



Estimating the social marginal cost of public transport in Victoria

Infrastructure Victoria

Transport Modelling Methodology and Assumptions Report

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Important note about this report

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1. Introduction

1.1 Project description and background

Jacobs and the Centre for International Economics (CIE) have been appointed by the Infrastructure Victoria (IV) to estimate the social marginal costs of public transport services in Victoria across modes (train, tram and bus) and by time of day (peak and off-peak) for metropolitan and regional services.

The social marginal cost of public transport will be determined through developing a spreadsheet-based economic model that considers rolling stock costs as well as short to long-term infrastructure costs. Transport modelling in the Victorian Integrated Transport Model (VITM) has been carried out by Jacobs, and provides inputs into the economic model produced by the CIE.

1.2 General approach

The general approach for estimating the social marginal cost of public transport in Victoria consists of:

- Developing estimates of external costs using the outputs from VITM runs using different modes and fare structures
- Developing estimates of incremental financial costs through assessing the need for more services and the feasibility of providing more services. This will provide a view of the cost of additional demand generated by changing fares
- Providing and presenting a report and spreadsheet-based economic model to IV

Figure 1-1 provides a summary of the stages of the work carried out during this study.

Jacobs are responsible for carrying out VITM transport modelling to produce outputs for use in the spreadsheet-based economic model. The modelling uses the latest version of VITM (V1.15), which was provided to Jacobs by DoT in January 2019.

The strategic transport modelling task consisted of the following stages:

- Refinement of the existing VITM fare structure to enable separate fare systems for different modes to be tested
- Testing of the refinements to ensure that the refined model is consistent with the existing DoT VITM
- Set-up of fare structure tests, as agreed with IV and the CIE
- Produce model outputs in a format agreed with the CIE for use in the economic model

Jacobs have also used a series of reference case future year models, provided by DoT to create outputs that will feed into the economic model assumptions on patronage growth rates.

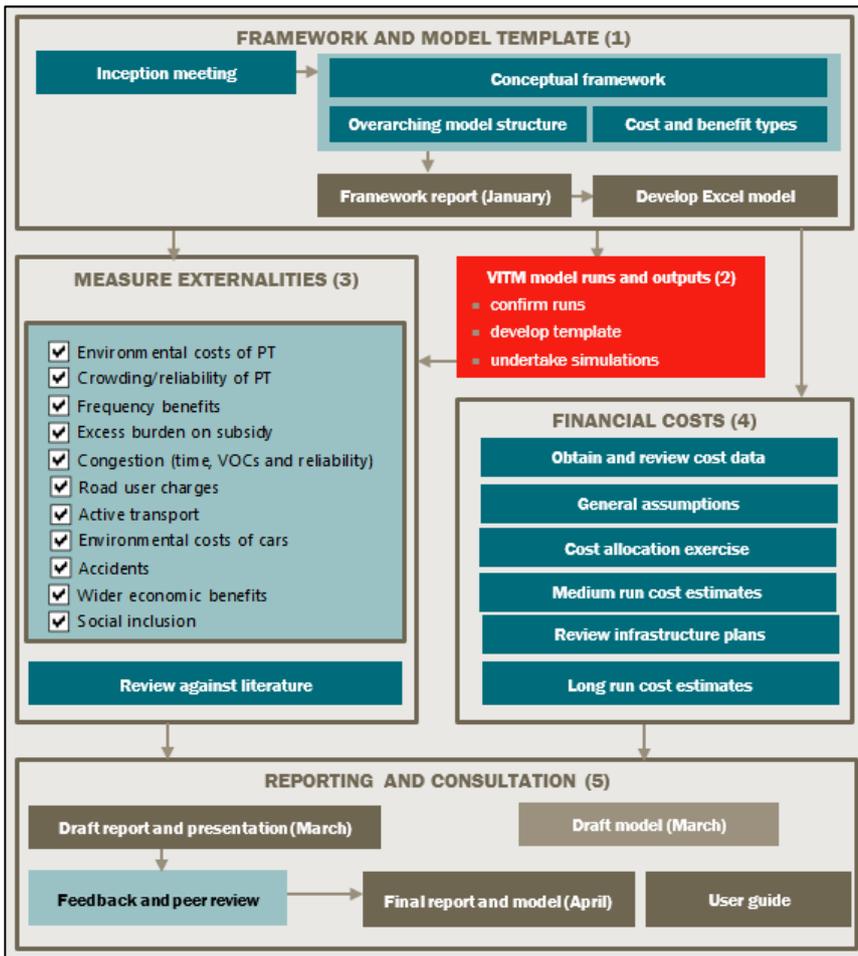


Figure 1-1: Social marginal cost of public transport general framework and economic model template (Source: CIE)

1.3 Purpose of this report

This report has been prepared by Jacobs to clearly document the VITM methodology and assumptions incorporated into setting up the models specifically for this project. It is intended to provide enough detail such that IV can be confident that the strategic transport modelling approach is sufficiently robust for the purposes of this study.

This report is structured as follows:

- **Chapter 1: Introduction** – provides a background to the work being undertaken
- **Chapter 2: Social marginal cost base model set up and review** – provides an overview of the strategic transport modelling approach and assumptions used, including refinements to VITM specific to this project
- **Chapter 3: VITM scenario testing** – outlines and defines all the runs produced during this project
- **Chapter 4: VITM model outputs provided to the CIE** – describes the package of outputs provided to the CIE by Jacobs
- **Chapter 5: Summary** – concludes the report by summarising the methodology and highlighting the key assumptions used

2. Social marginal cost base model set up and review

2.1 Background

The Victorian Integrated Transport Model (VITM), a state-wide transport demand model of Victoria, has been used for this study. VITM version 1.15 was provided by DoT in January 2019. For economic assessment, Economic Evaluation Suite module version 8.01 was provided in October 2018 and is compatible with the VITM model version 1.15.

The model provided has been modified for use in the social marginal cost study; the processes carried out and checks carried out to ensure its fitness for purpose are discussed in the sections that follow.

It is not in Jacobs' scope to make changes to any aspects of the reference case VITM models provided except when related to the public transport fare structure. As such, it is assumed that the reference case models provided by the DoT are correct and suitable for use on this project.

2.2 Modelled time periods

The VITM model incorporates four-time periods. All models are average two-hour models and represent the periods shown in Table 2.1. Collectively the models represent the entire day, with factors used to scale up the time periods to daily values if required.

Table 2.1: VITM time period definitions

Time period	Duration	Model scaling factor
AM	07:00-09:00	1
IP	09:00-15:00	3
PM	15:00-18:00	1.5
OP	18:00-07:00	3 (light vehicles) 6.5 (heavy vehicles)

2.3 Study area definition and zone aggregation

The state-wide VITM model has 6,981 zones with approximately 3,000 zones within the metropolitan area. The model allows for the implementation of a zone aggregation process to affect run time efficiencies and reduce 'model noise'. This process aggregates zones in areas of the model outside of the defined core study area, where less zonal detail is required.

Jacobs used the default Metropolitan Melbourne VITM travel zone aggregation, and as such regional areas were included but with a reduced level of detail. This level of aggregation is considered optimal as the zonal detail is still sufficient for assessing access to public transport at a high level of accuracy across Victoria.

This aggregation approach ensures that:

- Zoning detail in and around regional urban centres (such as Geelong, Bendigo, Ballarat) is retained to a good level of detail
- Important regional public transport such as V/Line services are included, and outputs are available for analysis
- Focusing on the metropolitan area ensures robust model results while reducing model run time to an acceptable timeframe (approximately 120 hours)

2.4 Spatial areas for analysis

The social marginal cost analysis will consider four spatial areas defined as:

- Melbourne Central Business District (CBD)
- Metropolitan Melbourne
- Peri-urban
- Regional Victoria

Modelled runs include fare changes that are both spatial and limited to one or more of the above spatial areas. This enables the social marginal cost analysis to investigate potential differences in the responsiveness of users to fare changes depending upon the origin and destination of their trip.

Section 3.5 describes the extent of each of the spatial areas and details of how the social marginal cost VITM aggregates these areas from the existing fare zone structure in the reference case VITM provided by DoT.

2.5 Modelled years

Jacobs have used 2026 as the only analysis year, as agreed with IV. The social marginal cost 2026 VITM model was used to test and compare the scenarios that were modelled.

Using 2026 as the analysis year ensures that:

- The public transport situation in this year represents a landscape post-completion of Melbourne Metro, which represents a significant change to public transport operation
- Other significant completed projects are included in the analysis; such as West Gate Tunnel and the Cranbourne-Pakenham Line Upgrade
- Despite 2026 being a future year, it is only seven years from the present, so assumptions over land use and the completion of other minor transport schemes are assumed to be robust

2.6 Refinement of the public transport fare structure with VITM

To perform the option tests required during this project (described in Section 3.1) it was necessary to make refinements to the VITM's fare system. The DoT VITM represents Melbourne's current fare system with a single matrix of fare zones, which defines the monetary cost of travelling between each fare zone pair in 2016\$. This fare matrix is used within a 'HILOW' fare structure.

To enable testing of fare levels by mode, the single fare matrix within VITM was replicated to create three separate matrices, one for each principal mode; train, tram and bus. The fare value for the base case was identical for each mode to retain accurate representation of the current fare system in Melbourne.

Several other elements of the model structure were refined to accommodate the fare matrix disaggregation; these are described as follows:

- Define the fare matrix parameters within the fare system file (.FAR)
- Update the public transport lines files to ensure that all services are aligned to the correct mode, with the correct fare system assigned (.LIN)
- Add additional fare matrices as inputs into the appropriate PT assignment procedures within the model itself, so that they are used in the assignment calculations. This was required in the following locations of the model:
 - 'PTASSIGN_INIT'
 - 'PT_AM'
 - 'PT_IP'
 - 'PT_PM'
 - 'PT_OP'

3. VITM scenario testing

3.1 Scenarios developed and run in VITM

Table 3-1 summarises the VITM scenarios that were developed and run for the social marginal cost project.

Table 3-1: Table of scenarios

Run Number	Name	Description
-	Base Case	2026 VITM Reference Case with fare structure adjustments
Core model runs		
1	All Vic – Train	-30% train fare changes across all of Victoria
2	Metro – Train	-30% train fare changes across only trips both starting and ending in metropolitan Melbourne
3	Peri-Urban – Train	-30% train fare changes across trips starting or ending in peri-urban areas, excluding trips between peri-urban and regional areas
4	Regional – Train	-30% train fare changes across trips starting or ending in regional areas
5	Non-CBD – Train	-30% train fare changes across all of Victoria excluding trips starting or ending in the CBD
6	Metro – Tram	-30% tram fare changes across only trips both starting and ending in metropolitan Melbourne
7	Non-CBD – Tram	-30% tram fare changes across all of Victoria excluding trips starting or ending in the CBD
8	All Vic – Bus	-30% bus fare changes across all of Victoria
9	Metro – Bus	-30% bus fare changes across only trips both starting and ending in metropolitan Melbourne
10	Regional & Peri-Urban – Bus	-30% bus fare changes across trips starting or ending in peri-urban or regional areas
11	Non-CBD – Bus	-30% bus fare changes across all of Victoria excluding trips starting or ending in the CBD
Additional model runs		
12	Metro – Express Bus	-30% fare changes across only trips both starting and ending in metropolitan Melbourne for express bus services only
13	Free Tram Zone (CBD) - Tram	Fare for travel within CBD by tram set to match what fares would be without free tram zone
Distance based model runs		
14	Melbourne distance-based fare system	Created a distance band-based fare system for Melbourne, with similar \$ value fares to the current system
15	Metro bus – all distance fares	Reduced metropolitan bus fares for all trips by 30% within the distance-based fare system
16	Metro tram – all distance fares	Reduced metropolitan tram fares for all trips by 30% within the distance-based fare system

Run Number	Name	Description
17	Metro train – all distance fares	Reduced metropolitan train fares for all trips by 30% within the distance-based fare system
18	Metro bus – short distance fares	Reduced fares for only metropolitan bus trips less than 4 km by 30% within the distance-based fare system
19	Metro tram – short distance fares	Reduced fares for only metropolitan tram trips less than 2 km by 30% within the distance-based fare system
20	Metro train – short distance fares	Reduced fares for only metropolitan train trips less than 10 km by 30% within the distance-based fare system

3.2 General VITM fare system assumptions

When testing the agreed scenarios in the social marginal cost model the following assumptions were made:

- VITM fares are in 2016 prices
- -30% implies that there is a 30% overall reduction in the fare prices
- The existing assumptions within the reference case for the SkyBus service will remain constant across all the model runs for this project. The impacts of SkyBus will not be considered within this project
- The VITM fare zone system matrices represent an average fare across all users for a given trip from one zone to another. VITM does not separate out and consider individual fare groups or complexities such as concessionary fares, senior fares, free-travel under 5 and myki pass options.
- The fare matrix system used in VITM is known as 'HILOW'. The processes treat direct travel differently from travel between travel zones with an interchange between zone systems.

3.3 Run specific fare system assumptions

Some changes over and above changes to the fare matrices were required for a couple runs. These additional adjustments are documented below.

3.3.1 Run 5: Non-CBD - Train

CBD railway stations on both the City Loop and Melbourne Metro Tunnel lines are defined as being within fare Zone 2 in the DoT VITM model. This is to prevent free travel by train in the CBD within the model. The stations considered as 'CBD stations' for this run are as follows:

- Flinders Street (City Loop)
- Southern Cross (City Loop)
- Flagstaff (City Loop)
- Melbourne Central (City Loop)
- Parliament (City Loop)
- State Library (Melbourne Metro Tunnel)
- Town Hall (Melbourne Metro Tunnel)

This run uses a modified 'Initial_Loaded_HwyNetwork_IP' network file, and within this file the CBD stations have been adjusted to be within fare Zone 1 by altering the 'FZONE' node parameter. Additionally, the run-specific train fare matrix contains a fare for travel solely within Zone 1 to ensure that this fare element is consistent with the 'Base Case' run. These modifications enabled the 'Non-CBD – Train' run to be carried out and produce meaningful results.

3.3.2 Run 12: Metro - Express Bus

This run isolates express buses across metropolitan Melbourne and tests a reduction in fares of 30% for these buses. Express buses are buses, which are categorised as 'Mode 5' in VITM; they are defined as 'SmartBus or DART Services' in the VITM PTS file. DART refers to the Doncaster Area Rapid Transit project.

An additional separate fare matrix was created for 'Express buses' and steps were followed to integrate this fourth matrix into the VITM model structure as described in Section 2.6. The fare reduction was represented within this matrix.

This refinement was carried out in a separate CUBE model structure, specifically created for this run.

3.4 Distance based runs fare system assumptions

The project team specified that analysis of distance-based fare runs would be a useful input into the economic spreadsheet model produced by CIE. Consequently, Jacobs agreed to model seven distance-based model runs as part of this project; these are defined as runs 14-20 in Table 3-1.

To consider distance-based runs, Jacobs first needed to move the fare structure of VITM to a distance-based fare that is approximately the same as the existing fare system. The model would then need to be flexible enough to adjust fares for particular distance bands. This approach was required because it is not possible to change only short or only long fares within the zonal structure of VITM.

The seven runs are defined as below:

- **Run 14:** A distance-based fare system which approximates the current fare structure in VITM. This is equivalent to the base case which is part of the core VITM modelling runs, except with a different fare structure (note that the precise modelled outputs between the base case runs do not match perfectly because of the approximated nature of the distance-based fare structure).
- **Runs 15-17:** Runs including a reduced fare for all trips for each mode (train, tram and bus) respectively. These runs estimate the same impacts as runs 1, 6 and 8 in Table 3-1 for this alternative fare structure.
- **Runs 18-20:** Runs that include a reduced fare for 'short trips' each mode respectively. Short trips are defined as less than 2km for tram trips, 4km for bus trips and 10km for train trips.

This methodology for distance-based model runs allowed the CIE to compare:

- Runs 18-20 to Run 14 (the base case) to determine the impact of changing fares for short trips (i.e. elasticities, marginal cost of congestion, capacity issues etc.).
- Runs 15-17 to Run 14 (the base case) to determine the impact of changing fares for all trips (i.e. elasticities, marginal cost of congestion, capacity issues etc.).
- An assessment can then be made of the impacts of lower prices for short trips, to the impact of lower prices for all trips for the purpose of analysis.

Table 3-2 below shows the distance bands used within Run 14 to approximate the current fare structure in VITM. Checks comprised of comparison of the model outputs from the two base-cases (default and distance-based) demonstrated that the two model runs produced similar network metrics for public transport across Melbourne and Victoria.

Table 3-2: Distance-based fare bands (Run 14)

Trip length band (km)	Coded fare (\$)
0-50	3.32
50-60	4.13
60-70	5.64
70-90	7.14
90-110	8.64
110-120	10.14
120-130	11.65
130-140	13.15
140-150	14.65
150-160	16.15
160-170	17.66
170-180	19.16
180-190	20.66
190-400	22.16
400+	23.67

3.5 Defining the spatial areas

The fare system in VITM is presented in an origin-destination matrix format. To develop each of the 20 scenarios and the base case outlined in Table 3-1, Jacobs had to aggregate the fare system zones (x18) according to the four spatial areas defined for this project (i.e. CBD, Metro, Peri-urban and Regional). By aggregating the existing fare system zones, fare changes can be made easily by a given area.

Figure 3-1 shows the spatial distribution of the 18 fare system zones that are currently assigned to the VITM nodes. Figure 3-2 shows Jacobs' aggregation of the 18 fare system zones to reflect the CBD, Metro, Peri-urban and Regional areas.

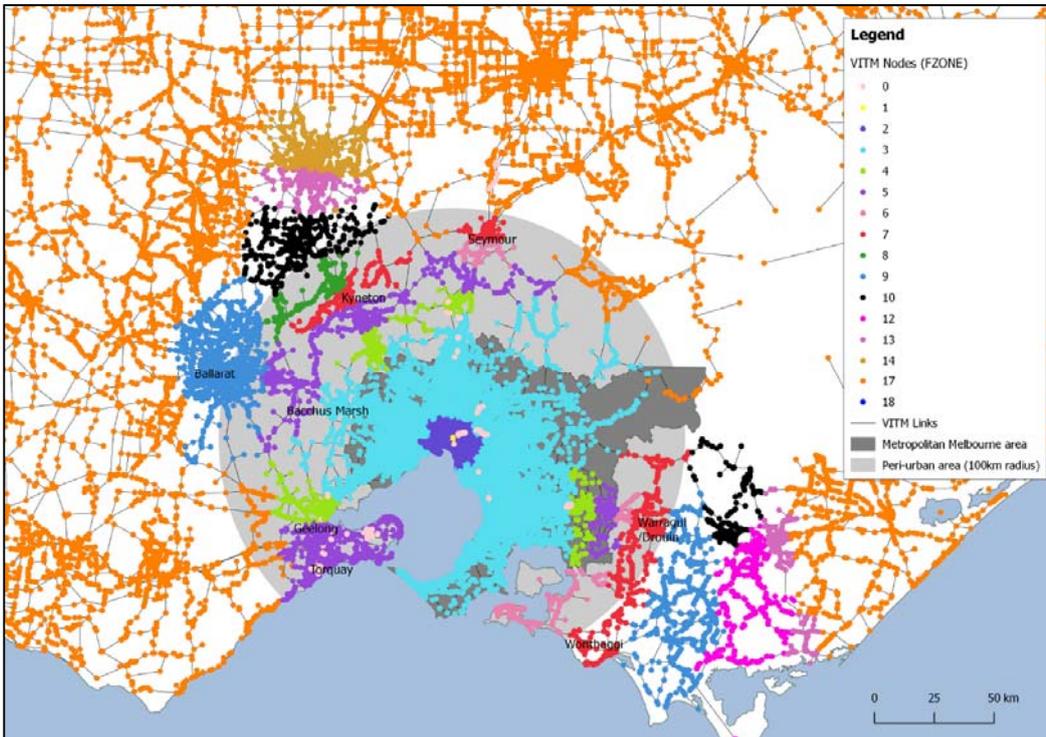


Figure 3-1: Existing spatial distribution of the x18 VITM fare zones

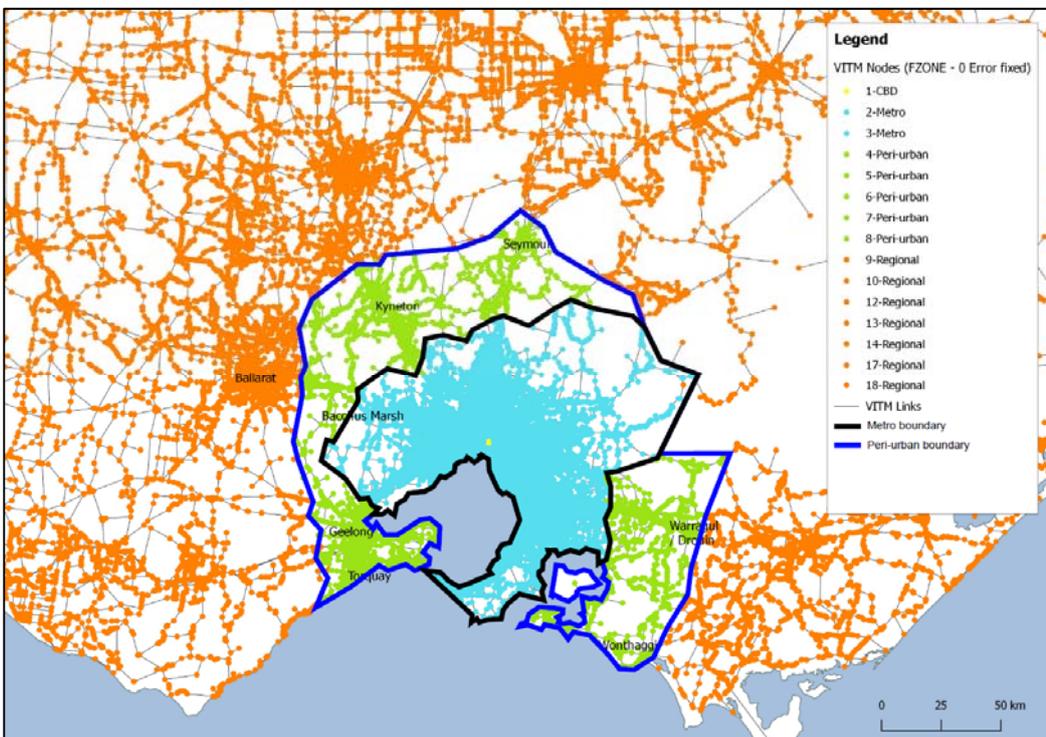


Figure 3-2: Aggregation of the x18 VITM fare zones to reflect the four spatial areas defined

4. VITM model outputs provided to the CIE

4.1 Time periods

Where possible results were provided for the following time periods:

- AM period 0700-0900
- Inter-peak period 0900-1500
- PM period 1500-1800
- Off-peak period 1800-0700

4.2 Economic Evaluation Module outputs

The VITM model has an associated economic module, which produces standardised metrics for use in economic analysis; this is in the form of a spreadsheet. The latest economic module (v8.01) used to produce outputs for the CIE team. Table 4.1 shows the final economic module outputs delivered to the CIE.

The Economic Evacuation Module outputs are the primary source of information for use in the CIE’s economic model. Metrics needed that are not provided by these outputs were provided separately and are described in the next section, Section 4.3.

Table 4.1: Final economic module outputs

Name of economic scenario	Economic module version	Description	Base-case run used	Fare scenario run used
Core model runs				
Train_All_Vic	Ec.M8.01	Base-case vs Train_All_Vic	Y2026	Train_All_Vic
Train_Metro	Ec.M8.01	Base-case vs Train_Metro	Y2026	Train_Metro
Train_PeriUrban	Ec.M8.01	Base-case vs Train_PeriUrban	Y2026	Train_PeriUrban
Train_Regional	Ec.M8.01	Base-case vs Train_Regional	Y2026	Train_Regional
Train_Non_CBD	Ec.M8.01	Base-case vs Train_Non_CBD	Y2026	Train_Non_CBD
Tram_Metro	Ec.M8.01	Base-case vs Tram_Metro	Y2026	Tram_Metro
Tram_Non_CBD	Ec.M8.01	Base-case vs Tram_Non_CBD	Y2026	Tram_Non_CBD
Bus_All_Vic	Ec.M8.01	Base-case vs Bus_All_Vic	Y2026	Bus_All_Vic
Bus_Metro	Ec.M8.01	Base-case vs Bus_Metro	Y2026	Bus_Metro
Bus_PeriUrban_Regional	Ec.M8.01	Base-case vs Bus_PeriUrban_Regional	Y2026	Bus_PeriUrban_Regional
Bus_Non_CBD	Ec.M8.01	Base-case vs Bus_Non_CBD	Y2026	Bus_Non_CBD
Additional model runs				
Express_Bus_Metro	Ec.M8.01	Base-case vs Express_Bus_Metro	Y2026	Express_Bus_Metro
Tram_CBD	Ec.M8.01	Base-case vs Tram_CBD	Y2026	Tram_CBD

Name of economic scenario	Economic module version	Description	Base-case run used	Fare scenario run used
Distance based model runs				
Bus_Metro_AllDistances	Ec.M8.01	Distance_Based_Fares vs Bus_Metro_AllDistances	Y2026	Bus_Metro_AllDistances
Tram_Metro_AllDistances	Ec.M8.01	Distance_Based_Fares vs Tram_Metro_AllDistances	Y2026	Tram_Metro_AllDistances
Train_Metro_AllDistances	Ec.M8.01	Distance_Based_Fares vs Train_Metro_AllDistances	Y2026	Train_Metro_AllDistances
Bus_Metro_ShortDistance	Ec.M8.01	Distance_Based_Fares vs Bus_Metro_ShortDistance	Y2026	Bus_Metro_ShortDistance
Tram_Metro_ShortDistance	Ec.M8.01	Distance_Based_Fares vs Tram_Metro_ShortDistance	Y2026	Tram_Metro_ShortDistance
Train_Metro_ShortDistance	Ec.M8.01	Distance_Based_Fares vs Train_Metro_ShortDistance	Y2026	Train_Metro_ShortDistance

4.3 Additional public transport metric outputs

A bespoke spreadsheet was developed by Jacobs to produce additional public transport metrics that were not available in the appropriate level of detail from the economic module outputs. The spreadsheet was populated and provided to the CIE for the base-case and each of 20 scenario model runs.

The spreadsheet utilises data from the 'DetailedPTRreporting' spreadsheet, which was developed and provided by DoT. The latest version of this is used, which is dated 10th January 2019.

The 'Additional_Metrics' spreadsheet contains the following metrics, as requested by the CIE:

- Vehicle Kilometres Travelled (VKT) by public transport line for Bus, Tram and Train
- Passenger Kilometres Travelled (PKT) by public transport line for Bus, Tram and Train
- Vehicle Hours Travelled (VHT) by bus service types
- Passenger Hours Travelled (PHT) by bus service types
- Initial Wait Time by public transport line for Bus, Tram and Train
- Seated Capacity by public transport line for Bus, Tram and Train
- Crush Capacity by public transport line for Bus, Tram and Train
- Adjusted (PTV load) Capacity by public transport line for Bus, Tram and Train
- Maximum Passenger Load by public transport line for Bus, Tram and Train
- Maximum Volume-Capacity Ratio (based on Crush Capacity) by public transport line for Bus, Tram and Train
- Maximum Volume-Capacity Ratio (based on Adjusted Capacity) by public transport line for Bus, Tram and Train

4.4 Future public transport patronage outputs

A bespoke spreadsheet was also developed by Jacobs to produce a future public transport boardings metric that was not available in the appropriate level of detail from the economic module outputs. Boardings was used as the metric that represents patronage. The spreadsheet was populated and provided to the CIE, it contains future patronage information for 2026, 2036 and 2051.

The 2026, 2036 and 2051 data was extracted from models provided by DoT in March 2019. These models are reference case VITM models that are consistent with each other and with the model version supplied for use on the marginal social cost project.

The bespoke spreadsheet utilises data from the 'DetailedPTRreporting' spreadsheet, which was developed and provided by DoT. The latest version of this is used, which is dated 10th January 2019.

These outputs were input into the CIE's economic spreadsheet-based model to produce growth factors by public transport line to inform longer term analysis of the marginal social cost of public transport.

The 'Future_Patronage_2026_2036_2051' spreadsheet contains the following metrics, as requested by the CIE:

- 2026 Boardings by public transport line for Bus, Tram and Train
- 2036 Boardings by public transport line for Bus, Tram and Train
- 2051 Boardings by public transport line for Bus, Tram and Train

It should be noted that the public transport line definitions can change between years with development and growth of Melbourne's train, tram and bus networks. The changes between years have been documented in the 'Future_Patronage_2026_2036_2051' spreadsheet and can be found in the sheet named 'Notes'.

5. Summary

Jacobs and the Centre for International Economics (CIE) were appointed by IV to estimate the social marginal costs of public transport services in Victoria across modes (train, tram and bus) and by time of day (peak and off-peak) for metropolitan and regional services.

Jacobs carried out transport modelling in VITM to test the alternative public transport fare levels in Victoria to inform parameters in the CIE's spreadsheet model for estimating social marginal costs. This involved testing fare levels for each mode (train, bus, tram) separately, which is not supported in the existing VITM set-up. Refinements to the VITM model structure were carried out to separate public transport modes to enable the fare testing required.

A single modelled year of 2026 was used as the only analysis year; using this year ensures that:

- The public transport situation in this year represents a landscape that is post completion of Melbourne Metro, which represents a significant change to public transport operation
- Other significant completed projects are included in the analysis situation such as West Gate Tunnel, Cranbourne-Pakenham Line Upgrade
- Despite 2026 being a future year, it is only 7 years away, so assumptions over land use and the completion of other minor transport schemes are assumed to be robust

The social marginal cost analysis considers four spatial areas defined as CBD, Metro, Peri-urban and Regional. Modelled runs include fare changes that are spatial and are limited to one or more of the above spatial areas. This enables the social marginal cost analysis to investigate potential differences in the responsiveness of users to fare changes depending upon the origin and destination of their trip.

In total, 21 runs have been produced by Jacobs for this project and they are defined in Table 3-1. Outputs were provided from each of these models to the CIE for use as inputs into their economic spreadsheet model. Two outputs spreadsheets were provided as follows:

- Economic Evacuation Module spreadsheet
- Additional Public Transport Metrics spreadsheet

In addition, Jacobs provided a future public transport boardings spreadsheet to the CIE for use in calculating growth factors for the years beyond 2026. This was created using outputs from models provided by DoT for 2026, 2036 and 2051.

Finally, a significant error related to public transport fare modelling was discovered within VITM, which was corrected to ensure the accuracy of results as described in Section 2.7.1. Several logic issues associated with the VITM Economic Evaluation Module were also investigated. However, resolutions to some of these issues were not found; Section 2.7.3 describes these issues and the actions taken in mitigation.