comparison to the central case scenario as costs have lower present values and benefits increase. It should be noted that delaying the delivery stage of the project may incur additional costs which are not captured in this analysis, such as additional overhead, planning and financial costs.

Table 31   CLR Conventional VITM sensitivity analysis – project delay (BCR, discounted at four and seven percent)

CLR sensitivities	Conventional VITM	Conventional VITM with WEBs
	BCR	BCR
Core (central case)	1.24 - 2.02	1.35 - 2.19
Delay in opening traffic by five years	1.44 - 2.26	1.56 - 2.45
Delay in opening traffic by 10 years	1.62 - 2.5	1.75 - 2.7

Table 32   CLR Conventional VITM sensitivity analysis – project delay (NPV, discounted at four and seven percent)

CLR sensitivities	Conventional VITM	Conventional VITM with WEBs
	NPV	NPV
Core (central case)	$1,085 - $7,311	$1,588 - $8,550
Delay in opening traffic by five years	$1,401 - $7,467	$1,785 - $8,555
Delay in opening traffic by 10 years	$1,413 - $7,293	$1,706 - $8,247

Table 33 and Table 34 illustrate the results of the sensitivity analysis for the growth in the value of travel time. In this test the value of travel time was increased at the rate of one percent per year. In the Conventional VITM and Conventional VITM with WEBs scenarios, the NPV remains positive and the BCR remains above 1.0 for all tests, indicating that the project would continue to remain economically viable. When compared to the central case, the BCR and NPV increase, reflecting the increase in the value of benefits over time.

Table 33   CLR Conventional VITM sensitivity analysis - value of travel time (BCR, discounted at four and seven percent)

CLR sensitivities	Conventional VITM	Conventional VITM with WEBs
	BCR	BCR
Core (central case)	1.24 - 2.02	1.35 - 2.19
Value of travel time	2.3 - 4.01	2.41 - 4.19

Table 34   CLR Conventional VITM sensitivity analysis - value of travel time (NPV, discounted at four and seven percent)

CLR sensitivities	Conventional VITM	Conventional VITM with WEBs
	NPV	NPV
Core (central case)	$1,085 - $7,311	$1,588 - $8,550
Value of travel time	$6,579 - $21,646	$7,082 - $22,884

3.7   Spatial/land use results

The spatial results are based on the outcomes of the VLUTI modelling.

Figure 7 and Figure 8 show the impact of the project on population redistribution compared to the transport base case in 2036 and 2051 respectively.

The CLR project will increase accessibility along the Craigieburn, Upfield and south east lines by providing capacity uplift to the rail network and electrification of the train network to Beveridge and Wallan. These improved connections are expected to make the surrounding areas more accessible – and by extension, more appealing – for residents. As a result, there is movement of people towards the northern corridor as well as the southern corridor, in 2036. By contrast, fewer people are opting to reside in inner Melbourne compared to the base case in 2036. This may be because improved accessibility (resulting in more efficient public transport options) provides opportunities for people to live further from the CBD, taking advantage of reduced density, larger residential lots, reduced housing prices and other amenity benefits.

By 2051, this pattern is seen more strongly. While still modest (each dot represents a change of five residents), there is a stronger shift in population towards the outer north, particularly new growth areas

such as Lockerbie and Wallan. This likely represents people taking advantage of enhanced public transport links to live further from the CBD as a way of improving amenity (lower prices, more space, less density etc). By contrast, the same drivers appear to be reducing the number of residents in inner city Melbourne compared to the transport base case. It is anticipated that there will be fewer inner city residents because of people moving further from the CBD (although not necessarily to the north) to take advantage of improved living opportunities.

Figure 7 CLR change in population in 2036 (each dot represents a change of five residents)
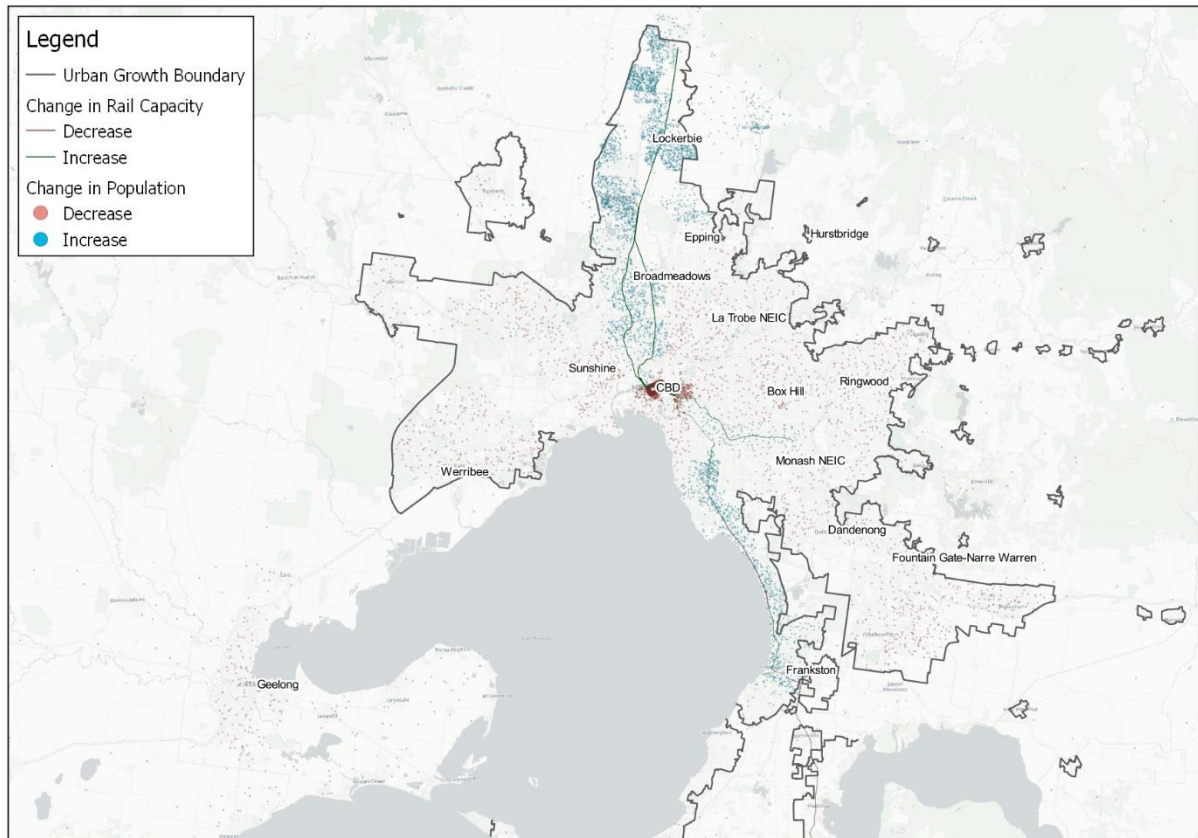
Figure 8 CLR change in population in 2051 (each dot represents a change of five residents)
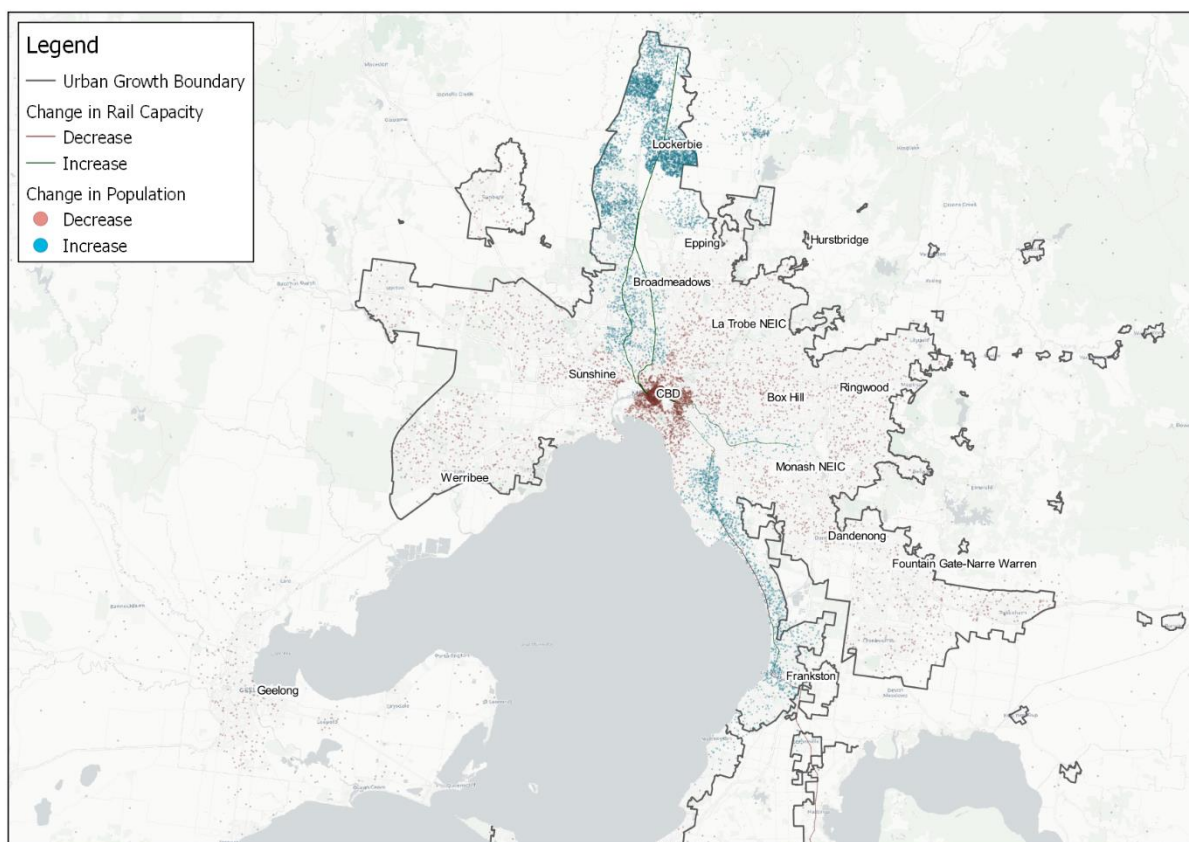
Figure 9 and Figure 10 show the impact of the project on employment redistribution compared to the base case in 2036 and 2051 respectively. The data suggests a modest redistribution of jobs by 2036, with a small number leaving the inner city and an increase along the main northern rail corridor as well as the rail corridor to Frankston. This reflects similar drivers to the population redistribution, with improved public transport services enabling employment to move further from the CBD.

In 2051, the trend is similar, with a slightly higher number of jobs shifting from the CBD to other areas, particularly the northern rail corridor.

Figure 9 CLR change in employment in 2036 (each dot represents a change of five jobs)
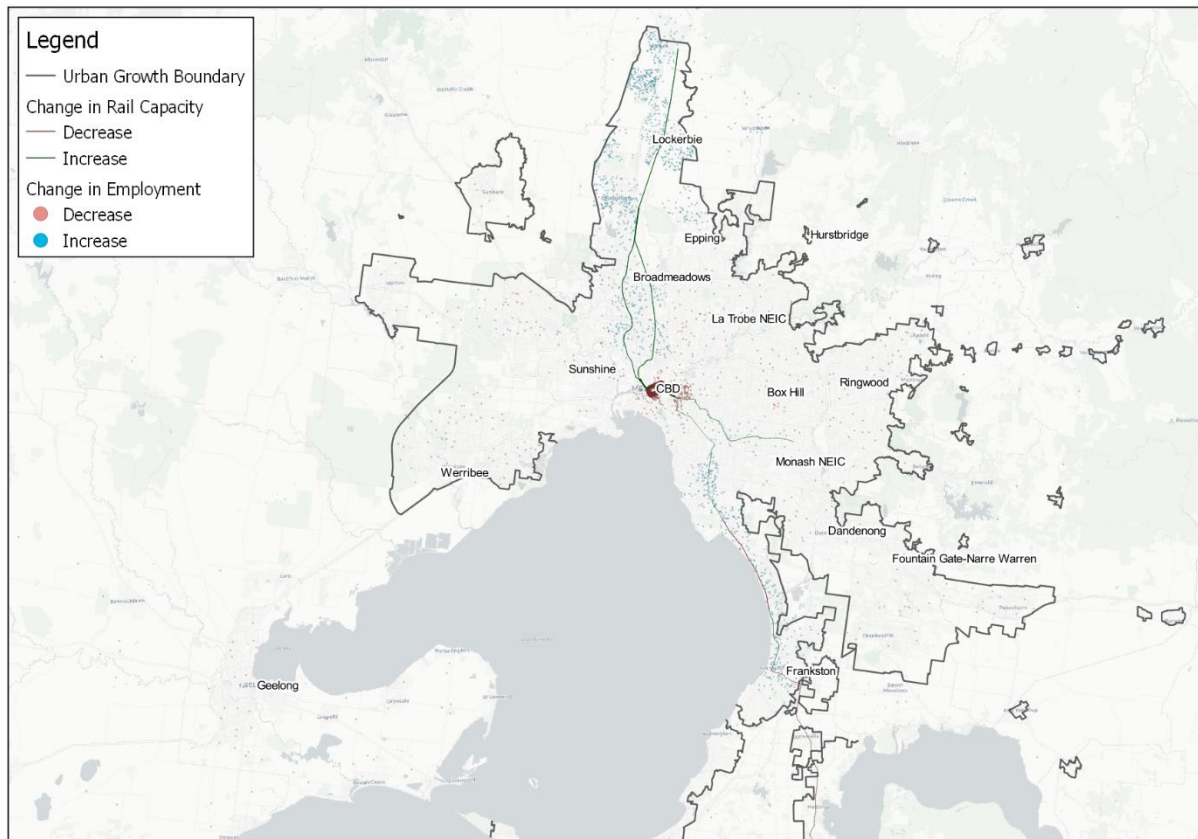
Figure 10 CLR change in employment in 2051 (each dot represents a change of five jobs)
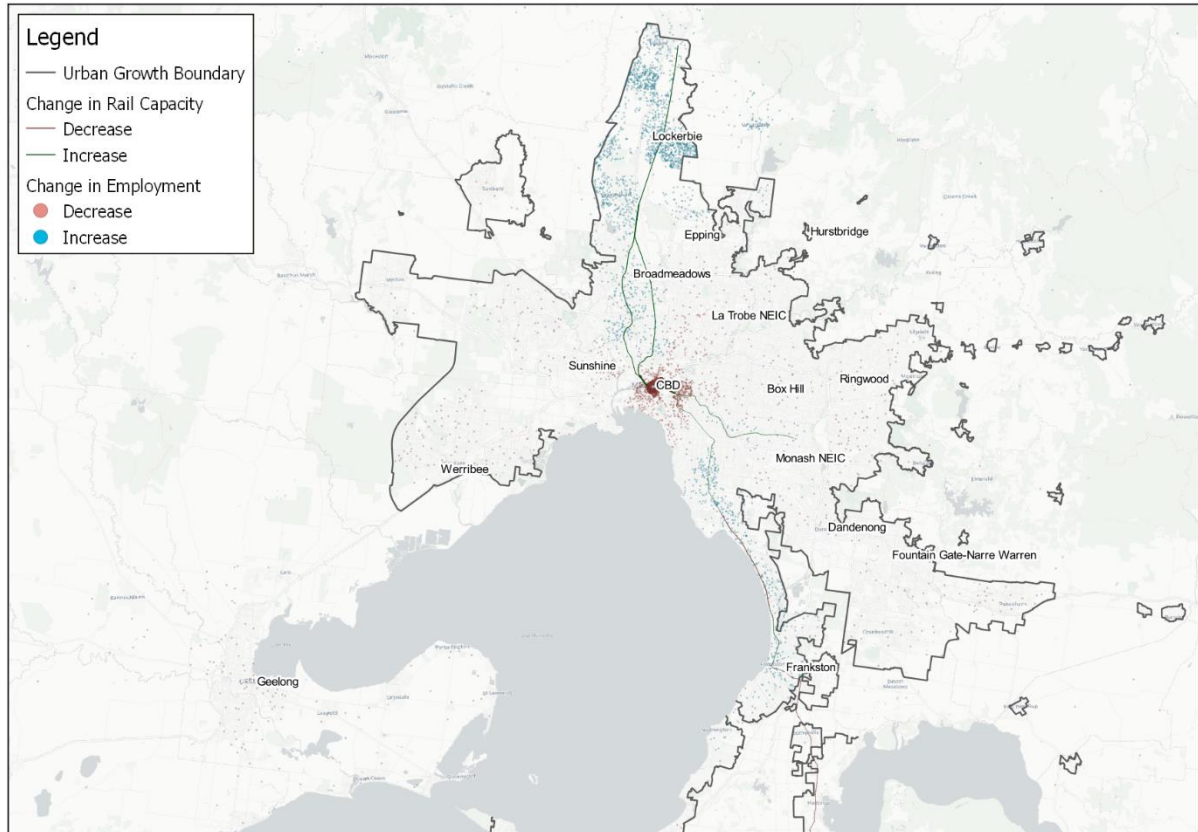
The increase in capacity of the Upfield, Craigieburn and south eastern lines and the extension of the metropolitan train network to Wallan increases the public transport consumer surplus in these areas after project completion in the year 2036 and 2051 as can be seen in Figure 11 and Figure 12. Increases in consumer surplus are largely a result of more frequent, more reliable train services.

Figure 11 CLR changes in consumer surplus, 2036 (each dot represents a change of 120 minutes)
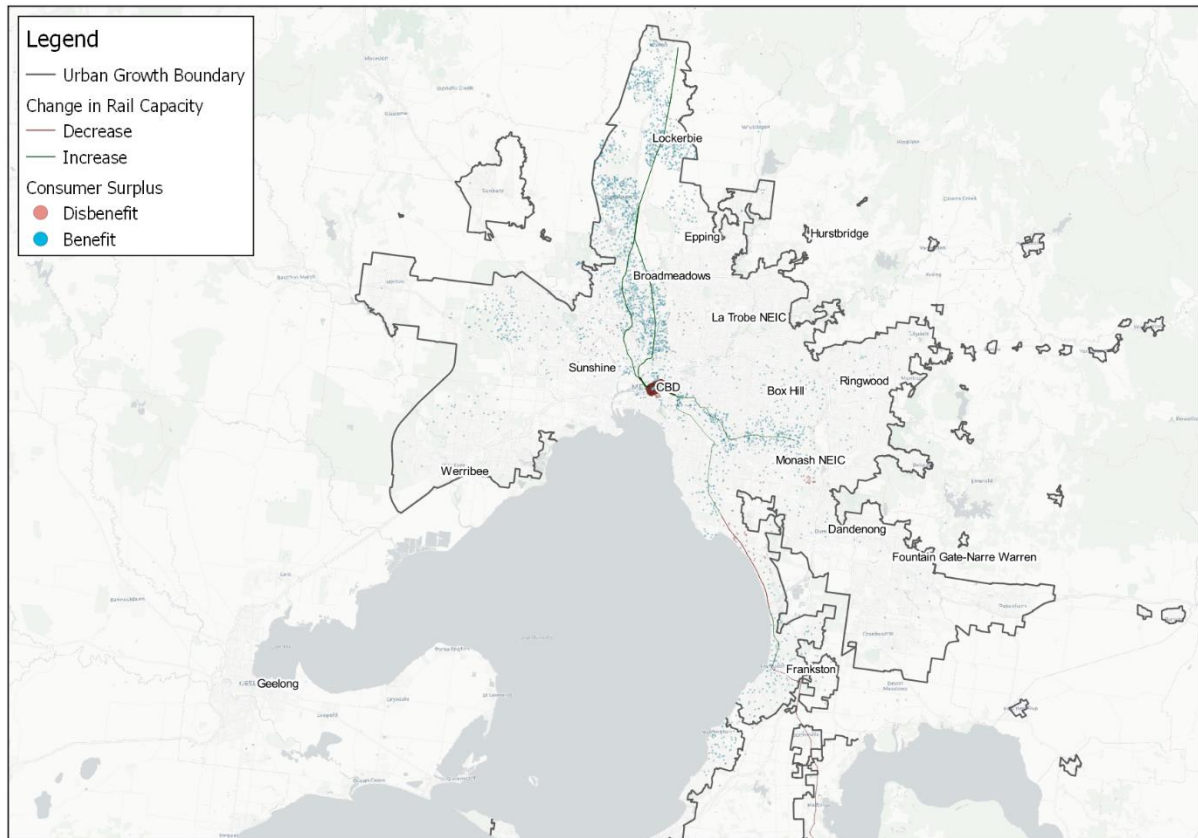
Figure 12 CLR changes in consumer surplus, 2051 (each dot represents a change of 120 minutes)
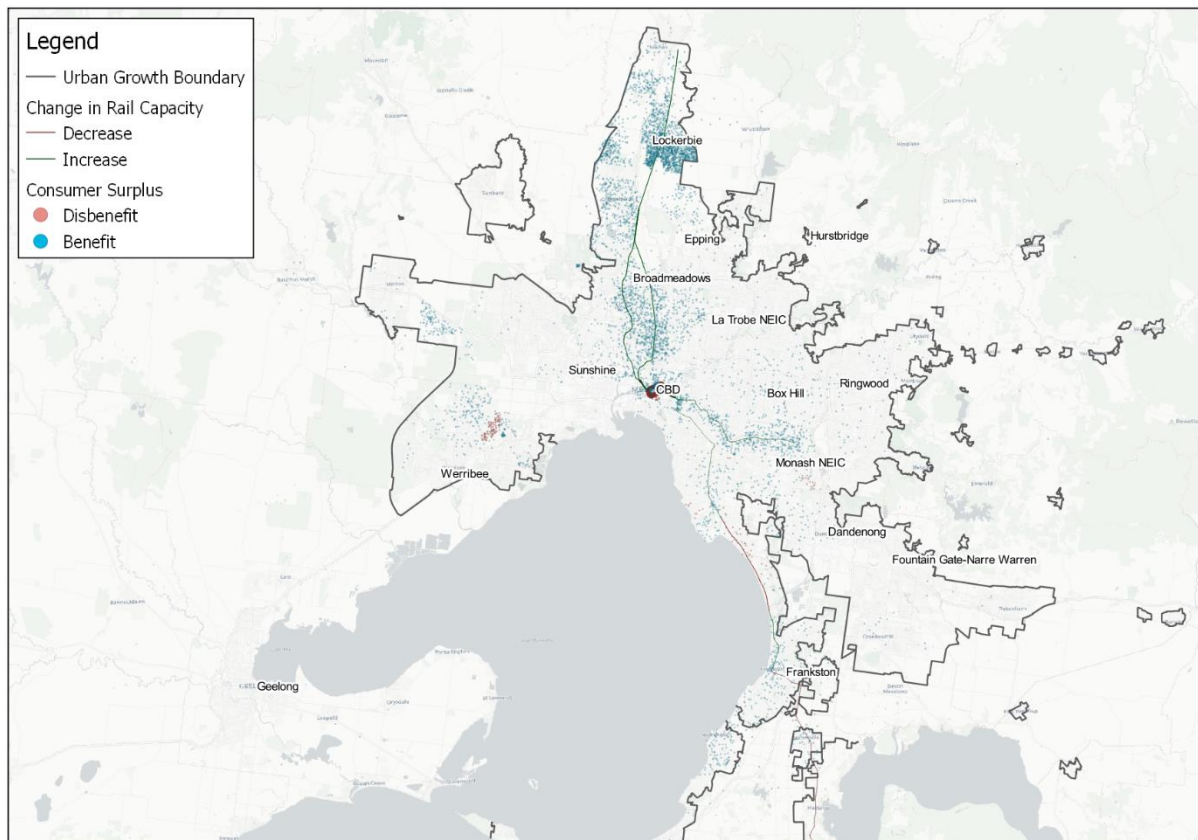
3.8   Conclusions

The CBA assessment indicates that this project is economically viable as modelled in this assessment, with an NPV in the range $438 million - $5.6 billion, and positive BCR of 1.09-1.76. While the costs are significant (capital cost of $4.1 and $5.8 billion PV), the benefits are larger, estimated to be between $5.1 - $13 billion.

The spatial analysis suggests a redistribution of population along the north and southern segments of the CLR alignment. By contrast there would be a redistribution of population away from the CBD and other areas of Melbourne. Employment redistribution would be expected to follow the same pattern, although the job redistribution is expected to be modest. Consumer surplus gains for public transport users would be realised along the north and south CLR alignments, roughly in line with population redistribution. This suggests that improved service provision will drive travel time and amenity benefits for people within the corridor.

# 4.	Project 2: Cross city motorway (CCM)

## 4.1	Project background

The CCM project comprises the connection of CityLink and the Eastern Freeway through a new tolled motorway. As modelled, the connection would be made via a road tunnel under Carlton and North Melbourne.

The project has been modelled and costed on the basis of two components, which are described below. These have been assumed to be constructed simultaneously.

Section A is 9.2 kilometres long and includes:

- Twin three lane road tunnels from Hoddle Street to Royal Park, exiting just west of the Upfield train line, connecting to the Eastern Freeway in the east

- Viaducts would connect to City Link south bound, adjacent to the existing Sound Tunnel and northbound close to Ormond Road

- Widening of the Eastern Freeway from Chandler Highway to Hoddle Street by one lane in each direction to accommodate additional traffic

- Allowance for an interchange with Hoddle Street.

Section B consists of a 3.2 kilometre viaduct corridor running adjacent to City Link with two traffic lanes plus one shoulder each direction. It connects from the tunnel exit at Royal Park to Footscray Road and the West Gate Tunnel, via a viaduct over City Link. A new northbound slip lane from the CCM viaduct would connect to City Link before Racecourse Road.

The alignment for the CCM project is shown in Figure 13.

Figure 13   CCM project

4.2   Cost and timing

The total project cost estimates are outlined in Table 35. The cost estimate considers the development of all aspects of the planning, construction, land acquisition costs and contingencies.

Key dates that have been assumed for the purposes of this assessment for the CCM project are:

- Construction is assumed to occur over the period 2030-2035 (financial years).

- Operational assessment has been undertaken for the period 2036-85 (financial years).

Table 35   CCM capex and opex cost profile (nominal with escalation, 2021 dollars, discounted at four percent and seven percent)

Project	Nominal capex ($m)	PV capex ($m)	Nominal opex ($m)	PV opex ($m)	Nominal asset renewal ($m)	PV asset renewal ($m)
CCM	$16,383	$6,990 - $9,993	$975	$104 - $242	$452	$13 - $53

PV capital expenditure for CCM is estimated to be in the range $7-10 billion, with the first year of benefits (operation) would be realised in financial year 2036.

The key components of capital expenditure are tunnelling (38 percent), bridges (16 percent) and contingencies (18 percent). There are also expected to be some land acquisition costs at around $338 million (three percent of costs).

4.3 Benefits

Table 36 summarises the value of benefits for CCM using a four percent and seven percent discount rate over a 50-year appraisal period.

Table 36   CCM summary of project benefits (PV, $ million, 2021 dollars, discounted at four percent and seven percent)

Benefits (PV $mil)	Static only	Dynamic only	WEBs only	Total
Safety benefits	-$108 - -$289	$46 - $126		-$62 - -$163
Environmental benefits	-$106 - -$263	$107 - $338		$1 - $75
Active transport benefits	-$33 - -$86	$2 - -$1		-$31 - -$87
Consumer surplus benefits	$2,017 - $4,777	-$79 - -$321		$1,938 - $4,456
Residual values	$7 - $45	$0 - $0		$7 - $45
WEBS			$385 - $918	$385 - $918
Total benefits	**$1,777 - $4,185**	**$76 - $143**	**$385 - $918**	**$2,238 - $5,246**

The project is expected to deliver between $1.8-$4.2 billion of benefits under the static scenario, $76-$143 million of additional benefits under the dynamic scenario and $385-$918 million of WEBs.

The majority of the benefits are derived from consumer surplus ($1.9-$4.5 billion) with WEBs and safety benefits comprising much of the remainder. Consumer surplus is negative under the dynamic scenario; changes in land use (population and employment being redistributed towards the central city) appear to have resulted in increased congestion and/or travel times, producing a slightly negative result.

The majority of the WEBs are derived from agglomeration benefits (53 percent), and tax revenue changes from labour markets (39 percent). This indicates that the project has resulted in increasing productivity as a result of greater business density, and this uplift can be seen through increased taxes from labour.

4.4 CBA outcomes

Table 37 summarises the results of the CBA conducted for CCM using a four and seven percent discount rate over a 50 year appraisal period.

Table 37   CCM CBA results (PV, $ million, 2021 dollars, discounted at four percent and seven percent)

Economic outcomes	Static	Dynamic	Total (incl WEBs)
NPV	-$5,330 - -$6,103	-$5,254 - -$5,960	-$4,869 - -$5,042
BCR	0.25 - 0.41	0.26 - 0.42	0.31 - 0.51
IRR	0.01%	0.1%	0.87%
FYRR	3.6% - 5.2%	3.9% - 5.6%	4.7% - 6.6%

The project generates a negative NPV and a BCR below one in all scenarios. This means that the project may not be economically viable as modelled in this assessment. This is largely a result of the significant project costs.

The IRR for this project, at 0.87 percent for the total, is significantly below the discount rates (four and seven percent), which confirms that the project may not be economically feasible. Similarly, the FYRR (4.7-6.6 percent) is not economically feasible with the proposed timing.

Figure 15 presents the cumulative present values of benefits and costs over the modelling period. As seen in this graph, benefits do not exceed the costs in the appraisal period, leading to a negative NPV and BCR below one. The green area represents the difference between costs and benefits.

Figure 14   CCM – total costs and benefits (PV)
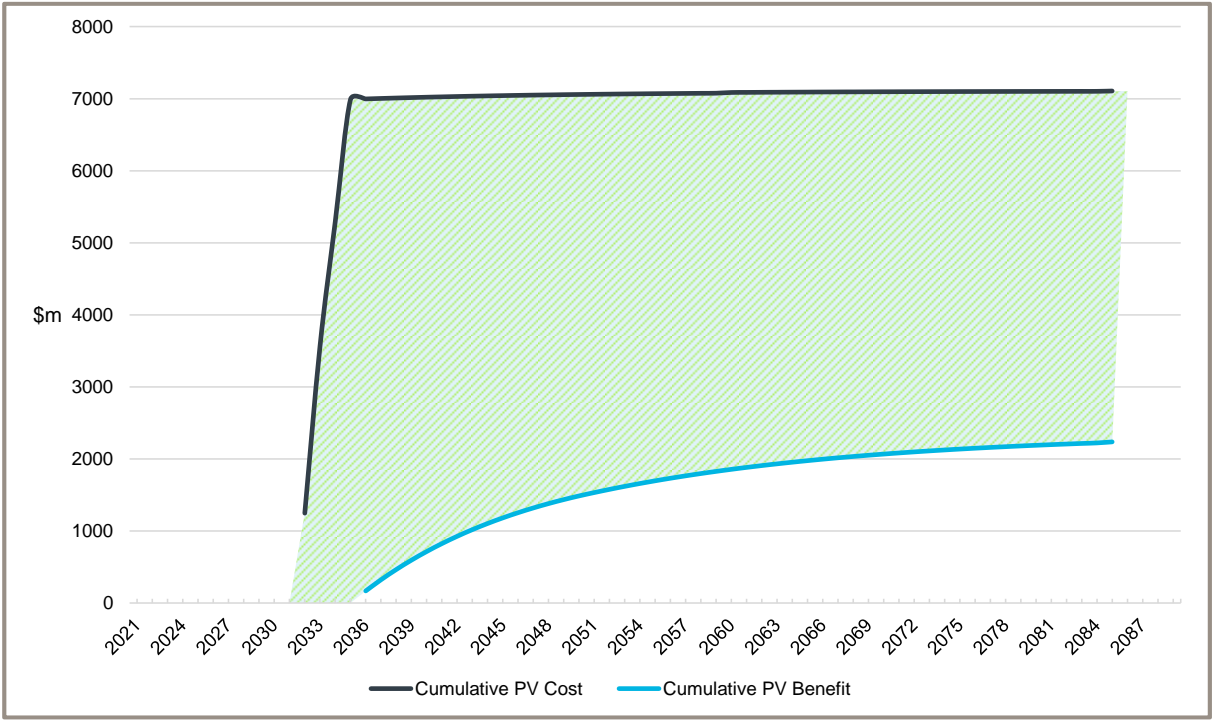
4.5   Sensitivity tests

The results of the sensitivity analysis carried out for discount rates of three and ten percent are shown in Table 38 and

Table 39. The project remains unviable with a three and ten percent discount rate, with a BCR of less than one and a negative NPV across all scenarios.

Table 38   CCM sensitivity analysis - discount rates (BCR)

CCM sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
4% discount rate (central case)	*0.41*	*0.42*	*0.51*
7% discount rate (central case)	*0.25*	*0.26*	*0.31*
3% discount rate	0.50	0.51	0.62
10% discount rate	0.17	0.18	0.22

Table 39   CCM sensitivity analysis - discount rates (NPV)

CCM sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
4% discount rate (central case)	-$6,103	-$5,960	-$5,042
7% discount rate (central case)	-$5,330	-$5,254	-$4,869
3% discount rate	-$5,909	-$5,727	-$4,452
10% discount rate	-$4,131	-$4,088	-$3,903

Table 40 and Table 41 show the results of the sensitivity analysis for changes in capital costs. In the static, static and dynamic and total scenarios, the NPV remains negative and the BCR remains below 1.0, indicating that the project may not economically viable even where capital costs are reduced by 20 percent.

Table 40   CCM sensitivity analysis - capex (BCR, discounted at four and seven percent)

CCM sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*0.25 - 0.41*	*0.26 - 0.42*	*0.31 - 0.51*
20% decrease in capital costs	0.31 - 0.50	0.32 - 0.52	0.39 - 0.63
20% increase in capital costs	0.21 - 0.34	0.22 - 0.35	0.26 - 0.43
40% increase in capital costs	0.18 - 0.29	0.19 - 0.30	0.23 - 0.37

Table 41   CCM sensitivity analysis - capex (NPV, discounted at four and seven percent)

CCM sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*-$6,103 - -$5,330*	*-$5,960 - -$5,254*	*-$5,042 - -$4,869*
20% decrease in capital costs	-$4,104 - -$3,932	-$3,961 - -$3,856	-$3,471 - -$3,043
20% increase in capital costs	-$8,102 - -$6,728	-$7,959 - -$6,652	-$7,040 - -$6,267
40% increase in capital costs	-$10,100 - -$8,126	-$10,100 - -$8,050	-$9,039 - -$7,665

Table 42 and Table 43 show the results of the sensitivity analysis for changes to total benefits. In the static, static and dynamic and total scenarios, the NPV remains negative and the BCR remains below 1.0. This suggests that the project may not be economically viable, even where benefits are higher than the central case assumptions.

Table 42   CCM sensitivity analysis - benefits (BCR, discounted at four and seven percent)

CCM sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*0.25 - 0.41*	*0.26 - 0.42*	*0.31 - 0.51*
40% decrease in total benefits	0.15 - 0.24	0.16 - 0.25	0.19 - 0.31
20% decrease in total benefits	0.20 - 0.33	0.21 - 0.34	0.25 - 0.41
20% increase in total benefits	0.30 - 0.49	0.31 - 0.50	0.38 - 0.61

Table 43   CCM sensitivity analysis - benefits (NPV, discounted at four and seven percent)

CCM sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*-$6,103 - -$5,330*	*-$5,960 - -$5,254*	*-$5,042 - -$4,869*
40% decrease in total benefits	-$7,777 - -$6,041	-$7,691 - -$5,995	-$7,140 - -$5,764
20% decrease in total benefits	-$6,940 - -$5,685	-$6,825 - -$5,625	-$6,091 - -$5,317
20% increase in total benefits	-$5,266 - -$4,975	-$5,094 - -$4,884	-$4,422 - -$3,993

Table 44 and Table 45 show the results of the sensitivity analysis when the opening year of operation is delayed. In the static, static and dynamic and total scenarios, the NPV remains negative and the BCR remains below 1.0. The BCR and NPV outcomes are almost identical to the central case, suggesting that delays in the project as modelled in this assessment may not enhance economic viability.

Table 44   CCM sensitivity analysis – project delay (BCR, discounted at four and seven percent)

CCM sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*0.25 - 0.41*	*0.26 - 0.42*	*0.31 - 0.51*
Delay in opening traffic by five years	0.24 - 0.41	0.25 - 0.42	0.31 - 0.51
Delay in opening traffic by 10 years	0.25 - 0.41	0.25 - 0.42	0.31 - 0.52

Table 45   CCM sensitivity analysis – project delay (NPV, discounted at four and seven percent)

CCM sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*-$6,103 - -$5,330*	*-$5,960 - -$5,254*	*-$5,042 - -$4,869*
Delay in opening traffic by five years	-$5,020 - -$3,828	-$4,945 - -$3,795	-$4,171 - -$3,517
Delay in opening traffic by 10 years	-$4,068 - -$2,727	-$4,025 - -$2,712	-$3,364 - -$2,508

Table 46 and

Table 47 illustrate the results for the value of travel time sensitivity test. In this test the value of travel time was increased at the rate of one percent per year. In the static, static and dynamic and total scenarios, the NPV remains negative and the BCR remains below 1.0 under all tests, indicating that the project would continue to remain economically unviable. When compared to the central case, the BCR and NPV increase, reflecting the increase in the value of benefits over time.

Table 46   CCM sensitivity analysis - value of travel time (BCR, discounted at four and seven percent)

CCM sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*0.25 - 0.41*	*0.26 - 0.42*	*0.31 - 0.51*
Value of travel time	0.30 - 0.54	0.31 - 0.54	0.36 - 0.63

Table 47   CCM sensitivity analysis - value of travel time (NPV, discounted at four and seven percent)

CCM sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*-$6,103 - -$5,330*	*-$5,960 - -$5,254*	*-$5,042 - -$4,869*
Value of travel time	-$4,793 - -$4,740	-$4,715 - -$4,751	-$4,366 - -$3,797

4.6   Conventional VITM modelling

To test the VLUTI outcomes, modelling was undertaken using the SALUP land use only in place of the static/dynamic scenarios. The purpose of this sensitivity was to enable comparison with previous assessments of this project. This approach also enabled a comparison between the core modelling outcomes and when land use change is not taken into account.

Table 48 summarises the value of benefits for the CCM conventional VITM run using a four percent and seven percent discount rate over a 50-year benefits appraisal period.

Table 48   CCM Conventional VITM summary of project benefits (PV, $ million, 2021 dollars, discounted at four percent and seven percent)

Benefits (PV $mil)	Conventional VITM	Conventional VITM with WEBs
Safety benefits	-$208 - -$74	
Environmental benefits	-$231 - -$85	
Active transport benefits	-$83 - -$32	
Consumer surplus benefits	$2,825 - $6,899	
Residual values	$7 - $45	
WEBS		$3,226 - $7,863
Total benefits	**$2,641 - $6,422**	**$3,226 - $7,863**

The project is expected to deliver between $2.6-$6.4 billion of benefits under the Conventional VITM (without WEBs) scenario and $3.2-7.9 billion of benefits when WEBs are included. In this conventional VITM scenario WEBs were estimated by using the VITM, and included only WEB1 and WEB2.

The majority of benefits are derived from consumer surplus ($2.8-$6.9 billion) with safety and environmental benefits comprising most of the remainder. The underlying transport modelling data shows that most of the consumer surplus benefit is as a result of travel time savings and associated reductions in vehicle operating costs for road transport, which is typical of a major road project. The majority of these savings are for private vehicles. The travel time gains are slightly offset by increases in road tolls and car parking, indicating an increase in the number of private vehicle users as a result of the project.

The majority of the WEBs benefits are derived from agglomeration benefits (94 percent), with output changes in imperfectly competitive markets being 6 percent. This indicates that the project has resulted in increasing productivity as a result of greater business density.

The small difference in benefits between the VLUTI-based and conventional tests is difficult to attribute to any single factor. It likely stems from the fact that under the VLUTI tests, the base case land use is adapted to the base case network assumptions whilst the CCM scenario land use reacts to the presence

of the project. In the case of the conventional tests, both the base and project cases use the same distribution of land use.

Conventional VITM CBA results are outlined in Table 49.

Table 49   CCM Conventional VITM CBA results (PV, $ million, 2021 dollars, discounted at four percent and seven percent)

Economic outcomes	Conventional VITM	Conventional VITM with WEBs
NPV	-$4,466 - -$3,866	-$3,881 - -$2,425
BCR	0.37 - 0.62	0.45 - 0.76
IRR	1.84%	2.72%
FYRR	4.5% - 6.3%	5.4% - 7.6%

Under the Conventional VITM (without WEBs) scenario, the NPV ranges between -$4.5 - -$3.9 billion, with a BCR below one. The BCR and NPV both indicate that the project is not economically viable at a discount rate of four and seven percent. This indicates that while the road transport benefits are substantial, they are not sufficient to provide a positive economic return. The Conventional VITM scenario FYRR ranges between 4.5-6.3 percent and is smaller than the upper band of project discount rates (seven percent), indicating deferral of the project may be warranted as it may improve the BCR. The IRR for this scenario is less than the seven percent discount rate (1.84 percent), indicating the project is not economically feasible.

The inclusion of WEBs outcomes results in improvements in the BCR and NPV, however, this is not sufficient to make the project economically viable. The inclusion of WEBs in the CBA results in an NPV range of -$3.8 - -$2.4 billion and a BCR range of 0.45-0.76, indicating that the project may not be economically feasible. Additionally, The Conventional VITM with WEBs scenario produces FYRRs similar to the discount rates at 5.4-7.6 percent, suggesting that a delay in project commencement is unlikely to improve the economic modelling outcomes.

Sensitivity analysis using three and ten percent discount rates is contained in Table 50 and

Table 51. The project remains unviable at the three and ten percent discount rates with BCRs below one and negative NPVs under both scenarios.

Table 50   CCM Conventional VITM sensitivity analysis - discount rates (BCR)

CCM sensitivities	Conventional VITM	Conventional VITM with WEBs
	BCR	BCR
4% discount rate (central case)	*0.62*	*0.76*
7% discount rate (central case)	*0.37*	*0.45*
3% discount rate	0.77	0.94
10% discount rate	0.25	0.30

Table 51   CCM Conventional VITM sensitivity analysis - discount rates (NPV)

CCM sensitivities	Conventional VITM	Conventional VITM with WEBs
	NPV	NPV
4% discount rate (central case)	*-3,866*	*-2,425*

7% discount rate (central case)	-4,466	-3,881
3% discount rate	-2,717	-693
10% discount rate	-3,746	-3,473

Sensitivity test outcomes for changes in capital cost are contained in Table 52 and Table 53. Where capital cost is reduced, the BCR and NPV are more positive compared to the central case, but the project remains economically unfeasible.

Table 52   CCM Conventional VITM sensitivity analysis - capex (BCR, discounted at four and seven percent)

CCM sensitivities	Conventional VITM	Conventional VITM with WEBs
	BCR	BCR
Core (central case)	0.37 - 0.62	0.45 - 0.76
20% decrease in capital costs	0.46 - 0.77	0.57 - 0.95
20% increase in capital costs	0.31 - 0.52	0.38 - 0.64
40% increase in capital costs	0.27 - 0.45	0.33 - 0.45

Table 53   CCM Conventional VITM sensitivity analysis - capex (NPV, discounted at four and seven percent)

CCM sensitivities	Conventional VITM	Conventional VITM with WEBs
	NPV	NPV
Core (central case)	-$4,466 - -$3,866	-$3,881 - -$2,425
20% decrease in capital costs	-$3,068 - -$1,867	-$2,483 - -$426
20% increase in capital costs	-$5,864 - -$5,864	-$5,279 - -$4,423
40% increase in capital costs	-$7,262 - -$7,863	-$6,676 - -$6,422

Sensitivity analysis was carried out for project benefits under three assumptions as shown Table 54 and Table 55.The project remains unviable in all scenarios, with a BCR less than 1.0 and a negative NPV across all scenarios.

Table 54   CCM Conventional VITM sensitivity analysis - benefits (BCR, discounted at four and seven percent)

CCM sensitivities	Conventional VITM	Conventional VITM with WEBs
	BCR	BCR
Core (central case)	0.37 - 0.62	0.45 - 0.76
40% decrease in total benefits	0.22 - 0.37	0.27 - 0.46
20% decrease in total benefits	0.30 - 0.50	0.36 - 0.61
20% increase in total benefits	0.45 - 0.75	0.54 - 0.92

Table 55   CCM Conventional VITM sensitivity analysis - benefits (NPV, discounted at four and seven percent)

CCM sensitivities	Conventional VITM	Conventional VITM with WEBs
	NPV	NPV
Core (central case)	-$4,466 - -$3,866	-$3,881 - -$2,425

40% decrease in total benefits	-$5,522 - -$6,434	-$5,171 - -$5,570
20% decrease in total benefits	-$4,994 - -$5,150	-$4,526 - -$3,997
20% increase in total benefits	-$4,422 - -$3,993	-$3,235 - -$852

Table 56 and Table 57 show the results from the sensitivity analysis for when the opening year of operation is delayed by five and ten years respectively. When undertaking sensitivity analysis by delaying the timing of the project, the results show an NPV higher than the central case under Conventional VITM, and Conventional VITM with WEBs scenarios. This is largely as a result of a lower discount factor as costs are incurred in a later time period, and thus have lower present values. Benefits also increase as there is higher demand in the future. The BCR increases in comparison to the central case scenario as costs have lower present values and benefits increase. It should be noted that delaying the delivery stage of the project may incur additional costs which are not captured in this analysis, such as additional overhead, planning and financial costs.

Table 56   CCM Conventional VITM sensitivity analysis – project delay (BCR, discounted at four and seven percent)

CCM sensitivities	Conventional VITM	Conventional VITM with WEBs
	BCR	BCR
Core (central case)	*0.37 - 0.62*	*0.45 - 0.76*
Delay in opening traffic by five years	0.39 - 0.65	0.48 - 0.8
Delay in opening traffic by 10 years	0.41 - 0.69	0.5 - 0.85

Table 57   CCM Conventional VITM sensitivity analysis – project delay (NPV, discounted at four and seven percent)

CCM sensitivities	Conventional VITM	Conventional VITM with WEBs
	NPV	NPV
Core (central case)	*-$4,466 - -$3,866*	*-$3,881 - -$2,425*
Delay in opening traffic by five years	-$3,107 - -$2,933	-$2,660 - -$1,666
Delay in opening traffic by 10 years	-$2,150 - -$2,175	-$1,809 - -$1,064

Table 58 and Table 59 illustrate the results of the sensitivity analysis for the growth in the value of travel time. In this test the value of travel time was increased at the rate of one percent per year. In the Conventional VITM and Conventional VITM with WEBs scenarios, the NPV becomes positive at the top of the range, suggesting increased viability where the value of time increases in the future.

Table 58 **CCM Conventional VITM sensitivity analysis - value of travel time (BCR, discounted at four and seven percent)**

CCM sensitivities	Conventional VITM	Conventional VITM with WEBs
	BCR	BCR
Core (central case)	*0.37 - 0.62*	*0.45 - 0.76*
Value of travel time	0.56 - 1.01	0.63 - 1.15

Table 59 **CCM Conventional VITM sensitivity analysis - value of travel time (NPV, discounted at four and seven percent)**

CCM sensitivities	Conventional VITM	Conventional VITM with WEBs
	NPV	NPV
Core (central case)	*-$4,466 - -$3,866*	*-$3,881 - -$2,425*
Value of travel time	-$2,886 - $103	-$2,301 - $1,544

4.7 Spatial/land use results

The spatial results are based on the outcomes of the VLUTI modelling.

Figure 15 and Figure 16 show the estimated changes in population distribution compared to the transport base case as a result of the project, for 2036 and 2051. The spatial changes indicate that in both 2036 and 2051, residents will be more attracted to Melbourne's inner north at the expense of the eastern suburbs.

This redistribution of population is due to the change in traffic congestion as a result of the project. The CCM project is expected to remove some traffic from the inner north, relieving congestion and as a result becoming a relatively more attractive location choice for residents. In contrast, the project is expected to funnel traffic via the Eastern Freeway resulting in additional traffic in the eastern suburbs.

Figure 15 CCM change in population in 2036 (each dot represents a change of five residents)
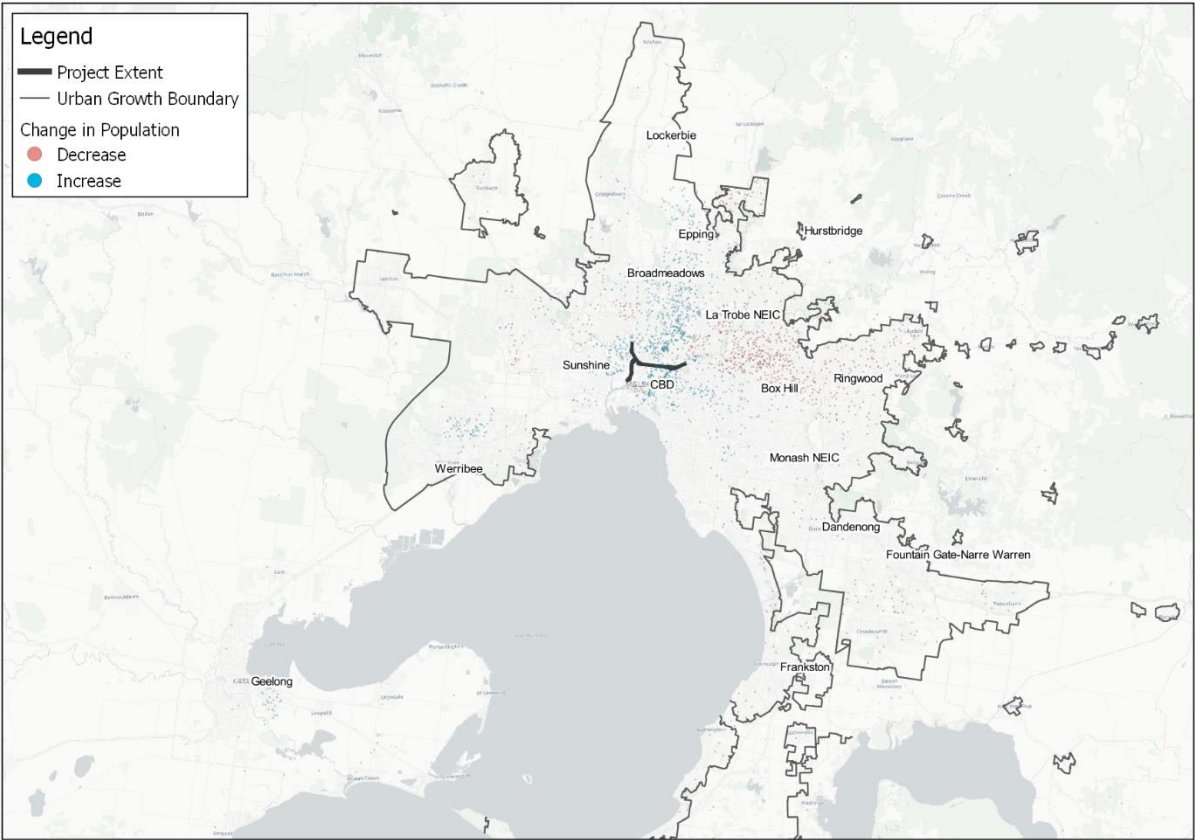
Figure 16 CCM change in population in 2051 (each dot represents a change of five residents)
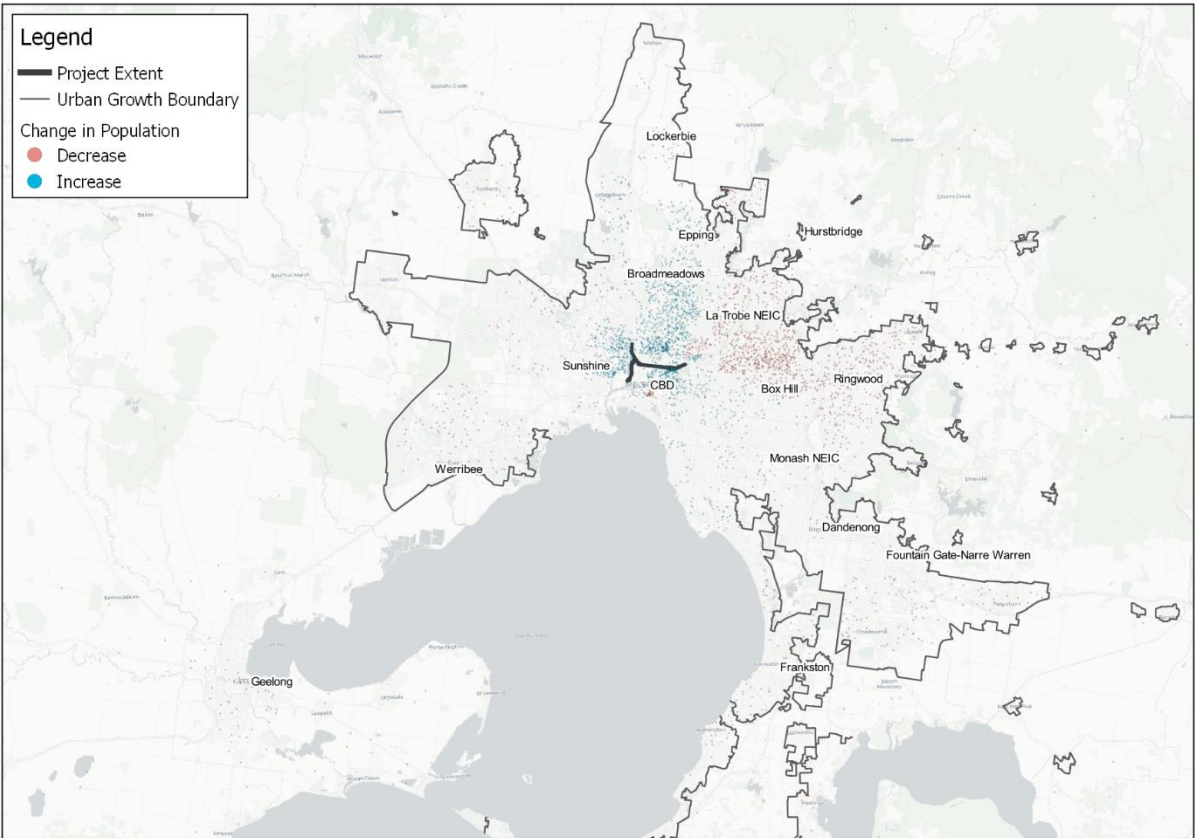
Figure 17 and Figure 18 show the impact of the project on employment location when compared against the transport base case in 2036 and 2051 respectively. Noting that each dot represents five jobs, the mapping suggests relatively little impact on employment distribution across Melbourne as a result of the CCM project. Where employment distribution change does occur, there is movement of jobs to the inner north of Melbourne and away from the east. While very limited in scale, this pattern reflects the changes in population distribution described in previous maps. There is slightly more movement in employment locations in 2051 compared to 2036.

Figure 17 CCM change in employment in 2036 (each dot represents a change of five jobs)
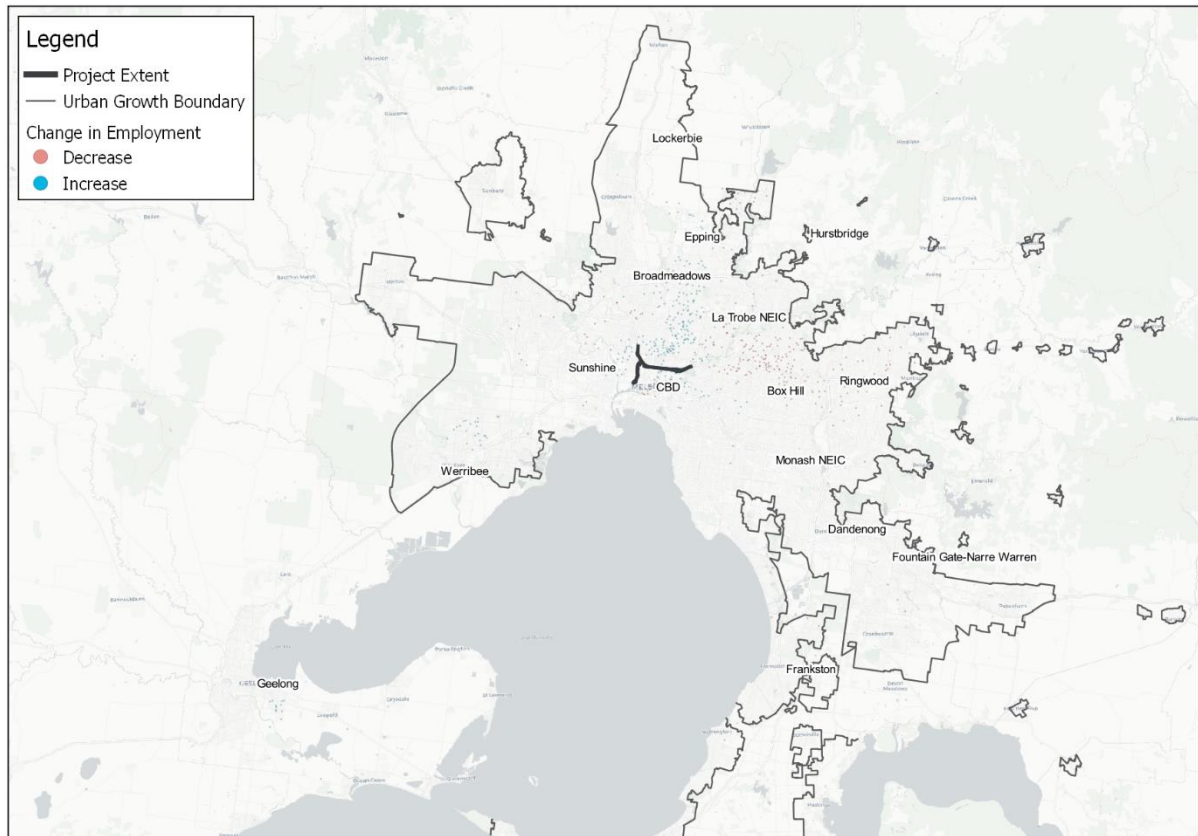
**Figure 18 CCM change in employment in 2051 (each dot represents a change of five jobs)**
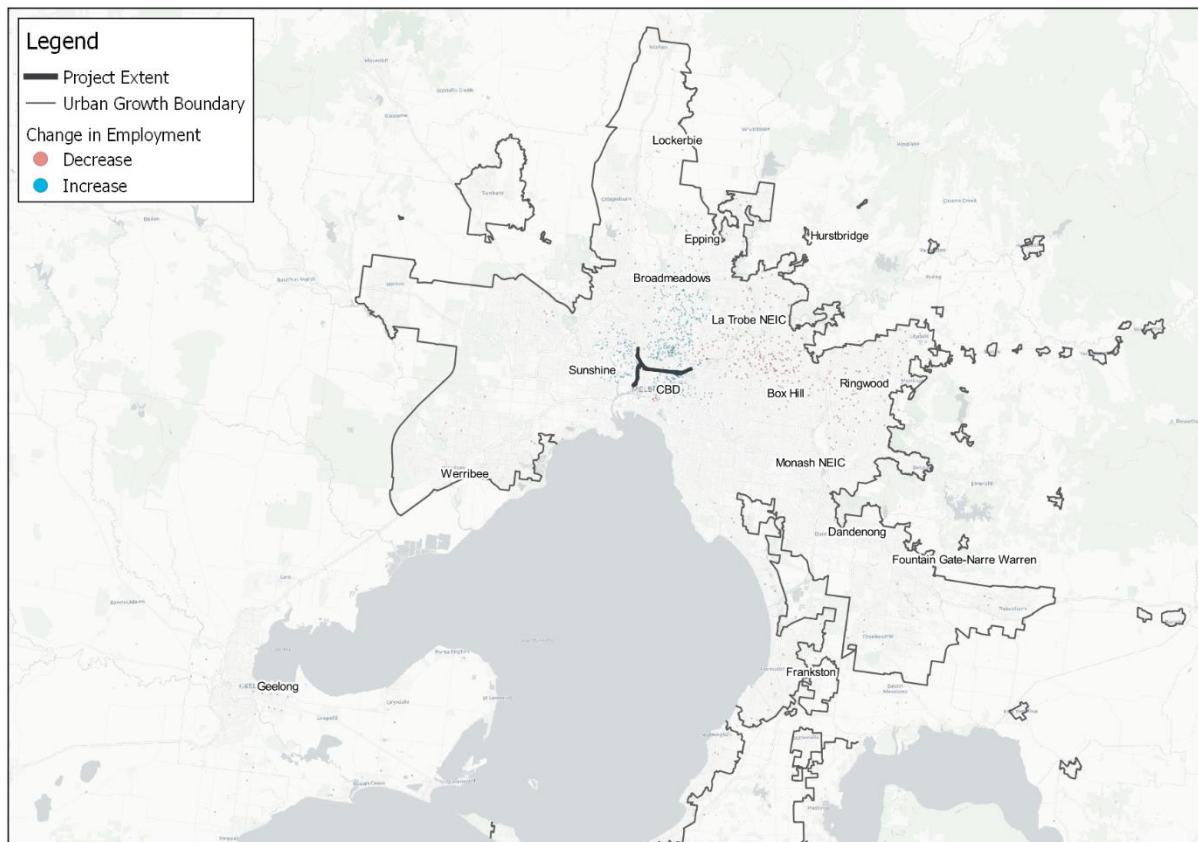
Figure 19 and Figure 20 show the spatial distribution of benefits associated with the project in 2036 and 2051. As a road project, the focus on highway consumer surplus indicates benefits or disbenefits of car users from the place of origin. Each dot represents a change in consumer surplus value equal to 120 minutes of travel time. In 2036 and 2051, there is a small increase in consumer surplus in inner and northern Melbourne, approximately the same areas which experience an uplift in employment and population compared to the transport base case. This suggests that there is a benefit for people when they relocate to areas proximate to the CCM project, or when employment is redistributed to these areas. By contrast, there is a minor reduction in consumer surplus in the rest of Melbourne.

Figure 19 CCM change in consumer surplus, 2036 (each dot represents a change of 120 minutes)
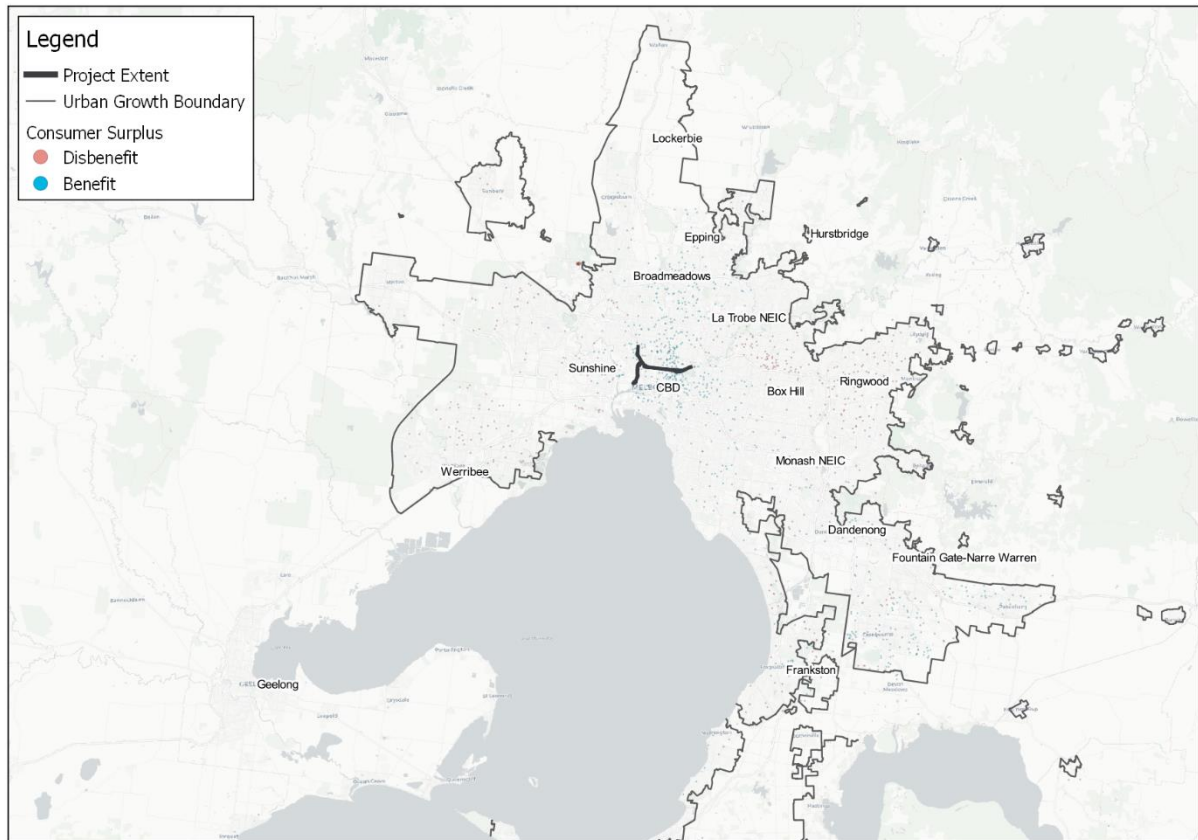
Figure 20 CCM change in consumer surplus, 2051 (each dot represents a change of 120 minutes)
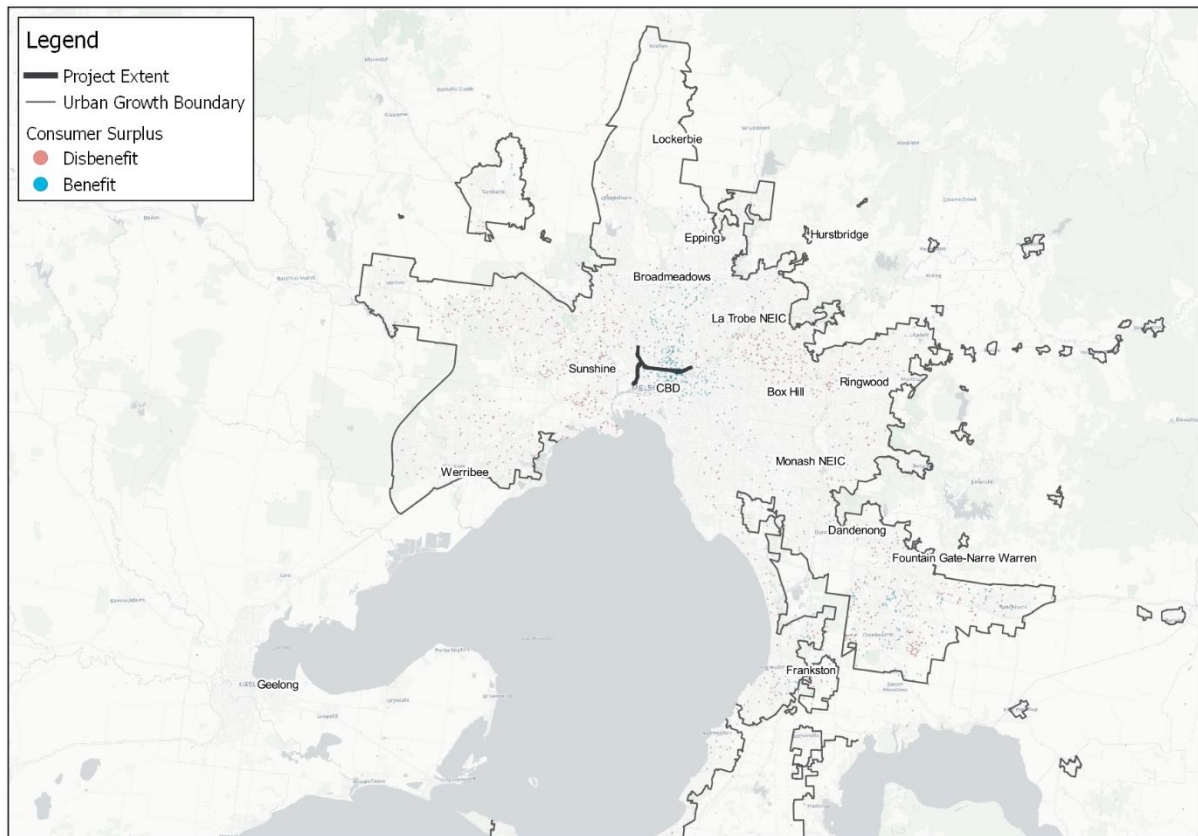
4.8   Conclusions

Based on the economic analysis, the CCM project does not appear to be economically viable as modelled for this assessment. Under the central case scenario with four and seven percent discount rates, as well as extensive sensitivity testing, the project generally has a BCR of less than one and consistently realises a negative NPV.

While the CCM project would generate significant benefits over time ($2.2-$5.2 billion in PV terms), this is substantially outweighed by the estimated costs of the project, mainly the capital cost.

The spatial assessment of this project indicates a redistribution of population and employment to inner and northern Melbourne. This increased density results in a small enhancement of consumer surplus in these areas.

5. Project 3: Melbourne Metro Two and direct Geelong rail line (MM2)

5.1 Project background

MM2 involves the construction of 15 kilometre twin tunnels through the Melbourne Central Business District (CBD) connecting Newport and Clifton Hill, via Fishermans Bend and Parkville on a new rail corridor. Eight new underground stations would be constructed at Newport, Fishermans Bend (Employment Precinct and Sandridge), Southern Cross, Flagstaff, Parkville, Fitzroy and Clifton Hill.

The new Metro service would enable an uplift on the Geelong, Werribee, Hurstbridge, Mernda, Laverton, Williamstown, Sandringham, Wyndham Vale and Grampian lines. The uplift of these services and the associated benefits have been included in the CBA.

For the purposes of this study, it is assumed that MM2 would be developed in two stages. These are:

- Stage 1, which would be constructed over the period 2030-40 (financial years), and would comprise four components:

    o Melbourne Metro Two Tunnel (MM2) from Newport to Southern Cross with a turnback box at Southern Cross station

    o Werribee to Newport Rail Corridor Upgrade

    o Manor to Werribee Rail Corridor Upgrade

    o Stabling and maintenance facilities at Manor to hold 47 High Capacity Metro Trains (HCMTs).

- Stage 2, which would be constructed over the period 2036-43 (financial years), and would comprise five components:

    o Melbourne Metro Two Tunnel (MM2) – Southern Cross to Clifton Hill

    o Altona Loop Partial Duplication (including second platform at Williamstown)

    o Mernda Rail Corridor Upgrade

    o Geelong (Waurn Ponds) to Werribee Rail Corridor Upgrade

    o Hurstbridge Rail Corridor Upgrade.

The capital cost also includes the initial acquisition of rolling stock.

Figure 21 shows the MM2 infrastructure corridor and service improvements.

Figure 21   MM2 corridor and service uplifts
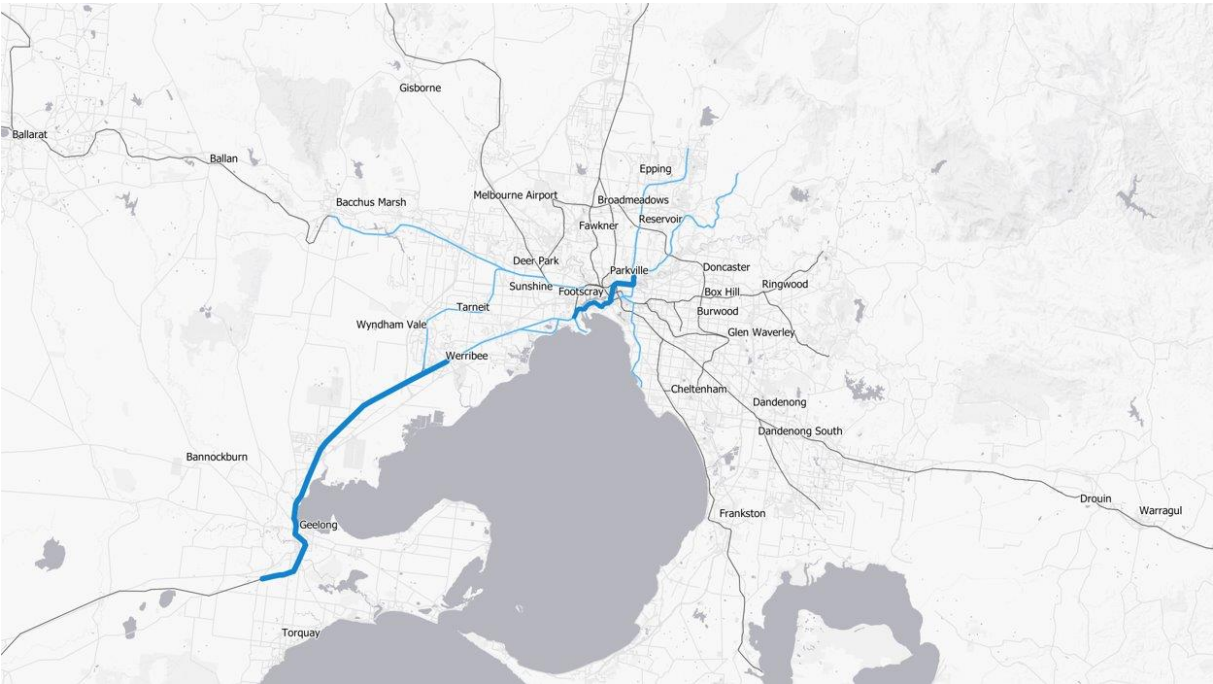
5.2   Cost and timing

The total project cost estimates can be seen in Table 60. The cost estimate considers the development of all aspects of the planning, construction, land acquisition costs and contingencies.

Key dates that have been assumed for the purposes of this assessment for the MM2 project are as follows:

- For Stage 1, construction is assumed to occur over the period 2030-40. Operational benefits have been assessed for the period 2040-90.

- For Stage 2, construction is assumed to occur over the period 2036-43. Operational benefits have been assessed for the period 2043-93.

Table 60   MM2 capex and opex cost (nominal with escalation, 2021 dollars, discounted at four percent and seven percent)

Project	Nominal capex ($m)	PV capex ($m)	Nominal opex ($m)	PV opex ($m)	Nominal asset renewal ($m)	PV asset renewal ($m)
MM2	$54,004	$17,207 - $27,663	$7,271	$515 - $1,433	$4,798	$196 - $689

PV capital expenditure for MM2 is estimated to be in the range $17.2-$27.7 billion. Operating expenditure is expected to be in the range $515 million to $1.4 billion over the 50 year benefits assessment. Major cost drivers are slightly different for each of the nine components of the project, but typically the largest components of cost include tunnels, stations and buildings and contingencies. The total also includes around $1.7 billion for rolling stock (real value, undiscounted).

5.3   Benefits

Table 61 summarises the value of benefits for MM2 using a four percent and a seven percent discount rate over a 50-year appraisal period.

Table 61   MM2 summary of project benefits (PV, $ million, 2021 dollars, discounted at four percent and seven percent)

Benefits (PV $mil)	Static only	Dynamic only	WEBs only	Total
Safety benefits	$7 - $20	$260 - $707		$267 - $727
Environmental benefits	-$47 - -$143	$45 - $290		-$2 - $147
Active transport benefits	$345 - $1,017	$386 - $117		$731 - $1,134
Consumer surplus benefits	$1,662 - $4,666	$3,650 - $6,164		$5,312 - $10,830
Residual values	$35 - $250	$35 - $0		$70 - $250
WEBs			$5,056 - $1,942	$5,056 - $1,942
Total benefits	$2,002 - $5,811	$4,376 - $7,278	$5,056 - $1,942	$11,434 - $15,031

The MM2 project is anticipated to deliver benefits in the range of $11.4 - $15 billion. For the lower end of the range, the largest contributor is WEBs (42 percent of all benefits). For the other end of the range (seven percent discount rate), the largest contributor is static scenario benefits (57 percent of total benefits).

In terms of benefit category, major benefits include consumer surplus ($5.3-$10.8 billion) and WEBs ($5.1-$1.9 billion). This is typical of rail projects as land use around the new public transport tends to change (with denser residential and employment patterns), increasing public transport demand and reducing road transport demand, leading to an overall reduction in costs.

5.4   CBA outcomes

Table 62 summarises the results of the CBA conducted for MM2 using a four percent and a seven percent discount rate over a 50-year appraisal period.

Table 62   MM2 CBA results (PV, $ million, 2021 dollars, discounted at four percent and seven percent)

Economic outcomes	Static	Dynamic	Total (incl WEBs)
NPV	-$15,916 - -$23,975	-$13,542 - -$16,697	-$12,862 - -$14,756
BCR	0.11 - 0.20	0.24 - 0.44	0.28 - 0.50
IRR	0%	0.57%	0%
FYRR	0% - 2.6%	0% - 3.4%	0% - 4.2%

The project generates a negative NPV and BCR below one at both ends of the range. The BCR ranges between 0.28-0.5 and the NPV ranges between -$12.9 and -$14.8 billion. Once land use change is taken into account (dynamic), the BCR increases by around 50 percent compared to the static scenario.

The key driver of this outcome is the high capital cost, which is significantly above the expected benefits that have been quantified.

Figure 22 presents the cumulative present values of benefits and costs over the project's life. As seen in this graph, the benefits do not exceed the costs in the appraisal period. The green area represents the difference between costs and benefits.

Figure 22   MM2 – total costs and benefits (PV)
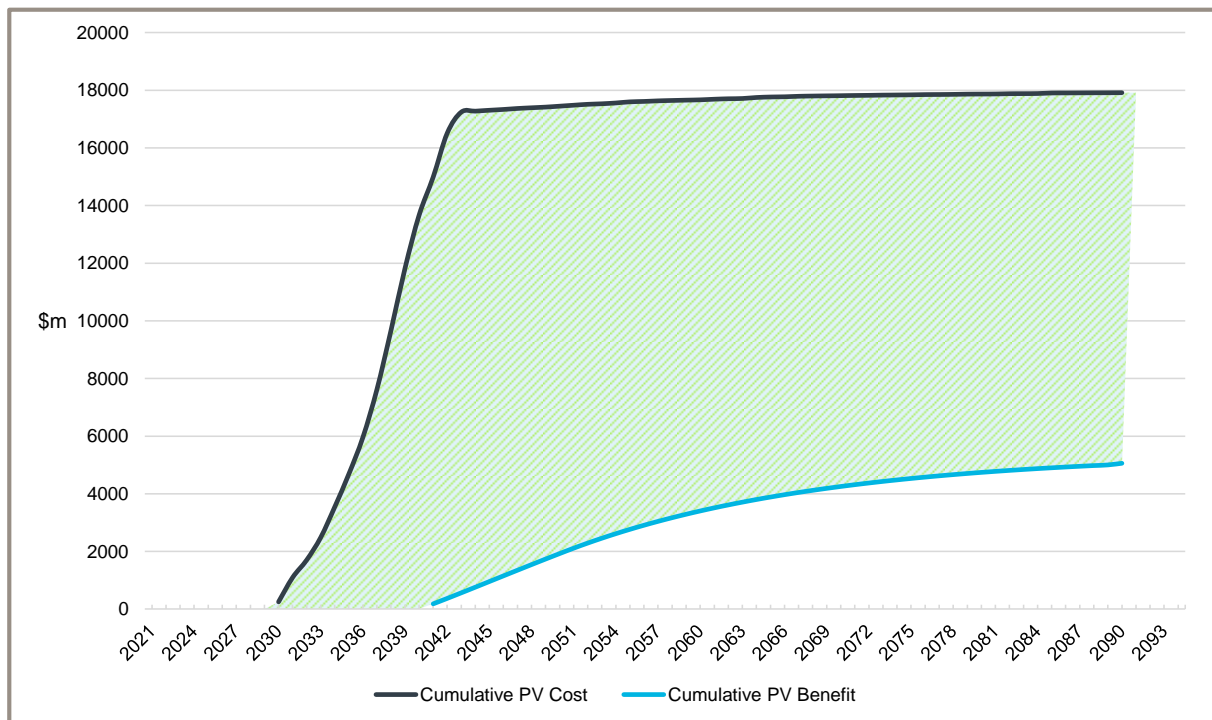
5.5   Sensitivity tests

Sensitivity analysis is outlined below.

Discount rate sensitivity tests were completed at three and ten percent discount rates. The results are outlined in Table 63 and Table 64.

The BCR results indicate that the project is not economically viable at either a three or ten percent discount rate. Similarly, there is a negative NPV result.

Table 63   MM2 sensitivity analysis - discount rates (BCR)

MM2 sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
4% discount rate (central case)	0.20	0.44	0.50
7% discount rate (central case)	0.11	0.24	0.28
3% discount rate	0.25	0.55	0.64
10% discount rate	0.07	0.15	0.18

Table 64   MM2 sensitivity analysis - discount rates (NPV)

MM2 sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
4% discount rate (central case)	-$23,975	-$16,697	-$14,756
7% discount rate (central case)	-$15,916	-$13,542	-$12,862
3% discount rate	-$27,575	-$16,571	-$13,086

10% discount rate	-$10,404	-$9,513	-$9,238

Table 65 and Table 66show the results of the sensitivity analysis for changes in capital costs. While the BCR and NPV improve, they are not positive, with a decrease of 20 percent in the capital cost of the project.

Table 65   MM2 sensitivity analysis - capex (BCR, discounted at four and seven percent)

MM2 sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*0.11 - 0.2*	*0.24 - 0.44*	*0.28 - 0.5*
20% decrease in capital costs	0.14 - 0.24	0.3 - 0.54	0.35 - 0.62
20% increase in capital costs	0.09 - 0.16	0.2 - 0.37	0.24 - 0.43
40% increase in capital costs	0.08 - 0.14	0.18 - 0.32	0.2 - 0.37

Table 66   MM2 sensitivity analysis - capex (NPV, discounted at four and seven percent)

MM2 sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*-$23,975 - -$15,916*	*-$16,697 - -$13,542*	*-$14,756 - -$12,862*
20% decrease in capital costs	-$18,442 - -$12,475	-$11,165 - -$10,101	-$9,421 - -$9,223
20% increase in capital costs	-$29,507 - -$19,357	-$22,230 - -$16,983	-$20,288 - -$16,303
40% increase in capital costs	-$35,040 - -$22,799	-$35,040 - -$20,425	-$25,821 - -$19,745

Table 67 and Table 68 show the results of the sensitivity analysis for changes in total benefits. Where benefits are increased by 20 percent the BCR remains at less than one and the NPV is negative, suggesting that the project is not economically viable.

Table 67   MM2 sensitivity analysis - benefits (BCR, discounted at four and seven percent)

MM2 sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*0.11 - 0.20*	*0.24 - 0.44*	*0.28 - 0.50*
40% decrease in total benefits	0.07 - 0.12	0.15 - 0.26	0.17 - 0.30
20% decrease in total benefits	0.09 - 0.16	0.20 - 0.35	0.23 - 0.40
20% increase in total benefits	0.13 - 0.23	0.29 - 0.53	0.34 - 0.61

Table 68   MM2 sensitivity analysis - benefits (NPV, discounted at four and seven percent)

MM2 sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*-$23,975 - -$15,916*	*-$16,697 - -$13,542*	*-$14,756 - -$12,862*
40% decrease in total benefits	-$26,299 - -$16,717	-$21,932 - -$15,292	-$20,767 - -$14,885
20% decrease in total benefits	-$25,137 - -$16,316	-$19,315 - -$14,417	-$17,761 - -$13,873
20% increase in total benefits	-$22,813 - -$15,515	-$12,667 - -$14,079	-$11,851 - -$11,750

Table 69 and Table 70 illustrate the results of the sensitivity analysis for delaying the opening year. The results remain negative under both the five and ten year delay sensitivity tests. Delays of five and ten years will sightly improve the BCR and NPV outcomes.

Table 69   MM2 sensitivity analysis – project delay (BCR, discounted at four and seven percent)

MM2 sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	0.11 - 0.20	0.24 - 0.44	0.28 - 0.5
Delay in opening traffic by five years	0.12 - 0.21	0.29 - 0.5	0.33 - 0.57
Delay in opening traffic by 10 years	0.13 - 0.22	0.31 - 0.54	0.36 - 0.62

Table 70   MM2 sensitivity analysis – project delay (NPV, discounted at four and seven percent)

MM2 sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	-$23,975 - -$15,916	-$16,697 - -$13,542	-$14,756 - -$12,862
Delay in opening traffic by five year	-$19,417 - -$11,260	-$12,305 - -$9,123	-$10,582 - -$8,596
Delay in opening traffic by 10 years	-$15,703 - -$7,959	-$9,244 - -$6,240	-$7,729 - -$5,836

Table 71 and Table 72 show the results of the sensitivity analysis for changes in the value of travel times. In this test the value of travel time was increased at a rate of one percent per year. Under this sensitivity test, the BCR remains below one, albeit with an improvement from 0.28-0.5 to 0.33-0.63. The NPV remains negative, but with an improvement.

Table 71   MM2 sensitivity analysis - value of travel time (BCR, discounted at four and seven percent)

MM2 sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*0.11 - 0.20*	*0.24 - 0.44*	*0.28 - 0.50*
Value of travel time	0.14 - 0.26	0.29 - 0.56	0.33 - 0.63

Table 72   MM2 sensitivity analysis - value of travel time (NPV, discounted at four and seven percent)

MM2 sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*-$23,975 - -$15,916*	*-$16,697 - -$13,542*	*-$14,756 - -$12,862*
Value of travel time	-$21,990 - -$15,229	-$13,023 - -$12,326	-$11,081 - -$11,646

5.6   Spatial/land use results

Figure 23 and Figure 24 illustrate changes in population distribution as a result of the MM2 project compared to the transport base case.

In 2036, it shows that there are movements in population distribution towards the rail corridors which experience improved services as a result of MM2, these being Hurstbridge and Mernda in the northeast, and the Geelong corridor in the southwest. There is also a shift of population towards the rail corridor in inner Melbourne. This is likely to be a result of people moving towards areas which are better served by

improved rail capacity. Residents may typically relocate for lifestyle or amenity, such as additional space, less crowding or cheaper housing prices.

By contrast, there is a movement of residents away from areas in the metropolitan area which are not served by the MM2 project. Suburbs in the northwest, west and south of Melbourne would experience a modest reduction in future residential population compared to the base case. The drivers of this shift are likely to be the same, that being people attracted to new areas because of improved transport links. Because each dot represents five residents, the population shifts are relatively modest in terms of overall population size.

By 2051, the population shift is slightly larger, with the same patterns being seen. Additional residents have moved to Melbourne's west, Geelong and the northeast compared to the base case, with small population reductions across the rest of the metropolitan area compared to the transport base case.

Figure 23   MM2 change in population in 2036 (each dot represents a change of five residents)
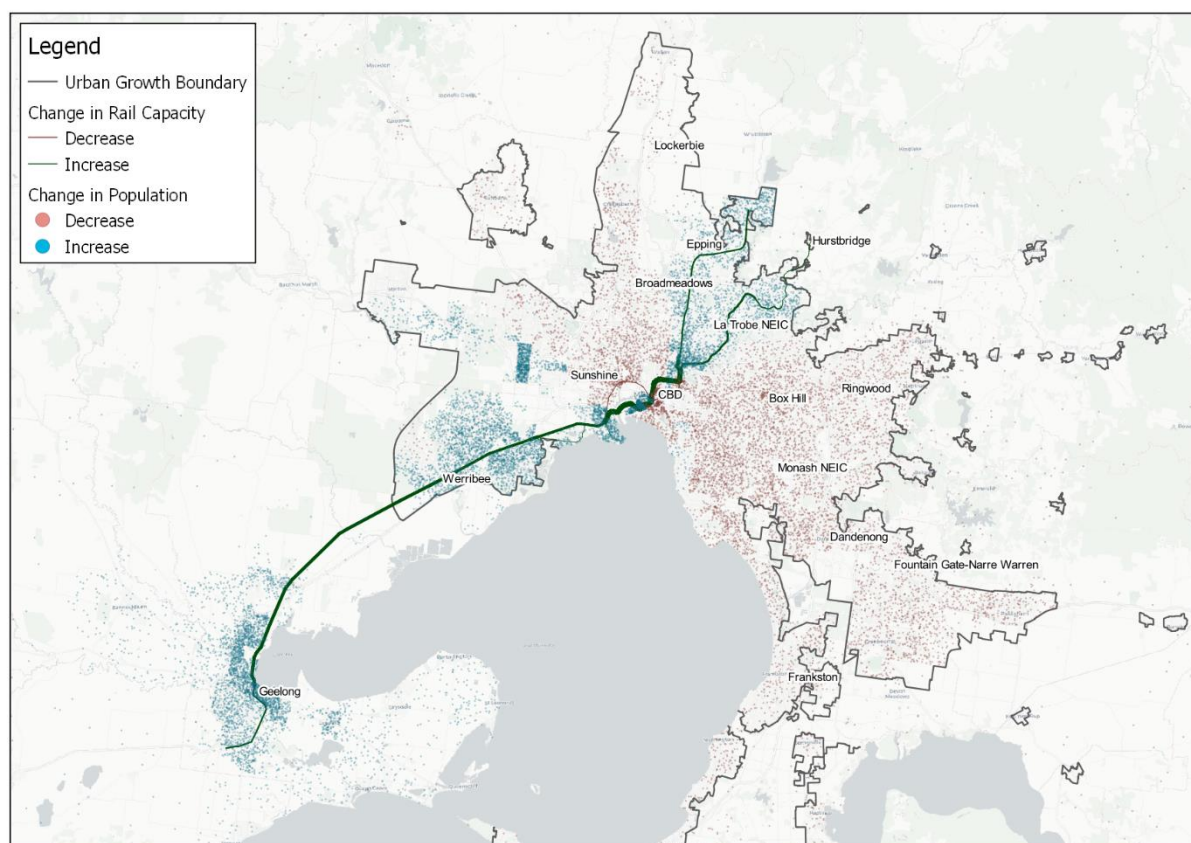
Figure 24   MM2 change in population in 2051 (each dot represents a change of five residents)
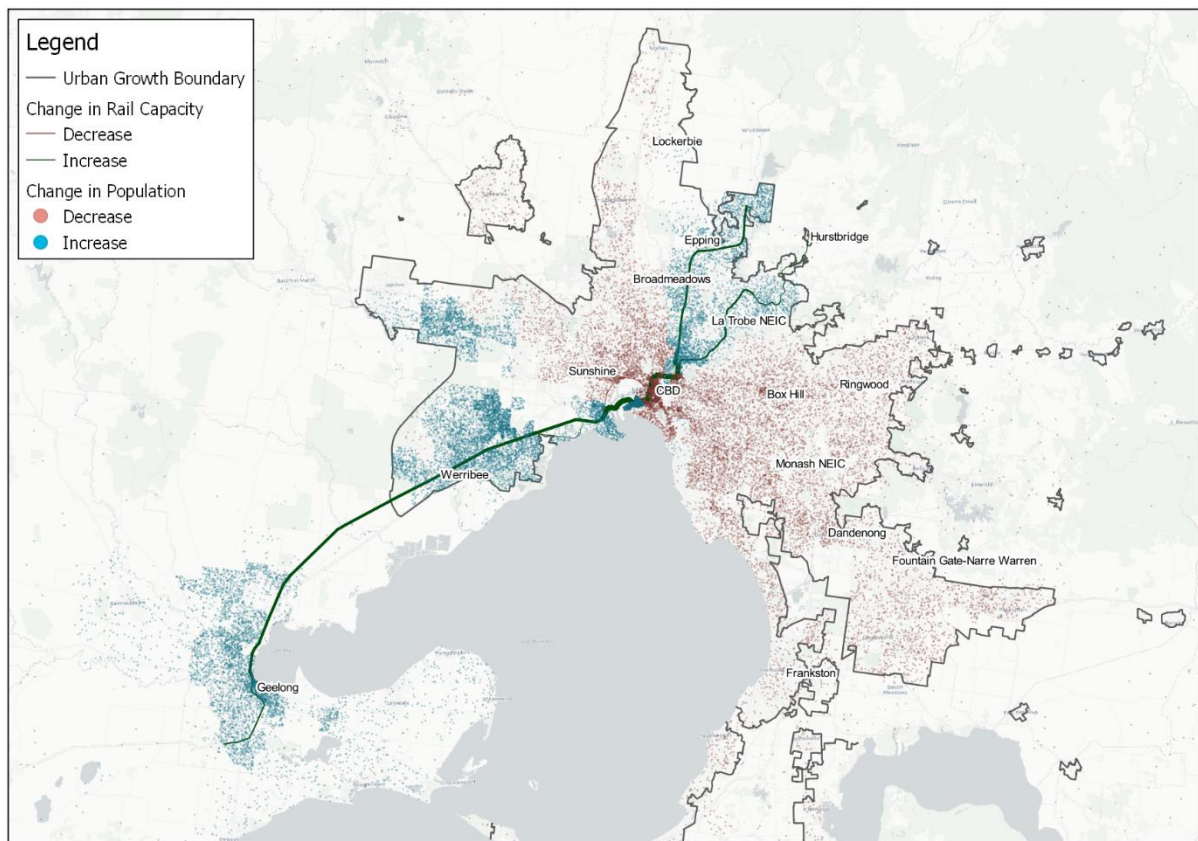
The impacts on employment compared to the transport base case are shown in Figure 25 and Figure 26. In 2036, employment distribution shows a moderate shift towards corridors with enhanced rail service capacity, to some extent mirroring the population redistribution effects of the project. Improved public transport connectivity is likely to be the key rationale of jobs moving towards the corridor. By contrast, there is a small movement of jobs away from other areas in Melbourne towards the new rail corridor. As each dot represents five jobs, this shift from the rest of the metropolitan area is relatively modest.

In 2051, the same patterns occur, with an uptick in jobs located along the corridor as far as Geelong, and a dip in jobs elsewhere in the metropolitan area compared to the transport base case.

Figure 25   MM2 change in employment in 2036 (each dot represents a change of five jobs)
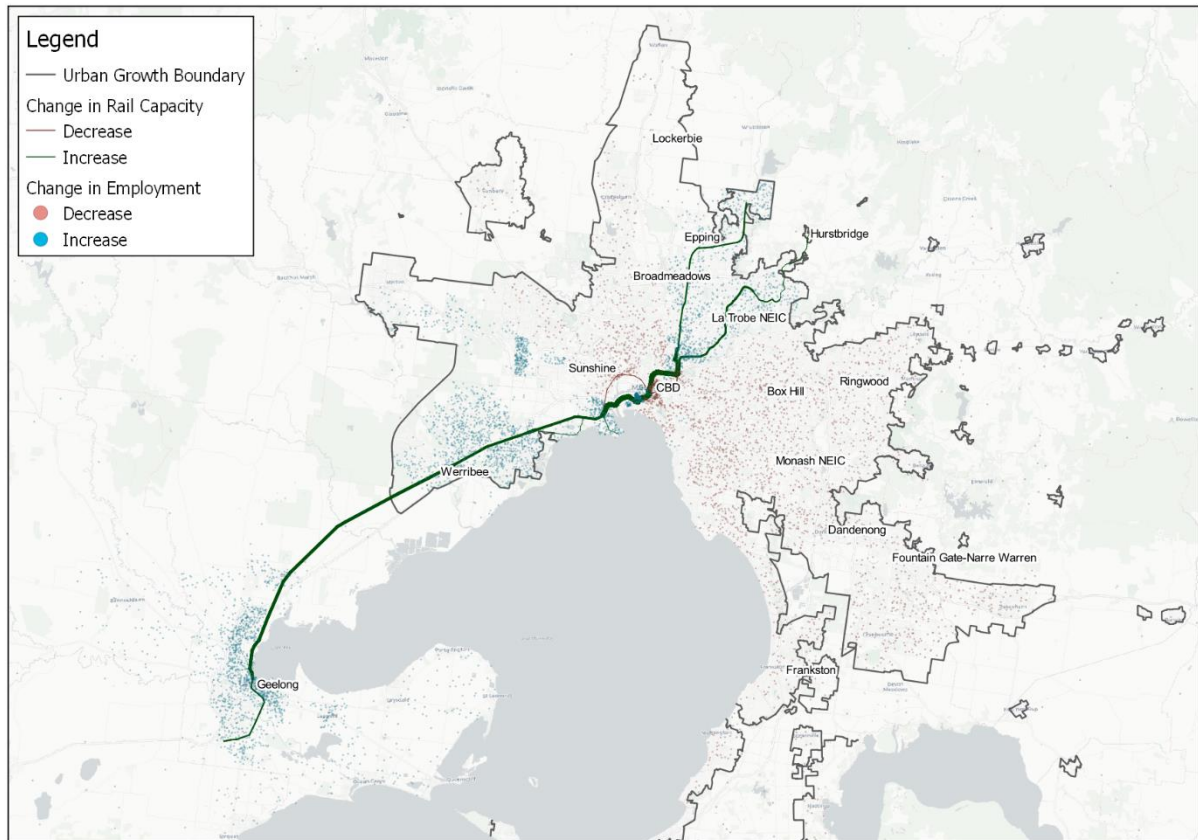
Figure 26   MM2 change in employment in 2051 (each dot represents a change of five jobs)
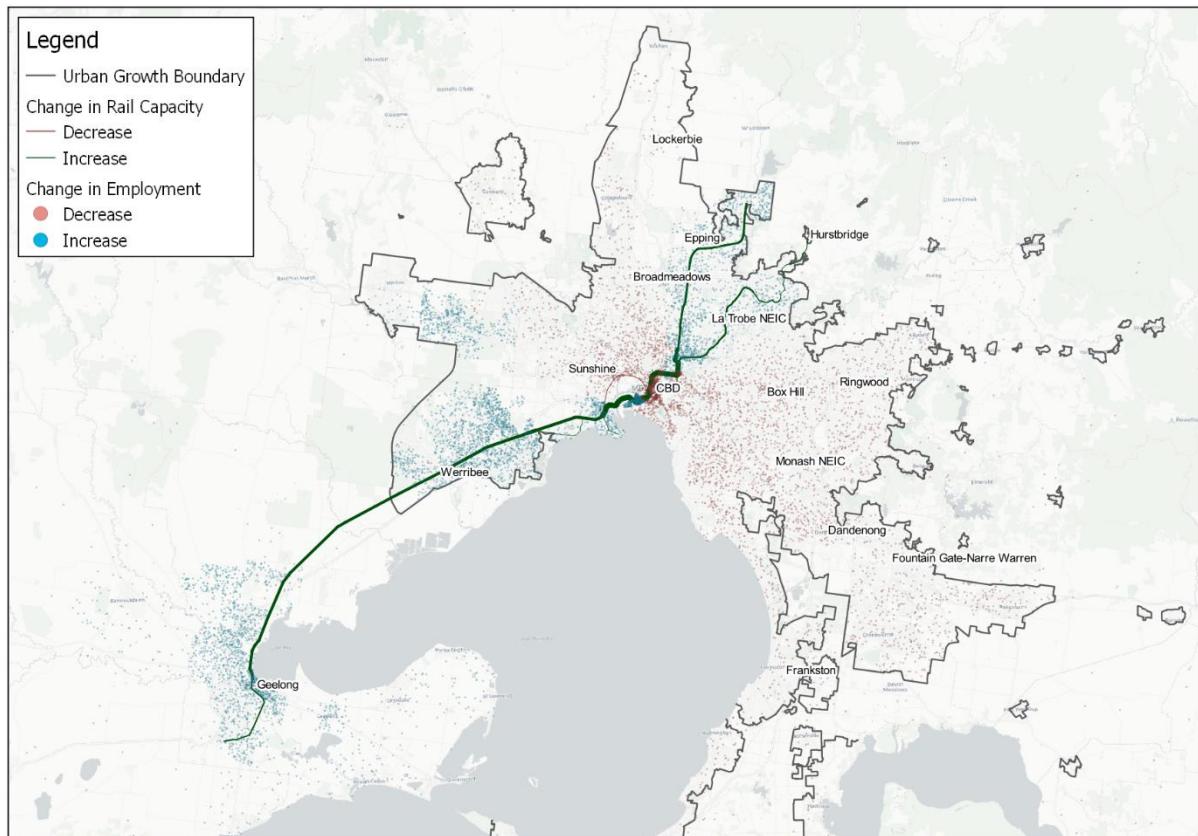
Figure 27 and Figure 28 show the expected impact of the project on consumer surplus in 2036 and 2051, respectively, compared to the transport base case.

Increases in public transport consumer surplus (blue) is consistent with the service uplift along the corridor and the land use redistribution. Consumer surplus benefits – typically derived from improvements in public transport service levels and amenity – are expected to be reasonably widespread along the MM2 corridor.

Figure 27   MM2 change in consumer surplus, 2036 (each dot represents a change of 120 minutes)
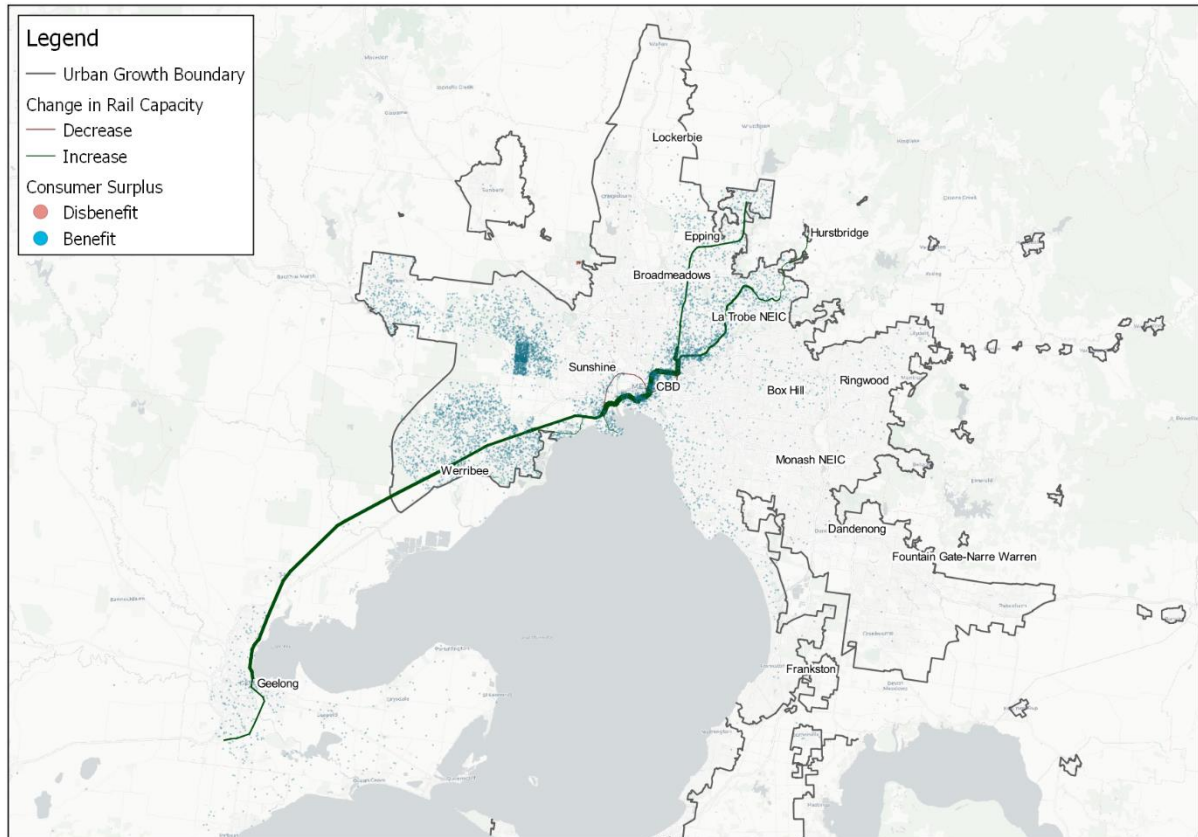
Figure 28 MM2 change in consumer surplus, 2051 (each dot represents a change of 120 minutes)
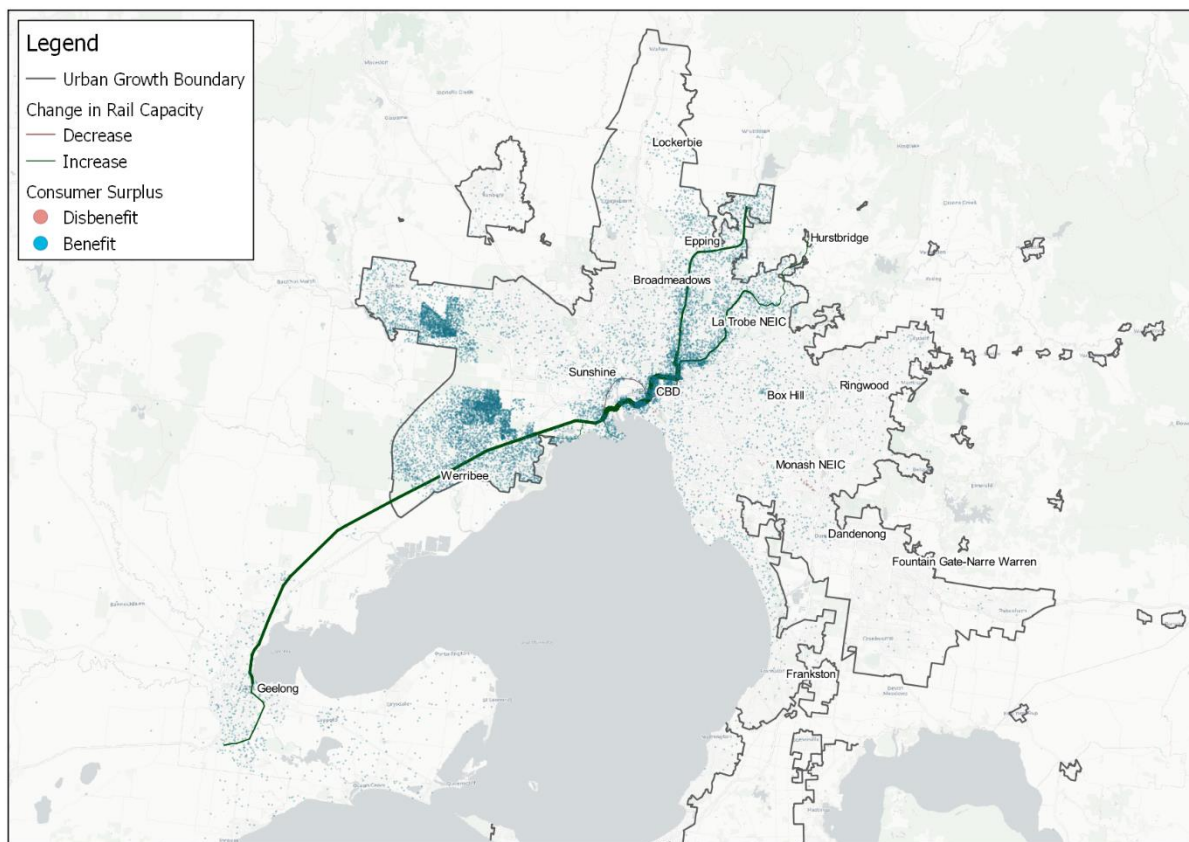
5.7   Conclusions

The MM2 project is estimated to realise a BCR of less than one and a negative NPV, suggesting that the project is not economically viable as modelled in this assessment. This conclusion remains the same under different sensitivity testing scenarios. As noted earlier, while the benefits are substantial ($11.4 - $15 billion in PV terms), they are outweighed by high project costs, particularly the capital cost.

In terms of spatial outcomes, MM2 would drive population and employment redistribution along the three key rail corridors impacted by the project, these being Geelong, Mernda and Hurstbridge. Increased service levels and quality would encourage the redistribution of jobs and population to these areas and away from the rest of the metropolitan area. Consumer surplus, driven by the benefits of improved rail services, is expected to be positive in areas around the rail alignment.

6. Project 4: Outer Metropolitan Ring Road (OMR)

6.1 Project background

The OMR is planned to be the major 'outer ring' road for Melbourne in the future, connecting the west of the metropolitan area and Geelong with the Hume Highway in the north, as well as connecting into the M80, providing a direct freeway link to North East Link and access to the east and southeast of Melbourne. The OMR is a part of Melbourne's long term freeway planning, and is expected to serve as both a commuter and major freight corridor (road and rail).

In addition to its function as a major arterial road, the OMR has also been conceived as a rail corridor. The OMR preliminary design outlined in the *Outer Metropolitan Ring/E6 Transport Corridor Planning Assessment Report* (2009) allowed for:

- A freeway standard road, with ultimate capacity of eight lanes (four in each direction)
- Four railway tracks to cater for interstate freight and high speed passenger trains. The 2009 design had the rail lines situated in the road median.

This whole project comprises OMR north and south, the E6, Tullamarine Freeway extension and Deer Park Bypass. The northern segment, the OMR/E6, will connect the M80 Ring Road, Hume Freeway and Melton Highway by 2036. The southern section, connecting the Melton Highway, Western Freeway and Princes Freeway, is expected to be built by 2051, along with upgrades to adjacent road infrastructure.

The redistribution of traffic would result in enhanced access to major employment and retail precincts in the north and west, including National Employment and Innovation Clusters (NEICs) in East Werribee, Sunshine, and La Trobe well as Melbourne Airport.

The alignment is illustrated in Figure 29.

The OMR is divided into three components, which are outlined in Table 73.

Table 73   OMR scope

Component	Sector	Length	Details (costing assumptions)
Phase A – E6	Hume Freeway to M80 Ring Road M80 widening	27.2 km	For E6: • Two lanes each way For M80 widening • E6 to Plenty Road Eastbound: widen existing four lanes + shoulder • E6 to Plenty Road Eastbound: widen existing four lanes + shoulder to five lanes + shoulder • Plenty Road overpass both directions: Provide extra outbound and inbound lanes • Plenty Road to E6 Westbound: Widen existing four lanes + shoulder
Phase B – OMR North	Melton Highway to Hume Freeway	32.3 km	For OMR North: • Two lanes each way

Component	Sector	Length	Details (costing assumptions)
	Tullamarine Freeway upgrade		For Tullamarine Freeway upgrade: • Two lanes each way
Phase C – OMR South	Princess Freeway to Melton Highway Deer Park Bypass Connection (DPBC)	40.1 km	For OMR South: • Two lanes each way For DPBC: • Two lanes each way

The OMR corridor is planned to contain up to four train lines and is nominally planned to be 240 metres wide. For the purposes of the costing and economics, only the road component has been considered, and a corridor of 120 metres in width has been assumed. While four lanes (two in each direction) have been costed, the OMR is ultimately panned to contain up to eight lanes (four in each direction). The cost therefore assumes that land acquisition and civil works are undertaken to accommodate a four lane each way roadway in the 120 metre wide corridor, with the roadway construction assuming four lanes in total only.

For the E6 corridor, the cost assumes that land acquisition and civil works are undertaken to accommodate a four lane each way roadway in a 70 metre wide corridor, with the road being constructed as two lanes in each direction. Provision has also been made for bus stops.

Road works required at the interfaces between the proposed corridor and existing roads include new interchanges, bridges, road upgrades, toll gantries and other infrastructure, which are detailed in the Cost Report.

The OMR and E6 alignment are illustrated in Figure 29.

Figure 29   OMR and E6 Alignment

AECOM

6.2 Cost and timing

The total cost estimates, inclusive of contingencies, 50-years renewal costs and operations and maintenance costs (O&M) are shown in Table 74.

Key dates that have been assumed for the purposes of this assessment for the OMR project are as follows:

- Construction of OMR Stage 1 (comprising Phases A and B) is assumed to occur during the period 2031-35 (financial years), with an operational period of 2036-85 (financial years).

- Construction of OMR Stage 2 (Phase C) is assumed to occur during the period 2045-50 (financial years), with an operational period of 2051-85 (financial years).

Table 74   OMR Capex and opex cost profile (nominal with escalation, 2021 dollars, discounted at four percent and seven percent)

Project	Nominal capex ($m)	PV capex ($m)	Nominal opex ($m)	PV opex ($m)	Nominal asset renewal ($m)	PV asset renewal ($m)
OMR Stage 1	$28,676	$13,094 - $18,189	$1,225	$131 - $304	$4,196	$150 - $561
OMR Stage 2	$20,720	$3,664 - $7,581	$441	$23 - $75	$2,242	$95 - $331
OMR (Total)	$49,396	$16,758 - $25,770	$1,666	$154 - $379	$6,438	$245 - $892

PV capital expenditure for OMR is estimated to be in the range of $13.1-18.2 billion for Stage 1 and $3.7-7.6 billion for Stage 2. Construction is expected to commence in 2031 and 2045, with the first year of benefits realised in financial year 2036 and 2051 for Stage 1 and Stage 2, respectively.

The key components of capital expenditure are pavements, bridges and land acquisition. Contingencies for design, construction and prolongation have also been included in the total cost.

6.3 Benefits

Table 75 presents a summary of the present value of the total benefits for OMR using a four and seven percent discount rate over a 50 year appraisal period.

Table 75   OMR summary of project benefits (PV, $ million, 2021 dollars, discounted at four percent and seven percent)

Benefit	Static only	Dynamic only	WEBs only	Total
Safety benefits	$132 - $300	-$9 - -$10		$123 - $290
Environmental benefits	-$458 - -$161	$93 - $246		-$212 - -$68
Active transport benefits	-$333 - -$123	$66 - $172		-$161 - -$57
Consumer surplus benefits	$14,246 - $35,381	$3,201 - $8,832		$17,447 - $44,213
Residual values	$56 - $346	$0 - $0		$56 - $346
WEBS			$1,405 - $3,361	$1,405 - $3,361
Total benefits	**$14,151 - $35,237**	**$3,351 - $9,241**	**$1,405 - $3,361**	**$18,907 - $47,839**

The major driver of benefits for OMR are consumer surplus benefits, regardless of whether there is a change in land use. The underlying transport modelling data shows that most of the consumer surplus

benefit is as a result of travel time savings and associated reductions in vehicle operating costs for road transport, which is typical of a major road project. Nearly all of these savings are for private vehicle rather than freight vehicles. The travel time gains are slightly offset by increases in road tolls and car parking, indicating an increase in the number of private vehicle users as a result of the project.

In terms of WEBs, nearly all of the benefit was derived from agglomeration (55 percent of the WEBs) and tax revenues from labour markets (39 percent of WEBs). This indicates that the project has resulted in increasing productivity as a result of greater business density, and this uplift can be seen through increased taxes from labour.

Figure 30 illustrates the trajectory of benefits over time, and shows a gradual increase in benefits over time, because they are derived from two transport modelling points in time (2036 and 2051), with the other years estimated based on an even accumulation of benefits. In reality, we would anticipate benefits to have a 'step change' shape in the way that costs have, following the opening of a new stage. It is unclear the extent to which this would have had an impact on total benefits. Additional transport modelling years would be required to demonstrate this expectation.

6.4   CBA outcomes

The results of the CBA conducted for OMR using four percent and seven percent discount rates are shown in Table 76.

Table 76   OMR CBA results (PV, $ million, 2021 dollars, discounted at four percent and seven percent)

Indicator	Static	Dynamic	Total (incl WEBs)
NPV ($m)	-$3,006 - $8,195	$345 - $17,436	$1,750 - $20,796
BCR	0.82 - 1.3	1.02 - 1.64	1.10 - 1.77
IRR	5.65%	7.14%	7.7%
FYRR	8.1% - 12.5%	8.5% - 13.1%	9.5% - 14.6%

Under the static scenario, the NPV ranges between -$3 and $8.2 billion, with a BCR ranging between 0.8 and 1.3. The BCR and NPV both indicate that the project is not economically viable at a discount rate at the lower end of the range, but is at the upper end. Once dynamic modelling is considered, the BCR is greater than one at the low end of the range as well, indicating that land use changes will enhance the project's economic viability.

The inclusion of WEBs further enhances BCR and NPV outcomes. The inclusion of WEBs in the CBA results in an NPV range of $1.8 to $20.8 billion and a BCR range of 1.1-1.8, indicating that the project has economic merit. Additionally, dynamic (which includes static) and dynamic with WEBs scenarios produce an FYRR greater than the project discount rates at 8.5-13.1 percent 9.5-14.6 percent, respectively, indicating deferral of the project is not warranted. The IRR for both scenarios is also greater than the discount rates, indicating the project is economically feasible at its current proposed timing.

The cumulative present value of benefits and costs over the project's life is shown below. The green area represents the difference between costs and benefits.

Figure 30   OMR – total costs and benefits (PV)
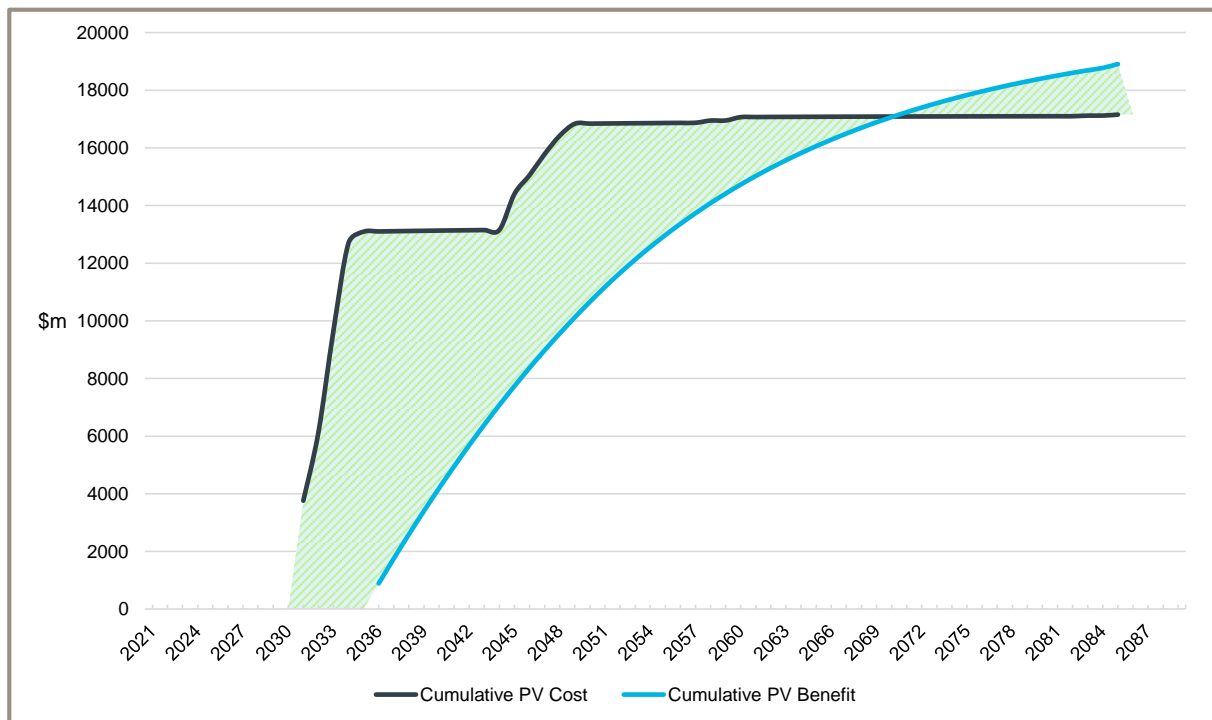
6.5   Sensitivity tests

The results of the sensitivity analysis undertaken at discount rates of three and ten percent are shown in Table 77 and Table 78. Under the three percent sensitivity tests, the OMR project generates a higher BCR and NPV compared to the central case scenario. This implies that the project remains economically viable under changes to this assumption. The project is, however, unviable at a discount rate of ten percent, with a BCR less than 1.0 and a negative NPV.

Table 77   OMR sensitivity analysis - discount rates (BCR)

OMR sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
4% discount rate (central case)	*1.30*	*1.64*	*1.77*
7% discount rate (central case)	*0.82*	*1.02*	*1.10*
3% discount rate	1.55	1.97	2.12
10% discount rate	0.57	0.69	0.75

Table 78   OMR sensitivity analysis - discount rates (NPV)

OMR sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
4% discount rate (central case)	*$8,195*	*$17,436*	*$20,796*
7% discount rate (central case)	*-$3,006*	*$345*	*$1,750*
3% discount rate	$17,720	$31,152	$35,826
10% discount rate	-$4,919	-$3,526	-$2,852

Table 79 and Table 80 show the results of the sensitivity analysis for capital costs. In the static, and static and dynamic scenarios, a 20 percent decrease in capital costs enhances the project's viability, with a BCR above 1.0. Where capital costs are increased by 20 and 40 percent, the project generates negative NPVs and BCRs below 1.0 at the bottom end of the range.

Table 79   OMR sensitivity analysis - capex (BCR, discounted at four and seven percent)

OMR sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*0.82 - 1.30*	*1.02 - 1.64*	*1.10 - 1.77*
20% decrease in capital costs	1.03 - 1.61	1.27 - 2.03	1.37 - 2.19
20% increase in capital costs	0.69 - 1.09	0.85 - 1.38	0.92 - 1.49
40% increase in capital costs	0.59 - 0.94	0.73 - 1.19	0.79 - 1.28

Table 80   OMR sensitivity analysis - capex (NPV, discounted at four and seven percent)

OMR sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*-$3,006 - $8,195*	*$345 - $17,436*	*$1,750 - $20,796*
20% decrease in capital costs	$346 - $13,349	$3,697 - $22,590	$5,102 - $25,951
20% increase in capital costs	-$6,357 - $3,041	-$3,006 - $12,282	-$1,601 - $15,642
40% increase in capital costs	-$9,709 - -$2,113	-$6,358 - -$2,113	-$4,953 - $10,488

Sensitivity analysis was carried out for project benefits under three assumptions as shown in Table 81 and Table 82. Where benefits are reduced by 40 percent, this results in a negative NPV and BCR less than 1.0 for both static and static and dynamic scenarios. By contrast, where benefits are increased by 20 percent, net benefits are enhanced and the total BCR is higher than the central case.

Table 81   OMR sensitivity analysis - benefits (BCR, discounted at four and seven percent)

OMR sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*0.82 - 1.30*	*1.02 - 1.64*	*1.10 - 1.77*
40% decrease in total benefits	0.49 - 0.78	0.61 - 0.99	0.66 - 1.06
20% decrease in total benefits	0.66 - 1.04	0.82 - 1.32	0.88 - 1.42
20% increase in total benefits	0.99 - 1.56	1.22 - 1.97	1.32 - 2.12

Table 82   OMR sensitivity analysis - benefits (NPV, discounted at four and seven percent)

OMR sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*-$3,006 - $8,195*	*$345 - $17,436*	*$1,750 - $20,796*
40% decrease in total benefits	-$8,666 - -$5,899	-$6,656 - -$355	-$5,813 - $1,661
20% decrease in total benefits	-$5,836 - $1,148	-$3,155 - $8,540	-$2,031 - $11,229
20% increase in total benefits	-$175 - $15,243	$3,846 - $26,331	$5,532 - $30,364

Table 83 and Table 84 show the results from the sensitivity analysis for when the opening year of operation is delayed by five and ten years respectively. When undertaking sensitivity analysis by delaying the timing of the project, the results show an NPV higher than the central case under static, static and dynamic and total benefit scenarios. This is largely as a result of a lower discount factor as costs are incurred in a later time period, and thus have lower present values. Benefits also increase as there is higher demand in the future. The BCR increases in comparison to the central case scenario as costs have lower present values and benefits increase. It should be noted that delaying the delivery stage of the project may incur additional costs which are not captured in this analysis, such as additional overhead, planning and financial costs.

Table 83   OMR sensitivity analysis – project delay (BCR, discounted at four and seven percent)

OMR sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*0.82 - 1.30*	*1.02 - 1.64*	*1.10 - 1.77*
Delay in opening traffic by five years	0.89 - 1.40	1.15 - 1.82	1.23 - 1.94
Delay in opening traffic by 10 years	0.96 - 1.50	1.26 - 1.97	1.34 - 2.11

Table 84   OMR sensitivity analysis – project delay (NPV, discounted at four and seven percent)

OMR sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*-$3,006 - $8,195*	*$345 - $17,436*	*$1,750 - $20,796*
Delay in opening traffic by five years	-$1,318 - $8,934	$1,780 - $18,149	$2,800 - $20,995
Delay in opening traffic by 10 years	-$363 - $9,142	$2,257 - $17,802	$3,008 - $20,239

Table 85 and Table 86 show the results of the sensitivity analysis for the value of travel time sensitivity test. Under all scenarios the BCR remains above 1.0 and the NPV remains positive, indicating that the project will be economically viable and deliver net economic benefits under this assumption. Under this sensitivity test, the value of benefit derived from each hour of positive travel time outcomes will increase over time.

Table 85   OMR sensitivity analysis - value of travel time (BCR, discounted at four and seven percent)

OMR sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*0.82 - 1.30*	*1.02 - 1.64*	*1.10 - 1.77*
Value of travel time	1.05 - 1.69	1.31 - 2.13	1.39 - 2.26

Table 86   OMR sensitivity analysis - value of travel time (NPV, discounted at four and seven percent)

OMR sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*-$3,006 - $8,195*	*$345 - $17,436*	*$1,750 - $20,796*
Value of travel time	$933 - $18,610	$5,249 - $30,615	$6,654 - $33,976

6.6   Spatial/land use results

Changes to population redistribution as a result of OMR are shown in Figure 31 and Figure 32 for 2036 and 2051, respectively

By 2036, there is a shift in population from the new growth areas in the north of Melbourne to the already established suburbs to the north and west of the CBD. There is also some population density in the CBD itself. By contrast, the fast growing and newly established urban areas to the north and west of the OMR would see a small reduction in population compared to the base case.

This outcome indicates that the OMR may have the effect of reducing traffic in the north and west of Melbourne, with the result that there is an increase in people opting to live in these areas. As the OMR pushes traffic out of the established urban areas, this appears to enhance amenity (mainly through reduced traffic and emissions) in these suburbs, leading to a slight uptick in population. By contrast, the changed traffic patterns as a result of the OMR may somewhat reduce the attractiveness of new urban growth areas compared to existing urban areas, for the reasons described above.

It is worth noting that the new urban areas in the north and east of Melbourne such as Lockerbie and Wallan are expected to have very high rates of population growth over the next three decades, regardless of the OMR project. As each dot represents five residents, the change in population distribution compared to the transport base case is still modest compared to overall population growth outcomes.

The pattern in 2051 is expected to be a continuation of the trend identified in 2036, with slightly more change in population distribution away from the new growth areas and towards existing suburbs.

Figure 31 OMR change in population in 2036 (each dot represents a change of five residents)
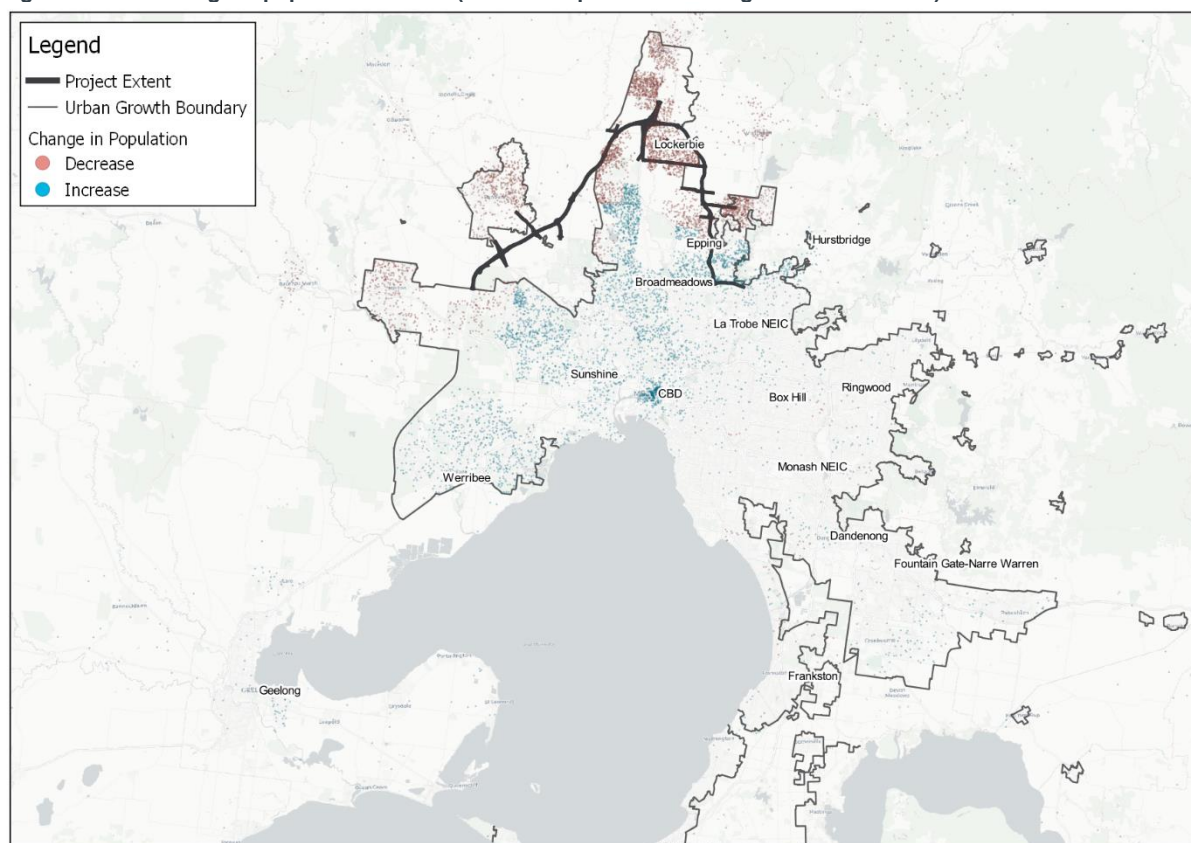
Figure 32 OMR change in population in 2051 (each dot represents a change of five residents)
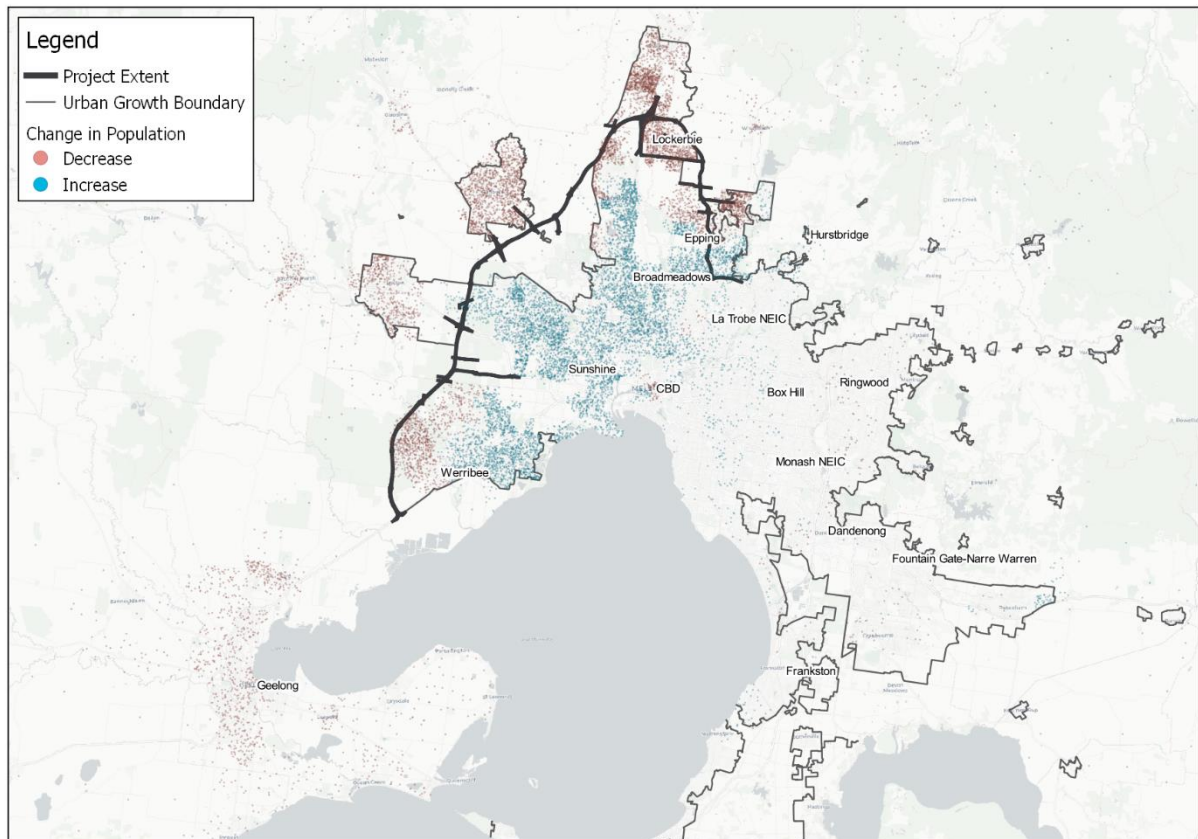
The estimated impacts of OMR on employment redistribution are illustrated in Figure 33 and Figure 34.

In 2036, there is little change in employment distribution as a result of the OMR project. There is a minor redistribution of jobs from the outer north and west to established suburbs in the north and west of the CBD. This employment redistribution is likely to be for similar reasons for the redistribution of population in 2036, that being reduced traffic and improved amenity in established suburbs encouraging employers to locate jobs in these areas. Noting that each dot represents five jobs, it is also important to recognise that job redistribution impacts in 2036 are minimal.

By 2051, there is a lightly stronger redistribution of employment to established areas and away from the outer north and west. This is a continuation (and slight strengthening) of the trend identified in 2036.

Figure 33 OMR change in employment in 2036 (each dot represents a change of five jobs)
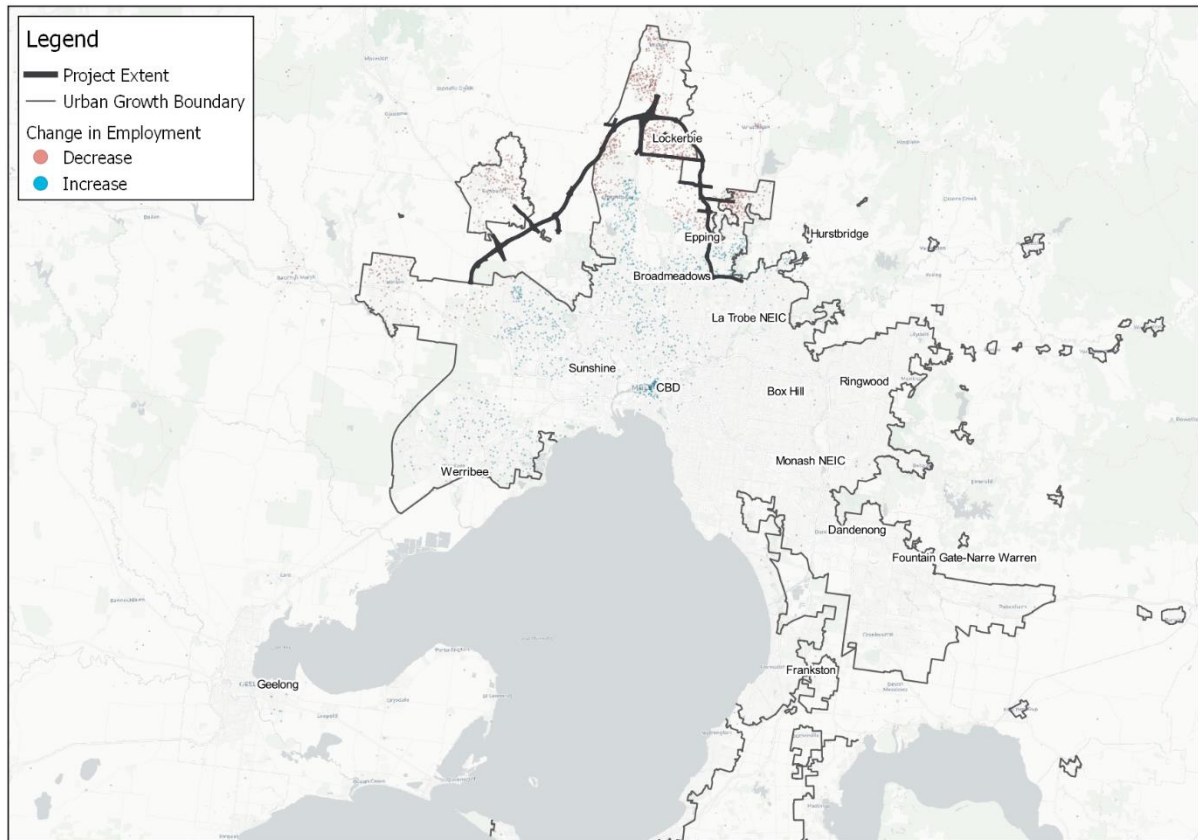
Figure 34 OMR change in employment in 2051 (each dot represents a change of five jobs)
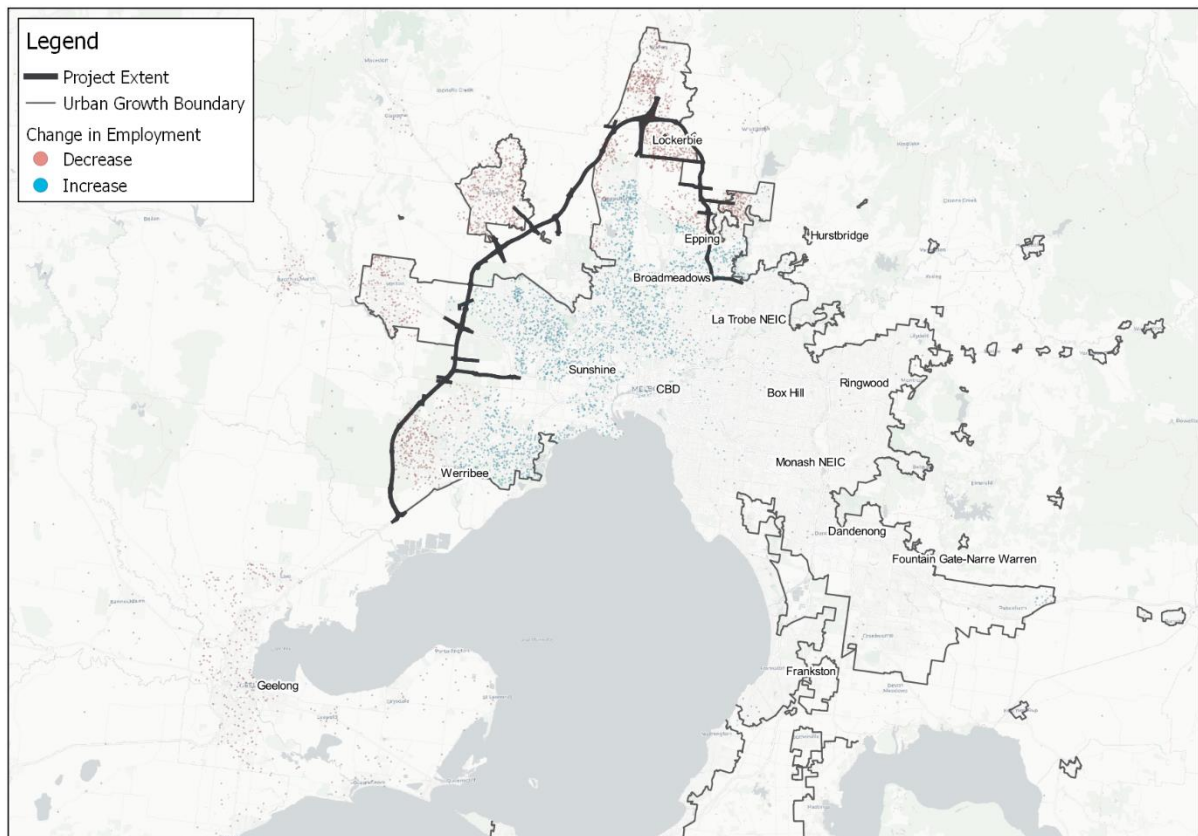
Figure 35 and Figure 36 show changes in consumer surplus for car users compared to the base case. Consumer surplus change in this instance comes about as a result of changes in road vehicle movement outcomes.

In 2036, consumer surplus benefits show an increase in the north and west of Melbourne, in those areas in relative proximity to the OMR. The opening of the OMR is likely to result in reductions in road based travel times, with a concomitant increase in consumer surplus. Changes in consumer surplus in other parts of the metropolitan area are insignificant.

In 2051, consumer surplus has increased compared to 2036 in areas close to the OMR corridor. As with 2036, this is likely to be because of the increased road capacity affected by the OMR, leading to reductions in travel times and increased travel efficiency for road based transport.

Figure 35 OMR changes in consumer surplus, 2036 (each dot represents a change of 120 minutes)
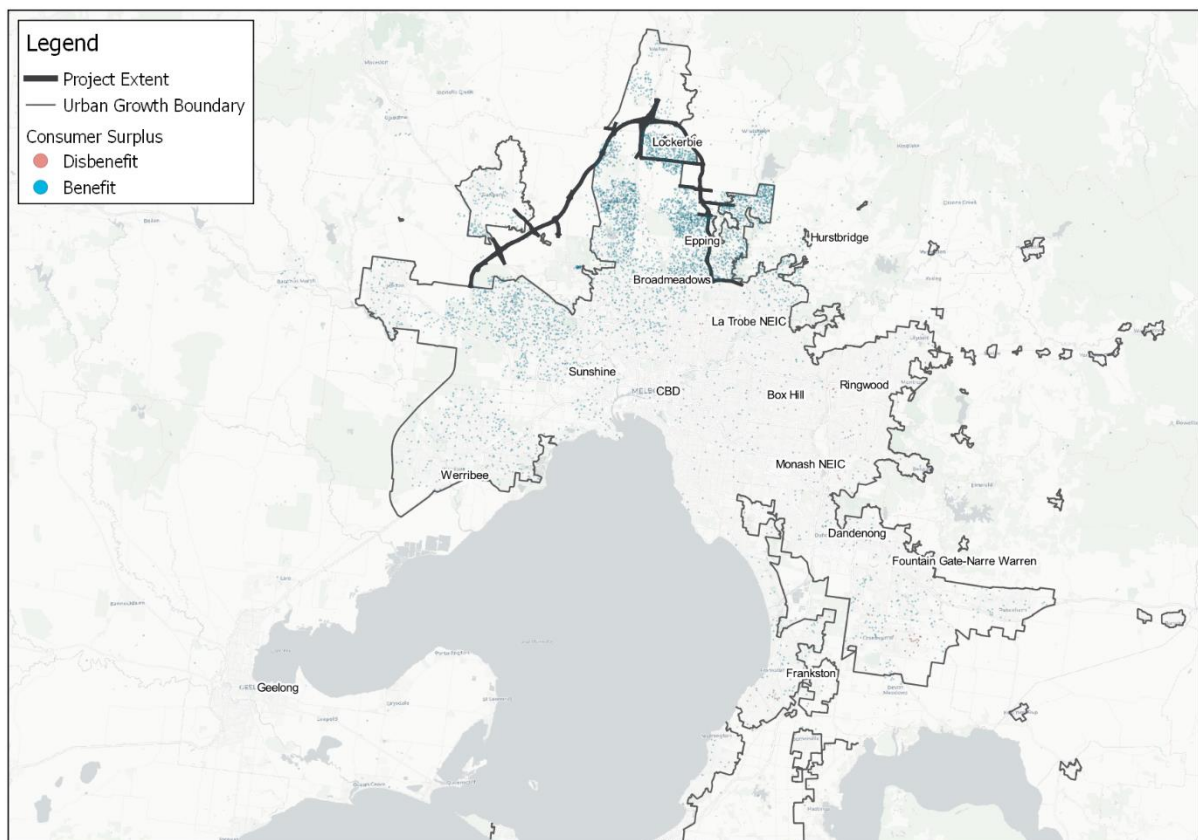
Figure 36 OMR changes in consumer surplus, 2051 (each dot represents a change of 120 minutes)
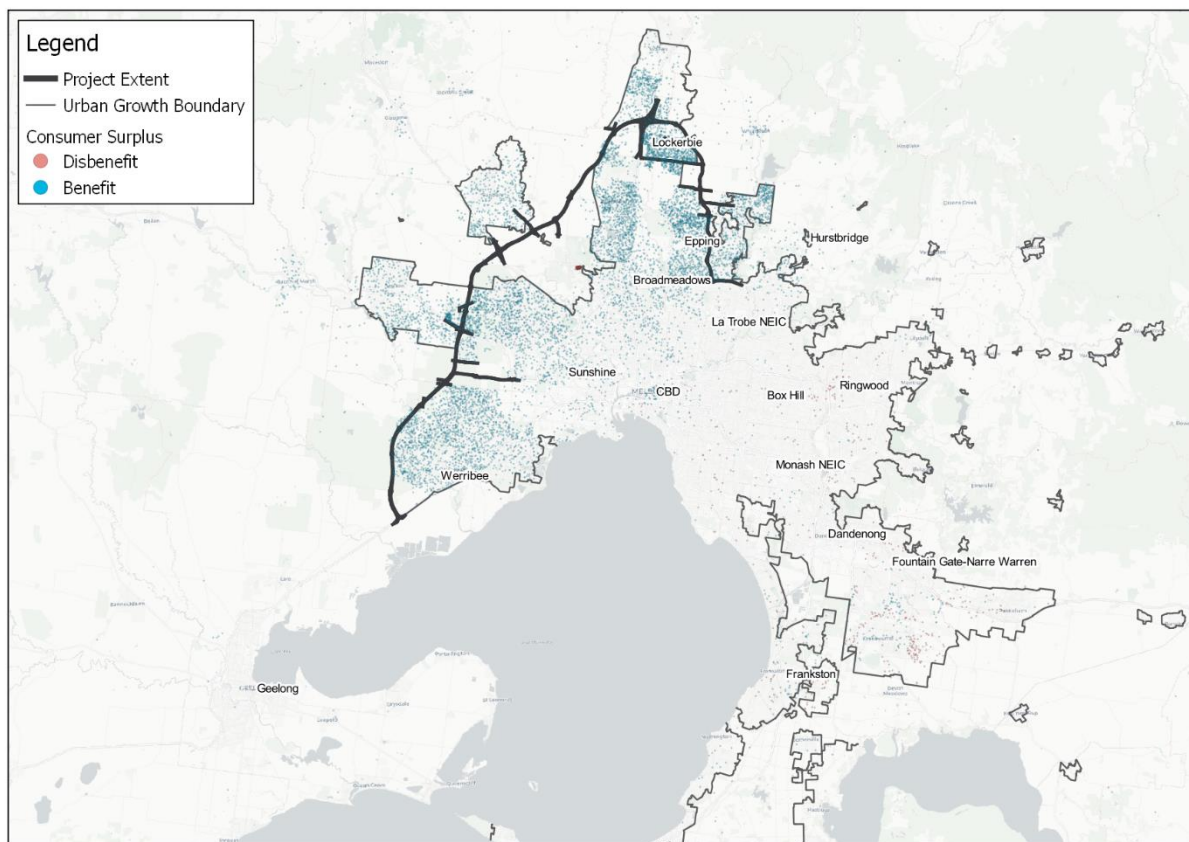
6.7   Conclusions

The analysis undertaken in the CBA indicates that there would be economic benefits associated with the delivery of the OMR project under dynamic (which includes static) and dynamic with WEBs scenarios. Both scenarios as modelled in this assessment would provide a positive return on investment, as measured by monetised costs and benefits, with the dynamic scenario producing a BCR between the range of 1.0-1.6 and NPV between the range of $345 million to $17.4 billion. Inclusion of total benefits produces a BCR between 1.1 and 1.8, and NPV of $1.8-20.8 billion. The BCR and NPV both indicate that OMR is economically viable under the core discount rates (four and seven percent).

While the inclusion of dynamic and WEBs outcomes result in positive BCR and NPV, the static only scenario is unviable at the bottom end of the range (four percent discount rate), but positive at the upper end.

The spatial analysis suggests a redistribution of population to the already established suburbs to the north and west of the CBD. By contrast, the fast growing and newly established urban areas to the north and west of the OMR would see a small reduction in population compared to the transport base case. Employment redistribution would also follow a similar pattern, albeit that employment redistribution impacts are limited. The impact of diverting traffic from the north and west of Melbourne to the OMR means that established suburbs become more attractive for residents and jobs. The outer growth areas of Melbourne would still expect to have high population growth trajectories with these project results. Gains in consumer surplus would be experienced in areas along the project corridor.

7. Project 5: Road management system (RMS)

7.1 Project background

The RMS project comprises a combination of network-wide operational improvements, such as improved traffic signal timings, for arterial roads in metropolitan Melbourne as well as intersection and lane configuration changes on select corridors. This will assist with traffic flows and public transport reliability and punctuality, which is assumed to drive an increase in efficiency across the network.

Parameters for the RMS project were guided by inputs from IV to estimate the impacts of a policy or technological change based on IV's internal analysis. This is different to the parameters in the other project scenario modelling. This approach is likely to have impacted the modelling outcomes for RMS.

Figure 37   RMS arterial improvements

7.2 Cost and timing

The total project cost estimates are outlined in Table 87. The cost estimate considers the development of all aspects of the planning, construction and contingencies.

Key dates that have been assumed for the purposes of this assessment for the construction of the RMS project are:

* Construction is assumed to occur over the period 2022-2035 (financial years).
* Operational assessment has been undertaken for the period 2026-75 (financial years).

Table 87   RMS capex and opex cost profile (nominal with escalation, 2021 dollars, discounted at four percent and seven percent)

Project	Nominal capex ($m)	PV capex ($m)	Nominal opex ($m)	PV opex ($m)	Nominal asset renewal ($m)	PV asset renewal ($m)
RMS	$5,471	$3,537 - $4,210	$962	$87 - $216	$0	$0 - $0

PV capital expenditure for RMS is estimated to be in the range of $3.5-4.2 billion, with construction expected to commence in 2021 and end in 2035. The first year of benefits (operation) would however be realised in financial year 2026. It is expected that the RMS project will be able to progressively deliver benefits from this time.

The key components of capital expenditure are the funding of assets, tools, data and resources (80 percent) and the general one-off cost for improving operational systems (20 percent).

7.3   Benefits

Table 88 summarises the value of benefits for each project for RMS using a four percent and seven percent discount rate over a 50-year appraisal period.

Table 88   RMS summary of project benefits (PV, $ million, 2021 dollars, discounted at four percent and seven percent)

Benefits (PV $mil)	Static only	Dynamic only	WEBs only	Total
Safety benefits	-$1,429 - -$2,793	-$63 - -$59		-$1,492 - -$2,852
Environmental benefits	-$720 - -$1,423	$18 - $41		-$702 - -$1,382
Active transport benefits	-$571 - -$1,120	-$38 - -$83		-$609 - -$1,203
Consumer surplus benefits	$41,223 - $78,587	-$5,285 - -10,354		$35,938 - $68,233
Residual values	$0 - $0	$0 - $0		$0 - $0
WEBS			$470 - $831	$470 - $831
Total benefits	**$38,503 - $73,251**	**-$5,368 - -10,455**	$470 - $831	**$33,605 - $63,627**

The project is expected to deliver between $38.5-$73.3 billion of benefits under the static scenario, -$5.4 - -$10.5 billion of disbenefits under the dynamic scenario, and $33.6-$63.6 billion of benefits when all scenarios are included. The majority of benefits are as a result of consumer surplus ($35.9-$68.2 billion), safety and active transport benefits.

Please note that benefits are expected to accrue before the full completion of construction. For this reason, benefits have been assumed to 'ramp up' progressively from 2026 until the end of the construction period.

7.4   CBA outcomes

Table 89 summarises the results of the CBA conducted for RMS using a four and seven percent discount rate over a 50 year appraisal period.

Table 89   RMS CBA results (PV, $ million, 2021 dollars, discounted at four percent and seven percent)

Economic outcomes	Static	Dynamic	Total (incl WEBs)
NPV	$34,880 - $68,825	$29,512 - $58,370	$29,982 - $59,201
BCR	10.62 - 16.55	9.14 - 14.19	9.27 - 14.37
IRR	48.01%	44.07%	44.52%
FYRR	96.3% - 114.6%	83.7% - 99.7%	85.1% - 101.3%

The project generates a positive NPV and a BCR above one in all scenarios. This means that the project is economically viable under all three scenarios at a discount rate of four and seven percent.

The IRR for this project, at a range of 44-48 percent for the total across static, dynamic and total scenarios, is significantly higher than the discount rates (four and seven percent), which confirms that the project is economically feasible. Similarly, the FYRR is greater than the project discount rates, indicating deferral of the project is not warranted as it is unlikely to improve the BCR.

Figure 38 presents the cumulative present values of benefits and costs over the modelling period. As depicted in this chart, benefits exceed the costs in the appraisal period, leading to a positive NPV and BCR above one. The green area represents the difference between costs and benefits.

Figure 38 RMS – total costs and benefits (PV)
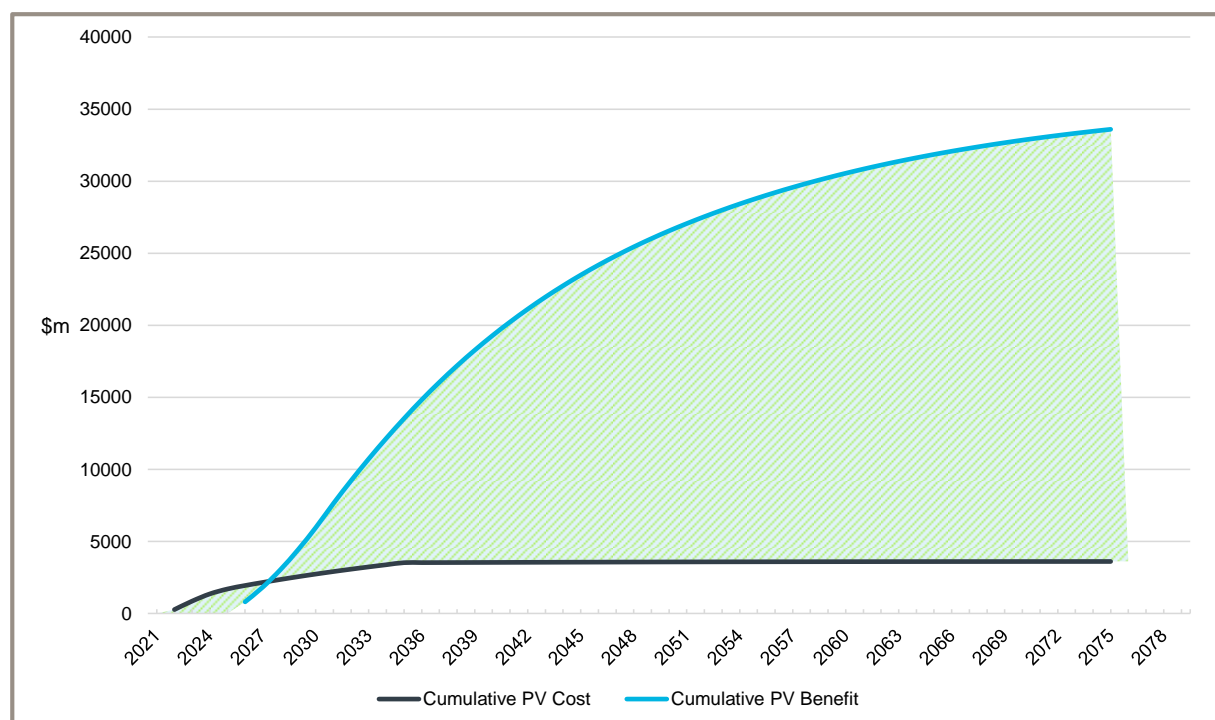
7.5   Sensitivity tests

The results of the sensitivity analysis undertaken at discount rates of three, four and ten percent are shown in Table 90 and Table 91.

Under the three and four percent sensitivity tests, the RMS project is viable and generates a higher BCR and NPV compared to the central case scenario. This implies that the project remains economically

viable under changes to this assumption. Similarly, the project is viable at a discount rate of ten percent, with a BCR above 1.0 and a positive NPV, however, the BCR and NPV are both less than the central case scenario.

Table 90   RMS sensitivity analysis - discount rates (BCR)

RMS sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
4% discount rate (central case)	*16.55*	*14.19*	*14.37*
7% discount rate (central case)	*10.62*	*9.14*	*9.27*
3% discount rate	19.66	16.83	17.05
10% discount rate	7.50	6.48	6.57

Table 91   RMS sensitivity analysis - discount rates (NPV)

RMS sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
4% discount rate (central case)	*$68,825*	*$58,370*	*$59,201*
7% discount rate (central case)	*$34,880*	*$29,512*	*$29,982*
3% discount rate	$89,262	$75,726	$76,764
10% discount rate	$19,907	$16,764	$17,060

Table 92 and Table 93 show the results of the sensitivity analysis for changes in capital costs. In the static, static and dynamic and total scenarios, the NPV remains positive and the BCR remains above 1.0, indicating that the project is economically viable even where capital costs are increased by 40 percent.

Table 92   RMS sensitivity analysis - capex (BCR, discounted at four and seven percent)

RMS sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*10.62 - 16.55*	*9.14 - 14.19*	*9.27 - 14.37*
20% decrease in capital costs	13.20 - 20.44	11.36 - 17.52	11.52 - 17.75
20% increase in capital costs	8.89 - 13.90	7.65 - 11.92	7.76 - 12.08
40% increase in capital costs	7.64 - 11.99	6.58 - 10.28	6.67 - 10.41

Table 93   RMS sensitivity analysis - capex (NPV, discounted at four and seven percent)

RMS sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*$34,880 - $68,825*	*$29,512 - $58,370*	*$29,982 - $59,201*
20% decrease in capital costs	$35,587 - $69,667	$30,219 - $59,212	$30,689 - $60,043
20% increase in capital costs	$34,172 - $67,982	$28,804 - $57,528	$29,274 - $58,359
40% increase in capital costs	$33,465 - $67,140	$28,097 - $67,140	$28,567 - $57,517

Table 94 and Table 95 show the results of the sensitivity analysis for changes total benefits. In the static, static and dynamic and total scenarios, the NPV remains positive and the BCR remains above 1.0. This suggests that the project is economically viable, even where benefits are lower than the central case assumptions.

Table 94   RMS sensitivity analysis - benefits (BCR, discounted at four and seven percent)

RMS sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*10.62 - 16.55*	*9.14 - 14.19*	*9.27 - 14.37*
40% decrease in total benefits	6.37 - 9.93	5.49 - 8.51	5.56 - 8.62
20% decrease in total benefits	8.50 - 13.24	7.31 - 11.35	7.42 - 11.50
20% increase in total benefits	12.75 - 19.86	10.97 - 17.02	11.13 - 17.25

Table 95   RMS sensitivity analysis - benefits (NPV, discounted at four and seven percent)

RMS sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*$34,880 - $68,825*	*$29,512 - $58,370*	*$29,982 - $59,201*
40% decrease in total benefits	$19,478 - $39,524	$16,257 - $33,252	$16,539 - $33,750
20% decrease in total benefits	$27,179 - $54,174	$22,885 - $45,811	$23,261 - $46,476
20% increase in total benefits	$42,580 - $83,475	$36,139 - $70,930	$36,703 - $71,927

Table 96 and Table 97 show the results of the sensitivity analysis for the delay in opening year. In the static, static and dynamic and total scenarios, the NPV remains positive and the BCR remains above 1.0 under all tests, indicating that the project remains economically viable under these changes to benefits.

Table 96   RMS sensitivity analysis - delay (BCR, discounted at four and seven percent)

RMS sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*10.62 - 16.55*	*9.14 - 14.19*	*9.27 - 14.37*
Delay in opening traffic by five years	6.32 - 13.13	5.28 - 10.80	5.34 - 10.92
Delay in opening traffic by 10 years	6.66 - 13.88	5.50 - 11.25	5.56 - 11.36

Table 97   RMS sensitivity analysis - delay (NPV, discounted at four and seven percent)

RMS sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*$34,880 - $68,825*	*$29,512 - $58,370*	*$29,982 - $59,201*
Delay in opening traffic by five years	$13,737 - $44,123	$11,063 - $35,664	$11,213 - $36,091
Delay in opening traffic by 10 years	$10,428 - $38,518	$8,297 - $30,639	$8,403 - $30,994

Table 98 and Table 99 illustrate the results for the value of travel time sensitivity test. In this test the value of travel time was increased at the rate of one percent per year. In the static, static and dynamic

and total scenarios, the NPV remains positive and the BCR remains above 1.0 under all tests, indicating that the project would continue to remain economically viable. When compared to the central case, the BCR and NPV decrease, reflecting that there is a decrease in the value of benefits over time.

Table 98   RMS sensitivity analysis - value of travel time (BCR, discounted at four and seven percent)

RMS sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*10.62 - 16.55*	*9.14 - 14.19*	*9.27 - 14.37*
Value of travel time	7.06 - 16.23	5.98 - 13.79	6.10 - 13.98

Table 99   RMS sensitivity analysis - value of travel time (NPV, discounted at four and seven percent)

RMS sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*$34,880 - $68,825*	*$29,512 - $58,370*	*$29,982 - $59,201*
Value of travel time	$23,766 - $67,426	$19,567 - $56,606	$20,037 - $57,438

7.6   Spatial/land use results

Estimated population changes compared to the base case for 2036 and 2051 are illustrated below.

In 2036, as a result of more efficient road operations, the spatial outcomes suggest that people will move from inner Melbourne to outer areas of the metropolitan area. The key drivers for this are likely to be that residents are attracted to areas with better amenity in the form of more space, lower housing costs or other factors. This redistribution becomes viable as a more efficient road system reduces travelling times for residents in these areas compared to the transport base case. Noting that each dot represents a gain or loss of five residents, it is likely that this population redistribution will have a broad based but minimal impact across Melbourne.

Population distribution compared to the base case in 2051 is very similar to that of 2036. The drivers of the population redistribution are expected to the same as those in 2036.

Figure 39   RMS change in population in 2036 (each dot represents a change of five residents)
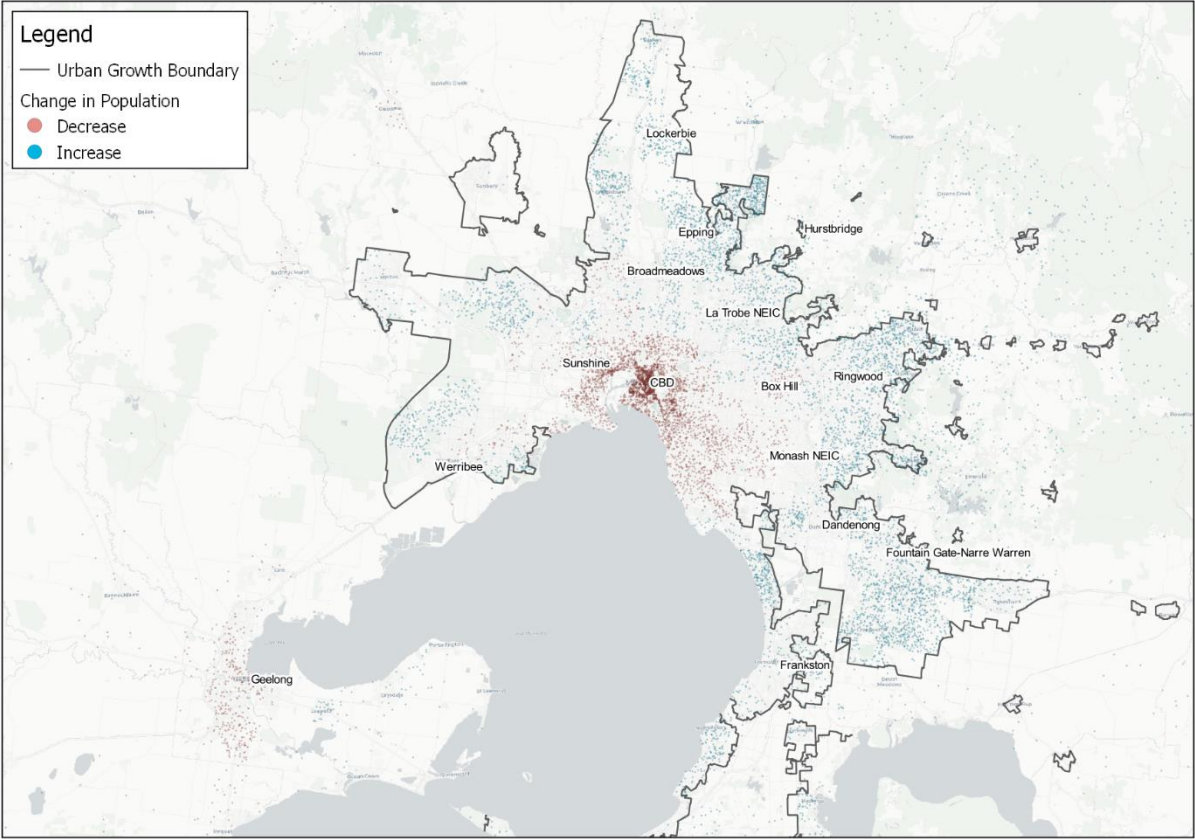
Figure 40   RMS change in population in 2051 (each dot represents a change of five residents)
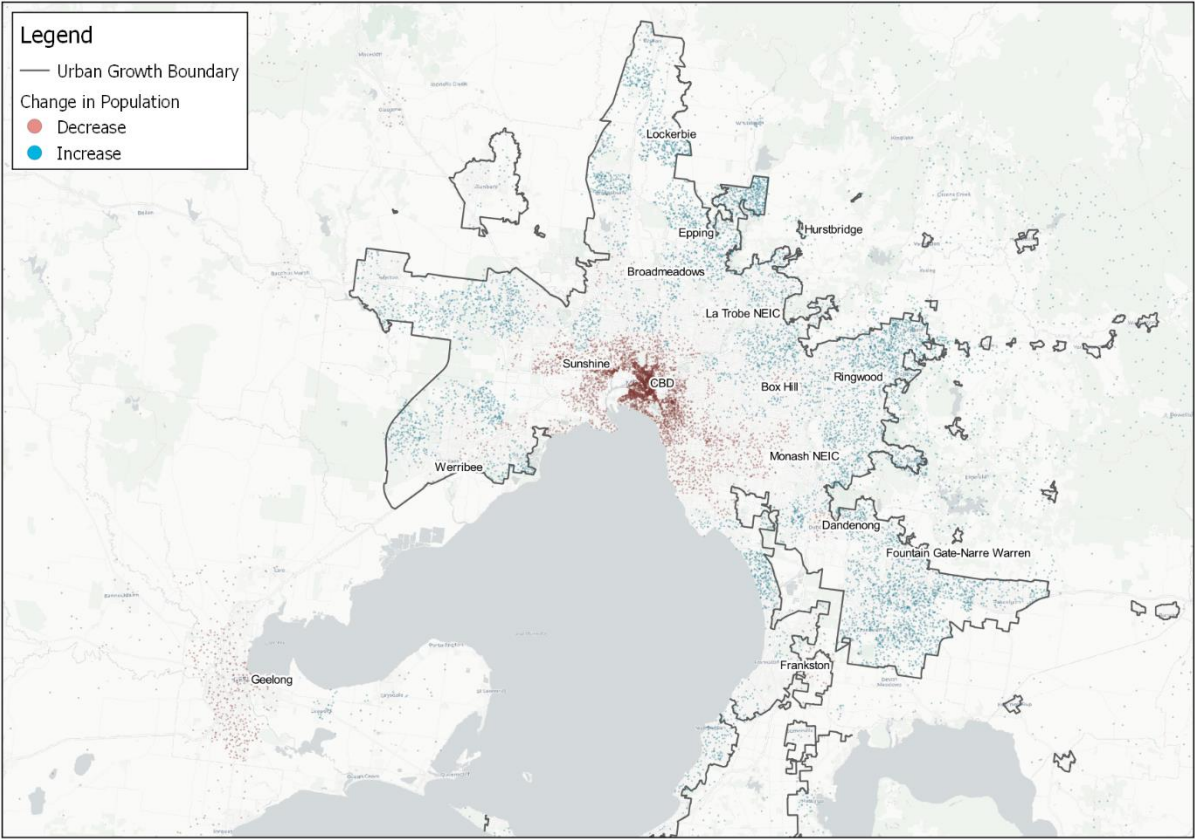
Changes in employment distribution are illustrated in Figure 41 and

Figure 42.

In 2036, there are some minor changes in employment distribution as a result of the project, with slightly fewer jobs based in inner Melbourne, and slightly more jobs based across the rest of the metropolitan area. The key driver for this change appears to be the improved efficiency of the road network, which has enabled employers to situate jobs in areas further from the CBD than would otherwise be the case.

This pattern is almost the same in 2051, suggesting that changes in employment distribution as a result of the project between these two years is minimal.

Figure 41   RMS change in employment in 2036 (each dot represents a change of five jobs)
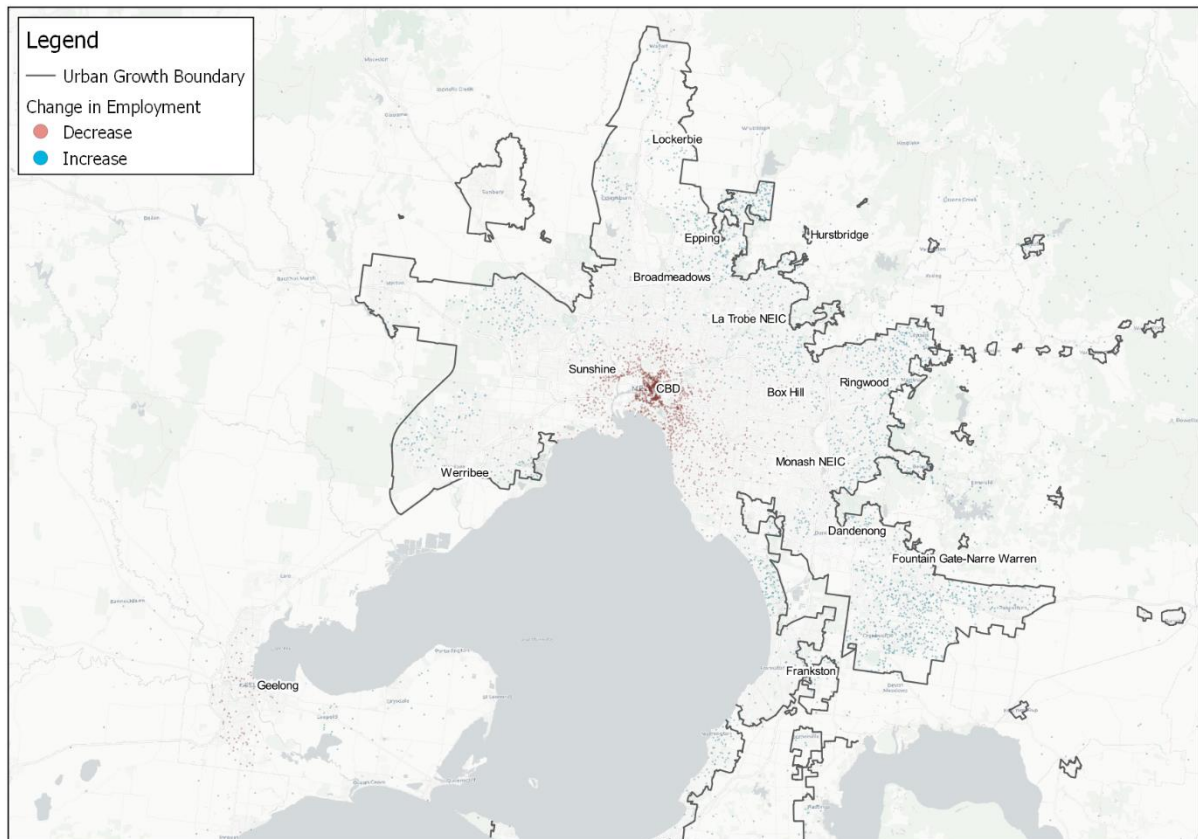
Figure 42   RMS change in employment in 2051 (each dot represents a change of five jobs)
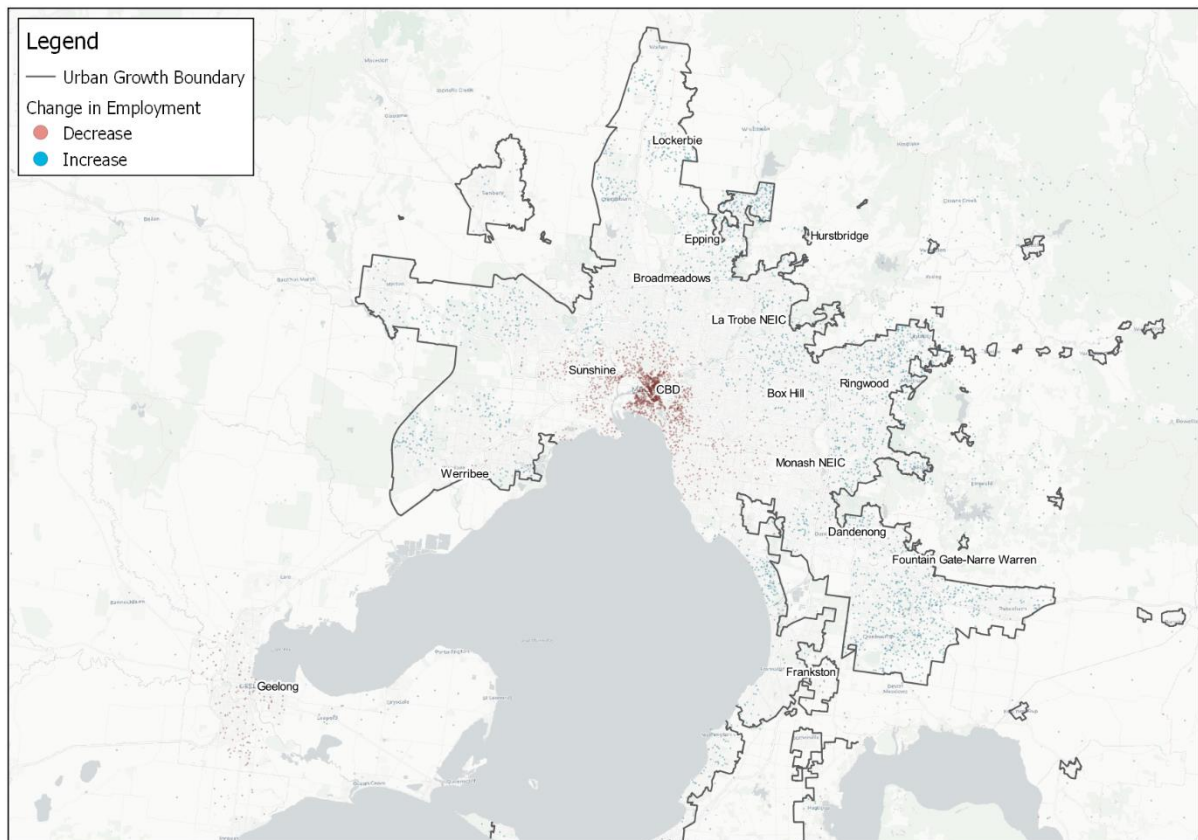
Changes in consumer surplus compared to the transport base case for 2036 and 2051 are illustrated in Figure 43 and Figure 44 respectively.

In 2036, there are increases in consumer surplus spread across the metropolitan area. This is largely a result of the more efficient road network reducing travel times and providing other productivity benefits. Because the RMS project has impacts across the metropolitan area, the benefits (while not substantial), are spread across Melbourne. The results for 2051 are similar to 2036, with widespread consumer surplus gains across the metropolitan area.

Figure 43   RMS change in consumer surplus, 2036 (each dot represents a change of 120 minutes)
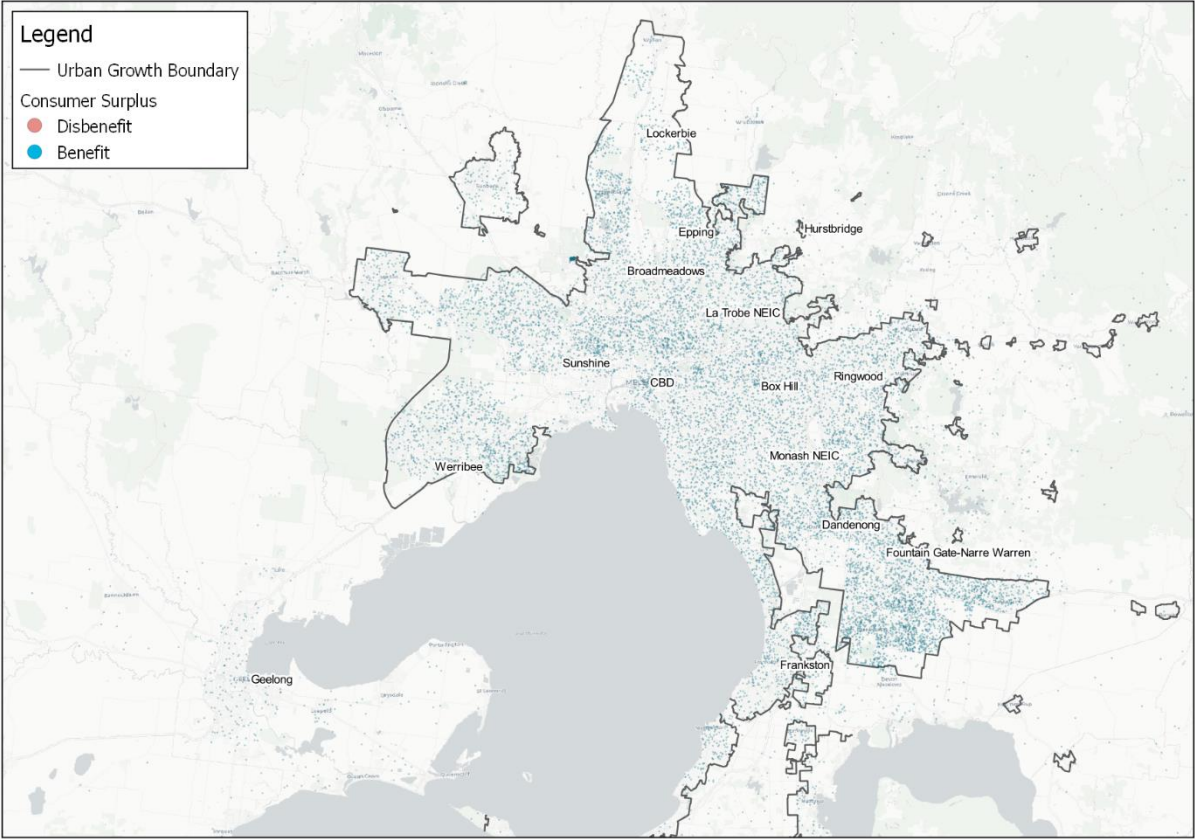
Figure 44   OMR change in consumer surplus, 2051 (each dot represents a change of 120 minutes)
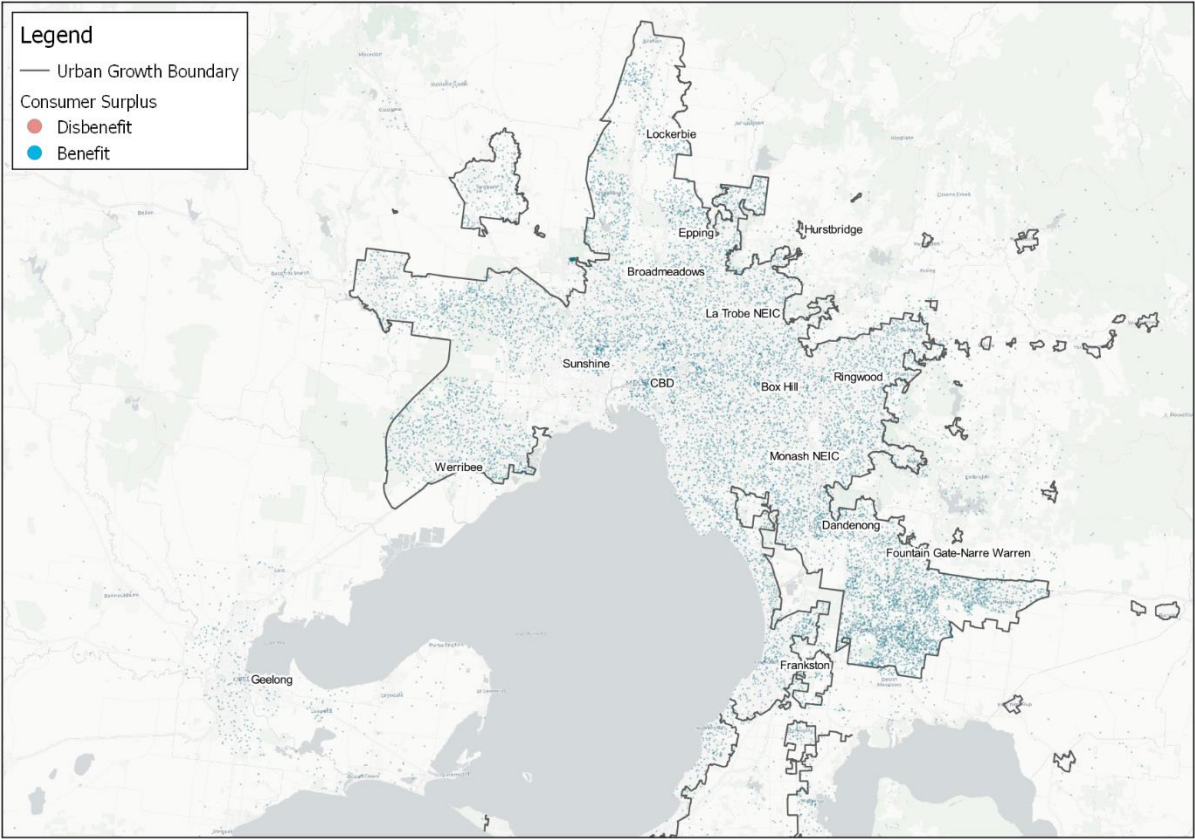
7.7   Conclusions

The RMS project is expected to provide a positive NPV in the range $30-59.2 billion, with a BCR well above one in the range 9.27-14.37 as modelled in this assessment. This reflects the expected uplift in road efficiency as a result of the investment.

The RMS project is expected to redistribute population and jobs away from the central city area to middle ring and outer suburbs. The increased efficiency of the road network means that people may benefit from living further away from the CBD and inner suburbs. This is also reflected in consumer surplus, which shows gains in 2036 and 2051 across the metropolitan area.

8. Project 6: Western rail corridor upgrade (WRU)

8.1 Project background

The WRU project seeks to increase rail capacity between Sunshine Station and Melton. It recognises that the Melton LGA is among Victoria's fastest growing, and that the current V/Line service is insufficient to meet future commuter needs. The project as modelled for this assessment has two components, these being:

- Sunshine to Mt Atkinson, where a new station would be built. This would involve 13 kilometres of new twin track, adjacent to the existing V/Line track. The work also encompasses the electrification of approximately 2.5 kilometres of the existing twin line, reconstruction of the Hampshire Road flyover, relocation and upgrading of the existing stations at Deer Park and Ardeer, and bridge over Kororoit Creek.

- Pakenham line improvements. This component of the project would include new substations and rail power upgrades, overhead infrastructures, communications and signalling upgrades, particularly between Westall and South Yarra. This allows for additional services along the line to Pakenham, which is included in the WRU project.

The alignment for the WRU project is illustrated in Figure 45.

Figure 45 WRU Alignment

8.2   Cost and timing

The total costs estimates, inclusive of contingencies, 50 years renewal costs and operations and maintenance costs are shown in Table 100.

Key dates that have been assumed for the purposes of this assessment for the WRU project are as follows:

- Construction is assumed to occur over the period 2030-35.

- Operations assessment has been undertaken for the period 2036-85.

Table 100 WRU capex and opex cost profile (nominal with escalation, 2021 dollars, discounted at four percent and seven percent)

Project	Nominal capex ($m)	PV capex ($m)	Nominal opex ($m)	PV opex ($m)	Nominal asset renewal ($m)	PV asset renewal ($m)
WRU	$2,784	$1,210 - $1,716	$2,358	$252 - $585	$816 - $816	$40 - $129

PV capital expenditure for WRU is estimated to be in the range of $1.2 to 1.7 billion. The cost estimates are based on construction commencing in 2031, with the first year of benefits beginning to accrue in 2036.

The different components of the project have been costed separately, but key elements of cost include overhead wiring, power supply and rolling stock.

8.3   Benefits

Table 101 presents a summary of the present value of the total benefits for WRU, based on four and seven percent discount rates over a 50 year benefits appraisal period.

Table 101 WRU summary of project benefits (PV, $ million, 2021 dollars, discounted at four percent and seven percent)

Benefit	Static only	Dynamic only	WEBs only	Total
Safety benefits	$10 - $34	-$50 - -$155		-$40 - -$121
Environmental benefits	$11 - $30	$13 - $23		$24 - $53
Active transport benefits	$137 - $342	$12 - $25		$149 - $367
Consumer surplus benefits	$2,841 - $7,095	-$2,416 - -$841		$2,000 - $4,679
Residual values	$5 - $33	$0		$5 - $33
WEBS			$936 - $2,162	$936 - $2,162
Total benefits	**$3,004 - $7,535**	**-$2,523 - -$866**	**$936 - $2,162**	**$3,074 - $7,174**

The major driver of benefits for WRU are the transport related consumer surplus benefits. Static only benefits ($3-7.5 billion) account for most benefits, with the majority of these derived from consumer surplus. The conventional benefits are largely as result of travel time savings for road users. Additionally, the project is expected to decrease the road user VKT, mainly from private vehicles, as users switch to public transport.

The $936 million to $2.2 billion in WEBs are nearly all derived from agglomeration (71 percent of WEBs) and tax revenues from labour markets (29 percent of WEBs). Both of these WEBs are an indication of

agglomeration productivity and employment benefits to the economy. This is indicated by the underlying transport data in 2051 that shows considerable increases to employment and population along the alignment of the two WRU project corridors.

8.4 CBA outcomes

The results of the CBA conducted for WRU using a four and seven percent discount rate are shown in Table 102. This analysis excludes non-monetiseable economic benefits, that is, those benefits that have not been quantified for the purpose of this assessment.

Table 102 WRU CBA results (PV, $ million, 2021 dollars, discounted at four percent and seven percent)

Economic outcomes	Static	Dynamic	Total (incl WEBs)
NPV ($m)	$1,502 - $5,104	$636 - $2,581	$1,572 - $4,743
BCR	2.00 - 3.1	1.42 - 2.06	2.05 - 2.95
IRR	13.16%	10.47%	15.08%
FYRR	24.0% - 34.1%	25.7% - 36.4%	37.5% - 53.2%

The NPV ranges between $1.6 and $5.1 billion for the static scenario and $636 million and $2.6 billion for the dynamic (and static) scenario, with BCR ranges of between 2.0-3.1 and 1.4-2.1, respectively. The inclusion of WEBs in the CBA also results in an NPV range between $1.6-4.7 billion and a BCR range between 2.1-3.0, indicating that the project has economic merit.

The cumulative present value of benefits and costs over the project's life is shown in Figure 46. The green area represents the difference between costs and benefits.

Figure 46 WRU – total costs and benefits (PV)
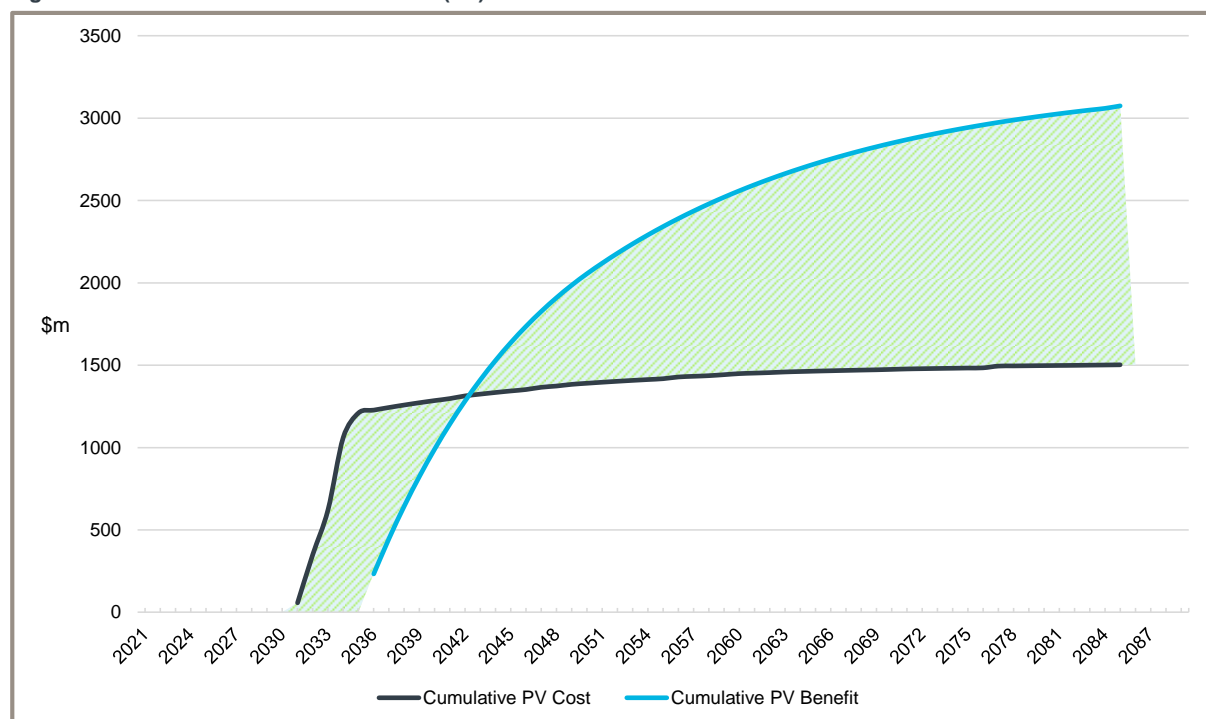
8.5 Sensitivity tests

Sensitivity analysis of WRU was completed at discount rates of three, four and ten percent. The results, outlined in Table 103 and Table 104 indicate that, at discount rates of three and ten percent, the project

is viable and generates a positive BCR across static, static and dynamic and total scenarios in comparison to the central case scenario.

Table 103   WRU sensitivity analysis - discount rates (BCR)

WRU sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
4% discount rate (central case)	*3.10*	*2.06*	*2.95*
7% discount rate (central case)	*2.00*	*1.42*	*2.05*
3% discount rate	3.63	2.36	3.37
10% discount rate	1.38	1.04	1.51

Table 104   WRU sensitivity analysis - discount rates (NPV)

WRU sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
4% discount rate (central case)	*$5,104*	*$2,581*	*$4,743*
7% discount rate (central case)	*$1,502*	*$636*	*$1,572*
3% discount rate	$7,716	$3,993	$6,962
10% discount rate	$381	$45	$507

Table 105 and

Table 106 show the results of the sensitivity analysis for changes in capital costs. Under the static, static and dynamic and total scenarios, the NPV remains positive and the BCR above one, indicating that under these assumptions the project is economically viable.

Table 105   WRU sensitivity analysis - capex (BCR, discounted at four and seven percent)

WRU sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*2.00 - 3.10*	*1.42 - 2.06*	*2.05 - 2.95*
20% decrease in capital costs	2.38 - 3.61	1.70 - 2.40	2.44 - 3.44
20% increase in capital costs	1.72 - 2.72	1.23 - 1.81	1.76 - 2.59
40% increase in capital costs	1.51 - 2.42	1.08 - 1.61	1.55 - 2.30

Table 106   WRU sensitivity analysis - capex (NPV, discounted at four and seven percent)

WRU sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*$1,502 - $5,104*	*$636 - $2,581*	*$1,572 - $4,743*
20% decrease in capital costs	$1,744 - $5,448	$878 - $2,925	$1,814 - $5,086
20% increase in capital costs	$1,260 - $4,761	$394 - $2,238	$1,330 - $4,400
40% increase in capital costs	$1,018 - $4,418	$152 - $4,418	$1,088 - $4,056

Table 107 and Table 108 show the results of the sensitivity analysis for changes to total benefits. In the static and total scenarios, the NPV remains positive and the BCR above 1.0 under all sensitivities. In the static and dynamic scenario, the NPV remains positive and the BCR above 1.0 for all sensitivities except for a 40 percent decrease in total benefits. Indicating that the project is economically viable under all other scenarios and changes to total benefits.

Table 107 WRU sensitivity analysis - benefits (BCR, discounted at four and seven percent)

WRU sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*2.00 - 3.10*	*1.42 - 2.06*	*2.05 - 2.95*
40% decrease in total benefits	1.20 - 1.86	0.85 - 1.24	1.23 - 1.77
20% decrease in total benefits	1.60 - 2.48	1.14 - 1.65	1.64 - 2.36
20% increase in total benefits	2.40 - 3.72	1.71 - 2.47	2.46 - 3.54

Table 108 WRU sensitivity analysis - benefits (NPV, discounted at four and seven percent)

WRU sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*$1,502 - $5,104*	*$636 - $2,581*	*$1,572 - $4,743*
40% decrease in total benefits	$300 - $2,091	-$219 - $577	$343 - $1,874
20% decrease in total benefits	$901 - $3,598	$208 - $1,579	$957 - $3,308
20% increase in total benefits	$2,103 - $6,611	$1,064 - $3,584	$2,187 - $6,178

Table 109 and Table 110 show the results of the sensitivity analysis when the opening year of operation is delayed by five and ten years. In the static, static and dynamic and total scenarios, the NPV remains positive and the BCR remains above 1.0, indicating that delays to the project enhance economic viability. The BCR is lower than the central case in the total scenario as WEBs have been discounted more due to the opening year of operation being delayed.

Table 109 WRU sensitivity analysis - delay (BCR, discounted at four and seven percent)

WRU sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*2.00 - 3.10*	*1.42 - 2.06*	*2.05 - 2.95*
Delay in opening traffic by five years	2.20 - 3.38	1.39 - 2.05	1.98 - 2.92
Delay in opening traffic by 10 years	2.39 - 3.65	1.39 - 2.09	1.97 - 2.97

Table 110 WRU sensitivity analysis - delay (NPV, discounted at four and seven percent)

WRU sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*$1,502 - $5,104*	*$636 - $2,581*	*$1,572 - $4,743*
Delay in opening traffic by five years	$1,289 - $4,753	$414 - $2,103	$1,052 - $3,845
Delay in opening traffic by 10 years	$1,064 - $4,344	$295 - $1,792	$743 - $3,234

Table 111 and Table 112 illustrate the results of the sensitivity analysis for the value of travel time. In this test the value of travel time was increased at the rate of one percent per year. Under this sensitivity, the NPV remains positive and the BCR remains above 1.0 for all scenarios. When compared to the central case, the BCR and NPV increase, reflecting the increase in the value of benefits over time.

Table 111 WRU sensitivity analysis - value of travel time (BCR, discounted at four and seven percent)

WRU sensitivities	Static	Static and dynamic	Total (incl WEBs)
	BCR	BCR	BCR
Core (central case)	*2.00 - 3.10*	*1.42 - 2.06*	*2.05 - 2.95*
Value of travel time	2.36 - 3.96	1.66 - 2.61	2.24 - 3.50

Table 112 WRU sensitivity analysis - value of travel time (NPV, discounted at four and seven percent)

WRU sensitivities	Static	Static and dynamic	Total (incl WEBs)
	NPV	NPV	NPV
Core (central case)	*$1,502 - $5,104*	*$636 - $2,581*	*$1,572 - $4,743*
Value of travel time	$2,291 - $7,200	$1,163 - $3,905	$2,099 - $6,066

8.6 Spatial/land use results

Changes to population as a result of land use redistribution for WRU are shown in Figure 47 and Figure 48.

In 2036, it is expected that there will be a modest redistribution of population towards both outer ends of the rail corridor, that is, the outer west and south east of the metropolitan area. Both of these areas would benefit from the service uplift as a result of the project. Through more efficient transport services, these areas become more attractive for residents. Conversely, there is a small redistribution of population away from the rest of Melbourne, as residents relocate closer to the improved services along the WRU corridor.

By 2051, the same trend is evidence, albeit with a slightly stronger redistribution of population towards both ends of the rail corridor. There is a more evident redistribution of population at the western end of the rail corridor, in the Mt Atkinson precinct as well as further west. This indicates that improved train services will strengthen the already fast population growth expected in these areas.

Figure 47 WRU change in population in 2036 (each dot represents a change of five residents)
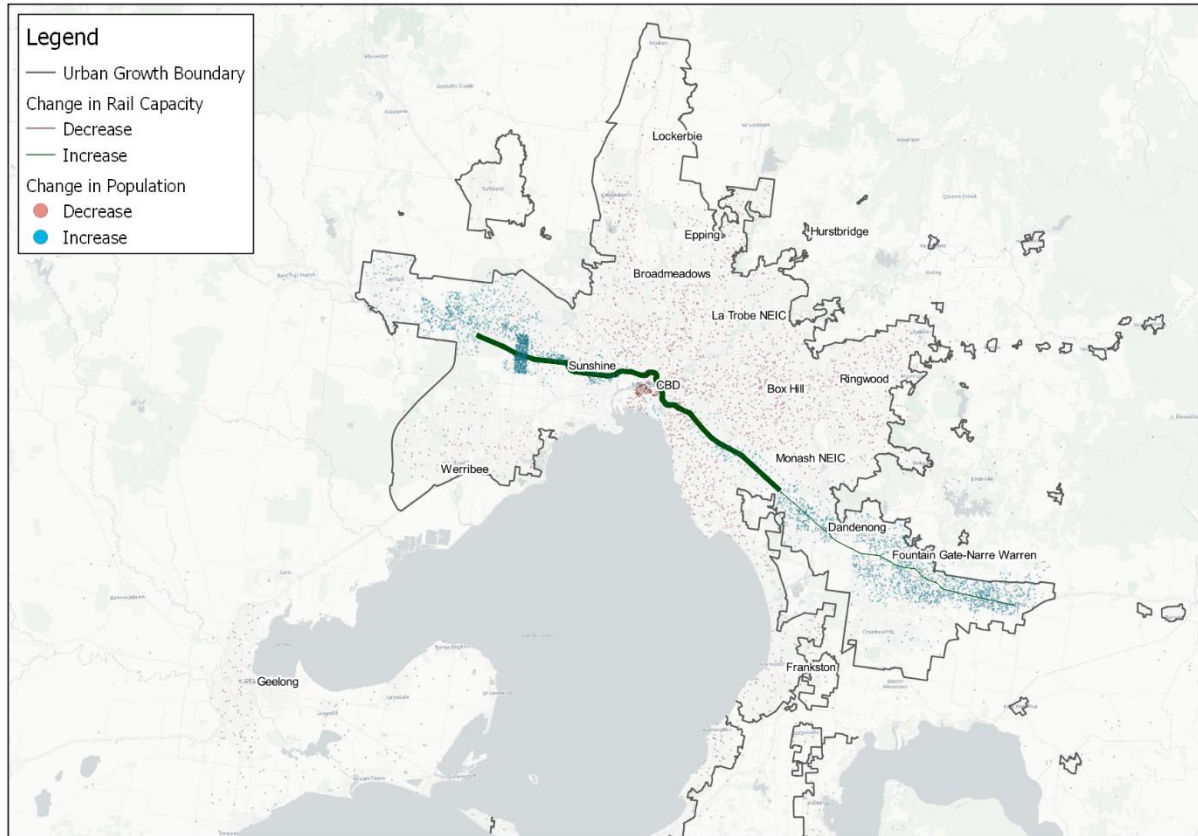
Figure 48 WRU change in population in 2051 (each dot represents a change of five residents)
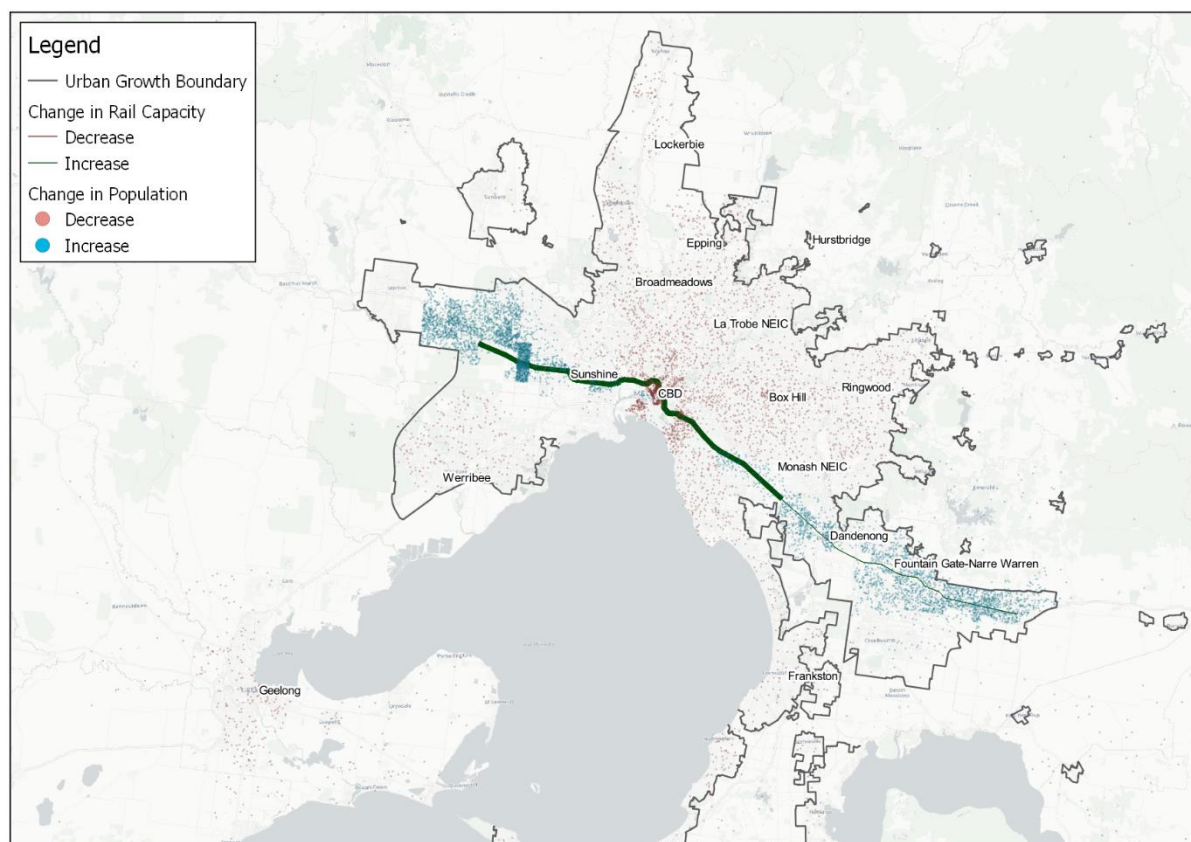
Figure 49 and Figure 50 show changes in employment distribution compared to the transport base case in 2036 and 2051.

Noting that each dot represents a change in distribution of five jobs, by 2036, there will be a very modest redistribution of jobs from across the broader metropolitan region towards the east and western ends of the WRU corridor. Jobs are likely to be redistributed as a result of improved rail services and accessibility to these areas, making them a more feasible location for employment opportunities. There is a modest redistribution of jobs away from the rest of metropolitan Melbourne, including from the CBD. A similar pattern is expected to occur in 2051, with redistribution of jobs to the east and western ends of the WRU corridor.

Figure 49 WRU change in employment in 2036 (each dot represents a change of five jobs)

Figure 50 WRU change in employment in 2051 (each dot represents a change of five jobs)

Figure 51 and Figure 52 illustrate changes in the consumer surplus for public transport users compared to the base case. Consistent with changes in population and employment distribution, consumer surplus increases are expected to be realised at the west and eastern ends of the WRU corridor. This reflects the increased train service levels and improved journey efficiency and reliability for residents and workers in those areas. By contrast, there is a slight reduction in consumer surplus for public transport users in other areas of Melbourne. This is potentially a result of fewer jobs accessible by public transport from those areas due to the slight decrease in jobs in the CBD.

2051 has a similar outcome, with stronger consumer surplus benefits for public transport users located in areas at both ends of the improved rail corridor.

Figure 51 WRU change in consumer surplus, 2036 (each dot represents a change of 120 minutes)

Figure 52 WRU change in consumer surplus, 2051 (each dot represents a change of 120 minutes)
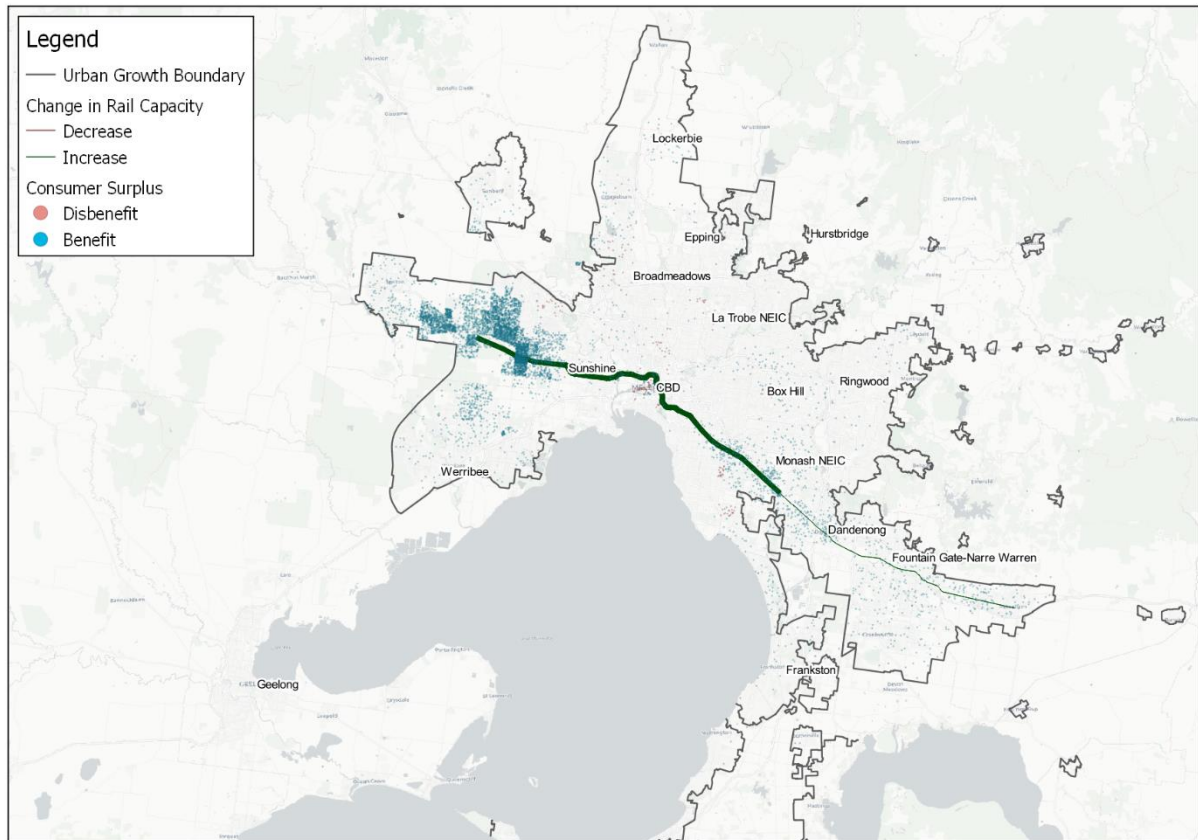
8.7   Conclusions

The economic assessment indicates that there is a positive economic return under the static land use and total (static, dynamic and WEBs) scenarios for WRU, as evidenced by positive NPV and BCR results. Total NPV is in the range of $1.6-$4.7 billion, with a BCR in the range 2.05-2.95, indicating that the project is economically feasible as modelled in this assessment.

In terms of spatial outcomes, the project results in additional population and employment growth along the two rail corridors, these being Melton and Pakenham. This reflects improved service efficiency along both of these lines.

APPENDIX A
ECONOMIC ASSESSMENT FRAMEWORK

ARUP AECOM

Subject	Revised Proposed Economic Framework Structure

Date	5 July 2021	**Job No/Ref**	277961

1 Purpose and introduction

The purpose of this document is to outline how the Arup/AECOM team completed the Cost Benefit Analysis (CBA) component of the broader IV118 engagement ('the project').

The project comprised four, inter-related, workstreams:

- Workstream 1: Potential future scenarios (economic, policy and technological shock scenarios)
- Workstream 2: Transport program modelling and assessment against a 'no project' base case
- Workstream 3: Transport infrastructure costing
- Workstream 4: Cost Benefit Analysis

As part of Workstream 4, the brief required a framework for monetising land use change benefits and costs, wider economic benefits, and changes to urban form including consolidation and dispersion. This document sets out the high-level framework for Workstream 4.

2 Overall evaluation approach

Project costs and benefits will be monetised via a Cost Benefit Analysis (CBA) model that was developed in accordance with Department of Treasury and Finance (DTF) guidance.[1] Key inclusions and exclusions of the CBA model are summarised in Table 2 and detailed in subsequent sections of this framework.

'Conventional benefits' are defined as those which typically comprise a transport CBA, although in this instance they will be derived from both dynamic and static land use scenarios (i.e. strategic transport modelling which assumes changes in land use over time).

Table 1. CBA framework

Item	Rationale for inclusion/exclusion and summary of approach
Costs included within the CBA	
Capital costs (CAPEX)	Conventional inclusion
Operating cost (OPEX)	Conventional inclusion
Conventional transport benefits included within the CBA	
Savings in generalised cost	The conventional transport benefits listed left were evaluated for static land use and dynamic land use scenarios. Static land use is whereby the location and density of population growth is modelled irrespective of transport infrastructure, while dynamic land use recognises that major transport infrastructure will impact land use planning decisions, thereby influencing the location and density of population growth. Dynamic land use was determined through spatial computable general
Public transport operating cost savings	
Crash cost savings	

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[1] *Economic Evaluation for Business Cases Technical Guidelines (2013), DTF*

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Externality cost savings	equilibrium (SCGE) modelling. This approach was developed in conjunction with Professor Daniel Graham of Imperial College London and is described further in Appendix A.
Residual asset value	It should be noted that the conventional benefits listed left are typically only calculated for the static land use scenario. Inclusion of dynamic land use impacts via use of the SCGE model is a relatively new approach to capture conventional transport benefits.
Active transport benefits	
Unconventional transport benefits included within the CBA	
Wider economic benefits (WEBs)	Economic indicators were developed with and without consideration of WEBs.
	Two forms of WEBs were included within the CBA:
	1) Agglomeration economies – this benefit is generated when connectivity is improved between firms and workers. They included knowledge sharing, labour pooling, etc…
	2) Tax revenues from labour markets – this benefit accrues through increased workforce participation as a direct result of improved job accessibility
	A third WEB - output change in imperfectly competitive markets – was also included.
Unconventional benefits excluded from the CBA	
Equity and distributional effects	In additional to being able to calculate conventional transport benefits associated with dynamic land use, the SCGE model developed for the project provides other land use change benefits via changes to household weighted expected utility – including commuting costs, other travel costs, housing prices, non-housing prices, real income and amenity.
Transport network reliability	Transport network reliability can be measured a number of ways, including through evaluating the standard deviation of transport trips. Reliability metrics are not a standard output of the EEM, however, and so are excluded from the CBA.

The above framework was used to model expected costs and benefits of six transport projects:

- City Loop reconfiguration and northern rail corridor upgrade (CLR).
- Cross city motorway (CCM).
- Melbourne Metro Two and direct Geelong rail line (MM2).
- Outer Metropolitan Ring Road (OMR).
- Road management systems (RMS).
- Western rail corridor upgrade (WRU).

Sensitivity testing was undertaken for each of the six transport projects, with the sensitivity tests being:

- Changes in discount rates (four and ten percent).
- Changes in capital expenditure:
    - Capex which is 20 percent less than the central case cost
    - Capex which is 20 percent above the central case cost
    - Capex which is 40 percent above the central case cost.
- Changes in total benefits:
    - 60 percent of total benefits
    - 80 percent of total benefits
    - 120 percent of total benefits.
- Changes in timing of delivery (delay by 5 and 10 years). These tests were selected as a realistic way of testing modest delays in the commencement of projects.
- Changes in the value of travel time. It is assumed that the value of travel time will increase by one percent per annum.
- Use of the conventional VITM as static scenario tests for CCM and CLR.

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Key inputs into the CBA model included traffic modelling outputs from the Victorian Integrated Transport Model (VITM) and the Victorian Integrated Transport and Land Use (VLUTI) model, as well as modelling parameters which relate to various components of the transport network and its operation. These key inputs are summarised below. Detailed descriptions and specific parameters are provided in subsequent sections of this document.

VITM and VLUTI outputs

Changes in travel costs were modelled using the VLUTI model. VLUTI models how future transport networks may operate under varying scenarios, which include changes to the transport network, land use patterns and population. The VLUTI model demonstrates how changes to the transport network can influence land use patterns (this approach is described further in the transport modelling framework document, provided separately). The consumer surplus benefits were calculated using the disaggregated VITM and the most recent Economic Evaluation Module (EEM) provided by DoT (version 8.1.1). The EEM provides changes in generalised time for different impacts upon which parameters are then applied to value the impacts.

Where applicable, we linearly interpolated between the modelled years values (2036 and 2051); that is, we assumed that changes between 2036 and 2051 were evenly distributed. For years prior to 2036 and post 2051, forecasts took into consideration population growth forecasts.

Modelling parameters

The CBA methodology as well as many of the parameters values have been primarily collated from the Australian Transport Assessment and Planning (ATAP) Guidelines or guidance documentation which ATAP references. ATAP provides a consistent framework for evaluating transport projects, and in doing so they ensure that proposals to improve transport systems across Australia are evaluated on a like-for-like basis. ATAP guidelines contain specific parameters for travel time, VOC, crash and environmental externality costs.

3   Overall modelling parameters

Economic parameters for the modelling refer to the values used in the different components of economic modelling. In this section we outline broad modelling parameters such as the modelling period, as well as the specific values which we apply to calculate travel costs.

The overall parameters for the economic modelling are those which define the broad parameters for the assessment, including modelling periods, discount rates and other key assumptions. Specific assumptions relating to input values such as the value of time are outlined in Section 3.

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Table 2.   **Modelling parameters and assumptions**

Parameter name	Value	Source/assumption
Modelling period	50 years from start of operation	*Economic Evaluation for Business Cases Technical guidelines, August 2013*, Department of Treasury and Finance. The guidelines note that the 'Period of analysis (should be) the economic life or service term. For infrastructure projects, the 'service term' generally refers to the design life (i.e. expected life or asset prior to replacement or major upgrade) of the asset in question. This covers both the operational and construction periods. For transport projects, design life can be up to 100 years (for rail projects and bridges) and less for road projects (30 years asphalt of major roads, although the delivered life can be much longer. Note that pavement surfaces are replaced every 10-15 years). We have suggested 50 years because: • Of the mix of assets, which includes road projects, and this provides a reasonable mid-point. • Benefits modelling beyond this period will be relatively meaningless once the discount rate is applied, which will mean any marginal benefits beyond this time will be extremely small.
Discount rate	4 % and 7%	*Economic Evaluation for Business Cases Technical guidelines, August 2013*, Department of Treasury and Finance The core discount rates are sourced from the Department of Treasury and Finance (DTF), as per Economic Evaluation for Business Cases Technical Guidelines, August 2013. Two core discount rates were selected for the analysis. The 'core' refers to the discount rates used for the standard present values and BCRs. This means that each of the NPV and BCRs (and other monetised results) are in effect presented as a range. The rationale for this approach was as follows: • The projects are planned a long way in the future, and with operating periods of 50 years being captured in the analysis, this means that there is a high level of uncertainty about future demands on the network. • The low level of design certainty means that a high level of contingency is used. As project design progresses and site conditions and risks are better understood, these contingencies would be expected to reduce. Seven percent is the recommended discount rate for investments in traditional core service delivery areas of government for which benefits attributed to the project can be translated to monetary terms (e.g. public transport and roads). This is a real discount rate, based on the long-term average government bond rates. A discount rate of four percent has also been used for the core analysis. This is consistent with DTF's guidelines, and is generally applied for investments which can be difficult to translate into monetary terms. In this instance, the high level of uncertainty about future demand scenarios is addressed through the use of the four percent discount rate.
Opening year	Year	IV's Draft Strategy recommendations and modelling specifications have been developed, and take into consideration the following economically optimal opening years were identified for each project
Construction period for projects	-	The six infrastructure projects in question have a different construction period. • CLR:

Parameter name	Value	Source/assumption
		- Construction FY 2032-35 - Opening year of operation FY 2036 - CCM: - Construction FY 2030-35 - Opening year of operation FY 2036 - MM2 Stage 1: - Construction FY 2030-40 - Opening year of operation FY 2041 - MM2 Stage 2: - Construction FY 2036-43 - Opening year of operation FY 2044 - OMR Stage 1: - Construction FY 2021-35 - Opening year of operation FY 2036 - OMR Stage 2: - Construction FY 2045-50 - Opening year of operation FY 2051 - RMS: - Construction FY 2022-35 - Opening year of operation FY 2027 ongoing - WRU: - Construction FY 2030-35 - Opening year of operation FY 2036.
Benefits growth rate pre 2036 and post 2051		*Victoria in Future 2019, Population Projections 2016 to 2056 (July 2019)*, Department of Environment, Land, Water and Planning. Increases in total benefits prior to 2036 and post 2051 were escalated in line with estimated population growth for the State, metropolitan Melbourne, local government areas (LGAs), or a combination of regions.
Expansion Factors	-	Expansion factors are outlined below. DoT has provided for factors for train, tram and bus; TfNSW for private vehicle and freight.

Volume expansion factor	Volume expansion factor
Daily urban road to annual urban road	345
Daily public transport to annual public transport (multi-mode)	291
Daily Rail to annual Rail	291
Daily Tram to annual Tram	306
Daily Bus to annual Bus	275

4   Conventional transport benefits and parameters

Conventional transport benefits were calculated using VLUTI outputs and modelling parameters. Conventional transport benefit categories comprise the following:

- **Savings in generalised costs:** Travel cost or termed as generalised cost including time, cost and inconvenience associated with travel is typically a disincentive to travel. It influences where we live and work, what we do with our leisure time and how freight moves. Calculating the **change in the consumer surplus** between the base and the project cases considered existing, new and lost users using the rule-of-a-half. This captured the change in generalised cost as well as the change in trip number for each origin and destination pair and for each mode. Savings in generalised cost considered the following factors:
  - Travel time
  - Public transport overcrowding relief on public transport and at stations
  - Resource corrections for vehicle operating costs (including car parking costs, road tolls, vehicle maintenance and operating costs for private vehicles) and public transport fares

- **Changes in public transport operating costs.**

- **Savings in crash costs**: Accidents occur on our transport network for numerous reasons, including road surface quality and geometry, speed limit, congestion and other factors. Each crash may cause property damage, injury and/or loss of life; these aspects can be attributed with an economic value. Crash cost savings were calculated using the willingness to pay method and changes to network safety.

- **Savings in environmental externality costs:** The transport network is a significant contributor to the State's net greenhouse gas emissions. It also impacts the urban and natural environments in which we live through noise, visual and other pollutants. These impacts have a detrimental economic impact and are calculated using vehicle composition and VKT.

- **Residual asset value (RAV):** RAV recognises that there is typically some value remaining in infrastructure at the end of the appraisal period. That is, while assets will be appraised over a 50-year operating period within the CBA model, the asset will endure beyond this time and continue to provide transport benefits that will not be directly captured within the model.

- **Active transport benefits** – VLUTI enables us to capture any additional active transport benefits associated with changes in transport mode or land use. These were monetised as contributing to health benefits for the community.

The estimation of benefits for a transport projects was derived from the EEM, which included benefits and/or disbenefits associated with relocation of residents (dynamic land use). The EEM calculates the generalised cost savings (measured in time units, i.e. minutes) for both road and public transport modes based on consumer surplus methodology. This enables changes in benefit for each mode to be estimated based on time unit impacts.

The EEM also produces the network performance such as travel distance change between a project and the base case, which can be used to estimate the savings in crash costs and environmental externality costs.

Static and dynamic land use benefits

Traditionally, benefits for transport projects were estimated using a demand model where the land use (population, employment and education forecasts) inputs are static or constant in both the base and project

cases. This implies that evolving land uses (e.g. from low to high density residential, or from residential to mixed commercial/residential) cannot be accounted for in strategic transport modelling.

In this project with the application of the VLUTI model, the land use inputs to the demand model become dynamic, where the model estimates the geographic relocation as well as growth of jobs and population as a result of improvements in transport services. This means, therefore, that the land use assumptions for each project case are different to the base case, and that major transport projects can drive changes in a city's spatial layout as well as providing transport benefits.

Land use benefits associated with dynamic land use were separated from conventional transport benefits associated with static land use within the CBA model as follows:

1. Static land use, using disaggregated VITM (3000+ zones)

    A. Base case: base case land use (from VLUTI base case) and base network

    B. Project case: base case land use (A) and project network

    C. Calculate the static conventional benefits and cost benefit analysis as usual

2. Dynamic land use, using disaggregated VITM (3000+ zones)

    A. Base case: base case land use (from VLUTI base case) and base network (as per 1A above)

    B. Project case: project land use (from VLUTI project case) and project network

    C. Calculate the dynamic conventional benefits

    D. Calculate WEB1 (as a check)

    E. Use VLUTI (SCGE) to calculate WEB1 and WEB3

    F. Conduct sensitivity analysis on conventional benefits for dynamic land use

As 1C represents conventional benefits/disbenefits associated with static land use and 2C represents conventional benefits/disbenefits associated with dynamic land use, the difference (2C - 1C) was the portion of conventional benefits/disbenefits that was directly attributable to dynamic land use.

Only conventional benefits were calculated for the static land use case, with conventional benefits, land use change benefits and WEBs developed for dynamic land use scenarios.

Static land use

Static land use benefits/disbenefits were calculated using VITM outputs.

'Consumer surplus' benefits result from a reduction of generalised transport costs in a project case compared to a project base case. Benefits from a transport project accrue to:

• Existing users, with benefits derived from a reduction in transport costs to existing users.

• New and lost users, which can be users either diverted from other modes of transport or generated as a result of a project. New or lost users are defined as those who change their mode.

Estimates of new and lost user benefits are based on the rule-of-a-half, applying half of the change in travel cost to the new and lost users.

Dynamic land use benefits

With the application of VLUTI which integrated the VITM with Victoria University's SCGE model, we are now able to simulate the relocation of jobs and people, i.e. land use changes, as a result of transport improvement.

There are three user or beneficiary groups identified using VLUTI and EEM. These are:

- New and lost users who shift from one mode of transport to another or who change their destination due to job relocation or trip redistribution.

- Existing users who stay at the same location and maintain their destination and travel patterns

- Existing users who relocate to a new residential location.

There are additional beneficiary groups, for example those who change modes and residential location, however, these cannot be separated using VLUTI and EEM and so the analysis will focus on the three user groups listed above.

The benefits of new/lost and existing-staying users are 'conventional' benefits, but those of existing-moving users are considered **land use benefit corrections**.

Value parameters for transport modelling

The value parameters for the static and dynamic land use benefits are largely drawn from ATAP guidelines. The key values are listed below for road and public transport projects. Note that many of the parameters are in $FY2005, $FY2013 and other year values. These were escalated to present values using relevant indices.

Public transport operating cost parameters

Operating cost parameters for bus, tram and train modes were determined through discussions with IV and DoT.

Crash cost parameters

Crash costs per injury type derived from Willingness to Pay (WTP) values are contained in Table 3. Note that these values include additional costs as compiled by the Bureau of Infrastructure and Transport Research Economics (BITRE) for emergency services and other costs.

Table 3.   **Inclusive WTP costs by injury ($FY2013)**

Injury severity	Urban ($)	Non-urban ($)
Value of statistical life	7,573,412	7,489,950
Value of serious injury	526,606	390,898
Value of hospitalised injuries	100,431	77,653
Value of minor injuries	31,739	36,121

Source: ATAP PV2 Road Parameter Values (2013) – Table 15

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Environmental externality cost parameters

ATAP Guidelines indicate that two resources should be referred to when identifying appropriate environmental externalities. These are:

- National Guidelines for Transport System Management (NGTSM) – Volume 3, Appendix C.
- Austroads Guide to Project Evaluation – Section 5.

We suggest NGTSM parameters, outlined below for passenger vehicles (Table 4), freight vehicles (Table 5) and rail operations (Table 6). Note that for buses, we used 'medium' freight vehicles as a proxy. An alternative approach would be to use Transport for NSW parameters which were updated in 2020.

Table 4.   Passenger vehicles (c/vkm – $FY2005)

Externality	Urban	Non-urban
Air pollution	2.45	0.02
Greenhouse/climate change	0.30	0.30
Noise	0.78	0.00
Water	0.37	0.04
Nature and landscape	0.33	0.11
Urban separation	0.56	0.00

Table 5.   Freight vehicles (urban - c/ntkm – $FY2005)

Externality	Urban			Rural		
Vehicle type	Light	Medium	Heavy	Light	Medium	Heavy
Air pollution	24.69	4.68	0.97	0.00	0.05	0.01
Greenhouse/climate change	1.73	0.20	0.07	1.73	0.20	0.07
Noise	2.56	NA	0.26	0.00	NA	0.026
Water	3.70	NA	0.10	0.04	NA	0.06
Nature and landscape	1.67	NA	0.26	0.02	NA	0.11
Urban separation	2.45	NA	0.22	0.00	NA	0.00

We recognise that although Table 5 is in net tonne kilometres, the difference in air pollution cost between light and heavy vehicle emissions appears to be incongruent. Nonetheless, these have been applied with the agreement of IV.

Table 6. **Rail (c/ntkm) – urban values only**

Externality	Value
Air pollution	0.33
Greenhouse/climate change	0.03
Noise	0.14
Water	0.01
Nature and landscape	0.08
Urban separation	0.08

RAV parameters

The residual asset value was calculated in the final modelling year via the straight-line depreciation approach.

$$RAV = Capital\ cost \times \frac{asset\ life\ remaining\ after\ appraisal\ period}{asset\ life}$$

Residual asset value considered a range of infrastructure components, including:

- Earthworks
- Structures (bridges and tunnels)
- Culverts
- Pavement
- Rail sleepers
- Station infrastructure

Active transport benefits

Active transport benefits include those derived from additional walking or cycling as a result of new or changed transport infrastructure. The most significant active transport benefit related to health outcomes. The ATAP *Mode Specific Guidance: M4 Active Travel* contains the following parameters for calculating walking and cycling benefits:

- Health benefit per additional kilometre walked in 2013 values is $2.77
- Health benefit per additional kilometre cycled in 2013 values is $1.40

Note that health benefits were calculated using outputs from the consumer surplus estimates from the EEM.

5   Wider Economic Benefits

WEBs are improvements in economic welfare that are acknowledged but not generally captured in traditional CBA. As part of our consideration of transport project benefits, we calculated WEBs in addition to conventional benefits.

ATAP guidance outlines three categories of WEBs:

- WEB1 – agglomeration economies

- WEB2 – output change in imperfectly competitive markets

- WEB3 – tax revenues from labour markets

Total WEBs = WEB1 + WEB2 + WEB3

These are discussed in more detail, below:

WEB1 – agglomeration economies

Agglomeration benefits are generated when connectivity is improved between firms and workers. Firms derive productivity benefits from being close to one another (e.g. supply chain, knowledge sharing etc.) and from being efficiently connected to labour markets.

A formulation of WEB1 based on *TAG UNIT A2.4 Appraisal of Productivity Impacts* (UK Department for Transport, 2018) can be described simply as below:

> WEB1 = *{elasticity of productivity x the percentage change in the effective density due to the scheme} x the GDP/worker of each industry sector x employment*

The SCGE component of the VLUTI model is currently capable of estimating WEB1

In addition, we used the disaggregated VITM run after the VLUTI to estimate WEB1 based on the methodology for dynamic cluster as presented by the *TAG UNIT A2.4 Appraisal of Productivity Impacts*, as an alternative to crosscheck the result from VLUTI. By employing the dynamic clustering method, both the generalised cost and employment distribution used to calculate effective densities for the Project case were different to the Base case due to land use change, and the result is called as dynamic WEB1.

WEB2 – output change in imperfectly competitive markets

A reduction in transport costs to business passengers or freight transport allows firms to profitably increase the outputs of the goods or services that use transport in their production. If the prices of the goods and services affected exceed costs, the increase in output will deliver a welfare gain as consumers' willingness to pay for the increased output exceeds the cost of producing it.

A practical estimation of WEB2 based on ATAP is:

> WEB2 = *the imperfect competition uprate factor (0.1) x the conventional business (in-work) user cost* savings

It can be estimated using conventional business (in-work) user cost savings estimated by the VITM multiplied by the imperfect competition uprate factor (0.1).

WEB3 – tax revenues from labour markets

Tax revenues collected by government may increase if, as a result of transport infrastructure, more people decide to work, increase the hours they work and/or are able to change to a higher paying or more productive job. Estimation of this benefit requires use of labour supply elasticities to estimate numbers of new workers and workers moving to more productive jobs as a result of a transport improvement.

WEB3 can be estimated approximately as the tax component of GP1, GP2 and GP3 where:

- GP1 – more people choosing to work as a result of commuting time savings;
- GP2 – some people choosing to work longer hours (because they spend less time commuting); and
- GP3 – changing jobs to a more distant but higher productivity (higher wage) area (because reduced travel costs resulting from a transport project make this more accessible).

Currently, GP1 and GP2 of WEB3 are not captured by the SCGE model. Further modifications to the SCGE model to estimate GP1 may be possible, whilst literature suggests that the value of GP2 is quite small. The application of this project would thus focus on the estimation of GP3 – noting that only the tax component of GP3 is counted as additional benefits.

The SCGE model was used to estimate WEB3 (GP3) as the changes in Victorian Gross State Product (GSP) with respect to:

- Reallocation of workers between occupations
- Reallocation of workers between industries
- Reallocation of workers between locations

6   Findings and analysis

Conventional benefits for a transport project are calculated by comparing the difference in travel costs for two scenarios; the base case and the project case. The base case is assumed to be the same for all projects for consistent comparison, that being the future network without the addition of major projects or other change scenarios. By contrast, the project case is an alternate future scenario whereby the transport network is expanded upon or improved.

Economic model results: NPV, BCR (with and without land use change benefits & WEBS)

The results of the CBA were presented via the following economic indicators:

- Benefit Cost Ratio (BCR) – the ratio of Net Present Benefits divided by Net Present Costs. A project or set of projects with a ratio greater than 1 is considered to have a positive economic return
- Net Present Value (NPV) – the net value of Net Present Benefits less Net Present Costs. NPV values are those accrued over time and subject to discounting to account for opportunity costs
- Internal Rate of Return (IRR) – this is the rate of return that equalises the present value of benefits to the present value of costs, i.e., the discount rate, which gives an NPV of zero
- First Year Rate of Return (FYRR) – this measures the benefits received in the first full year of a project's operation per dollar of capital cost.

BCR and NPV results will be presented for three groupings of benefits:

- Transport derived benefits for static land use
- Transport derived benefits for static and dynamic land use
- Transport derived benefits for static and dynamic land use plus WEBs

Sensitivity analysis

As per DTF's *Economic Evaluation for Business Cases Technical guidelines, August 2013*, we undertook sensitivity test on the results for each of the six scenarios. The purpose of sensitivity was to consider impacts of high-risk items that could impact the economic assessment.

The sensitivity tests were:

- Differential discount rates (three and 10 percent).
- Changes in capital expenditure (20 percent decrease in capital costs, 20 percent increase in capital costs and 40 percent increase in capital costs).
- Changes in total benefits (40 percent decrease in total benefits, 20 percent decrease in total benefits and 20 percent increase in total benefits.
- Changes in timing of delivery (delay by five and 10 years).
- Changes in the value of travel time.

Equity & distributional effect

The economic report included a discussion about the impacts of each project scenario on equity and distribution, by geography and by household type. This discussion was supported by data outputs from the SCGE component of the VLUTI.

The assessment was presented using maps, which demonstrate the spatial outcomes of different indicators, compared to the base case. The spatial analysis focuses on:

- Changes in population distribution compared to the transport base case in 2036 and 2051.
- Changes in employment distribution compared to the transport base case in 2036 and 2051.
- Changes in consumer surplus compared to the transport base case in 2036 and 2051. Consumer surplus is defined as the benefits resulting from a reduction of generalised transport costs in a project case compared to a project base case.

APPENDIX B
PROJECT BENEFIT ESTIMATION

B.1　Introduction

Infrastructure Victoria (IV) is responsible for preparing a 30-year Infrastructure Strategy and updating it on a rolling basis every 3 to 5 years. As part of this process, IV commissioned Arup and AECOM to undertake modelling and assessment of transport policy and initiatives which can be categorised under four workstreams:

- Workstream 1 (WS1): Potential Future Scenarios (Economic, policy and technological shock scenarios)

- Workstream 2 (WS2): Transport Program Modelling & Assessment against a 'no project' base case

- Workstream 3 (WS3): Transport Infrastructure Costing

- Workstream 4 (WS4): Cost Benefit Analysis

The project involves developing the Victorian Land Use Transport Interaction Model (VLUTI) and using the model to estimate travel demand and traffic impact of future scenarios in WS1, as well as the transport and wider economic benefits of six infrastructure projects in WS2. The project benefits will be the key inputs to the cost benefit analysis of WS4.

VLUTI is an integration of the Victorian Integrated Transport Model (VITM) and the Spatial Computable General Equilibrium (SCGE) model of Victoria developed by the Centre of Policy Studies Victoria University. The SCGE model of Victoria is also called Spatial Interactions Within and Between Regions and Cities (SIRCV) model (see Appendix E).

This appendix is structured as follows:

- Section B.2 describes the impact on land use distribution

- Section B.3 presents the estimation of conventional benefits

- Section B.4 discusses the estimation of wider economic benefits (WEBs)

B.2　Impact on land use distribution

This section presents the impact of each project on land use redistribution by looking into the change of employment accessibility when compared against the base case.

The employment accessibility (EA) is calculated using the equation below:

$$EA_i = \sum_j \frac{E_j}{E} e^{-\beta TTij}$$

Where:

E_j/E	=	The share of employment at Transport Zone j of the total employment E
TT_{ij}	=	The composite transport cost from zone i to zone j.
β	=	The decay parameter adopted from VITM mode choice

The EA is a number between 0 and 1 representing the accessibility from one zone to all other zones weighted by employment share at destination. It is the inverse of an exponential function of generalised cost to employment. The shorter the generalised cost the higher the EA.

B.3　Estimation of conventional benefits

The conventional benefits of a transport project are common welfare benefits to users and non-users of the project. The conventional benefits estimated in this study include:

- Generalised Cost Savings (time & VOC & parking &toll/fare)
- Safety benefits (Accident (Crash) Cost Savings)
- Environmental benefits
- Active transport benefits
- Residual asset values

B.3.1 Generalised cost savings

The generalised cost savings are calculated separately for highway users and public transport users as the way they perceive their cost is different.

1. Private vehicle user:

$$GC = VOC \times Distance + VOT \times Time + Parking + Tolls$$

Where:

GC = *Generalised cost ($)*

VOC = *Vehicle Operating Cost ($ / km)*

VOT = *Value of Time ($ / min)*

2. Public transport user:

$$GC = VOT \times [(T_{access} \times W_a) + (T_{wait} \times W_w) + (T_{in\text{-}vehicle} \times W_i) + (T_{xfer} \times W_x) + (N_{xfer} \times P_{xfer})] + Fare$$

Where:

T = *Individual travel time components (Access, Wait, In-Vehicle and Transfers)*

W = *Weighting*

N_{xfer} = *Number of transfers*

P_{xfer} = *Transfer penalty time*

The benefits of generalised cost savings are estimated using the consumer surplus theory and the rule of a half. For each project the benefits were estimated under two land use scenarios:

- Static land use: where the land use inputs are the same for both base and project case
- Dynamic land use: where the land use inputs to the project case are not the same as those to the base case.

Under the dynamic land use, benefits were estimated for three types of users:

- New and lost users who shift from one mode of transport to the other or change their destination due to job relocation or trip redistribution
- Existing users who stay at the same location (existing-staying users).
- Existing users who relocate to a new location (existing-moving users).

The benefits of the existing-moving users are called as the land use correction benefits (**see Appendix C** for more description).

In order to provide estimates of the economic effects of each project, Economic Evaluation Model (EEM) was enhanced, which encompassed the following main components:

- Generalised cost savings (consumer surplus) for PT, car and truck;

- Resource cost correction; and

- Land use change correction.

The consumer surplus and resource cost correction are the standard output of the standard EEM provided by the Department of Transport, which has been used to estimate the conventional benefits for static land use scenarios. The resource cost correction is included to account for the differences between the generalised cost produced by VITM based on the costs perceived by transport users, and the resource costs to be used in the standard CBA. For example, the perceived VOC for car would include only petrol cost, but the resource VOC includes the fuel cost as well as non-fuel elements such as tyres, maintenance and depreciation. The perceived costs of tolls are the actual toll amounts and charges paid by toll road users. However, the resource costs of tolls for cars are near zero.

The enhanced EEM includes the land use change correction module to enable the estimation of conventional benefits for dynamic land use scenarios.

Figure 1 below shows a comparison of generalised cost savings between static and dynamic land use scenarios and between 2036 and 2051.

Figure 1 **Comparison of Generalised Cost Savings between 2036 & 2051 and between static (BLU) and dynamic scenarios**
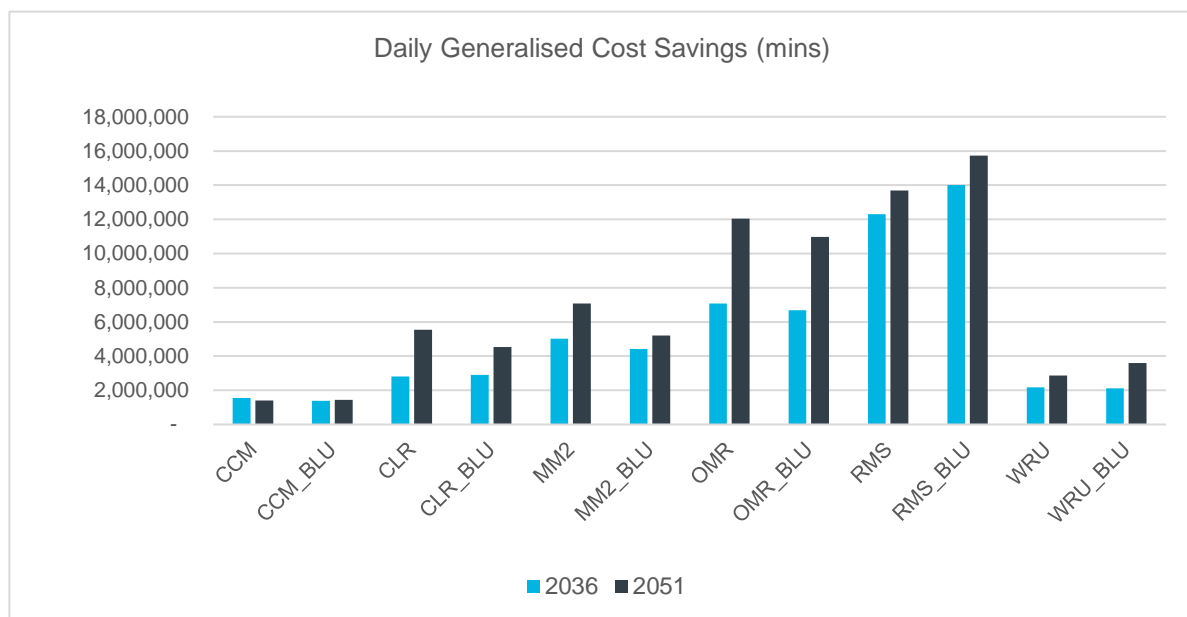
Generally, the generalised cost savings in 2051 are higher than in 2036 due to higher travel demand and traffic congestion in the base case. The generalised cost savings for dynamic scenarios are also higher than static scenarios for most projects except the RMS and WRU. The rise of generalised cost savings in dynamic scenarios would be due to the redistribution of land use to locations of improving accessibility and/or of less traffic congestion. The following section would explain further differences of benefits between static and dynamic scenarios.

B.3.2   Total conventional benefits

The daily generalised cost saving benefits in minutes presented in the previous section were converted to monetary terms by multiplying with an appropriate day-to-year factor and value of time (VOT) by mode. The annual benefits in 2036 and 2051 were interpolated to a stream of benefits for 50 years starting from the project opening year. The relevant factors are summarised as below:

- VOT for personal travel (vehicle passenger and PT passenger) (in $2021): $18.19 / hour

- VOT for business travel (in $2021): $59 / hour

- VOT for rigid truck passenger: $39.31 / hour

- VOT for articulated truck passenger: $77.68 / hour

- Day-to-Year Factor for car users: 345

- Day-to-Year Factor for PT users: 291

The other conventional benefits including safety, environmental and active transport benefits, and residual values of asset are described as follows:

- The safety benefits are savings in crash costs and calculated using the change in VKT for different road types between a project case and the base case.

- The environmental benefits are savings in environmental externality costs calculated using vehicle composition and VKT.

- The active transport benefits are those associated with the use of active mode. The VITM does not model explicitly all trips by active mode but represents it as part of a public transport trip such as walking to access to and egress from a PT node and transfer between PT modes. Therefore, the active transport benefits estimated in this study do not cover a full spectrum of travels by active mode, but are limited within those associated with PT.

Table 1 shows the sum of conventional benefits by components over 50 years. Please note these values are for comparison purpose, and hence are not discounted.

Table 1   Conventional benefits by components ($mil.)

Project	Gen. cost savings	Safety	Environment	Active Transport	Residual	Total
Static ($mil.)						
OMR	159,531	1,209	- 2,380	- 1,651	6,989	163,697
CCM	20,300	- 1,404	- 1,184	- 406	4,029	21,335
MM2	25,718	185	- 812	5,903	6,676	37,670
CLR	38,957	601	455	2,462	2,037	44,512
WRU	32,193	200	157	1,552	479	34,582
RMS	249,753	- 9,161	- 4,734	- 3,693	204	232,369
Dynamic ($mil.)						
OMR	203,991	1,227	- 1,186	- 834	6,989	210,186
CCM	18,201	- 769	722	- 438	4,029	21,745
MM2	64,349	580	1,045	6,558	6,676	79,207
CLR	52,365	1,152	1,696	2,031	2,037	59,282
WRU	19,566	- 659	214	1,635	479	21,236
RMS	215,702	- 9,094	- 4,580	- 4,001	204	198,232

Table 2 shows the proportion of conventional benefits by component. The generalised cost savings are the largest contributor to the total conventional benefits.

Table 2   Proportions of conventional benefits

Project	Gen. cost savings	Safety	Environment	Active Transport	Residual	Total

Static						
OMR	97%	1%	-1%	-1%	4%	100%
CCM	95%	-7%	-6%	-2%	19%	100%
MM2	68%	0%	-2%	16%	18%	100%
CLR	88%	1%	1%	6%	5%	100%
WRU	93%	1%	0%	4%	1%	100%
RMS	107%	-4%	-2%	-2%	0%	100%
Dynamic						
OMR	97%	1%	-1%	0%	3%	100%
CCM	84%	-4%	3%	-2%	19%	100%
MM2	81%	1%	1%	8%	8%	100%
CLR	88%	2%	3%	3%	3%	100%
WRU	92%	-3%	1%	8%	2%	100%
RMS	109%	-5%	-2%	-2%	0%	100%

A comparison of total conventional benefits between static and dynamic land use scenarios is shown in Table 3 below.

Table 3   Comparison of static and dynamic conventional benefits

Project	Static ($mil.)	Dynamic ($mil.)	% Diff.
OMR	163,697	210,186	28%
CCM	21,335	21,745	2%
MM2	37,670	79,207	110%
CLR	44,512	59,282	33%
WRU	34,582	21,236	-39%
RMS	232,369	198,232	-15%

The table indicates that the dynamic scenario of MM2, CLR and OMR provides more benefits than the static case, while WRU displays an opposite direction. As discussed earlier, if the land use change moves population and job to less congested areas, the dynamic scenario would produce more benefits than the static case. This is the case for MM2, CLR and OMR. Conversely, WRU involves moving population and job to more congested areas, its dynamic scenario would produce less benefits than the static case.

B.4   Estimation of WEBs

B.4.1   Introduction

WEBs are improvements in economic welfare, that have not been typically captured in traditional cost-benefit analysis (CBA). They arise from productivity gain and from market imperfections which exist when the price of goods and services is different from the cost to society (or the marginal cost).

As suggested by the Australian Transport Assessment and Planning (ATAP) Guidelines, three categories of WEBs were estimated in this study:

- WEB1 – agglomeration economies
- WEB2 – output change in imperfectly competitive markets
- WEB3 – tax revenues from labour markets.

The SCGE model provides an estimation of WEB1 and gross WEB3.

The full VITM was also used to estimate independently WEB1 and WEB2.

B.4.2   Estimation of WEB1 and WEB3 from SCGE (SIRCV) model

The SCGE model estimates the components of gross state products (GSP) for each scenario. By calculating the difference of GSP between a project and the base, the contribution of GSP components by the project was estimated.

Table 4 shows the difference of GSP components for each WS2 project. The productivity spillover represents WEB1, and the labour relocation represents the gross WEB3.

Table 4   Difference of GSP components between a project and base case ($mil./year)

Summary Name	MM2	OMR	CLR	WRU	CCM	RMS
2036						
Real GSP Total ($m)	4,190	2,005	1,033	1,750	1,177	4,048
Productivity Spillovers ($m)	318	146	97	139	30	109
Labour Reallocation ($m)	549	409	19	264	93	-351
Land Reallocation ($m)	37	- 24	18	0	-0	46
Capital Stocks ($m)	1,810	842	546	678	191	589
Intermediate Inputs - Tech Change ($m)	-	-	-	-	-	-
Indirect Taxes – Intermediate Quant. ($m)	46	20	11	20	5	-0
Indirect Taxes - Rates ($m)	-	-	-	-	-	-
Freight/Business Travel Costs ($m)	1,430	611	342	647	858	3,654
2051						
Real GSP Total ($m)	3,037	2,543	- 528	1,867	2,239	6,549
Productivity Spillovers ($m)	135	119	- 57	112	34	127
Labour Reallocation ($m)	175	435	- 326	136	162	-537
Land Reallocation ($m)	36	- 33	37	- 4	- 6	37
Capital Stocks ($m)	843	818	- 430	654	210	705
Intermediate Inputs - Tech Change ($m)	-	-	-	-	-	-
Indirect Taxes - Intermediate Quant.($m)	27	20	-3	13	7	- 6

Summary Name	MM2	OMR	CLR	WRU	CCM	RMS
Indirect Taxes - Rates ($m)	-	-	-	-	-	-
Freight/Business Travel Costs ($m)	1,821	1,182	251	956	1,833	6,224

Table 5 shows a summary of WEB1 & WEB3 ($mil./year) in which WEB3 was estimated by multiplying the average worker tax rate in Australia of 23.6%[1] to the labour reallocation or the gross WEB3 shown in Table 4.

Table 5   A summary of WEB1 & WEB3 ($mil./year) estimated by SCGE

	MM2	OMR	CLR	WRU	CCM	RMS
2036						
WEB1	318	146	97	139	30	109
WEB3	129	97	4	62	22	- 83
2051						
WEB1	135	119	- 57	112	34	127
WEB3	41	103	- 77	32	38	- 127

The table indicates that generally WEB3 is lower than WEB1. Surprisingly, WEB1s in 2051 are lower than those in 2036, although the economy (GSP) in general is growing. An unexpected result in 2051 is the negative WEBs for CLR in 2051.

B.4.3   Estimation of WEB1 from VITM

The land use outputs from the VLUTI (or SCGE) were disaggregated from 458 zones to 3000 zones and input to the full disaggregated VITM run.

WEB1 was calculated independently for dynamic and static land uses by using VITM generalised cost and employment. The methodology was based on the Transport Appraisal Guidance (TAG) Unit A2.4 (Department for Transport (UK), 2020) presented in Appendix D.

In the dynamic scenario, both the land use and generalised cost used to calculate the effective density in the project case are different to those in the base case. Whereas, in the static scenario, the land use was kept constant for both project and base cases; only the generalised cost in the project case was changed due to the transport improvement.

The adopted agglomeration elasticity and distance decay parameters are shown in Appendix D.

The productivity estimated from the change in effective densities was multiplied by GDP per employment. In Victoria, the GDP is represented by the gross value added (GVA) per employee based on June 2019 current price. A summary of GVA per employee as shown in

Table 6 was estimated for four aggregated industry, Manufacturing, Construction, Consumer Services, and Business Services, using ABS data.

Table 6   Estimated GVA per employment (June 2019 price)

Aggregated Industry	Employment (May-19)	Annual GVA (Jun-19) Current Prices	GVA-Per Employee Current Prices

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[1] 2019 taxing wages in Australia (OECD report, 2020)

Manufacturing	420,320	58,286,000,000	138,671
Construction	316,194	37,146,000,000	117,478
Consumer Services	1,838,815	157,206,000,000	85,493
Business Services	837,363	135,142,000,000	161,390

Table 7 shows the estimated WEB1 for each WS2 project. The project name e.g. MM2 represents the dynamic land use scenario, why the name with suffix BLU e.g. MM2_BLU represents the static scenario.

Table 7 Estimated WEB1 ($mil/year) by VITM

Project	MM2	MM2_BLU	OMR	OMR_BLU	CLR	CLR_BLU	WRU	WRU_BLU	CCM	CCM_BLU	RMS	RMS_BLU
2036												
Manuf.	2	8	3	6	2	4	1	4	8	2	32	37
Const.	6	9	7	9	3	4	2	4	5	2	46	49
Cons.	24	25	24	28	12	13	11	11	19	12	168	169
Bus.	549	375	92	57	91	40	109	41	6	54	435	394
Total	**581**	**416**	**126**	**99**	**108**	**62**	**123**	**61**	**38**	**70**	**682**	**649**
2051												
Manuf.	9	14	- 5	- 2	5	5	3	7	-11	3	38	44
Const.	9	12	12	13	7	6	5	7	- 2	3	55	59
Cons.	36	36	52	54	24	19	17	19	10	15	207	211
Bus.	510	376	120	75	85	49	103	52	355	74	517	475
Total	**564**	**437**	**179**	**140**	**121**	**80**	**128**	**85**	**352**	**95**	**815**	**789**

The following trend is observed as below:

- The contribution of the agglomeration impact of business service employment is usually the highest, and then followed by consumer service employment

- Excluding RMS, the WEB1 for MM2 is the highest as MM2 brings more employment to the CBD area as well as reduces travel cost to CBD.

- The WEB1s in 2051 are mostly higher than in 2036 for the same project.

- The dynamic WEB1s are higher than the static ones, except the CCM in 2036.

Table 8 shows a comparison of WEB1 between the SCGE and VITM.

Table 8   Comparison of WEB1 ($mil/year) between SCGE model and VITM

Project	MM2	OMR	CLR	WRU	CCM	RMS
2036						
SIRCV	318	146	97	139	37	109
VITM	581	126	108	123	38	682
2051						
SIRCV	135	119	-57	112	33	127
VITM	564	179	121	128	352	815

It can be seen that:

- Excluding RMS, the WEB1 between two methods are quite comparable in 2036. They follow the same order from highest to lowest: MM2, OMR, WRU, CLR, CCM

- The results in 2051 are remarkably different. The WEB1 by SIRCV in 2051 are all lower than 2036. And the result for CLR is negative in 2051.

The most striking contrast between the VITM and SIRCV WEB1 is seen in the CLR scenario in 2051, where the VITM WEB1 are positive but SIRCV WEB1 are negative. The latter result is explained firstly by significant net job loss from the four central city SA2s. This occurs both because baseline productivity levels and physical agglomeration of jobs are much higher in these zones than in the inner and outer suburban zones into which jobs move in the CLR scenario. In 2036, the effects of the project on accessibility are less significant. Consequently, while there is relocation of jobs between the inner city SA2s, the total inner city jobs is not significantly changed. A subtler feature of the two sets of estimates is that for scenarios in which both SIRCV and VITM WEB1 are positive in both 2036 and 2051, SIRCV WEB1 tend to increase relatively less from 2036 to 2051 than do VITM WEB1.

WEB1 computed using VITM, the partial equilibrium approach would typically differ to SIRCV using the general equilibrium approach for several reasons. In certain circumstances, they can even differ in sign.

- The most important reason is that VITM WEB1 consider only four types of jobs (by industry) and assume the same wage for workers in these jobs across all locations. By contrast, SIRCV considers wages in 43 occupations and wages vary spatially.

- The second main difference between the VITM and SIRCV WEB1 is that effective densities in VITM are estimated with a much gentle decay function than those in SIRCV. Thus, spillovers result from much more local agglomeration patterns in SIRCV than in VITM.

- The third reason is noted that while the elasticities with respect to effective density applied in the two methods appear to be broadly aligned, they apply to 100 industries in SIRCV but just four aggregate sectors in the VITM WEB1 method.

The occupational wage structure underlying SIRCV WEB1 should be a significantly better approximation of reality than the broad industry wage structure underlying VITM WEB1. However, while the spatial variation in calibrated occupational wages in SIRCV is qualitatively plausible, there are currently no small area wage datasets publicly available in Australia that could be used to determine their accuracy; or better, used directly in the model calibration.

When comparing the SIRCV estimates across years, the interaction of projects with the 2036 and 2051 baselines respectively may play an important role. In particular, the outward expansion of the city between 2036 and 2051 results in relatively more decentralized patterns of both residence and

employment. This may potentially increase the potential of any given project to play a less centralizing/more decentralizing role in 2051 than it does in 2036. Unfortunately, there is no way to isolate the effects of different baselines in the simulations themselves.

B.4.4   Estimation of WEB2 from VITM

According to ATAP, the WEB2 relates to additional benefits to businesses over and above the conventional appraisal benefits of journey time and operating cost savings. Firms which derive these conventional benefits could make use of them to reduce their prices to stimulate demand and increase output to match. It was estimated by applying an uprate factor of 10 percent to business user benefits.

The daily business travel time savings estimated from the EEM for each project in 2036 and 2051 are shown in Table 9 below.

Table 9   Daily Business Travel Time savings (mins)

Year	MM2	MM2_BLU	OMR	OMR_BLU	CLR	CLR_BLU
2036	55,400	54,742	402,961	409,721	28,161	42,965
2051	(1,974)	(47,730)	711,689	676,175	100,481	55,698

Year	WRU	WRU_BLU	CCM	CCM_BLU	RMS	RMS_BLU
2036	29,338	27,288	130,478	124,632	963,913	1,018,184
2051	(9,500)	29,298	108,482	122,263	1,125,440	1,222,306

Applying the following parameters to the daily business travel time savings, the WEB2 were estimated and shown in Table 10:

- VOT for business travel: $59 / hour
- Day-to-Year Factor: 345
- Uprate factor: 0.1

Table 10   Estimated WEB2 ($mil./year)

Year	MM2	MM2_ BLU	OMR	OMR_ BLU	CLR	CLR_ BLU	WRU	WRU_ BLU	CCM	CCM_ BLU	RMS	RMS_ BLU
2036	1.9	1.9	13.7	13.9	1.0	1.5	1.0	0.9	4.4	4.2	32.7	34.5
2051	-0.1	-1.6	24.1	22.9	3.4	1.9	-0.3	1.0	3.7	4.1	38.2	41.5

B.4.5   Total WEBs

Table 11 summarises WEB1 and WEB3 from the SIRCV model and WEB2 from the VITM, and shows the total WEBs for the dynamic scenario of each project in 2036 and 2051.

Table 11   Total WEBS ($mil./year)

Project	MM2	OMR	CLR	WRU	CCM	RMS
2036						
WEB1	318	146	97	139	30	109
WEB2	1.9	13.7	1	1	4.4	32.7
WEB3	129	97	4	62	22	-83
Total	449	257	102	202	56	59
2051						
WEB1	135	119	-57	112	34	127
WEB2	-0.1	24.1	3.4	-0.3	3.7	38.2
WEB3	41	103	-77	32	38	-127
Total	176	246	-131	144	76	38

The percentage of components of WEBs in 2036 were calculated and shown in Table 12. WEB1 or the agglomeration benefits contribute the highest percentage to the total WEBs. It is then followed by WEB3 and WEB2.

Table 12   Percentage of WEB components

Project	MM2	OMR	CLR	WRU	CCM	RMS
2036						
WEB1	71%	57%	95%	69%	53%	186%
WEB2	0%	5%	1%	0%	8%	56%
WEB3	29%	38%	4%	31%	39%	-141%
Total	100%	100%	100%	100%	100%	100%

B.5   Total project benefits

Table 13 shows the sum of undiscounted project benefits over 50 years of project life for each project under static land use, dynamic land use, and with WEBS. The table also shows the percentage of WEBs to the total project benefits. It can be seen that WEBs would contribute approximately 10% to 30% of the total benefits.

Table 13   Total undiscounted project benefits ($mil.)

Project	Static	Dynamic	WEBS	Dynamic & WEBS	% WEBS
OMR	163,697	210,186	14,470	224,656	6%
CCM	21,335	21,745	3,249	24,994	13%
MM2	37,670	79,207	11,826	91,034	13%
CLR	44,512	59,282	- 4,033	55,249	-7%
WRU	34,582	21,236	8,878	30,114	29%
RMS	232,369	198,232	2,374	200,606	1%

APPENDIX C LAND USE CHANGE BENEFIT CORRECTION

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C.1 Introduction

The Australian Transport Assessment and Planning Guidelines (ATAP) Guidelines, T2 Cost Benefit Analysis indicates that the conventional benefits for a transport project could include:

- Travel time cost savings

- Vehicle operating cost savings

- Crash cost savings

- Environmental externality cost savings

- Residual asset value if applicable

The estimation of benefits for a transport project in Victoria has been performed using an Economic Evaluation Module (EEM) together with the VITM.

The EEM calculates the travel time cost savings or broadly the generalised cost (measured in time unit) savings for both highway and public transport modes based on consumer surplus methodology.

The EEM also produces the network performance such as travel distance change between a project and the base case, which can be used to estimate the vehicle operating cost, crash cost and environmental externality cost savings.

Traditionally the conventional benefits have been estimated by using a demand model where the land use inputs are static or constant in both the base and project cases. In this project with the application of the Victorian Land Use Transport Interaction model (VLUTI), the land use inputs to the demand model become dynamic when there is relocation of job and population as a result of improvement of transport in the project case. Therefore, the land use inputs to the project case are different to the base case with the redistribution of population and employment.

With the introduction of dynamic land use, we propose to modify the EEM to enable it to calculate correctly the generalised cost savings based on the consumer surplus, which represent the significant component of conventional benefits. However, the estimation of other benefits based on change of network travel distance remains unchanged.

This section firstly reviews the calculation of generalised cost saving benefits in the case of static land use, then discusses the estimation of benefits in the case of dynamic land use.

C.2 Static land use

Figure 1 shows the benefits or consumer surplus of a project as a result of reduction of generalised cost (GC) from the base to the project case. The benefits are determined commonly by the "rule-of-a-half". They can be divided into two parts:

- The benefit to existing users (the shaded rectangle). It is calculated as the reduction in cost for all the existing users.

- The benefit to new (diverted or generated) users (the shaded triangle). It is calculated as the triangle area. The same calculation applies to lost users.

Figure 1 Estimation of Benefit from a Transport Improvement (Source: ATC Guidelines Vol.5, page 41)
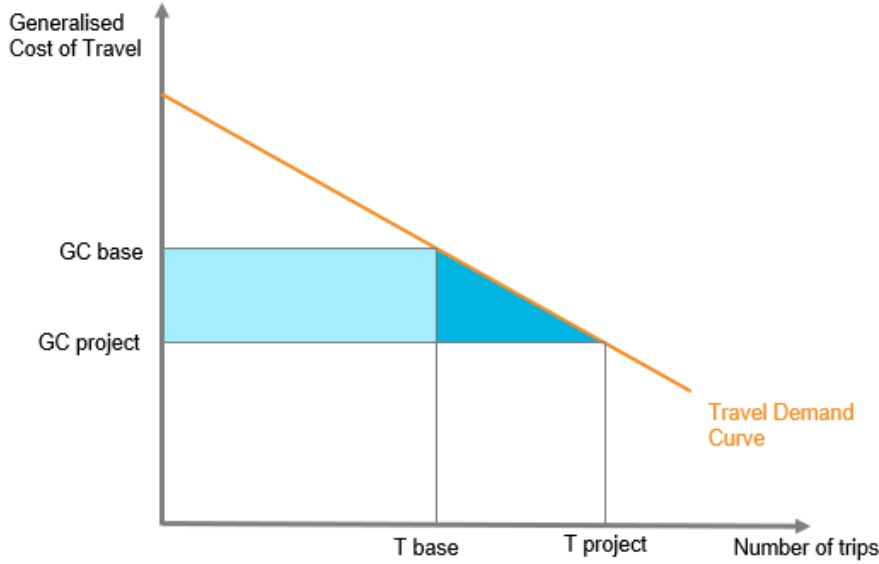
The Economic Evaluation Module calculates the consumer surplus for three user types:

- Existing
- New
- Lost

The existing users are the one who do not change their mode of travel nor their destination as a result of the project. Their benefits are simply the product of the existing users to the reduction of travel cost as below:

$$Benefit_{existing\ users} = Min(Trips_{base}, Trips_{project}) \times (GCost_{base} - GCost_{project})$$

Please note that the number of existing users is defined as the minimum number of trips between the base and the project case. In the case of increase of demand in the project case, the number of trips in the base is the existing users. Whereas in the case of demand reduction in the project case, the number of trips in the project is the existing users.

New or lost users are defined as those who change their mode or destination as a result of the project. They are identified by calculating the difference of demand for an origin destination pair between the project and the base case. If the difference is positive, the increase of demand is new users. Similarly, if the difference is negative, the reduction of demand is defined as lost users.

The new and lost user benefits are based on the rule-of-a-half, applying half of the change in travel cost to the new and lost users. The number of trips is calculated as the absolute trip difference between base and project cases. The benefit would be positive or negative (benefit or disbenefit) depending on the change in cost being positive or negative.

For example, in the case of an improved public transport option between two zones, the benefit to a new user switching from car to PT would include half of the benefit of the decrease public transport cost (their new mode).

$$Benefit_{new/lost\ users}) = {}^{1}/_{2} \times |Trips_{project} - Trips_{base}| \times (GCost_{base} - GCost_{project})$$

C.3   Dynamic land use

C.3.1   Benefits by user type

As the VLUTI is capable of simulating the relocation of job and population – i.e. land use change - as a result of transport improvement, transport users can now be divided into three main categories:

- New and lost users who shift from one mode of transport to the other or change their destination due to job relocation or trip redistribution

- Existing users who stay at the same location (existing-staying users).

- Existing users who relocate to a new location (existing-moving users).

The benefits of new/lost and existing-staying users are conventional benefits, but those of existing-moving users are considered as **land use change benefits**. The latter's benefits will be calculated similarly to that of traditional transport users (i.e. full benefits) but considering the user's moved location. Strictly speaking, the benefits/disbenefits of new/lost users due to job relocation could also be classified as land-use change benefits related to change at destination. However due to the complication of separate this user movement, the land use change benefits at this stage consider only existing users who relocate to a new location or existing-moving users.

The benefit of existing-staying users for example i-j is calculated in the same way as in the static land use, because i-j was the same in the base and project case.

$$Benefit_{existing-staying\ users} = Min(Trips_{base\ i-j}, Trips_{project\ i-j}) \times (GCost_{base\ ij} - GCost_{project\ ij})$$

The benefit of existing-moving users – for example a user moving from i to k and her destination remains as j – is estimated as below:

$$Benefit_{existing-moving\ users\ (i\ to\ k)} = Trips_{base\ i-j\ via\ k} \times (GCost_{base\ ij} - GCost_{project\ kj})$$

Figure 2 below shows an example to illustrate the calculation of benefits in the case of land use change.

Figure 2   Illustration of land use change benefits
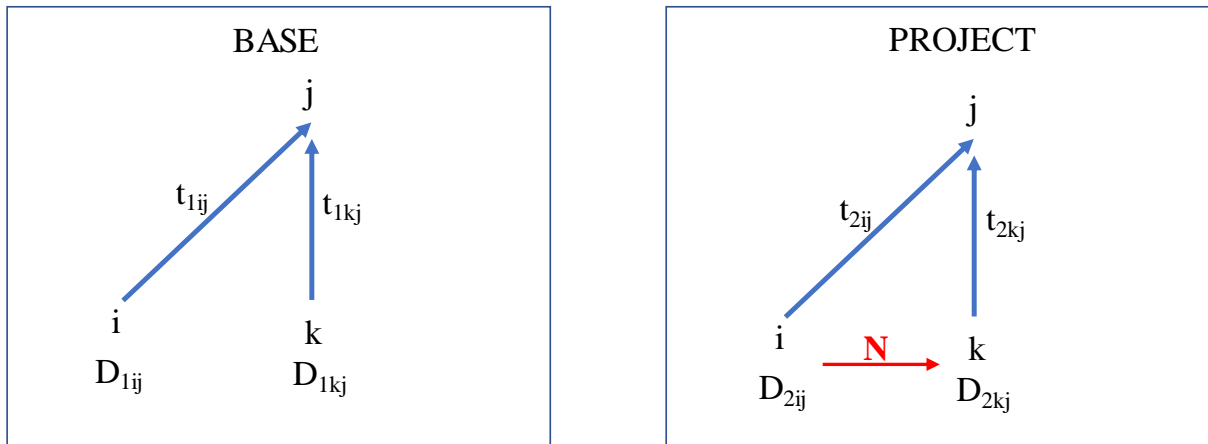
In this example,

D_{1ij}, D_{2ij} the travel demand or number of trips from i to j for the Base (1) and Project case (2) respectively

Assuming $D1_{ij} > D2_{ij}$ and $D_{1kj} < D_{2kj}$

t_{1ij}, t_{2ij} the travel time from i to j for the Base and Project case respectively

N   the number of trips move from i to k due to population relocation (N>0)

Table 1   Calculation of benefits for different user types

Static Land Use	Dynamic Land Use
Existing users $E_{ij} = D_{2ij}$ x $(t_{1ij} - t_{2ij})$ $E_{kj} = D_{1kj}$ x $(t_{1kj} - t_{2kj})$	Existing staying users $E_{ij} = D_{2ij}$ x $(t_{1ij} - t_{2ij})$ $E_{kj} = D_{1kj}$ x $(t_{1kj} - t_{2kj})$ Existing moving users $M_{ij\ via\ k} = N$ x $(t_{1ij} - t_{2kj})$
New users $N_{kj} = |D_{2kj} - D_{1kj}|$ x $(t_{1kj} - t_{2kj})$ x 1/2	New users $N_{kj} = (|D_{2kj} - D_{1kj}|-N)$ x $(t_{1kj} - t_{2kj})$ x 1/2
Lost users $L_{ij} = |D_{1ij} - D_{2ij}|$ x $(t_{1ij} - t_{2ij})$ x 1/2	Lost users $L_{ij} = (|D_{1ij} - D_{2ij}|-N)$ x $(t_{1ij} - t_{2ij})$ x ½

As indicated in Table 1, when calculating the benefits for N existing-moving users moving from origin i to origin k, it is necessary to reduce the number of lost users at i by N and also reduce the new users at k by N, to avoid double counting.

C.3.2   Numerical example

Figure 3   Example of land use change benefits

Table 2   Example of calculation of benefits for different user types

Static Land Use	Dynamic Land Use
Existing users $E_{ij} = 80 \times (40 - 38) = 160$ mins $E_{kj} = 70 \times (30 - 20) = 700$ mins	**Existing staying users** $E_{ij} = 80 \times (40 - 38) = 160$ mins $E_{kj} = 70 \times (30 - 20) = 700$ mins **Existing moving users** $M_{ij\ via\ k} = 15 \times (40 - 20) = 300$ mins
New users $N_{kj} = 20 \times (30 - 20) \times \frac{1}{2} = 100$ mins	**New users** $N_{kj} = (20\text{-}15) \times (30 - 20) \times \frac{1}{2} = 25$ mins
Lost users $L_{ij} = 20 \times (40\text{-}38) \times \frac{1}{2} = 20$ mins **Total savings** = 980 mins	**Lost users** $L_{ij} = (20\text{-}15) \times (40\text{-}38) \times \frac{1}{2} = 5$ mins **Total savings** = 1,190 mins --- Land use change benefit corrections = $15 \times (40\text{-}20) - 15 \times (30\text{-}20) \times 1/2 - 15 \times (40\text{-}38) \times 1/2 = 210$mins **Total savings** = 980 + 210 = 1,190 mins

C.3.3   Relocation matrix

In order to estimate the number of existing-moving users from i to k, it is necessary to estimate a relocation matrix to represent the movement of population from one zone to the others. The SCGE model at the present only provides the net change in residents, e.g. total number of residents moving out a zone, and moving to a zone, but does not allocate the movement of residents from one zone to the others. Nevertheless, the SCGE could be further enhanced to provide a transition matrix representing a relocation of population from the base year to a future year for a scenario. The difference in the transition matrix of population between a project and a base case would represent approximately a relocation matrix. Once available, the relocation matrix from SCGE would be expanded to VITM zones and used in the economic model.

Pending the development of a relocation matrix from SCGE, a practical and approximate approach within VITM is to employ a distribution function considering:

- Resident would only move to locations with accessibility higher than her existing one

- Generalised cost between her existing and potential locations. The relocation would be dissipated with the increase of generalised cost

- The total population moving out of all zones is equal to the total population moving in of all zones

APPENDIX D
METHODOLOGY TO ESTIMATE WEB1 USING VITM

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D.1   Introduction

This note is to provide the methodology for WEB1 calculation, using a calculation of dynamic clustering.

The evaluation of transport projects is thought to be underserved by traditional cost-benefit analysis due to the fact that transport infrastructure projects are thought to induce economic effects not modelled by standard economic assumptions (e.g. perfect competition, no market failures) (Graham & Van Dender, 2011). The reason these assumptions are likely not to hold are due to what are called **agglomeration economies**. Agglomeration occurs when there are place-based productivity elasticities relating to density of economic activity.

The effects of transport investment on agglomeration economies can be modelled via:

- Static clustering

  - Increased accessibility facilitates increased interactions between firms.

  - No change to land use.

- Dynamic clustering

  - Changes to the density and make-up of cluster drives changes in productivity.

  - Dynamic land use.

AECOM and Arup have used the process elaborated by the Department for Transport (United Kingdom) to calculate the wider economic benefits for agglomeration economies with dynamic clustering.

D.2   Methodology

This section details the calculations required in the proposed framework, as elaborated in the Transport Appraisal Guidance (TAG) Unit A2.4 (Department for Transport (UK), 2020). First it is necessary to calculate effective densities for the base case *and* the project/scenario case. This is done in two steps:

1. Calculate average generalised travel costs, weighted by journey purpose:

$$g_{ij}^{Smf} = \frac{\sum_p g_{ij}^{Smpf} T_{ij}^{Smpf}}{\sum_p T_{ij}^{Smpf}}$$

Where:

$g =$ generalised cost from zone i to zone j

$S =$ scenario: base or project case

$m =$ transport mode

$f =$ forecast year

$T_{ij}^{Smpf} =$ Trips from zone i to j for scenario S, trip type p, mode m and year f

2. These costs are then fed into a calculation of effective density:

$$d_i^{Skf} = \sum_j \sum_m \frac{E_j^{Sf}}{\left(g_{ij}^{Smf}\right)^{\alpha^k}}$$

Where:

$d^{Skf} =$ effective density of origin i, for given scenario S, year f and sector k

$E_i^{Sf} =$ employment at each zone j for a given scenario S

$\alpha^k =$ the distance 'decay' factor for industry sector k

The industry distance decay factor recommended by the Department for Transport (UK) has been estimated by Graham et al, shown in Table 1 (Graham et al., 2009)[1].

Once the effective densities are calculated, they are multiplied by the average GDP per worker in each industry, to provide a measure of increased productivity for each industry from the denser urban economy. This is then multiplied by the total employment in each sector to arrive at the total zonal productivity increase/decrease in dollars:

$$WI_i^{kf} = \left[\left(\frac{d_i^{Akf}}{d_i^{Bkf}}\right)^{\rho^k} - 1\right] GDPW_i^{Skf} \times E_i^{Skf}$$

Where:

$WI_i^{kf} =$ productivity impact by sector k and area i

$d =$ the effective density by zone i, year f and scenario (B =base, $A =$

$GDPW_i^{Skf} =$ GDP per worker for area i, in industrial sector k, scenario S and year f

$\rho^k =$ elasticity of productivity with respect to effective density for sector k

The agglomeration elasticity ρ (i.e. the increase in productivity per increase in effective density) provided by Daniel Graham is specified in Table 1 below:

Table 1   Agglomeration elasticity and distance decay factors for four industries

Industry	Agglomeration Elasticity ρ	Distance Decay α
Manufacturing	0.024	1.122
Construction	0.034	1.562
Consumer services	0.024	1.818
Business services	0.083	1.746
Economy (weighted average)[2]	**0.044**	**1.659**

Finally, we can calculate the overall change in productivity due to the project as the sum of the previous equation across all zones and industry sectors:

$$WI^f = \sum_i \sum_k WI_i^{kf}$$

D.3   References

Department for Transport (UK). (2020, May 29). Transport Analysis Guidance (TAG) on the analysis of productivity impacts in transport appraisals. Retrieved from TAG unit A2-4 productivity impacts - GOV.UK: https://www.gov.uk/government/publications/tag-unit-a2-4-productivity-impacts

Graham D. J., Gibbons S., Martin R. 2009. Transport investments and the distance decay of agglomeration benefits. Working paper, Imperial College of London.

Graham, D. J., & Van Dender, K. (2011). Estimating the agglomeration benefits of transport investments: some test for stability. Transportation, 409-126.

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[1] The values for Manufacturing (and thus economy) provided were provided by Professor Graham in 2019, and are slightly higher than those originally estimated in 2009.

[2] Weighted by employment in each sector

APPENDIX E SIRCV INPUTS TO VLUTI

SIRCV inputs to VLUTI

James Lennox

January 28, 2021

1 Spatial Interactions Within and Between Regions and Cities in Victoria (SIRCV)

1.1 Commuting gravity

To explain aggregate commuting flow data, gravity models typically fit negative exponential or negative power functions that give rise to linear regressions, i.e.

$$\ln \pi_{rs} = -\zeta \, t_{rs}^{\mathrm{C}} + a_r + b_s + \varepsilon_{rs} \tag{1}$$

or

$$\ln \pi_{rs} = -\zeta \, \ln t_{rs}^{\mathrm{C}} + a_r + b_s + \varepsilon_{rs}. \tag{2}$$

The dependent variable π_{rsi} is the probability that an individual i will choose to live in r and work in s. The cost of commuting between r and s is t_{rs}^{C}, a_r and b_s are fixed effects and ε_{rs} is an error term. The estimated parameter of primary interest is ζ, the magnitude of which determines the rate at which commuting probabilities drop off with rising travel cost, other things being equal.

SIRCV distinguishes commuters by 43 occupational groups. The data suggest that commuting patterns differ significantly between occupations. Also, the fixed effects are likely to capture occupational-specific factors inter alia. We therefore estimate a separate gravity equation for workers in each occupation. We find that the negative power form provides a better fit for some occupations but the negative exponential for others. Rather than adopting completely different functional forms for different occupations, we adopt a more flexible form

$$\pi_{ors} = \exp\left(-\zeta_o (t_{rs}^{\mathrm{C}})^{1-\vartheta_o}\right) \tag{3}$$

where the subscript o denotes occupation and the two parameters should satisfy $0 \leq \vartheta_o \ll 1$ and $\vartheta_o > 0$. This form is motivated by the common observation in the literature that a negative exponential results in commuting probabilities dropping off too fast with distance, whereas a negative power results in probabilities dropping off too slowly.

Using a simple grid search, we estimate the parameters ζ_o and ϑ_o to minimise the root mean squared error (RMSE) between predicted and actual commuting patterns between SA3s in Victoria by two-digit ANZSCO occupation (ABS

2016). These observations are drawn from the 2016 Census (ABS 2016) and relate to usual places of residence and work, rather than to actual commutes on any given day. The gravity model is estimated at the SA2 level at which SIRCV operates and the predictions aggregated to SA3 level. The main purpose of this procedure is to reduce the number of zero and censored observations. Additionally, the parameter estimates will be less influenced by the localised distributions of very short commutes. Travel times for very short commutes are likely to be measured with large relative errors. Additionally, factors other than generalised commuting costs may be more important for very short commutes.

1.2 Modelling working from home

We are not aware of any study that estimates a gravity model with explicit consideration of WFH. This may be due simply to the fact that available datasets do not include quantitative (or any) information on this dimension of commuting behaviour. Since the cost t_{rs} is typically observed as the measured distance or time for a return commute (or one way, if costs are symmetric)[1], the equations above imply that either there is a fixed commuting frequency or, more generally, there may be some cost-dependence of frequency absorbed by the estimated coefficient ζ.

There is some empirical literature on WFH that suggests a dependence on commute cost amongst other factors (e.g. occupation, sex, age) that has been reviewed separately as part of this project. However, none of these studies treat both commuting costs as a continuous variable and annual (or even weekly) commuting frequencies as consecutive integers. Consequently, their findings are not readily translatable to simple gravity specifications like that above. We therefore propose a simple approach whereby we—somewhat arbitrarily—reduce each coefficient ζ_o by 20%. Note that since commuting frequencies are not explicit in the gravity specification this does *not* necessarily correspond simply to a 20% reduction of 2016 commuting frequencies.

1.3 Households and discrete choices

Thus, the Spatial Interactions within and between Regions and Cities in Victoria (SIRCV) model incorporates disutility of commuting according to the following indirect utility function for an individual making the discrete choices of occupation o, residence r and workplace s:

$$u_{ors}^{\mathrm{W}} = \epsilon_{ors}^{\mathrm{W}} B_r \frac{(1 - \tau^{\mathrm{W}})(1 + \chi) W_{os}}{\mathcal{P}_r^{\mathrm{W}}} \exp\left(-\zeta_o (t_{rs}^{\mathrm{C}})^{1-\vartheta_o}\right). \tag{4}$$

The composite cost of daily commutes is t_{rs}^{C}. Note that the commuting parameters ζ_o and ν_o are occupation-specific. The remaining variables are residential

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[1] Time may be self-reported by commuters or estimated by researchers. Distance is usually estimated by researchers; in recent studies, normally by computing shortest paths over a road network.

amenity B_r, occupational wage rate W_{os}, income tax rate τ^{W}, a local price index of housing and other living costs $\mathcal{P}_r^{\mathrm{W}}$, and a mark-up χ on wage income that accounts for the worker's share of capital income.

Each household chooses a combination of occupation, residence and workplace that maximises their utility, given their idiosynratic shock $\epsilon_{ors}^{\mathrm{W}}$.

1.4   Choice probabilities

We assume a distribution of the random utility shocks $\epsilon_{rso}^{\mathrm{W}}$ such that choice probabilities (i.e. the fraction of the population choosing particular options) are given by a nested logit structure.

Conditional on choosing occupation o and city of residence u, the probability of choosing localities of residence and work, $r \in u$ and s respectively, is given by

$$\pi_{rs|uo}^{\mathrm{W}} = \frac{E_{or}\left(B_r W_{os} \exp\left(-\zeta_o (t_{rs}^{\mathrm{C}})^{1-\vartheta_o}\right)/\mathcal{P}_r^{\mathrm{W}}\right)^{\epsilon_\ell}}{\sum_{r' \in u}\sum_{s'} E_{or'}\left(B_{r'} W_{os'} \exp\left(-\zeta_o (t_{r's'}^{\mathrm{C}})^{1-\vartheta_o}\right)/\mathcal{P}_{r'}^{\mathrm{W}}\right)^{\epsilon_\ell}}, \tag{5}$$

where E_{or} reflect average preferences for particular occupation–residence combinations and ε_ℓ reflects their variance. The conditional probability of choosing city u is given by

$$\pi_{u|o}^{\mathrm{W}} = \frac{\Psi_{uo}^{\epsilon_u/\epsilon_\ell}}{\sum_{u'} \Psi_{u'o}^{\epsilon_u/\epsilon_\ell}}, \qquad \Psi_{uo} \equiv \sum_{r \in u}\sum_{s} E_{or}\left(B_r W_{os} \exp\left(-\zeta_o (t_{rs}^{\mathrm{C}})^{1-\vartheta_o}\right)/\mathcal{P}_r^{\mathrm{W}}\right)^{\epsilon_\ell} \tag{6}$$

and the probability of choosing occupation o is given by

$$\pi_o^{\mathrm{W}} = \frac{\Omega_o^{\epsilon_o/\epsilon_u}}{\sum_{o'} \Omega_{o'}^{\epsilon_o/\epsilon_u}}, \qquad \Omega_o \equiv \sum_u \Psi_{uo}^{\epsilon_u/\epsilon_\ell}. \tag{7}$$

The number of resident workers by occupation in each locality is

$$H_{or}^{\mathrm{W}} = \pi_o^{\mathrm{W}} \pi_{u|o}^{\mathrm{W}} \sum_s \pi_{rs|uo}^{\mathrm{W}} \mathcal{H}^{\mathrm{W}}, \tag{8}$$

where $\mathcal{H}^{\mathrm{W}}$ is the total working population. The number of jobs by occupation in each locality is

$$L_{os} = \pi_o^{\mathrm{W}} \sum_u \pi_{u|o}^{\mathrm{W}} \sum_{r \in u} \pi_{rs|uo}^{\mathrm{W}} \mathcal{H}^{\mathrm{W}}, \tag{9}$$

In each occupations, the distribution of jobs is directly related to that of resident workers by

$$L_{os} = W_{os}^{\epsilon_\ell} \sum_r \frac{H_{or}^{\mathrm{W}} (t_{rs}^{\mathrm{C}})^{-\zeta_o \epsilon_\ell}}{\sum_s \left(W_{os} (t_{rs}^{\mathrm{C}})^{-\zeta_o}\right)^{\epsilon_\ell}}.$$

Note that the outer summation is over all r, since workers may commute between cities.

1.5 Production

Production in each sector is undertaken by a continuum of heterogeneous firms à la Eaton and Kortum (2002). Firms operate constant returns to scale technologies to produce intermediate varieties. In each industry i and locality r, firms produce many varieties of intermediate goods using Cobb-Douglas technologies combining primary factor and intermediate inputs. The latter are local sectoral composites of intermediates sourced from all locations s, described below.

The unit cost of a firm's input bundle is given by

$$p_{ri} = \frac{1}{(1-\tau_i)} \left(\frac{R_{r\mathrm{K}}}{\alpha_{\mathrm{K}}^i}\right)^{\alpha_{\mathrm{K}}^i} \left(\frac{R_{r\mathrm{D}}^i}{\alpha_{\mathrm{D}}^i}\right)^{\alpha_{\mathrm{D}}^i} \prod_o \left(\frac{W_{or}}{\alpha_{or}^i}\right)^{\alpha_{or}^i} \prod_j \left(\frac{P_{rj}}{\alpha_j^i}\right)^{\alpha_j^i}. \tag{10}$$

The output tax rate τ_i and cost shares α_{K}^i, α_{D}^i and α_j^i are assumed identical across locations because we calibrate the model using a national input-output table. Overall labour cost $\alpha_{\mathrm{L}}^i \equiv \sum_o \alpha_{or}^i$ shares are also location-independent, but the cost shares for each occupation α_{or}^i vary by location to match employment data. $R_{r\mathrm{K}}$ is the rental price of the local composite capital good, also produced using a Cobb-Douglas technology. The capital rental cost function is

$$R_{r\mathrm{K}} = (\delta + r) \prod_j \left(\frac{P_{rj}}{\alpha_j^{\mathrm{V}}}\right)^{\alpha_j^{\mathrm{V}}}, \tag{11}$$

where δ is the depreciation rate and r is the interest rate.

Four types of productive land are distinguished: Rural, Industrial, Commercial and Residential. Land used for transportation infrastructure is not explicit in the model. Nor are areas of parklands, natural reserves and the like that do not directly support significant economic activity. In any given location, firms in each non-housing industry may use only their most preferred available land type. For this type, the type-specific cost share is equal to the overall land cost share α_{D}^i:

$$\alpha_{rd}^i = \begin{cases} \alpha_{\mathrm{D}}^i, & \text{for the highest priority } d \text{ available in } s \\ 0 & \text{otherwise} \end{cases}, \tag{12}$$

where d indexes land types. For example, accommodation firms are assigned to Commercial land if available, but otherwise may be assigned to the Residential or even the Rural land type. This system is *ad hoc.* but effectively works around the general unavailability of data on actual land uses by industries in Australia. It also addresses the problem of working with an industry- rather than function-based classification of establishments.[2] Thus, the effective land rental rate for

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[2]For example, the head office of a coal mining firm will be classified as 'Coal Mining', whereas its function is to provide services (management, financial, legal, marketing, human resources, etc.) to the firm's business units that actually extract coal from the ground. While we could devise some sort of functional classification relating to occupations, this would then be difficult to relate to industries' full input-output structures.

non-housing industries is given by

$$R_{rD}^i = r_{rd} \quad \text{if} \quad \alpha_{rd}^i > 0, \tag{13}$$

where r_{rd} is the market-clearing rental rate for a hectare of land of type d in location r.

Housing may use one or both of Residential and Commercial land types, as we have population data for each of the Mesh Blocks from which initial land areas by type are calculated. For simplicity, we model the provision of housing services as involving a Cobb-Douglas aggregation of these land types.[3] The land rental price for housing is given by

$$R_{rD}^i = \left(\frac{r_{r\text{RES}}}{\alpha_{r\text{RES}}^i}\right)^{\alpha_{r\text{RES}}^i} \left(\frac{r_{r\text{COM}}}{\alpha_{r\text{COM}}^i}\right)^{\alpha_{r\text{COM}}^i}, \quad \text{where} \quad \alpha_{r\text{RES}}^i + \alpha_{r\text{RES}}^i = \alpha_D^i. \tag{14}$$

As in Caliendo and Parro (2015), firms' productivity is explained by two terms. The first term, A_{sj}, accounts for systematic differences in total factor productivity between regions. The second term, z_{sj}, is a Fréchet-distributed variety-specific effect augmenting the productivity of all inputs. Firms are competitive, and so output (mill) prices are given by

$$\frac{p_{ri}}{z_{rj} A_{rj}^{\alpha_F}} \tag{15}$$

where, for convenience, $\alpha_F \equiv \alpha_L^i + \alpha_K^i + \alpha_D^i$.

1.6 Spillovers

Firms operate with constant returns to scale, but as in Ahlfeldt et al. (2015), total factor productivity is positively influenced by spillovers related to the effective density of all jobs in their vicinity; i.e. urbanisation rather than localisation effects. The elasticity γ_i of firms' productivity to effective job density varies between industries. Effective job density is measured by travel distance-weighted job counts. Productivity of housing service provision is assumed to be uniform.

$$A_{si} = a_{si} \left(\sum_r \exp^{-\nu_a t_{rs}^c} \sum_o L_{or} \right)^{\lambda_i} \tag{16}$$

1.7 Trade

As in Caliendo, Dvorkin, and Parro (2019), local sectoral composite goods and services are formed by combining individual varieties sourced from different locations. Here, given the much finer spatial resolution of our model, all services except housing are considered to be tradable. This includes trade by means of

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[3]More realistically, households would make discrete choices between different types of housing produced using either Residential or Commerical land. In Anas and Liu (2007), households make choices between housing types with a discrete range of building heights.

travel to consume services in person (e.g. restaurant meals). Each variety is sourced from the location that can supply it at the lowest delivered cost. As we model an open economy, these locations include an 'external zone' that represents trade with the rest of the world.[4] The production of composite sectoral goods is given by

$$Q_{rj} = \left(\int \left(x_{rsj}(z_j) \right)^{1-1/\eta_j} d\phi_j(z_j) \right)^{\eta_j/(\eta_j-1)}, \qquad (17)$$

where $\phi_j(z_j)$ is the joint distribution of variety-specific productivity levels z_{nj}.

Assuming again a Fréchet distribution and that $1 + \sigma_j > \eta_j$, the price of composite sectoral goods j for users in location r is given by

$$P_{rj} = \Gamma_{nj} \left(\sum_s \left(\frac{\kappa_j t_{rsj} p_{rsj}}{A_{sj}^{\alpha_{\mathrm{F}}}} \right)^{-\sigma_j} \right)^{-1/\sigma_j}, \qquad (18)$$

where A_{sj} is the average productivity level of industry j firms in s, t_{rsj} is the shipping cost between r and s and κ_j converts this to an iceberg cost for transport of good j and Γ_{nj} is a constant (see Caliendo, Dvorkin, and Parro (2019) for details, noting some differences in nomenclature).

For users in a given location r, expenditure shares are given by

$$\Pi_{rsj} = \frac{\left(\kappa_j t_{rsj} p_{rsj} / A_{sj}^{\alpha_{\mathrm{F}}} \right)^{-\sigma_j}}{\sum_{s'} \left(\kappa_j t_{rs'j} p_{rs'j} / A_{s'j}^{\alpha_{\mathrm{F}}} \right)^{-\sigma_j}}, \qquad (19)$$

thus the more productive are firms in location s and the lower transport costs between r and s, the more is purchased from s by firms and households in r.

2 Interactions within VLUTI

2.1 Consistent measures of residential utility

For use within VLUTI, SIRCV produces a measure of expected utility conditional on choosing each place of residence in each occupation.

$$\mathbb{E}\{u_{or}^{\mathrm{W}} | o, r\} = E_{or}^{1/\epsilon_\ell} \left(\frac{B_r}{\mathcal{P}_r^{\mathrm{W}}} \right) \left[\sum_s \left(W_{os}^{\epsilon_\ell} \exp\left(-\epsilon_\ell \, \zeta_o (t_{rs}^{\mathrm{C}})^{1-\vartheta_o} \right) \right) \right]^{1/\epsilon_\ell} \qquad (20)$$

This summarises the attractiveness of a residential location for a worker who has chosen occupation o. The wage and commuting term accounts for accessibility to jobs and rates of pay for those jobs. The second term takes into account

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[4]Multiple external zones could be defined to differentiate trade flows by domestic and/or international regions of origin/destination. Each such zone would have its own set of transport costs.

residential amenity (fixed in the model for each location) and accessibility to all manner of goods and services. The latter accounts for private travel costs for services and freight costs for goods, as well as the producer prices of goods and services.

For non-working households, expected utility is simply

$$\mathbb{E}\{u_r^{\mathrm{N}}\} = \left(\frac{B_r}{\mathcal{P}_r^{\mathrm{w}}}\right).\tag{21}$$

In the model, residential location choices are nested beneath occupational choices, while working and non-working households are treated as distinct populations. Thus, we cannot compute a model-consistent measure of expected residential utility for the resident population as a whole, or even for the resident workforce as a whole. If such a measure is required, a practical solution is to compute person-weighted averages based on the above measures.

2.2 Gross relocations

The SIRCV model is not dynamic. More particularly, it does not model dynamics in terms of migration flows. Thus, it cannot show 'who moved where' when making a projection to a future year.[5] Yet, in the conventional paradigm of transport appraisal, we must distinguish between:

1. people who would choose 'A' in both base and project

2. people who would choose 'B' in both base and project

3. people who would choose 'A' in base but 'B' in project

4. people who would choose 'B' in base but 'A' in project

In this context, benefits may be estimated in the conventional manner for people in the first two categories, whereas the second two categories correspond to what could be described as 'land use change benefits'. If we allow that conventional appraisal may allow for land use change in employment and, more generally, all destinations of home-based trips but not the place of residence, then the key choice with which we are concerned is the place of residence.

Given the limitations of a comparative static model, the only practical solution is to consider preference shocks in the present, in the base case and in the project case to be distributed independently of each other. Thus, we assume the probability of choosing a place of residence in the base or project case is unconditional on place of current residence. This assumption is rather unrealistic and is unlikely to plausible gross migration flows between current and future SA2s. Nevertheless, the approach is probably adequate for the present purposes because:

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[5]Note also that over a long period, births, deaths, immigration and emigration flows will also be significant.

- We are ultimately interested in *differences* between gross flows in the project case and gross flows in the base case.

- We need only to know the total additional/lost/existing users of a particular transport project and are not concerned with the particular origins of additional users or particular destinations of lost users.

Transitions of workers by both occupation and residence dimensions are given by

$$M_{or,ms}^{\mathrm{W}} \equiv H_{ms}^{\mathrm{W}} - H_{or}^{\mathrm{W}} = H_{or}^{\mathrm{W}} \frac{H_{ms}^{\mathrm{W}}}{\sum_{o'} \sum_{r}' H_{o'r'}^{\mathrm{W}}}, \tag{22}$$

where o, r index current (2018) occupation and residence and m, s index future occupation and residence in a base or project scenario. Note that we divide by total current workforce so that the sum of the transition matrix is equal to the total future workforce. Effectively, this allocates the population increase pro-rata with current occupations and residence locations.

To distinguish 'movers' versus 'stayers' (see above) as a result of the project, we compute this transition matrix for a project case and a base case, then subtract the latter from the former, i.e.

$$T_{or,ms}^{\mathrm{W,Proj}} \equiv M_{or,ms}^{\mathrm{W,Proj}} - M_{or,ms}^{\mathrm{W,Base}}. \tag{23}$$

Doing so eliminates those workers who make the same choices in the base and in the project case and leaves us with net flows due to the project. As a simple illustrative example, a project having strong localised benefits to resident workers and diffuse costs would result in significant inflows to the benefit area and small outflows spread evenly over the rest of the region. For use in VLUTI, we wish to distinguish transitions for blue versus white collar rather than the individual occupations. This is simply achieved by aggregating the two occupational dimensions appropriately.

2.3 Elasticities

The SIRCA model has a very large number of calibrated parameters, including the input cost shares and household expenditure shares. Here, we present just the key behavioural parameters, including our estimate of the commuting gravity coefficient and other values that we adopt/adapt from the literature.

For choices of localities, we use the value estimated for Berlin in Ahlfeldt et al. (2015) while for choices between cities, we use the upper end of the range in Baum-Snow and Han (2019) for choice between neighbourhoods in the United States. For choice between occupations, we choose a value of 1.5. This is just above the upper end of the range of estimates (1.21 ∼ 1.44) in Lee (2020) for occupational choices in the United States conditional on different levels of education.

For trade elasticities, we adopt values of 5 for goods, business services, accommodation and 'urban' services (e.g. arts, healthcare) and a value of 10 for retail and 'local' services (e.g. school education, personal services). For

Table 1: Estimated and assumed parameter values

Parameter	Value
Discrete choice parameters:	
- local choices	$\varepsilon_\ell = 6.5$
- SUA choices	$\varepsilon_u = 3.8$
- occupational choices	$\varepsilon_o = 1.5$
Estimated commuting gravity coefficient	$-\zeta_o \varepsilon_\ell = -2.425$
- implied commuting exponent	$\zeta_o = 0.373$
Frèchet parameters for trade:	
- goods, business services, accommodation:	$\sigma_j = 5$
- urban services:	$\sigma_j = 5$
- retail and local consumer services:	$\sigma_j = 10$
Effective residential density decay rate	$\nu_a = 0.76$
Effective job density decay rate	$\nu_a = 0.36$
Elasticity of amenity to density	$\varrho = 0.07$
Elasticities of productivity to density:	
- primary production:	$\lambda_i = 0.0$
- manufacturing:	$\lambda_i = 0.056$
- services:	$\lambda_i = 0.047 - 0.18$

goods, this is in line with aggregate estimates in the trade literature, e.g. 4.8 in Caliendo and Parro (2015). That and other studies provide sectoral estimates that are in some cases, significantly larger or smaller. However, it is difficult to use such estimates given substantial differences in the definitions/aggregations of sectors and wider variation in sector-specific estimates across studies. For internationally traded services, the value of 5 is also in keeping with the literature (e.g. Costinot and Rodríguez-Clare, 2014); however, these elasticities are rarely estimated because of trade data limitations. There is very little data, or indeed literature, on trade in urban and consumer services. Arguably though, most 'local' services such as schools, supermarkets, cafes tend to be very close substitutes for similar services provided in different locations. Indeed, many chain stores aim explicitly to provide near-identical services to customers in all of their outlets. For industries providing these types of services, we adopt an elasticity of 10.

Maré and Graham (2013) estimate spillover elasticities for ANZSIC Divisions, to which our industries map exactly (i.e. many-to-one). However, some Divisions contain several industries that seem very likely to have much lower or much higher elasticities than average. For these, we make some ad hoc adjustments. For example, the estimated elasticity for Education (Division) is 0.107, but we apply a lower value of 0.06 for school education and higher value of 0.12 for post-school education. These adjustments are only made for services Divisions. For the (single) Division of Manufacturing, we apply the value of 0.056 to all industries. We assume that local agglomeration effects do not operate

at all in agricultural or mining industries. A full list of spillover elasticities is available on request.

From the solution of the commuting gravity sub-model, average occupational wages rates by place of residence can be determined in every locality. Applying households' expenditure shares to their disposable incomes, the value of final demand for each product is identified in each location. Assuming a constant labour cost share for each industry, the value of each industry's output in every location is obtained from its wage bill (i.e. the sum over occupations of local wage rates times jobs). Assuming constant cost shares also for each intermediate input, the total value of intermediate demands for each product in each location is also determined. A second gravity sub-model is solved iteratively to determine the set of market-clearing prices of composite goods.

2.4 Gross State Product (GSP)

Balk (2003) reviews decompositions of index numbers (multiplicative) and indicators (additive) into the contributions of two or more multiplicative factors (e.g. price and quantity) and N commodities. We use the additive Montgomery decomposition to distinguish the contributions of factor price and factor quantity changes to the nominal value of Victorian GSP.

Following Balk's exposition, an Montgomery decomposition of value changes into additive contributions of price and quantity changes for N commodities (e.g. different primary factors in a decomposition of value added) is:

$$\mathcal{V}^1 - \mathcal{V}^0 = \mathcal{P}\left(p^1, q^1, p^0, q^0\right) + \mathcal{Q}\left(p^1, q^1, p^0, q^0\right) \tag{24}$$

where

$$\mathcal{P}\left(p^1, q^1, p^0, q^0\right) \equiv \sum_{n=1}^{N} \frac{\mathcal{L}\left(v^1, v^0\right)}{\mathcal{L}\left(p^1, p^0\right)}\left(p^1 - p^0\right),$$

$$+\mathcal{Q}\left(p^1, q^1, p^0, q^0\right) \equiv \sum_{n=1}^{N} \frac{\mathcal{L}\left(v^1, v^0\right)}{\mathcal{L}\left(q^1, q^0\right)}\left(q^1 - q^0\right),$$

and

$$v^i = p^i q^i.$$

Superscripts 0 refers to the original state and superscripts 1 to the new state. Operations are performed element-wise on vectors. The operator $\mathcal{L}\left(x, y\right)$ denotes the logarithmic mean of values x and y, i.e.

$$\mathcal{L}\left(x, y\right) \equiv \frac{(x - y)}{\ln(x/y)} \quad \text{and} \quad \mathcal{L}\left(x, x\right) \equiv 1.$$

2.4.1 Contributions associated with primary factor inputs

The above form extends directly to values formed by multiplying $M > 2$ contributing factors. Firstly, we have to account not only for price levels, but for

the power of input tax rates.[6] The tax power (one plus the tax rate) thus becomes a third factor. With the addition of the value of taxes on intermediate inputs, this gives a complete decomposition of nominal GSP. However, to correctly distinguish between real quantity and price changes, we must also account for technological changes. Technological gains increase real output and decrease real prices. We therefore add TFP levels as a fourth factor and their inverse as a fifth factor:

1. Factor prices (P)

2. Factor input quantities (Q)

3. Tax powers[7] on factor inputs (P)

4. TFP levels (Q)

5. Reciprocal of TFP levels (P).

The labels (Q) and (P) indicate which components of the decomposition correspond to real quantity and which to real price changes.

Practically, the computation involves the use of quantities, prices and technology levels from the base simulation (0) and the project/policy simulation (1). The quantities used are:

1. Jobs by SA2, 43 occupations and 100 industries (excludes housing)

2. Land use by SA2, 4 categories and 101 industries

3. Capital use by SA2 and 101 industries

The factor prices (common to all using industries) are

1. Wage rates by SA2 and 43 occupations

2. Land rental prices by SA2 and 4 categories

3. Capital rental prices by SA2

Total factor productivity by SA2 is common to all factor inputs of each industry.

2.4.2 Other contributions of indirect taxes and technological change

Completing the decomposition of GSP, we firstly account for quantity and price effects associated with indirect taxes:

1. Tax rates on intermediate inputs (P)

2. Input prices (P)

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[6] Although we represented it above as an output tax, this is equivalent to imposing the same rate of tax on all inputs.

[7] The power of a tax is equal to one plus the tax rate.

3. Input quantities (Q)

Note that tax rates rather than powers are used, because the value of the intermediate inputs themselves does not contribute to nominal GSP.

Secondly, quantity and price effects associated with intermediate input-augmenting technological changes are accounted for:

1. Tax-inclusive values of intermediate inputs (−)

2. Input cost shares (Q)

3. The reciprocal of input cost shares (P)

Note that technological changes act on the full value of the flows, but again, the value of the flows themselves is excluded, as indicated by the label (−).

Thirdly, quantity and price effects associated with transport cost changes (i.e. the technologies of trade) are accounted for:

1. Value of trade flows. (−)

2. Trade costs (freight costs and business travel costs, but not private travel costs). (Q)

3. The inverse of trade costs. (P)

As with intermediates, the value of the trade flows themselves do not contribute to nominal GSP.

2.5   Wider Economic Benefits

In principle, SIRCV should capture most direct and indirect costs and benefits of transport projects other than environmental and other externalities. The most obvious limitation of scope in the model is that the role of transport in social interactions is not accounted for. With that caveat, after adjusting for externalities (quantified separately), the expected utility of the two SIRCV household types (equations 20 and 21) could be used as a measure of welfare benefits accruing to the respective household populations.

The main practical disadvantage of this approach is that highly simplified representation of the transport system within SIRCV provides a less reliable basis for assessing direct transport benefits than does a full four-step transport model like Victorian Integrated Transport Model (VITM). Composite transport costs derived from VITM serve as inputs to SIRCV and attempt to summarise much more detailed information: generalised costs incurred by users of all transport modes travelling between all origin and destination transport zones belonging to a given SA2-level origin and destination pair. Household demographics and other details considered within VITM are also suppressed.

Thus, it is preferred to use the standard measures of direct transport benefits produced by VITM. Importantly though, endogenising land use (meaning in this context, the locations of household and jobs) within VLUTI means that the

usual measures of transport benefits also incorporate what might be described as the 'dynamic' impacts of transport projects. What is still potentially missing are indirect benefits (and costs) related to agglomeration and any possible market imperfections or distortions. These latter are commonly referred to as Wider Economic Benefits (WEBs).[8]

There are three main categories of WEBs:

1. Agglomeration economies

2. Output change in imperfectly competitive markets

3. Tax revenues from labour markets

    (a) Extensive margin of labour supply (i.e. participation rate)
    (b) Intensive margin of labour supply (i.e. days/hours per worker)
    (c) Changes in job location, industry or occupation.

WEB 1, agglomeration economies, overlaps with phenomena modelled within SIRCV. WEB 2 relates to product market imperfections that are assumed away in SIRCV. WEBs 3a and 3b relate to margins of individual labour supply that are also assumed away in SIRCV. However, WEB 3c relates to accessibility to employment and consequent choices of job locations—and occupation and industry—which are modelled in SIRCV.

Thus, our approach will be to compute WEBs 1 and 3c directly from model outputs but to compute WEBs 2, 3a and 3b using off-model equations. The latter may nevertheless draw on model database values such as gross value added by industry. Note that the WEBs thus computed will be 'dynamic', in the sense that they will be based on changed rather than fixed land uses. That is in contrast to 'static' WEBs based on fixed land uses, which are more commonly estimated.

2.6 WEB 1 computation

As described above, we equate WEB 1 with the value of the contribution of production technological changes to GSP. Computing WEB 1 in this way means that in VLUTI, productivity changes will be influenced by land use change as well as by business travel time savings, since both of these determine effective density jointly. Due to the form of the decomposition, changes in value added also play an indirect role. All of these values are mutually and consistently determined in spatial general equilibrium. By contrast, partial equilibrium approaches typically consider only the effect of business travel time savings on effective density, with land use held fixed.

Referring back to the generic additive decomposition formulate introduced in section 2.4, the real value of spillovers is equal to

$$\sum_{r=1}^{R}\sum_{j=1}^{J}\frac{\mathcal{L}\left(V_{rj}^{1},V_{rj}^{0}\right)}{\mathcal{L}\left(A_{rj}^{1},A_{rj}^{1}\right)}\left(A_{rj}^{1}-A_{rj}^{0}\right),$$

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[8] https://www.atap.gov.au/tools-techniques/wider-economic-benefits

where V_{rj}^1 and V_{rj}^0 are value added and A_{rj}^1 and A_{rj}^0 are TFP levels in the policy and base cases respectively.

2.7   WEB 2 computation

For WEB 2, it has been proposed to use an uprate factor of 0.1 on conventional business user cost savings. Thus, this WEB would not draw directly on SIRCV results, although values would reflect land use changes in VLUTI.

2.8   WEB 3 computation

WEB 3 has three sub-components relating to:

3.1 The extensive margin of labour supply (i.e. more people choosing to work)

3.2 The intensive margin of labour supply (i.e. people choosing to work longer hours)

3.3 Workers shifting from less to more productive jobs as a result of increased accessibility.

The value of these WEBs is the income/labour tax wedge on the change in real wage bills associated with each of the above.

Neither of the labour supply margins exist within SIRCV, as aggregate labour supply is fixed. Thus, we have no basis in VLUTI to estimate any associated tax benefits. However, the model does provide the basis for computation of the third sub-component.

In SIRCV, workers can alter not only their place of work, but also their occupation. Occupational shifts occur due both to general equilibrium effects and to local compositional effects. The latter refers to the fact that particular locations tend to favour particular types of production and work.

Referring back to the generic additive decomposition formulate introduced in section 2.4, the real value of changed employment occupations and locations is equal to

$$\sum_{o=1}^{O} \sum_{r=1}^{R} \frac{\mathcal{L}\left(W_{or}^1 L_{or}^1, W_{or}^0 L_{or}^o\right)}{\mathcal{L}\left(L_{or}^1, L_{or}^1\right)} \left(L_{or}^1 - L_{or}^0\right),$$

where W_{or}^1 and W_{or}^0 are wage rates and L_{or}^1 and L_{or}^0 are jobs by location and occupation in the policy and base cases respectively. Since taxes on labour/income are not explicitly modelled in SIRCV, it is necessary to apply an appropriate tax rate to the above value to compute WEB 3b.

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