INFRASTRUCTURE VICTORIA

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PUBLIC

BETTER BUSES FOR MELBOURNE STRATEGIC MODELLING

VALIDATION REPORT

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Better Buses for Melbourne Strategic Modelling Validation Report

Infrastructure Victoria

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REV	DATE	DETAILS
A	6 April 2023	Draft Calibration and Validation Report
B	10 May 2023	Final Calibration and Validation Report
C	8 September 2023	Proposed SteerCo changes

	NAME	DATE	SIGNATURE
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Reviewed by:	Alex Gu	10 May 2023	

Approved by:	Alex Gu	10 May 2023	

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ABBREVIATIONS

ATAP	Australian Transport Assessment and Planning
BRT	Bus Rapid Transit
DTP	Department of Transport and Planning, formerly Department of Transport. DTP is Government Agency in the State of Victoria, Australia.
LGA	Local Government Area
MSD	Melbourne Statistical Division
VITM	Victorian Integrated Transport Model

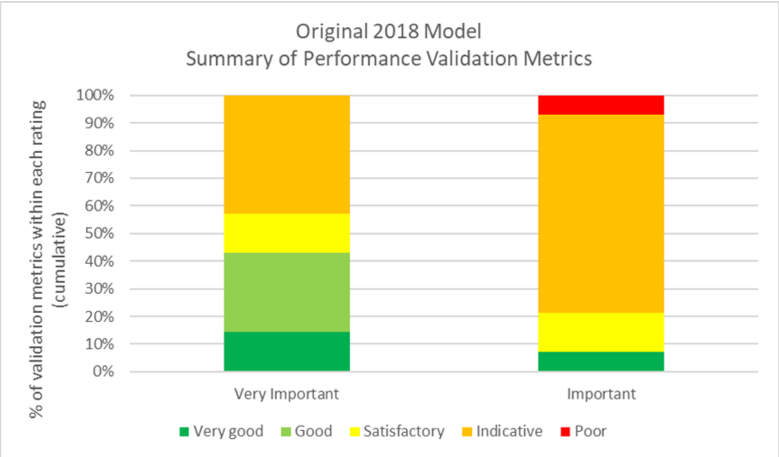
EXECUTIVE SUMMARY

Infrastructure Victoria is undertaking independent and interdisciplinary research into opportunities to reform the existing bus network. Infrastructure Victoria's aim is to help inform the Victorian Government on how to improve Melbourne's bus services. Its broader research project will explore how bus reform can improve travel for people, how it can integrate with land use to support Melbourne's growth, as well as address social and environmental challenges. The Victorian Government has also recognised the potential for a better bus system in Victoria. Victoria's Bus Plan signals a renewed interest in substantial bus reform for the first time in a decade.

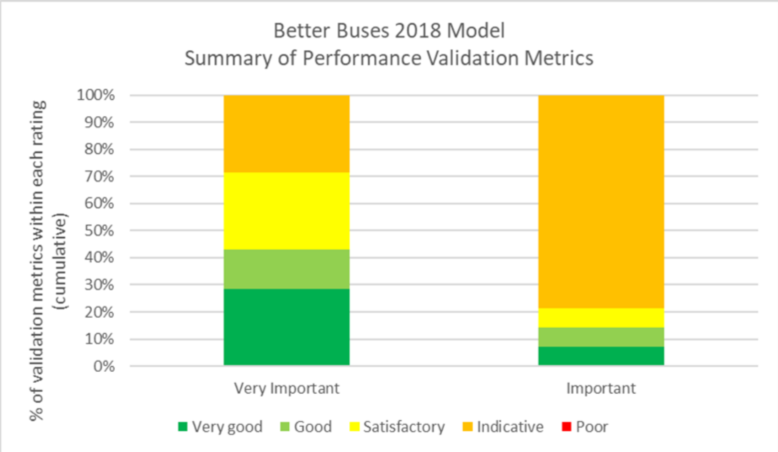
Infrastructure Victoria will publish a final report, including recommendations to the Victorian Government informed by stakeholder engagement, transport modelling, and other evidence-based inputs. WSP is assisting Infrastructure Victoria in this research program with strategic modelling services using the Victorian Integrated Transport Model (VITM).

The first stage of the strategic modelling process is to improve the validation performance of VITM, focussing on bus demands. Validation activities included, **static validation** comparing modelled demands to observed data from 2018, and **response validation** checking the model's response to changes in services and parameters expected to form part of bus reforms to be tested.

In recognition that the target and nature of validation needs to be consistent with project objectives, WSP and Infrastructure Victoria have developed a validation framework specific for the Better Buses project. The framework includes a priority rating, importance rating and target for static validation metrics, as well as a rating ranging from 'poor' to 'very good' depending on the percentage of validation elements meeting the targets. The validation of VITM against a range of metrics was materially improved over the course of this phase of work. This is demonstrated in the graphics below, summarising how the model validates according to the project validation framework before and after model improvements respectively.



Summary of priority validation metrics, initial 2018 base model



Summary of priority validation metrics, Better Buses 2018 base model

Highlights of the validation include:

— The Better Buses 2018 model achieves a ‘very good’ rating for just over 30 per cent of ‘very important’ validation metrics and dimensions, compared with 10 per cent in the original base model.

— Considerable improvements to the geographic representation of bus demands, with a significantly higher percentage of modelled LGA bus boardings falling within 25 per cent of observed by time period, or 15 per cent across the day.

— A strong improvement in the representation of bus demand by route, improving the validation rating from ‘indicative’ to ‘good’ with 70 per cent of validation elements hitting the target criteria.

— Better representation of activity centre and corridor bus boardings, with an increase in the percentage of areas with boardings within 25 per cent of observed compared with the original 2018 base year.

Based on these improvements, the Better Buses 2018 model is better suited to support the needs and objectives of the Better Buses project and we recommend using this version of VITM to test the impacts of bus reform.

Despite the range of activities undertaken to improve VITM with the Better Buses project objectives in mind, there are several residual limitations. These include:

— While we have improved bus boardings in the Melbourne CBD materially from the starting point in the model, they are still much higher than indicated by the observed data.

— Testing of the model’s sensitivity to changes in bus in-vehicle time resulted in unexpectedly high additional bus boardings, which suggests an overestimation of the effects of congestion on travel speeds.

— Passenger load data describes how many passengers are using a specific part of the network during a defined period. Observed data of this nature is limited, meaning that corridor and activity centre validation rely on bus boardings data, which is not intended for such detailed applications. These validation results are indicative only. By extension, we do not have a strong picture of how reasonably VITM is representing public transport transfers due to low confidence levels in the observed data.

A summary of the how VITM validates against key metrics, the level of validation achieved for each of these metrics and the recommended approach to forecasting is provided in the table overleaf.

MODELLED OUTPUTS	VALIDATION METRIC	VALIDATION RATING	RECOMMENDED FORECASTING APPROACH
Model-wide boardings	Model-wide bus boardings	Very good	Forecasts from the model scenarios can generally be used without adjustments.
	Bus boardings by LGA	Good	

MODELLED OUTPUTS	VALIDATION METRIC	VALIDATION RATING	RECOMMENDED FORECASTING APPROACH
Bus boardings by LGA	Bus boardings by LGA (excluding Melbourne LGA)	Very good	— Forecasts from model scenarios can generally be used without adjustments. — Where the focus of a scenario is on absolute bus boardings within a small spatial area and high levels of variation between modelled vs. observed (particularly within the Melbourne, Yarra, Port Phillip and Yarra Ranges LGAs), we recommend an approach of using observed data and then applying a growth factor as forecast by the model.
	Total bus boardings by LGA (within 25% by time period, 15% daily)	AM and IP: Satisfactory	
		PM: Good	
		OP and daily: Indicative	
Bus boardings by route	Bus boardings by route (scatterplot)	Good	— Forecasts from model scenarios can generally be used without adjustments, particularly along busy bus routes and where multiple bus routes are grouped together for the purpose of analysis — Caution should be exercised in using forecasts for routes with low passenger numbers. Where absolutely necessary, we recommend adjusting base year observed data using growth forecast by the model for these routes.
	Bus boardings by route (GEH)	Very good	
	Bus boardings by route, within 25% of observed	Indicative	
Boardings by activity centre and corridor[1]	Bus boardings by activity centre and corridor within 25%	Indicative	There is uncertainty in the appropriateness of observed data at the level of geographic detail required for these metrics. Caution should be exercised when using forecasts from model scenario. Where the focus of a scenario is on absolute bus boardings by corridor or activity centre, we recommend developing a forecast 'range' developed using both the absolute modelled demand and base year observed demand adjusted using growth forecast by the model.
	Bus boardings by activity centre and corridor (scatterplot)	Indicative	
	Bus boardings by activity centre and corridor (scatterplot, excluding Melbourne LGA)	Satisfactory	
Bus transfers	Transfers	Poor	While the is model almost certainly over-estimating transfers at City Loop stations, the quality of the observed data is unclear. VITM is still useful to understand general transfer trends because of bus reform, for example overall growth in transfers and key transfer hubs on the network. However, we recommend caution in using absolute transfer numbers, particularly at specific locations on the network.
Bus travel times	Bus travel times	Poor	Bus travel times are slow compared to observed by around 20 per cent. While this does not appear to substantially impact the model's ability to reasonably reflect observed bus travel, we may consider making out

1 See Figure 5-4 on page 24 for the definition of these areas

MODELLED OUTPUTS	VALIDATION METRIC	VALIDATION RATING	RECOMMENDED FORECASTING APPROACH
			of model adjustments to develop a 'range' of travel times for routes / corridors where required. If modelled travel times for buses were closer to observed, bus boardings maybe higher overall.
Global travel demand	Public transport boardings / mode share	Very good	Forecasts from the model scenarios can be used without adjustments.
	Traffic demand	Very good	

Through the validation process we have developed a strong understanding of the availability, strengths and limitations of observed bus data, which will allow us to assist in forming recommendations for additional types of useful data to collect in future. Recommendations include:

- More robust bus boarding and alighting data that reliably captures where people enter and exit the network at a stop and route level. For example, through GPS-enabled passenger counters on-board buses.
- More reliable transfer data to understand how and where passengers transfer between services on the network.

LIMITATIONS OF THE MODELLING IN THIS REPORT

The modelling contained in this report is suitable for supporting planning and policy decisions and has been developed to assist Infrastructure Victoria in their research and recommendations on how to improve Melbourne's bus services.

As future events are inherently uncertain, even the most comprehensive and sophisticated forecasting tool will produce forecasts that are different from the eventual outcomes. VITM is useful to test the effects of different policies and infrastructure investments, adding to the evidence-base used by decision-makers, however in interpreting the results of the modelling presented in this report, it is helpful to keep key limitations in mind:

- **Strategic models like the VITM use input assumptions to forecast future travel:** VITM combines demographic, land use and transport network data with behavioural parameters derived from historical travel surveys to estimate how travellers with different characteristics will behave under different conditions. It is only as accurate as the input data used to generate forecasts (future year population and employment, expected network configurations and travel costs etc.)
- **Strategic models like the VITM predict future travel largely based past trends:** By using behavioural parameters derived from historical travel surveys to estimate how travellers with different characteristics will behave under different conditions, strategic models do not always capture the impacts of broader social changes that can drive changing trends in behaviour.

1 INTRODUCTION

1.1 PURPOSE

Infrastructure Victoria is undertaking independent and interdisciplinary research into opportunities to reform the existing bus network. Infrastructure Victoria's aim is to help inform the Victorian Government on how to improve Melbourne's bus services. Its broader research project will explore how bus reform can improve travel for people, how it can integrate with land use to support Melbourne's growth, as well as address social and environmental challenges. The Victorian Government has also recognised the potential for a better bus system in Victoria. Victoria's Bus Plan signals a renewed interest in substantial bus reform for the first time in a decade.

Infrastructure Victoria will publish a final report, including recommendations to the Victorian Government informed by stakeholder engagement, transport modelling, and other evidence-based inputs. WSP is assisting Infrastructure Victoria in this research program with strategic modelling services using the Victorian Integrated Transport Model (VITM).

As VITM will be used to evaluate and provide commentary on the performance of various bus reform programs, we need to have confidence in the model's representation of observed travel behaviour, particularly on the bus network, as well as confidence in how modelled demand responds to bus reform. This report summarises the process undertaken to validate VITM and the improved validation performance. It covers validation from two perspectives:

— **static validation** comparing modelled demands to observed data from 2018

— **response validation** checking the model's response to changes in services and parameters we expect to form part of bus reforms to be tested

1.2 STRUCTURE OF THIS REPORT

This report is structured as follows:

— Chapter 1 provides an overview of the role of strategic modelling in the Better Buses for Melbourne project

— Chapter 2 presents a summary of the model validation approach, including priorities, metrics and targets set in collaboration with Infrastructure Victoria and the Department of Transport and Planning (DTP)

— Chapter 3 summarises key limitations of VITM of relevance to the Better Buses project

— Chapter 4 outline the changes made to the baseline version of VITM to improve the model's representation of bus travel

— outlines the version of VITM used for this project, the baseline validation at the start of the project and details the key changes made to improve the level of validation

— Chapter 5 summarises the improved validation with reference to the framework described in Chapter 2

— Chapter 6 summarises conclusions and implications of the model's validation for the Better Buses for Melbourne project.

The following full validation spreadsheets have been provided as attachments to this report:

— ValidationReporting_VITM21_v220815_BLANK_Y2018_RUN18_(CalibratedBaseYear)

— DetailedPTReporting_VITM21_v210430_RUN18_(Calibrated2018)

— Better Buses – Pilot Dashboard_RUN18

2 MODEL VALIDATION APPROACH

VITM is a strategic travel model, which means it is useful for a range of high-level applications, including scenario modelling (which is the core task of this project). Australian Transport Assessment and Planning (ATAP) transport modelling guidance provides a hierarchy of transport modelling applications (Figure 2-1). A key objective of strategic modelling for Better Buses is to understand the benefits and impacts of alternative scenarios and strategies at a metropolitan scale, meaning that Better Buses modelling sits at the middle of ATAP's hierarchy.

In recognition that the target and nature of validation needs to be consistent with project objectives, WSP and Infrastructure Victoria have developed a validation framework specific for the Better Buses project, with input from DTP. This builds on the model validation guidance typically used for strategic modelling projects in Victoria and focusses on the representation of bus service provision and passenger demands.

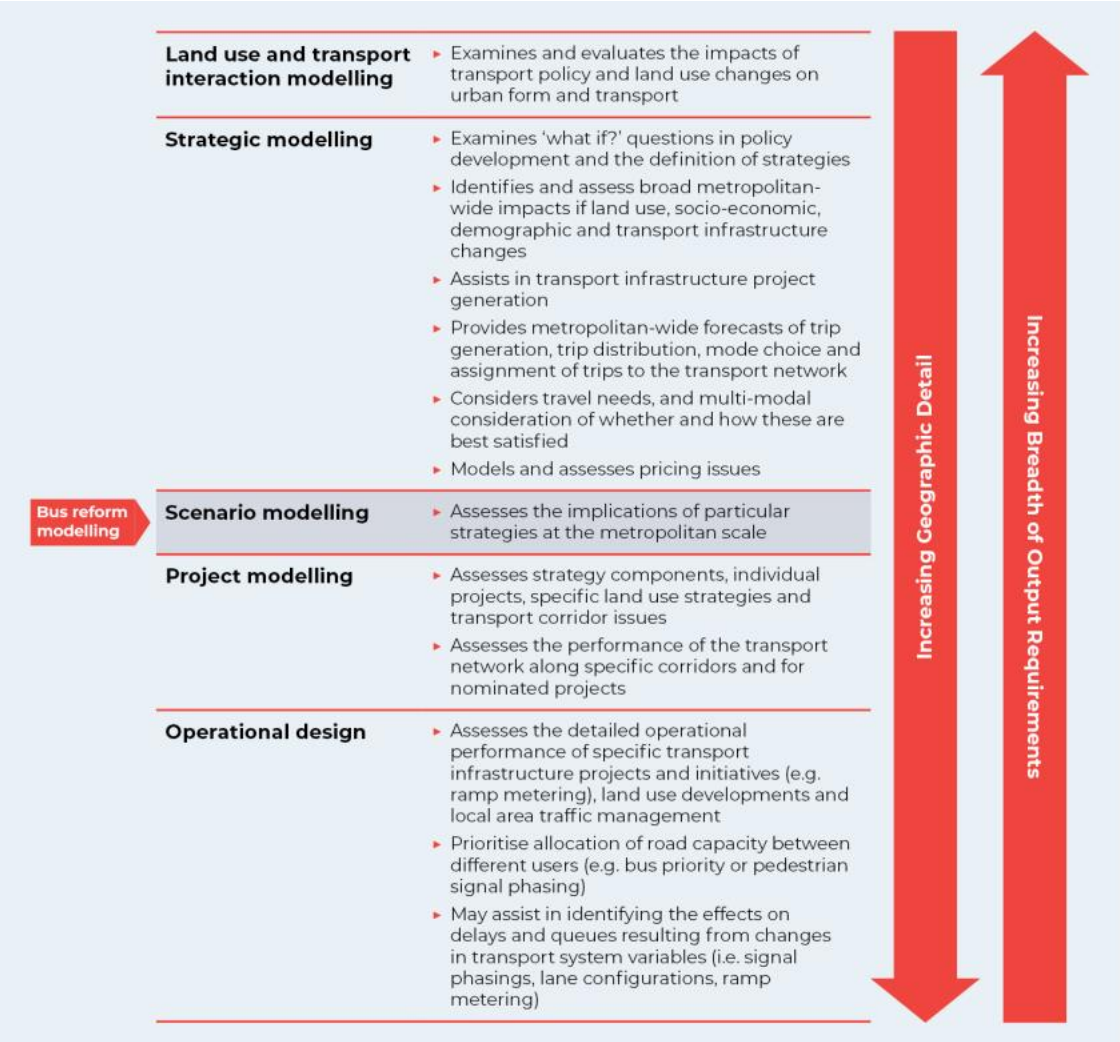


Figure 2-1 Australian Transport Assessment and Planning's (ATAP) Hierarchy of transport modelling applications

The considerations taken and inputs used to develop the validation framework are shown in Figure 2-2 below, highlighting the following key elements:

— The validation framework has been informed by the priorities of the Better Buses project and by the availability and quality of observed data.

— Our validation approach incorporates two elements: **static validation** comparing modelled demands to observed data from 2018, iteratively improving these to address areas of underperformance, and **response validation** checking the model's response to changes in services and parameters we expect to form part of bus reforms to be tested.

— Static validation metrics have each been assigned a **priority** rating, **importance** rating, a **target** with reference to the available observed data and an associated **validation target**. These have been informed by the quality of the **observed data available**.

— Response validation checks the modelled changes in demand relative to **literature and modelling guidance**.

— VITM represents demand in Greater Melbourne and large regional centres. As Infrastructure Victoria's bus reform will focus on Greater Melbourne, validation improvements have focussed on Greater Melbourne.

— We explored a range of opportunities to improve VITM's validation. While some changes were implemented, in other instances changes worsened model performance or the risks associated with that change outweighed the expected benefits. Model changes considered, as well as details of implemented changes, have been provided in Chapter 4.

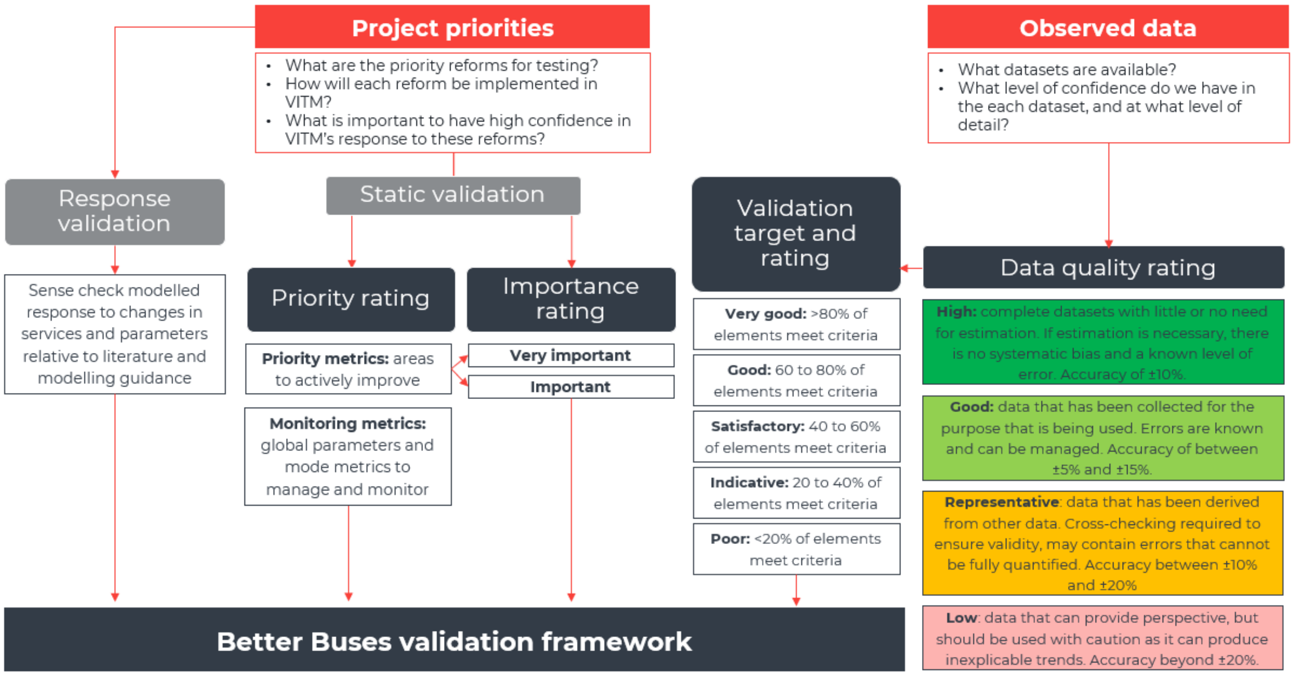


Figure 2-2 Considerations in developing the validation framework

2.1 PROJECT PRIORITIES

At the time of model validation, Infrastructure Victoria had prioritised five key reform themes which were used to inform the validation framework. These themes were developed into a list of key services and parameter changes that would likely be implemented in VITM to represent each reform. We then further expanded them to develop a set of validation priorities, representing aspects of the model in which we must have confidence for VITM to be reliably used to inform each type of bus reform (Table 2-1). The reform themes and validation priorities were then developed into a hierarchy of metrics (Figure 2-3).

Table 2-1 Reform themes, model implementation and validation priorities

REFORM	DESCRIPTION	MODEL IMPLEMENTATION	VALIDATION PRIORITIES
Service provision	— Higher service frequencies — Better timetable integration between	— Reduce headways by time period — Flatten wait time curves	— Improve the geographic distribution of bus demand — Check modelled demand response to increases in service frequency

REFORM	DESCRIPTION	MODEL IMPLEMENTATION	VALIDATION PRIORITIES
	feeder and trunk services		— Check modelled response to flattening wait time curves
Network design	— More direct bus routes — More connections with trains stations and activity centres	— Realignment of bus routes	— Improve the geographic distribution of bus demand — Check modelled response to reduced travel times
Bus priority	— Implement through bus lanes where congestion levels are high and along high priority/ patronage corridors	— Add dedicated bus-only infrastructure representing bus lanes	— Improve the geographic distribution of bus demand — Improve passenger demands along candidate bus priority corridors
Bus rapid transit (BRT)	— Convert a selection of routes / corridors to BRT	— Add dedicated bus-only infrastructure representing bus lanes — Modify perception parameters of BRT to approach ‘preferred’ modes (such as tram)	— Improve the geographic distribution of bus demand — Improve passenger demands along candidate bus priority corridors — Check modelled response to reduced travel times — Checked modelled response to improved mode perception parameters
Region specific bus reform	— Target a combination of the above reforms to areas experiencing transport disadvantage	— Combination of reforms listed above	— As above

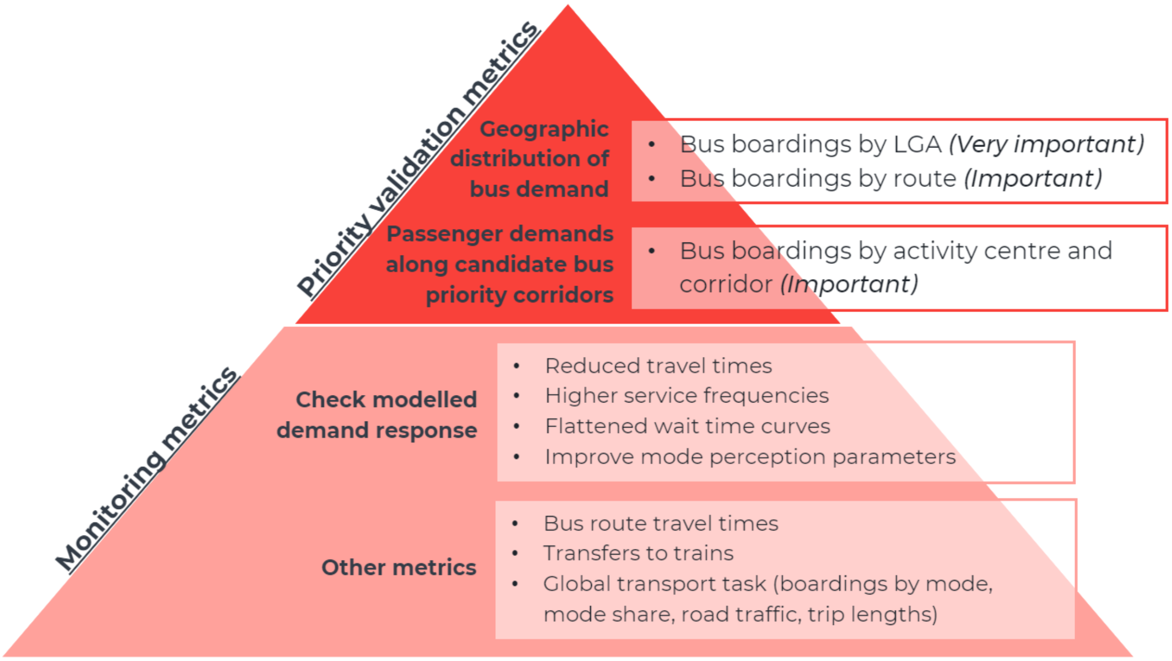


Figure 2-3 Validation priority and monitoring metrics

2.2 OBSERVED DATA AND VALIDATION FRAMEWORK

The quality of observed travel data can be highly variable, especially when it represents demand or performance for a detailed part of the network. Understanding confidence levels in each observed data source is important to ensure that validation metrics and targets set using this data are appropriate. We provide an assessment of the quality and confidence levels for each data set, including its suitability to evaluate the performance of the base model against each metric. This assessment has been developed with reference to data caveats and limitations from the data provider (usually DTP), cross-checking against other similar data sets, and professional judgement. The data quality assessment framework is summarised in the Figure 2-2 on Page 3, while data quality descriptions, priority and desired criteria are linked to the validation metrics in Table 2-3 overleaf.

Enforcing rigid static validation criteria for detailed elements of the transport network (such as individual bus routes or stops) runs the risk of overfitting the model, particularly where there are gaps or concerns in the observed travel data VITM is trying to replicate. To account for this, we have applied a validation rating approach that documents the percentage of priority validation elements that achieve the desired target, grouped by importance rating (see Table 2-2 below).

Table 2-2 Validation rating

LEVEL	RATING	% OF ELEMENTS THAT MEET CRITERIA
1	Very good	>80%
2	Good	60% to 80%
3	Satisfactory	40% to 60%
4	Indicative	20% to 40%
5	Poor	<20%

Derived from KPMG SRL Appendix C1 Demand Modelling Report and VITM Refresh 2019 Report

2.3 SETTING VALIDATION TARGETS

The following types of validation targets have been set as a part of the validation framework:

— % Difference: This compares the total observed demand to the total modelled demand for a particular metric. The closer to the percentage difference is to zero, the more closely the model reflects observed conditions.

— Scatterplot: Scatterplot validation displays the relationship between the observed dataset (usually shown on the x-axis) and the equivalent modelled data (usually shown on the y-axis). The closer the slope of the trendline (gradient) and the coefficient of determination (R^2) are to 1, the better the model is at representing the observed data.

— GEH Statistic: GEH has been developed explicitly for use in demand forecasting, comparing two sets of volumes. Unlike percentage difference analysis, GEH accounts for the higher significance of differences in high demand volumes compared to differences in lower volumes. A lower GEH index indicates a better match between modelled and observed volumes.

Table 2-3 Validation framework

SOURCE	DESCRIPTION, KNOWN LIMITATIONS	METRIC	DATA QUALITY RATING	DATA QUALITY RATING RATIONALE	CATEGORY / IMPORTANCE	TARGET
VITM validation spreadsheet	The VITM validation spreadsheet contains observed data that have been prepared explicitly with validation of the 2018 base year model of VITM in mind.	Bus boardings, model-wide by time period	High	Myki touch-on are adjusted to account for missing touch-on at a network level, with regular surveys, providing robust patronage estimate at modal, time period and LGA disaggregation.	Priority / Very important	±10%
		Bus boardings by Local Government Area (LGA), by time period	High		Priority / Very important	Difference Daily: ±15% Time period: ±25% Scatterplot Gradient: 0.9 to 1.1 R^2: ≥0.75
		Public transport boardings by mode and time period	High		Monitoring / Very important	±10%
		Highway screenline totals by time period	High	Spreadsheet has been developed for the purpose of validating VITM. Confidence in traffic data is higher than public transport data as it is more straightforward to collect.	Monitoring / Important	Scatterplot Gradient: 0.9 to 1.1 R^2: ≥0.85
Metropolitan bus boardings by route, route and stop	Hourly bus boarding data by stop and route for May 2018 and May 2019. Patronage has been developed via BusSUM, which uses myki touch-ons and is boosted based on survey data to account for trips where passengers have not touched on. The data also contains 'headless mode' entries, where boardings could not be assigned to a route. The data cover states: 'This methodology provides estimates at a macro level and is not designed to produce accurate stop-level estimates'	Bus boardings by route, by time period	Good	Bus route validation is a macro-level application of the data	Priority / Important	Difference Routes within ±25% of observed Scatterplot Gradient: 0.9 to 1.1 GEH Routes <5: 50% Routes <10: 85%
		Bus boardings by corridor and activity centre, by time period	Representative	In the absence of passenger load estimates, corridor and activity centre validation is based on aggregations of a small number of bus stops this is a detailed application of the data.	Priority / Important	Difference Activity centres and corridors within ±25% of observed Scatterplot Gradient: 0.9 to 1.1 R^2: ≥0.75
Per cent transfer from train to other modes (bus/tram)	Average daily estimates – May / August 2019, typical weekday A transfer is defined as a change in mode of transport, involving a touch-off at the train station followed by a touch-on aboard a bus or tram within 30 minutes. The data has not been boosted or cleansed. The observed data was aggregated to combined tram and bus transfers to train to match transfer outputs available in VITM.	Train transfers to bus and tram, daily	Low	Multiple known issues in the data that have not been managed	Monitoring / Very important	Scatterplot Gradient: 0.9 to 1.1 R^2: ≥0.75 To facilitate the inclusion of the transfer metric in the validation summary, we have applied the same scatterplot target as for other metrics. However we do not recommended fitting the model to the observed transfer data until better data is available.
Bus performance data	Stop to stop level journey time aggregations for 2019 for each individual service. The data includes arrival and departure times at each stop for each bus service, meaning dwell times can also be inferred. Some records were filtered out, for example where bus services arrived at their destination prior to the origin departure time (implying a negative total journey time). However, overall the dataset displayed consisted travel time patterns across time periods.	Bus travel times by route, by time period	High		Monitoring / Very important	Scatterplot Gradient: 0.9 to 1.1 R^2: ≥0.75

3 LIMITATIONS OF VITM

Future events are inherently uncertain, and even the most comprehensive and sophisticated forecasting tool will produce forecasts that are different from the eventual outcomes. However, VITM is a useful tool to test the effects of different policies and infrastructure investments, adding to the evidence-base used by decision-makers.

In interpreting the results of VITM, it is helpful to keep several key limitations in mind:

3.1 VITM SIMPLIFIES COMPLEX REAL-WORLD BEHAVIOURS INTO FOUR-STEPS

VITM is a four-step strategic transport model covering the whole of the Melbourne metropolitan area as well as some key regional centres. It is owned and maintained by the Department of Transport and Planning (DTP). VITM provides road and public transport network forecasts for a series of future years based on an underlying set of land use and demographic forecasts and transport network assumptions.

The model uses mathematical equations which are in part determined by the availability of data and computing constraints. To achieve a practical and workable model, it simplifies real-life behaviours into four-steps:

- Trip generation (What travel do I need to make and for what purpose?
- Destination choice (where will I go?)
- Mode choice (will I drive, get a lift or take public transport?)
- Route assignment (which route will I use to get to my destination?)

This simplification means that, like most four-step models, there are certain travel behaviours that VITM does not reflect. This includes:

- <u>A change in departure time (including peak-spreading):</u> in the face of unreliable or long travel times resulting from network congestion, many travellers will choose to leave slightly earlier or later before changing their route, mode or destination. As VITM comprises four discrete time periods with fixed travel demand within each period, this behaviour is not reflected in the model.
- <u>A choice to not travel (trip suppression):</u> in some cases, a person with poor options may choose not to undertake an activity at all. VITM does not reflect this type of response.

3.2 VITM IS A STRATEGIC MODEL

Strategic models do not provide insight into transport questions at a scale more detailed than the models themselves. For example, as the VITM does not reflect car parking facilities or driveways, it is of limited use in car parking strategies. Similarly, the VITM does not include detailed local roads, pedestrian pathways, and does not include detailed bus and tram stop locations. Care must be taken when interpreting results at individual bus stop level.

According to ATAP (refer Figure 2-1 on Page 2), strategic models like VITM are useful for a range of applications, including:

- Examining 'what if?' questions in policy development
- Considering travel needs, and multi-modal considerations of whether and how these are best satisfied
- Assessing the implications of particular strategies at the metropolitan scale
- Assessing strategy components, individual projects and transport corridor issues

A comprehensive bus reform program is likely to involve operational design considerations, including things like signal priority and consolidation of bus stop locations. Evidence developed outside of VITM may be more appropriate to support these types of reform.

3.3 VITM PREDICTS FUTURE BEHAVIOUR BASED ON PAST TRENDS

VITM combines demographic, land use and transport network data with behavioural parameters derived from historical travel surveys to estimate how travellers with different characteristics will behave under different conditions. This means that VITM largely assumes a continuation of historical travel behaviour, calibrated to a relatively small sample of observations. It therefore does not always capture the impacts of broader social changes that can drive changing trends in behaviour.

Due to the uncertainty introduced by COVID-19 and the significant changes in travel behaviour over the past three years, VITM retains a 2018 base year to allow the model to be calibrated and validated to stable pre-COVID 19 behavioural data. VITM's future reference case assumes a higher proportion of working from home, which at the time of this report is occurring at a higher rate than pre-2020. The effects of other behavioural changes can be tested through sensitivity testing future scenarios, if deemed necessary.

3.4 VITM RELIES ON ASSUMPTIONS TO FORECAST FUTURE DEMAND

Strategic models are only as accurate as the input data used to generate forecasts, including future year population and employment, expected network configurations and travel costs at each forecast horizon.

3.5 ADDRESSING MODEL LIMITATIONS

Some of the model limitations above can be managed through sensitivity testing of inputs and parameters, particularly where these may impact the recommendations drawn from the modelling. In other cases, sources of evidence outside of VITM may be more appropriate to inform the benefits and impacts of specific reforms and investments. Where model limitations relate to the quality of the model validation, the forecasting approach can be informed by the framework shown in Table 3-1 below.

Table 3-1 Model validation guidelines – forecasting approach given quality of validation.

<table>
<tr><th>LEVEL</th><th>RATING</th><th>APPLICATION IN FORECASTING ENVIRONMENT</th></tr>
<tr><td>1</td><td>Very good</td><td rowspan="3">Forecasts from the model scenarios can be used without adjustments. Out-f-model adjustments may be required if an aspect of the model is not satisfactory and is the focus of the model scenario.</td></tr>
<tr><td>2</td><td>Good</td></tr>
<tr><td>3</td><td>Satisfactory</td></tr>
<tr><td>4</td><td>Indicative</td><td rowspan="2">Base year observed data should be adjustment based on the growth forecast by the model.</td></tr>
<tr><td>5</td><td>Poor</td></tr>
</table>

4 MODEL CHANGES

The version of VITM used as the starting point for this project is VITM22_v2_04 provided by the Department of Transport and Planning (DTP).

The primary objective of this validation exercise is to improve the representation of buses in VITM to inform the Better Buses project and to better support the planning of bus services and infrastructure across the transport portfolio. In the process of improving model validation, we undertook more than 26 model runs to examine the individual and combined effect of various model changes.

In making model refinements to improve bus validation we have also considered, and in some cases tested, whether these changes improve the model more broadly or will affect the likelihood of the Better Buses base model being used on other projects. The model changes considered during validation are summarised in Table 4-1 below.

Table 4-1 Model changes considered and implemented during validation

CHANGE	OVERVIEW	CONSIDERATIONS AND WORK UNDERTAKEN	DETERMINATION
Zone system	Bus services are typically the nearest public transport service available to households, used for local trips or acting as a feeder to rail services. Travel zones are the geographic units used to represent land use and trip generation of different areas across Melbourne. Trips generated from each zone are then assigned a destination travel zone according to the purpose of that trip and the types of land uses within the destination zone. If a trip is short with an origin and destination within the same zone, the trip becomes an 'intrazonal'. Smaller travel zones reduce the number of intrazonal trips and offer more realistic walking times to the bus network. This allows the model to assign shorter trips onto the transport network, including bus trips.	We considered developing a custom zone system for the Better Buses model, however this is unlikely to be used by other projects. We also tested validation effects of running with the most detailed 'standard' VITM zone system.	We selected the most detailed VITM 'standard' zone system for the Better Buses model. This materially improved the representation of access to the bus network in outer suburbs. For example, the original VITM 2018 showed no modelled boardings in the Yarra Ranges LGA, while the more detailed zone system modelled over 3,000 daily boardings with no other changes to the model. See Section 4.1.1 for figures showing the revised zone system.
Bus network changes	We reviewed the operation of the bus network, particularly focussing on areas with large discrepancy between observed and modelled demands, to verify that it provides a reasonable	We compared the alignment of modelled bus routes with the observed 2018 bus network We also compared the stopping patterns of bus routes in with stopping patterns in the 2018 bus network.	We implemented changes to stopping patterns and route alignments within Melbourne and Monash LGAs to better represent actual service operation in the base year, which reduced modelled boardings to make

CHANGE	OVERVIEW	CONSIDERATIONS AND WORK UNDERTAKEN	DETERMINATION
	representation of base year service operations.		them align more closely to observed data. See Section 4.1.2 for images showing these changes.
Mode split alternative specific constants (ASC)	These constants provide for variations in trip patterns that are not captured by the generalised cost (e.g. service reliability, security, personal tastes, habits, etc.). Within VITM, different ASC factors are used for each trip purpose, and includes geographic segmentation of the production zone and attraction zone.	We did not consider changing these factors as this would have impacted the boardings for metropolitan train and tram including road traffic. As the rail, tram and highway traffic validated well at the model wide level, we focused on implementation of changes targeting bus demand.	No change – this type of adjustment is better suited to a model calibration and validation exercise with a broader scope and longer program.
School bus mode share assumptions	School bus mode share assumptions are determined through VISTA. As school bus services are not reflected in VITM, the percentage of home-based education trips made using school buses are removed from the overall demand matrix.	We scoped the tasks required to review (and update) the school bus mode share assumptions in VITM. Tasks included: analysis VISTA and producing updated observed mode share estimates; checking these estimates against current VISTA mode share; incorporating any changes required from this review.	Given the time and effort required, the potential effect of updated mode share assumptions on validation of other modes and the relatively small proportion of trips that use school buses. We ultimately decided not to pursue this line of inquiry as this type of adjustment is better suited to a model calibration and validation exercise with a broader scope and longer program.

CHANGE	OVERVIEW	CONSIDERATIONS AND WORK UNDERTAKEN	DETERMINATION
Off-peak service representation:	Off peak demand for buses is generally overestimated in VITM. One potential cause is the way that services are represented in this period, which spans from 6pm to 7am. The supply of services is highly variable over this period. For example, there are considerably more services running from 6pm to 12am than from 12am to 7am, but as VITM runs a frequency-based assignment the timetable needs to be converted into an average headway that represents the entire 13-hours. The modelled off-peak frequency generally represents headways in the evening (prior to midnight), but this can result in an overrepresentation of services in the early morning period and a corresponding overestimation of demand. Advice from DTP is that for the capacity of roads and the number of public transport services, the equivalent of 6 hour period is used for the off-peak period.	We explored whether revising the way that off peak service assumptions are represented in VITM would help to reduce high off-peak modelled bus demand.	We did not proceed with this line of inquiry. The approach to converting off-peak services from the timetable into the model is consistent across all public transport modes, but tram and metro train are not overestimating demand in the same way as buses. This could be a result of many bus routes operating with a shorter span of hours than rail modes, however this involves a detailed line-by-line network assessment that was not achievable within the scope and program of this project.
Boarding penalties	Boarding penalties capture the preference travellers have for one public transport mode over another for factors unobserved in the model, such as the safety and comfort of stop infrastructure, legibility of the network, ease of obtaining a ticket before boarding etc. Buses penalties are typically higher than for rail and tram, reflecting a general preference for rail.	While model-wide bus boardings were within 7% of observed in the original VITM, the model generally underestimated bus boardings in middle and outer ring LGAs, and overestimated inner city boardings. We tested several adjustments to penalties in isolation and in combination with some of the changes listed above, including: — Reducing penalties by between 0.5 and 2 minutes in different combinations across modelled time periods	Testing indicated that a minor reduction in penalties of 1 minute in both peak and off-peak periods provided an uplift in demand in the outer LGAs without impacting validation of other public transport modes. The boarding penalties for standard and SmartBus services were therefore reduced by 1 minute in both the peak (from 12 to 11 minutes) and off peak (from 9 to 8 minutes) periods, to address the underestimation of bus boardings in outer LGAs.

CHANGE	OVERVIEW	CONSIDERATIONS AND WORK UNDERTAKEN	DETERMINATION
		— Reducing transfer penalties by between 1 and 2 minutes across all time period	
Free tram fare zone	To represent Melbourne's integrated ticketing system, VITM applies a single fare system for all metropolitan public transport modes. This fare system includes the free tram zone, where passengers with origins and destinations inside this area can travel for free. This is likely one source of the high bus boardings in the CBD compared to observed.	VITM also applies the free tram zone to bus and train trips. There is no simple way in Cube to apply free fares to trams without either: — Also applying them to buses and trains — Causing passengers to pay a fare when transferring between public transport modes. We ran a test win which buses were assigned a separate fare system so that bus boardings starting and ending within the CBD attract a fare. This reduced overall public transport trips by over 2 per cent, affecting both rail and bus boardings.	No change – this type of adjustment is better suited to a model calibration and validation exercise with a broader scope and longer program. Due to limitations within the modelling software (Cube), implementing a fare system where the free tram zone applies only to tram trips, without charging passengers transferring between public transport modes, may require model development activities. This type of adjustment would also need to consider that there are already stop access penalties for each mode which reduce the attractiveness of public transport for short trips across the CBD.

4.1.1 ZONE SYSTEM

The Better Buses base model uses a detailed 3762 zone system, achieved by using the most detailed standard zones available in the Melbourne Statistical Division (MSD). This allows the model to assign shorter trips onto the transport network, including bus trips. Original and revised zone systems are shown in Figure 4-1 and Figure 4-2 respectively.

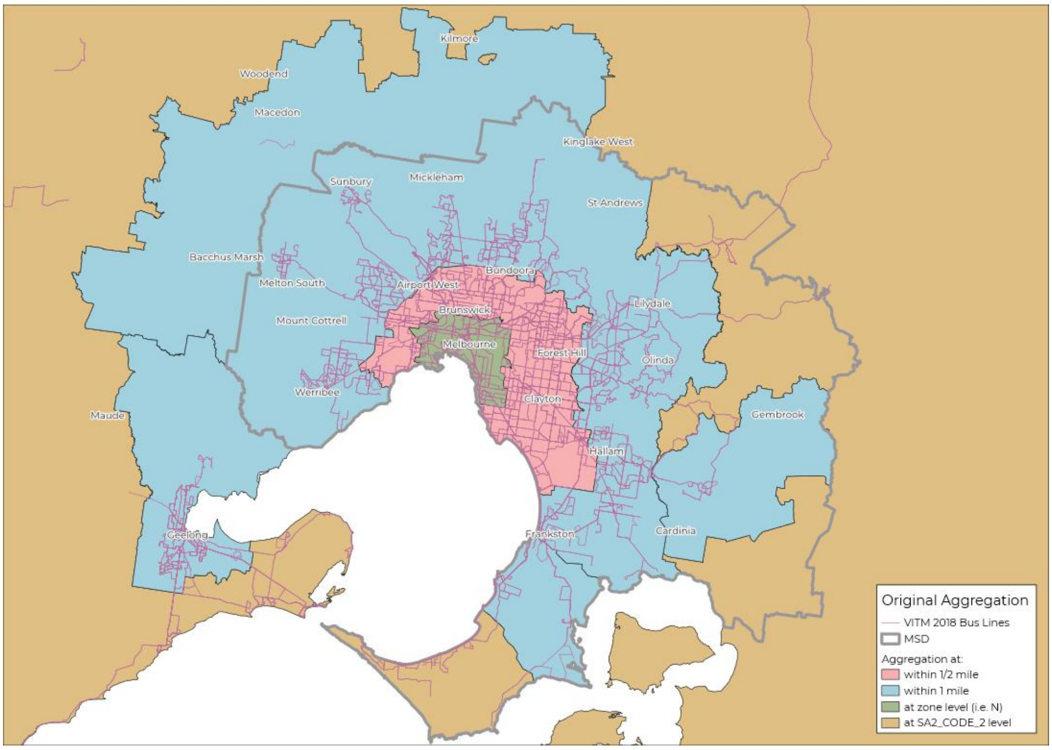


Figure 4-1 Original 2018 base model zone system

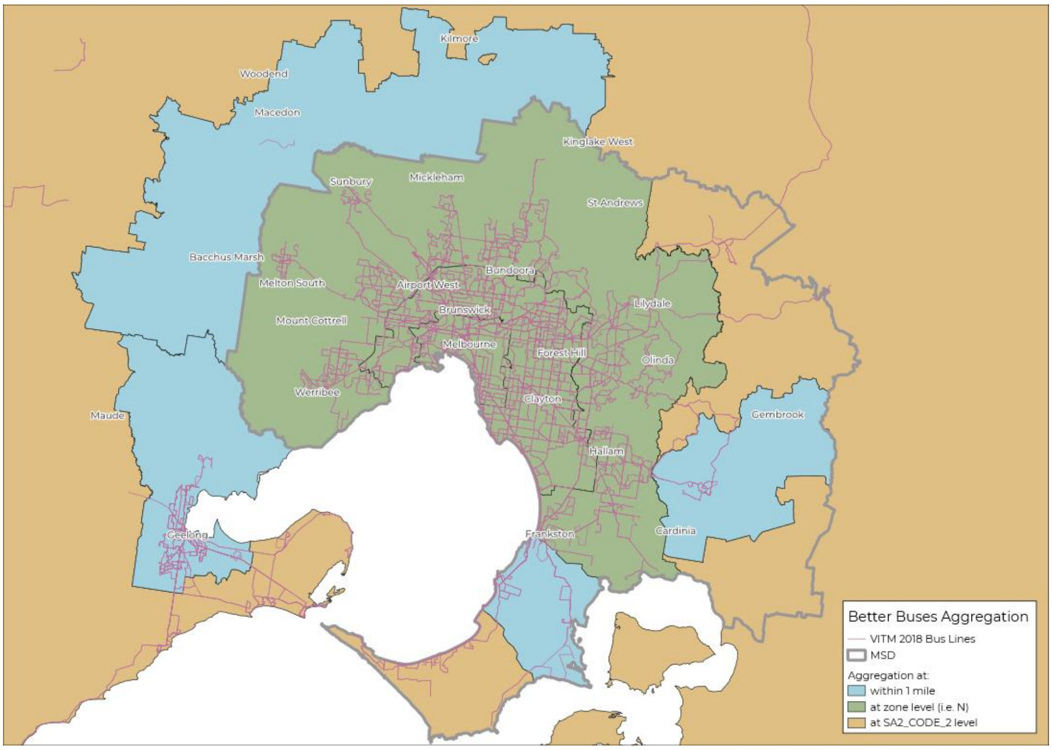


Figure 4-2 Better buses base model zone system

4.1.2 REVISIONS TO THE BASE YEAR BUS NETWORK

We realigned bus routes and reviewed route stopping patterns within the Melbourne CBD to better represent the operation of the bus network. This included re-routing services that operated via Flinders Street, Exhibition Street and St Kilda Road (Figure 4-3). We also implemented 'non-stop' nodes to better reflect opportunities to board bus services along key corridors including Lonsdale, Latrobe and Queen Streets (Figure 4-4).

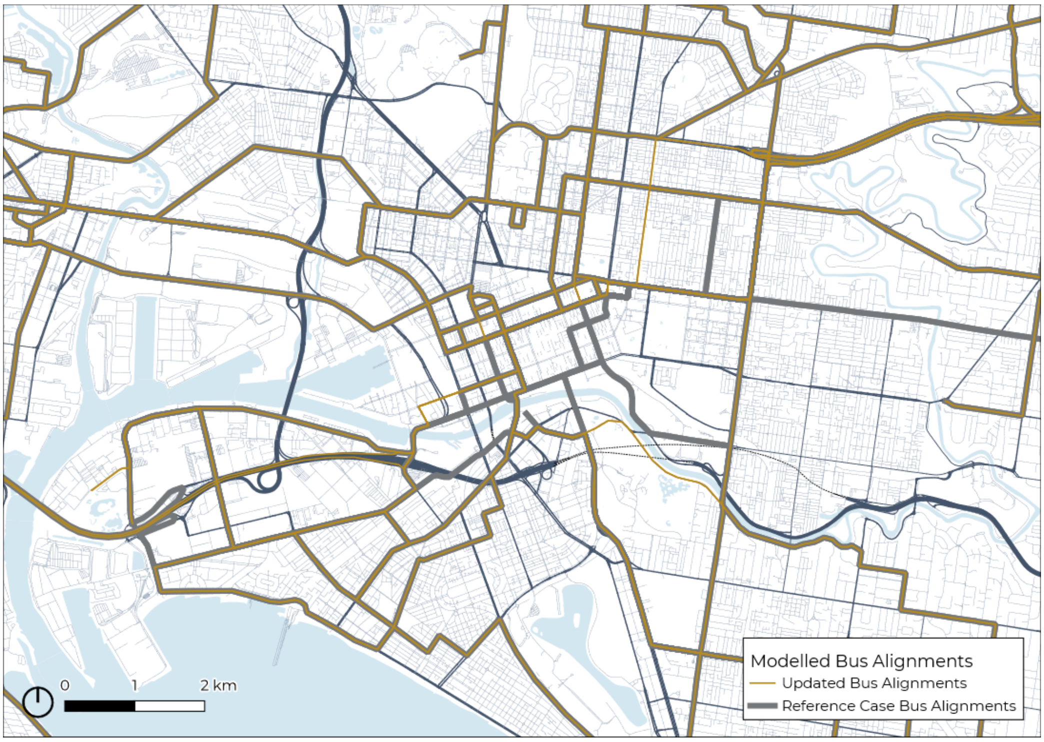


Figure 4-3 Update of Melbourne CBD bus alignments

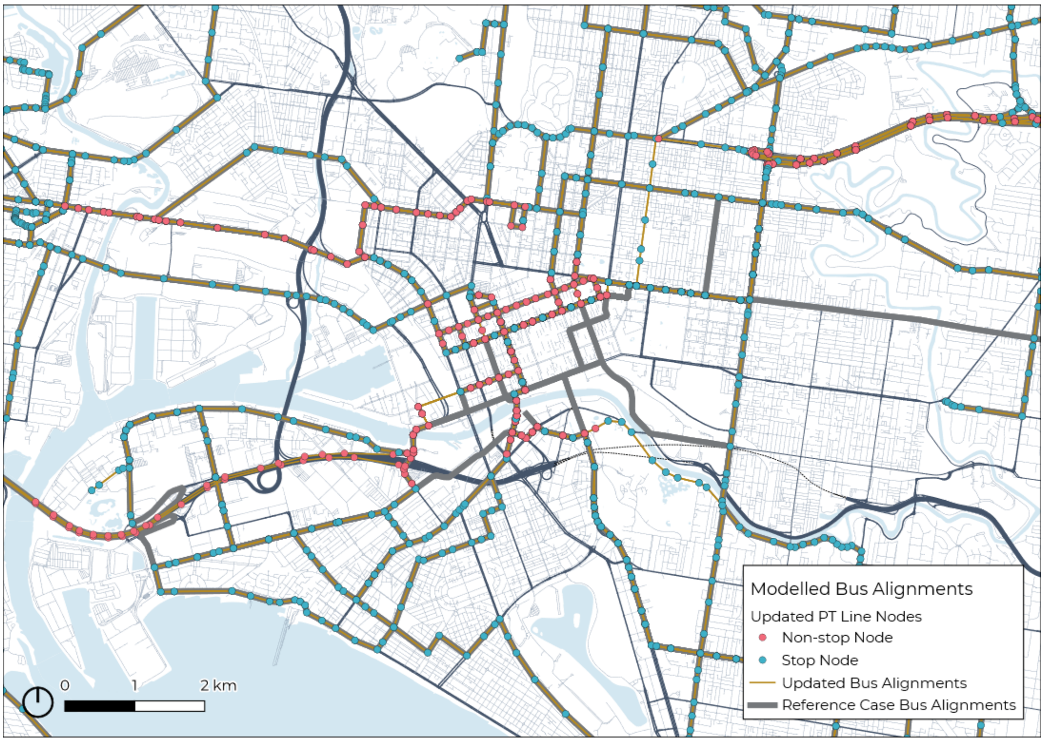


Figure 4-4 Update of Melbourne CBD bus stop nodes

We also modified the stopping patterns of Route 403 (Footscray Station to Melbourne University via Royal Melbourne Hospital) and Route 601 (Huntingdale to Monash University) to reflect their operation as express services. In the original 2018 base model, these services stopped at multiple nodes attracting a considerable number of boardings.

4.1.3 SUMMARY OF BASE YEAR MODEL CHANGES AND IMPACT ON FUTURE YEAR 2026 AND 2036 MODELS

The following changes to the base year model will be carried into the future year models:

- The more detailed zone system of 3,762 zones
- Slightly reduced boarding penalties for standard and Smart buses to address the underestimation of bus boardings in outer LGAs
- Realignment of bus routes and updates to stop nodes within the Melbourne CBD to improve the representation of the bus network within the Melbourne CBD
- Removal of stop nodes along shuttle bus route 403 and 601 reflecting the express nature of these services

5 MODEL VALIDATION

5.1 PRIORITY METRICS

This section presents the validation of the initial base model received from DTP using the project validation framework described in Chapter 2. The overall performance of the original 2018 VITM and the revised Better Buses 2018 base model with reference to priority validation metrics is shown in Figure 5-1 and Figure 5-2 respectively, showing that:

— Just over 30 per cent of 'very important' validation metrics and dimensions achieved a 'very good' rating (compared with 10 per cent in the original base model)

— Around 10 per cent of 'very important' validation metrics achieved a 'good' rating (compared with 30 per cent in the original model)

— Just under 30 per cent of 'very important' validation metrics were indicative only (compared to 40 per cent in the original model)

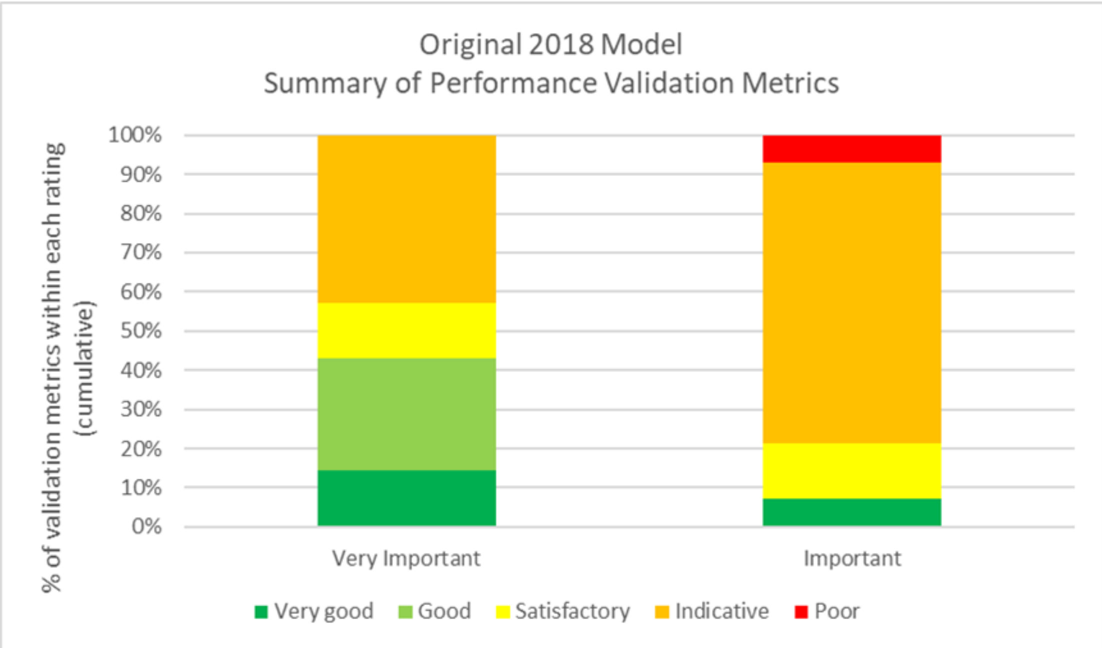


Figure 5-1 Summary of priority validation metrics, initial 2018 base model

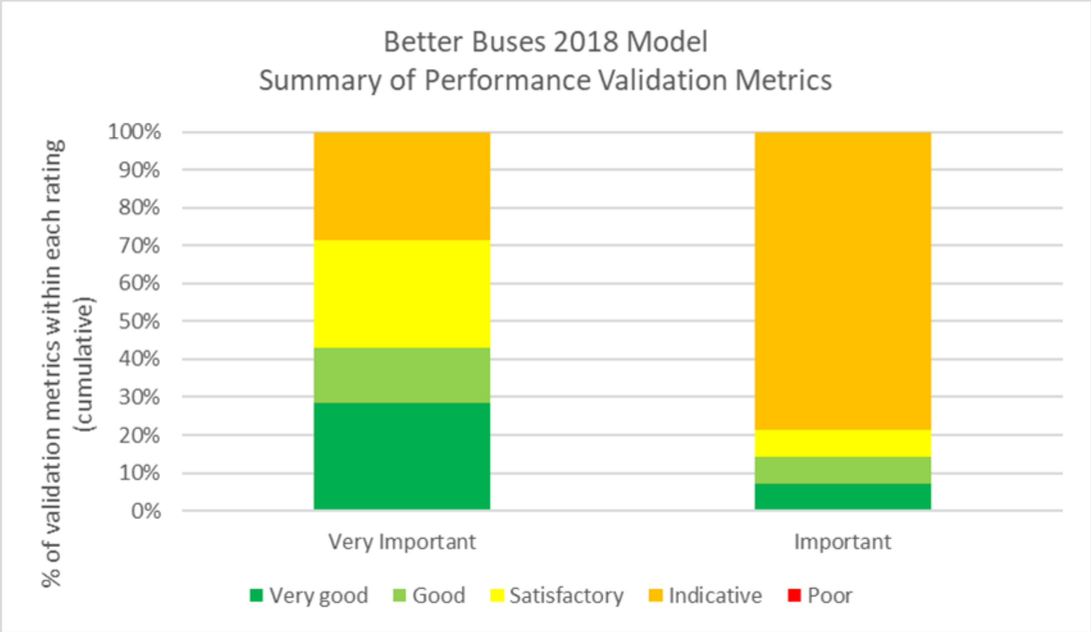


Figure 5-2 Summary of priority validation metrics, Better Buses 2018 base model

5.1.1 MODEL-WIDE BUS BOARDINGS

Both the original base year VITM and the Better Buses 2018 model achieved a 'very good' validation rating for system-wide bus boardings, with all time periods except the off-peak falling within the target of ±10 per cent (Table 5-1). This suggests that both versions of VITM are reasonably representing metropolitan-wide demand for bus travel.

While metropolitan daily demand in the original 2018 model is slightly closer to observed data than the Better Buses 2018 model, the revised model materially improves validation across a range of more detailed metrics, which will be described in more detail in this chapter.

The off-peak was the only period that did not fall within the target range in both VITM versions. Note that the off-peak period is particularly challenging to represent in VITM, as it spans 6pm to 7am. The supply of services is highly variable over this period. For example, there are considerably more services running from 6pm to 12am than from 12am to 7am, but as VITM runs a frequency-based assignment the timetable needs to be converted into an average headway that represents the entire 13-hours. The modelled off-peak frequency generally represents headways in the evening (prior to midnight), but this can result in an overrepresentation of services in the early morning period and a corresponding overestimation of demand.

Table 5-1 Total metropolitan bus boardings by time period, original VITM and Better Buses models (Very important)

TIME PERIOD	OBSERVED	TARGET	ORIGINAL 2018 MODEL				BETTER BUSES 2018 MODEL			
			MODEL	+/-	%	RATING	MODEL	+/-	%	RATING
FULL PERIOD VOLUMES										
AM (7 to 9AM)	97,542	±10%	90,930	-6,612	-7% (✓)	Very good	92,393	-5,149	-5% (✓)	Very good
IP (9AM to 3PM)	128,367		130,695	2,328	2% (✓)		131,607	3,240	3% (✓)	
PM (3 to 6PM)	119,654		124,067	4,413	4% (✓)		128,991	9,338	8% (✓)	

TIME PERIOD	OBSERVED	TARGET	ORIGINAL 2018 MODEL				BETTER BUSES 2018 MODEL			
			MODEL	+/-	%	RATING	MODEL	+/-	%	RATING
OP (6PM to 7AM)	56,535		82,563	26,028	46% (x)		82,899	26,364	47% (x)	
Daily (24 hr)	402,098		428,255	26,157	7% (✓)		435,890	33,793	8% (✓)	
2 HOUR EQUIVALENT VOLUMES										
AM (2hr)	97,542	±10%	90,930	-6,612	-7% (✓)	Very good	92,393	-5,149	-5% (✓)	Very good
IP (2hr)	42,789		43,565	776	2% (✓)		43,869	1,080	3% (✓)	
PM (2hr)	79,769		82,711	2,943	4% (✓)		85,994	6,225	8% (✓)	
OP (2hr)	18,845		27,521	8,676	46% (x)		27,633	8,788	47% (x)	

5.1.2 BUS BOARDINGS BY LGA

The representation of bus boardings by LGA were materially improved through the validation phase of the Better Buses project.

In the original 2018 base model, none of the bus boarding by LGA scatterplots achieved both R^2 and gradient targets in any period, although AM and interpeak periods achieved gradients within the target range and the PM peak achieved an R^2 just inside the target range (Table 5-2). However, to a large extent this is skewed by the large overestimation of boardings within Melbourne CBD (around 85,000 daily boardings in the model compared to just over 25,000 observed).

The Better Buses base year model achieves a good validation for bus boardings by LGA. Bus boardings within the Melbourne LGA have been greatly reduced from the original 2018 model, down from 85,000 per day to 76,000 per day. Despite this, the LGA is still much higher than the 25,000 observed daily boardings. The Melbourne LGA has the second highest number of observed boardings, following the Monash LGA, meaning that this overestimation introduces considerable bias into the scatterplot analyses, dragging the gradient for the PM, off peak and daily validation above the target range.

Table 5-2 Total bus boardings by LGA – scatterplots, original VITM and Better Buses models (Very important)

TIME PERIOD	TARGET R^2	TARGET GRADIENT	ORIGINAL 2018 MODEL			BETTER BUSES 2018 MODEL		
			R^2	GRADIENT	VALIDATION RATING	R^2	GRADIENT	VALIDATION RATING
AM (7 to 9AM)	≥0.75	0.9 – 1.1	0.68 (x)	0.94 (✓)	Indicative	0.77 (✓)	0.98 (✓)	Good
IP (9AM to 3PM)			0.64 (x)	0.99 (✓)		0.74 (o)	1.03 (✓)	
PM (3 to 6PM)			0.76 (✓)	1.12 (x)		0.82 (✓)	1.19 (x)	
OP (6PM to 7AM)			0.71 (x)	1.56 (x)		0.76 (✓)	1.61 (x)	
Daily (24 hr)			0.70 (x)	1.11 (x)		0.77 (✓)	1.16 (x)	

While this validation exercise significantly improved bus representation in Melbourne CBD, there are some residual limitations to the model that could not be addressed during this project. Recalibration activities to target these issues are discussed in Chapter 4 of the report, while proposed out-of-model activities to address residual limitations are detailed in the report conclusions.

The Melbourne CBD and inner suburbs are candidates for bus reform due to high levels of congestion, however, buses are the only form of public transport available to many Melburnians, especially in some outer and new growth suburb that do not have access to either tram or train. For this reason, ensuring a good level of validation middle and outer suburbs was deemed a priority over improving validation within inner city LGAs.

When the Melbourne LGA is excluded from the scatterplots, both daily and PM validation fell within the target range for both criteria, and the correlation between observed and modelled data improved considerably across all periods in both original VITM and Better Buses models, the latter achieving a 'very good' validation rating (Table 5-3).

Table 5-3 Total bus boardings by LGA – scatterplots, excluding Melbourne LGA, original VITM and Better Buses models (Very important)

TIME PERIOD	TARGET R^2	TARGET GRADIENT	ORIGINAL 2018 MODEL			BETTER BUSES 2018 MODEL		
			R^2	GRADIENT	VALIDATION RATING	R^2	GRADIENT	VALIDATION RATING
AM (7 to 9AM)	≥0.75	0.9 – 1.1	0.86 (✓)	0.83 (x)	Satisfactory	0.87 (✓)	0.90 (✓)	Very good
IP (9AM to 3PM)			0.89 (✓)	0.83 (x)		0.91 (✓)	0.89 (o)	
PM (3 to 6PM)			0.95 (✓)	0.91 (✓)		0.95 (✓)	1.00 (✓)	
OP (6PM to 7AM)			0.93 (✓)	1.12 (x)		0.93 (✓)	1.22 (x)	
Daily (24 hr)			0.93 (✓)	0.90 (✓)		0.93 (✓)	0.99 (✓)	

In the original model, just 26 percent of LGAs achieved boardings within 15 per cent of observed (Table 5-4). This was improved in the Better Buses mode, with 39 per cent of LGAs meeting the target of daily boardings within 15 per cent of observed. The off-peak period is the weakest in the Better Buses model, with 35 per cent of LGAs within target.

Table 5-4 Total bus boardings by LGA – within 25% of observed by time period, or 15% daily, original VITM and Better Buses models (Very important)

TIME PERIOD	ORIGINAL 2018 MODEL		BETTER BUSES 2018 MODEL	
	% OF LGAS WITHIN TARGET	VALIDATION RATING	% OF LGAS WITHIN TARGET	VALIDATION RATING
AM (7 to 9AM)	29%	Indicative	42%	Satisfactory
IP (9AM to 3PM)	39%	Indicative	48%	Satisfactory
PM (3 to 6PM)	61%	Good	68%	Good
OP (6PM to 7AM)	48%	Satisfactory	35%	Indicative
Daily (24 hr)	26%	Indicative	39%	Indicative

The validation of daily bus boardings is shown spatially in Figure 5-3 overleaf, showing that while inner city LGAs are generally higher than observed, most middle ring LGAs fall within 25 per cent of observed boardings.

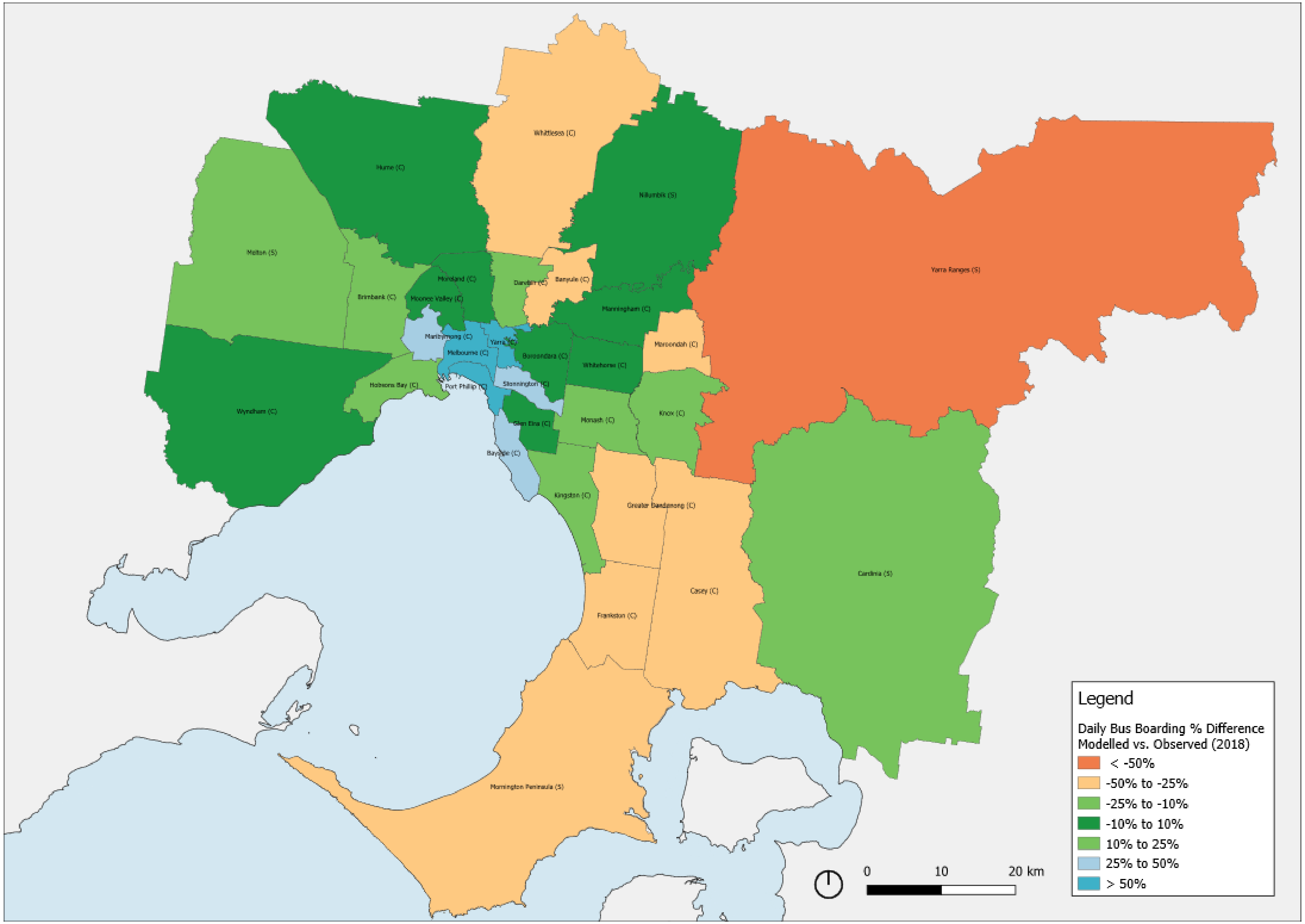


Figure 5-3 Daily bus boardings by LGA, modelled vs. observed

5.1.3 BUS BOARDINGS BY ROUTE

In the bus boardings by route scatterplots for the original VITM, the AM peak was the only period to achieve both R^2 and gradient targets (Table 5-5). The interpeak achieved a gradient within the target range, while the PM and daily scatterplots had R^2 values above target. The off-peak gradient was considerably above target at 1.35, reflective of the general overestimation of bus boardings in this period.

After model refinements, the Better Buses model achieved AM and interpeak R^2 and gradients within the target ranges, while all time periods show a good correlation between observed by route boardings and modelled by route boardings. The off-peak period remains considerably above target at 1.40, which is expected given the general overestimation of bus boardings in this period.

We also undertook GEH analysis to compare modelled route boardings to observed route boardings (Table 5-6). Both the original 2018 base VITM and the Better Buses model achieved all GEH targets across all time periods.

The final angle against which we evaluated bus boardings by route was to evaluate the percentage of bus routes with total boardings within 25 per cent of observed. While both the original VITM and Better Buses models present an indicative level of validation in all time periods, the percentage of routes within 25 per cent has improved by between 3 and 5 per cent across all time periods except the off-peak in the Better Buses model compared with the original 2018 base model (Table 5-7).

Table 5-5 Total bus boardings by route – scatterplots, original VITM and Better Buses models (Important)

TIME PERIOD	TARGET R^2	TARGET GRADIENT	ORIGINAL 2018 MODEL			BETTER BUSES 2018 MODEL		
			R^2	GRADIENT	VALIDATION RATING	R^2	GRADIENT	VALIDATION RATING
AM (7 to 9AM)	≥0.75	0.9 – 1.1	0.80 (✓)	1.08 (✓)	Indicative	0.86 (✓)	1.10 (✓)	Good
IP (9AM to 3PM)			0.69 (x)	0.96 (✓)		0.78 (✓)	1.00 (✓)	
PM (3 to 6PM)			0.82(✓)	1.16 (x)		0.86 (✓)	1.21 (x)	
OP (6PM to 7AM)			0.74 (x)	1.35 (x)		0.77 (✓)	1.40 (x)	
Daily (24 hr)			0.80 (✓)	1.12 (x)		0.84 (✓)	1.16 (x)	

Table 5-6 Total bus boardings by route – GEH, original VITM and Better Buses models (Important)

TIME PERIOD	TARGET <5	TARGET <10%	ORIGINAL 2018 MODEL			BETTER BUSES 2018 MODEL		
			GEH < 5	GEH < 10	VALIDATION RATING	GEH < 5	GEH < 10	VALIDATION RATING
AM (7 to 9AM)	50%	85%	57% (✓)	89% (✓)	Very good	62% (✓)	92% (✓)	Very good
IP (9AM to 3PM)			73% (✓)	94% (✓)		77% (✓)	95% (✓)	
PM (3 to 6PM)			67% (✓)	92% (✓)		69% (✓)	92% (✓)	
OP (6PM to 7AM)			86% (✓)	97% (✓)		86% (✓)	96% (✓)	
Daily (24 hr)			66% (✓)	91% (✓)		68% (✓)	92% (✓)	

Table 5-7 (Important) Total bus boardings by route, within 25% of observed, original VITM and Better Buses models

TIME PERIOD	ORIGINAL 2018 MODEL		BETTER BUSES 2018 MODEL	
	% OF ROUTES WITHIN TARGET	VALIDATION RATING	% OF ROUTES WITHIN TARGET	VALIDATION RATING
AM (7 to 9AM)	30%	Indicative	33%	Indicative
IP (9AM to 3PM)	24%	Indicative	29%	Indicative
PM (3 to 6PM)	30%	Indicative	33%	Indicative
OP (6PM to 7AM)	27%	Indicative	28%	Indicative
Daily (24 hr)	29%	Indicative	32%	Indicative

5.1.4 BUS BOARDINGS BY ACTIVITY CENTRE AND CORRIDOR

To align with the project validation priority of improving passenger demands along candidate bus priority corridors, we developed a selection of activity centres and corridors to understand how VITM performs in representing demand in these areas (defined in Figure 5-4). These are generally derived from activity centres and corridors identified in Plan Melbourne, with the addition of major bus corridors across Melbourne.

Passenger load data describes how many passengers are using a specific part of the network during a defined period. With no bus passenger load data available, we have compared modelled and observed bus boardings as an alternative validation method (see Table 2-3 for a detailed overview of validation data). Note that this is a more detailed use of the observed by stop boarding data than recommended by DTP, and the validation results presented in the following tables should be regarded with this in mind.

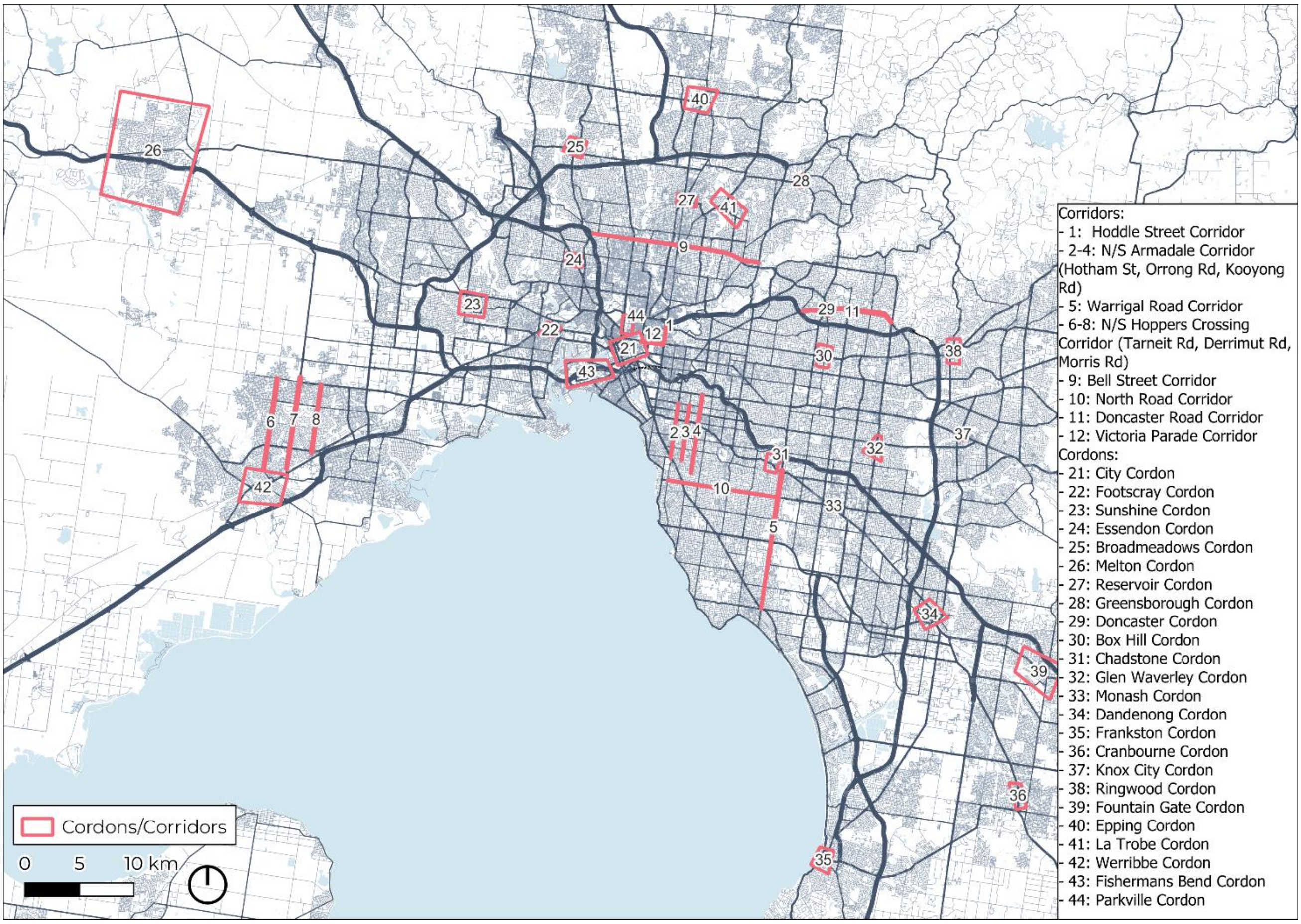


Figure 5-4 Activity centres and corridors definitions

While validation by activity centre and corridor is the weakest performing high priority metric, the Better Buses base model validation is a material improvement compared with the original base model, where we observed a 'poor' validation rating across multiple metrics.

Looking at activity centres and corridors where modelled boardings fall within 25 per cent of observed, in the Better Buses model the percentage of activity centres and corridors with boardings within 25 per cent of observed is sitting at around one-third across most time periods, with the interpeak slightly lower at 23 per cent (Table 5-8). This is an improvement across all time period, except the off-peak.

While bus boarding validation at an activity centre level receives an 'indicative' rating due to the high gradient across all time periods in both the original VITM and Better Buses model. However, as was the case with boardings by LGA, these results are considerably biased by the overestimation of bus boardings in Melbourne, as the CBD is one of the activity centres. When this activity centre is excluded, it appears that the model slightly underestimates boardings at activity centres, with only the PM peak period achieving a gradient within the target range (Table 5-10). Detailed cordon and corridor validation has been provided in the Appendix A.

Due to limitations in the data, we do not suggest any out of model adjustments specific to this metric. However, if adjustments are made at an LGA-level, we suggest applying a similar adjustment to corridors and activity centre within that LGA.

Table 5-8 Bus boardings by activity centre / corridor – within 25% of observed, original VITM and Better Buses models (Important)

TIME PERIOD	ORIGINAL 2018 MODEL		BETTER BUSES 2018 MODEL	
	ACTIVITY CENTRES / CORRIDORS WITHIN 25%	VALIDATION RATING	ACTIVITY CENTRES / CORRIDORS WITHIN 25%	VALIDATION RATING
AM (7 to 9AM)	25% (x)	Indicative	33%	Indicative
IP (9AM to 3PM)	17% (x)	Poor	23%	Indicative
PM (3 to 6PM)	29% (x)	Indicative	33%	Indicative
OP (6PM to 7AM)	42% (✓)	Satisfactory	33%	Indicative
Daily (24 hr)	21% (x)	Indicative	28%	Indicative

Table 5-9 Bus boardings by activity centre / corridor – scatterplots, original VITM and Better Buses models (Important)

TIME PERIOD	TARGET R^2	TARGET GRADIENT	ORIGINAL 2018 MODEL			BETTER BUSES 2018 MODEL		
			R^2	GRADIENT	VALIDATION RATING	R^2	GRADIENT	VALIDATION RATING
AM (7 to 9AM)	≥0.75	0.9 – 1.1	0.48 (x)	1.82 (x)	Poor	0.54 (x)	1.52 (x)	Indicative
IP (9AM to 3PM)			0.43 (x)	1.40 (x)		0.50 (x)	1.31 (x)	
PM (3 to 6PM)			0.75 (✓)	1.54 (x)		0.79 (✓)	1.44 (x)	
OP (6PM to 7AM)			0.73 (x)	2.14 (x)		0.79 (✓)	1.88 (x)	
Daily (24 hr)			0.62 (x)	1.71 (x)		0.68 (x)	1.55 (x)	

Table 5-10 Bus boardings by activity centre / corridor, initial 2018 base model excluding Melbourne CBD – scatterplots (Important)

TIME PERIOD	TARGET R^2	TARGET GRADIENT	ORIGINAL 2018 MODEL			BETTER BUSES 2018 MODEL		
			R^2	GRADIENT	VALIDATION RATING	R^2	GRADIENT	VALIDATION RATING
AM (7 to 9AM)	≥0.75	0.9 – 1.1	0.75 (✓)	0.84 (x)	Satisfactory	0.81 (✓)	0.73 (x)	Satisfactory
IP (9AM to 3PM)			0.61 (x)	0.76 (x)		0.71 (x)	0.74 (x)	
PM (3 to 6PM)			0.82 (✓)	0.96 (✓)		0.77 (✓)	1.03 (✓)	
OP (6PM to 7AM)			0.80 (✓)	0.84 (x)		0.79 (✓)	0.86 (x)	
Daily (24 hr)			0.77 (✓)	0.86 (x)		0.78 (✓)	0.85 (x)	

5.2 MONITORING METRICS

While the metrics presented in this section were not actively improved over the course of validating the Better Buses base model, they are summarised in this report to:

- Demonstrate that, over the course of improving bus demand metrics, global model validation remains good
- Highlight model limitations and weaknesses that may require consideration as VITM is used to evaluate the impacts of different types of bus reform

These validation metrics are presented for the Better Buses 2018 model only.

5.2.1 TRANSFERS

Validation of transfers between trains and buses / trams are shown in Figure 5-5 below. The data confidence rating is low and is unlikely to provide a genuine indication of how the model is validating (refer to Table 2-3 on Page 7 for detail on this data). However, the data is still useful in identifying trends between the observed data and the model. For example, the graph in Figure 5-5 suggests that the VITM significantly overestimates the number of transfers between the rail and bus/tram network. However, the high gradient is largely driven by City Loop stations – the top five railway stations with the largest difference between modelled and observed transfers are all City Loop railway stations (Table 5-11). The same analysis with these stations removed suggests a gradient of 1.49 and an R^2 of 0.89 (Figure 5-6), suggesting a slight overestimation but reasonable correlation between modelled and observed station transfers outside of the City Loop.

Tram / bus transfers from city loop stations can also be influenced by the coding of public transport fares in the CBD, which may overestimate demand (refer to the more detailed explanation provided in Table 4-1).

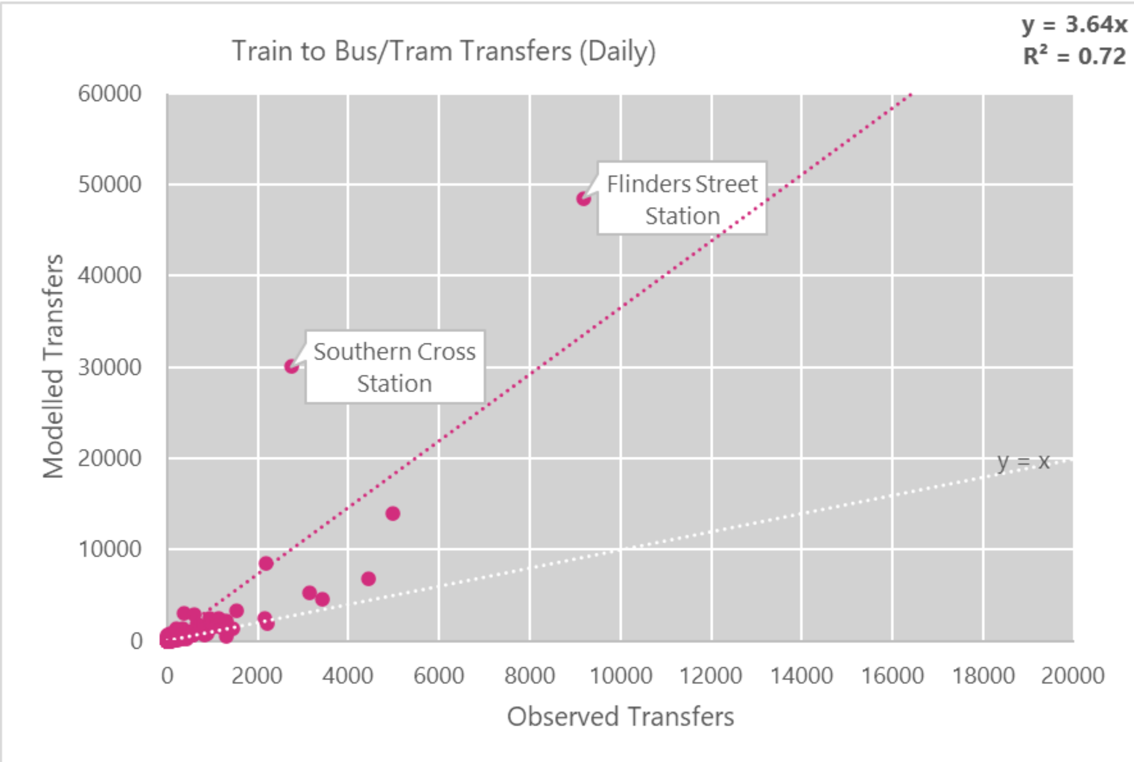


Figure 5-5 Train transfers to bus and tram, daily (Very important)

Table 5-11 Railway stations with the largest difference between modelled and observed transfers between trains and buses/trams (top five)

RAILWAY STATION	OBSERVED TRANSFERS	MODELLED TRANSFERS	PERCENTAGE DIFFERENCE	ABSOLUTE DIFFERENCE
Flinders Street Railway Station	9,188	48,492	428%	39,304
Southern Cross Railway Station	2,734	30,065	1000%	27,331
Melbourne Central Railway Station	4,964	14,021	182%	9,057
Parliament Railway Station	2,194	8,476	286%	6,282
Flagstaff Railway Station	369	3,056	728%	2,687

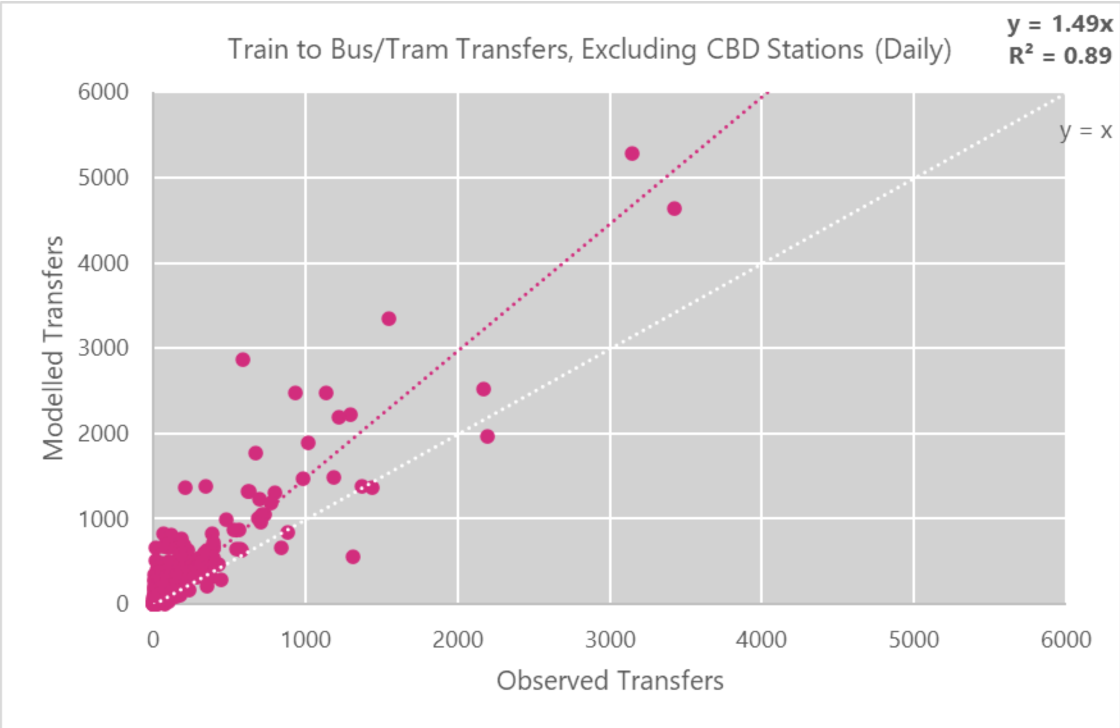


Figure 5-6 Train transfers to bus and tram, daily excluding City Loop Stations (Very important)

5.2.2 BUS TRAVEL TIMES

Bus in-vehicle travel time is calculated as follows:

— The highway link travel time is multiplied by a **factor of 1.4**, reflecting the additional delays incurred by buses due to acceleration / deceleration, dwell time at stops and conflicts with general traffic such as changing lanes and re-entering traffic after stopping. This is applied to links on the highway and arterial network.

— A delay of **48 seconds** per kilometre is applied to the route travel time, reflecting further travel time impacts of stop dwell times. This delay affects route sections operating on the arterial network only.

Note that there is also a perception weighting factor applied to bus trip in-vehicle travel times of 1.2, which is applied during route enumeration to calculate the generalised cost of public transport travel. However, this factor is not used in the calculation of bus network travel times.

Overall, VITM is consistently overestimating bus travel times, with modelled travel times around 20 per cent longer than observed across all time periods (shown in Figure 5-7 through Figure 5-10). As described above, the calculation of bus in-vehicle travel time is relatively complex, and several factors could be contributing to this:

— The overall modelled approach to representing bus in-vehicle travel times, including the additional delays reflecting acceleration / deceleration, traffic conflicts and dwell times, is resulting in buses travelling too slowly on the network

— There are undetected misspecifications in the base year network, including link speeds that are too slow, causes longer bus travel times.

— VITM generally overestimates the effects of congestion on travel times. This would affect general traffic as well as public transport modes using the bus network.

The scope of this project did not allow for detailed investigation of these theories. However, we completed a preliminary test to provide further insight into the source of the slow travel times by comparing modelled free-flow (i.e. uncongested) travel times by bus route (with on-board public transport crowding excluded) to observed bus travel times by route. The rationale behind this comparison is that:

— If free-flow bus route travel times are slow compared to observed, then the likely cause is network coding. This could include incorrect road network speed limits, or the generalised representation of stop dwell times in the bus travel time calculations.

— If free-flow bus route travel times are comparable to or faster than observed bus travel times, then the likely cause is that VITM is overestimating the effect of congestion on bus travel speeds in VITM.

This test indicated that, when the effects of congestion are removed, VITM's modelled bus travel times are faster than observed (Figure 5-11), pointing to an overestimation of the effect of congestion on bus travel speeds. It is not clear whether this affects general traffic as well as buses, as we did not undertake a highway assignment travel time validation as a part of this project, however by definition bus travel times are more heavily affected by congestion delays due to the additional travel time penalty factor of 1.4 described above.

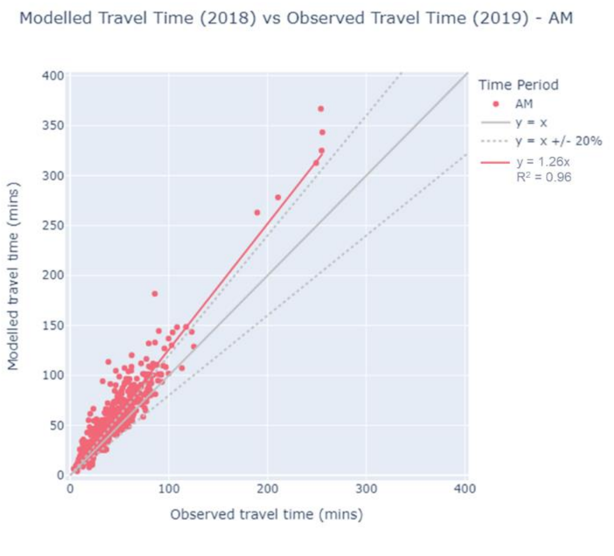


Figure 5-7 Travel time by route – observed (2019) vs modelled (2018), AM (Very important)

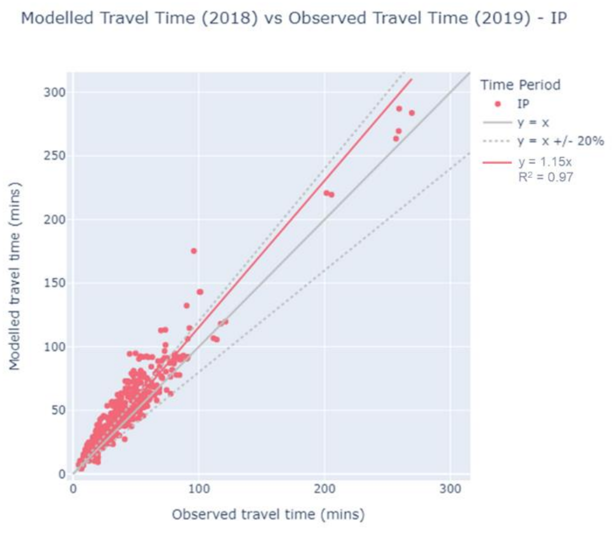


Figure 5-8 Travel time by route – observed (2019) vs modelled (2018), IP (Very important)

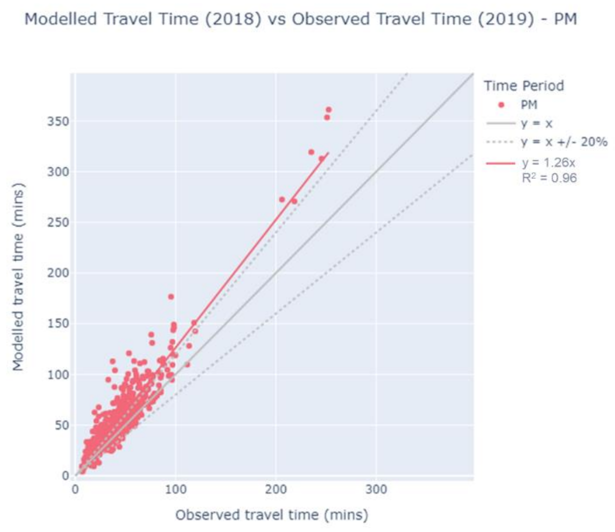


Figure 5-9 Travel time by route – observed (2019) vs modelled (2018), PM (Very important)

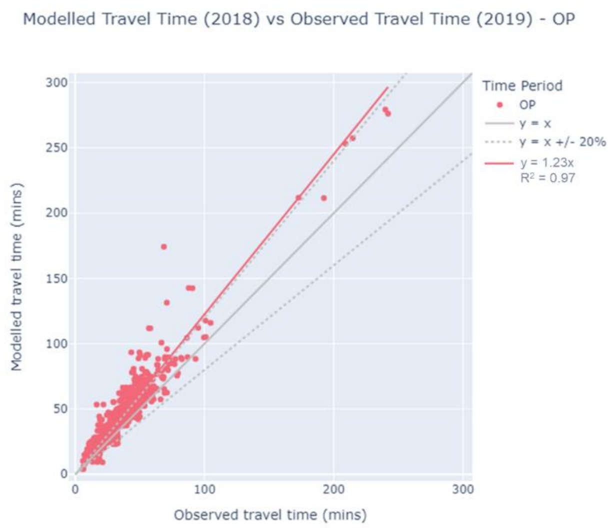


Figure 5-10 Travel time by route – observed (2019) vs modelled (2018), OP (Very important)

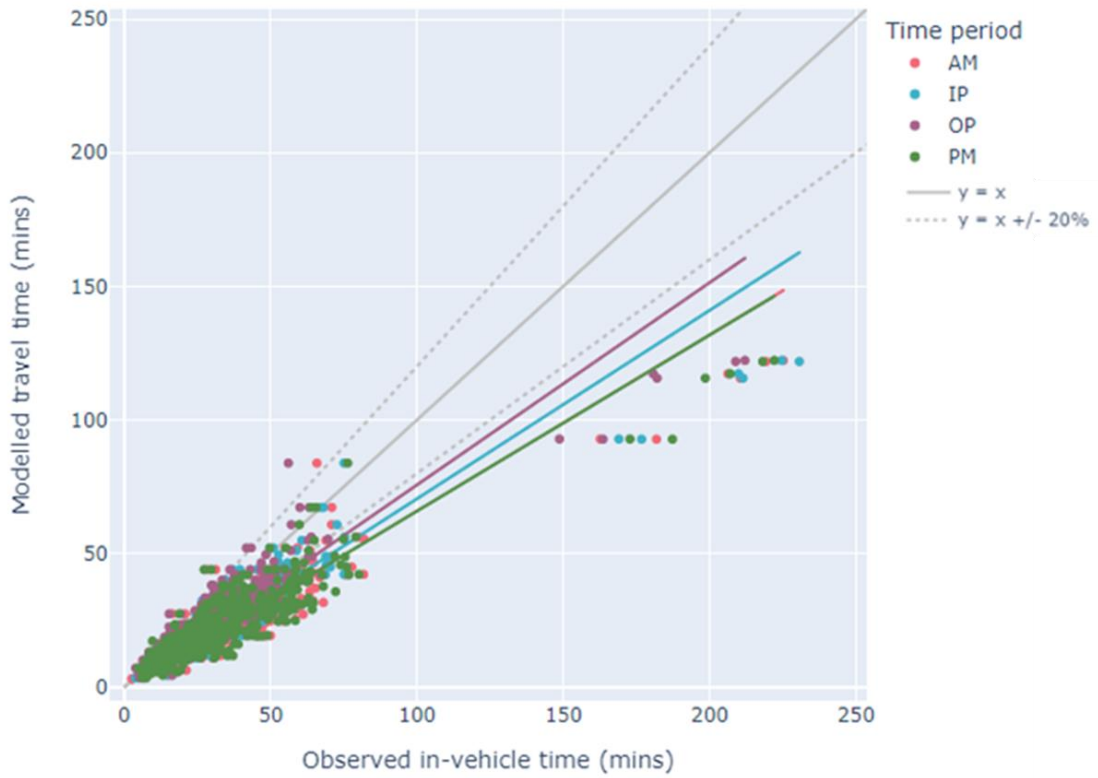


Figure 5-11 Travel time – observed in-vehicle time (2019) vs modelled free-flow travel time (2018)

5.2.3 PUBLIC TRANSPORT MODE SHARE AND BOARDINGS

Globally, the Better Buses base model is validating well across the public transport network, with system-wide boardings falling within ten per cent of observed across all time periods (Table 5.12 showing 2-hour equivalents). While V/Line demands are generally overestimated, this is consistent with the original 2018 base model and is not an issue for Better Buses given the project's metropolitan focus.

Table 5.12 Total public transport boardings by time period – 2-hour equivalents (Very important)

MODE	TIME PERIOD	OBSERVED	MODELLED	+/-	%	TARGET	VALIDATION RATING
Train	AM Period (2hr)	212,667	207,700	-4,967	-2% (✓)	±10%	Very good
	IP Period (2hr)	60,428	65,671	5,243	9% (✓)		
	PM Period (2hr)	169,849	170,097	248	0% (✓)		
	OP Period (2hr)	60,943	63,145	2,202	4% (✓)		
	Daily (24 hr)	831,551	849,297	17,746	2% (✓)		
V/Line	AM Period (2hr)	13,459	16,158	2,699	20% (x)	±10%	Indicative
	IP Period (2hr)	2,532	4,961	2,429	96% (x)		
	PM Period (2hr)	3,006	4,243	1,238	41% (x)		
	OP Period (2hr)	2,891	2,618	-273	-9% (✓)		
	Daily (24 hr)	34,236	45,400	11,164	33% (x)		
Tram	AM Period (2hr)	117,528	135,641	18,113	15% (x)	±10%	Very good
	IP Period (2hr)	74,228	68,533	-5,695	-8% (✓)		
	PM Period (2hr)	119,817	124,417	4,600	4% (✓)		
	OP Period (2hr)	49,195	51,350	2,156	4% (✓)		
	Daily (24 hr)	667,523	681,919	14,396	2% (✓)		
Metropolitan Bus	AM Period (2hr)	97,542	92,393	-5,149	-5% (✓)	±10%	Very good
	IP Period (2hr)	42,789	43,869	1,080	3% (✓)		
	PM Period (2hr)	79,769	85,994	6,225	8% (✓)		
	OP Period (2hr)	18,845	27,633	8,788	47% (x)		
	Daily (24 hr)	402,097	435,892	33,795	8% (✓)		
Total	AM Period (2hr)	441,196	451,892	10,696	2% (✓)	±10%	Very good
	IP Period (2hr)	179,977	183,034	3,057	2% (✓)		
	PM Period (2hr)	372,441	384,751	12,310	3% (✓)		
	OP Period (2hr)	131,874	144,746	12,872	10% (✓)		
	Daily (24 hr)	1,935,407	2,012,508	77,101	4% (✓)		

5.2.4 TRAFFIC

Traffic validation by screenline, presented in Table 5.13 below, achieved both gradient and R^2 targets across all time periods and directions of travel.

Table 5.13 Traffic screenlines by time period (Important)

METRIC	OBSERVED	MODELLED	+/-	%	GRADIENT (0.9 - 1.1)	R^2 (≥0.85)	VALIDATION RATING
SCREENLINE TOTALS - ALL VEHICLES - AM (2HR)							
Inbound	1,074,419	1,128,580	54,161	5%	1.05 (✓)	0.99 (✓)	Very good
Outbound	757,009	756,430	-580	0%	1.01 (✓)	0.98 (✓)	
Two-Way	1,831,429	1,885,010	53,581	3%	1.03 (✓)	0.99 (✓)	
SCREENLINE TOTALS - ALL VEHICLES - PM (2HR)							
Inbound	839,496	841,525	2,029	0%	1.02 (✓)	0.98 (✓)	Very good
Outbound	1,075,387	1,132,988	57,602	5%	1.06 (✓)	0.99 (✓)	
Two-Way	1,914,882	1,974,513	59,631	3%	1.04 (✓)	0.99 (✓)	
SCREENLINE TOTALS - ALL VEHICLES - DAILY (24 HR)							
Inbound	6,405,574	6,474,575	69,002	1%	1.01 (✓)	0.99 (✓)	Very good
Outbound	6,383,290	6,398,539	15,249	0%	1.01 (✓)	1.00 (✓)	
Two-Way	12,788,864	12,873,114	84,250	1%	1.01 (✓)	1.00 (✓)	

5.3 TRIP LENGTHS BY MODE

Through the process of refining VITM's representation of bus travel demands, we monitored trip lengths across all motorised modes to ensure that these remained stable into the Better Buses 2018 model. As shown in Figure 5-12 and Figure 5-13, public transport trip lengths are nearly identical between model versions. Private vehicle trips are on average slightly longer in the Better Buses model (between 300 and 400 metres) compared with the original VITM. This shift is likely to a result of the change in zone system, resulting in subtle changes to the total network distance travelled between travel zones across the modelled network.

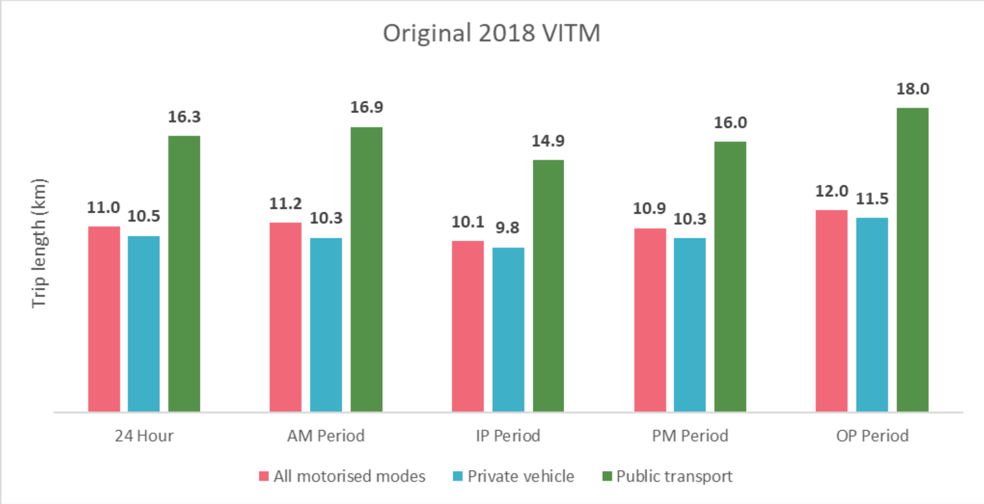


Figure 5-12 Average trip lengths by mode, Original 2018 VITM

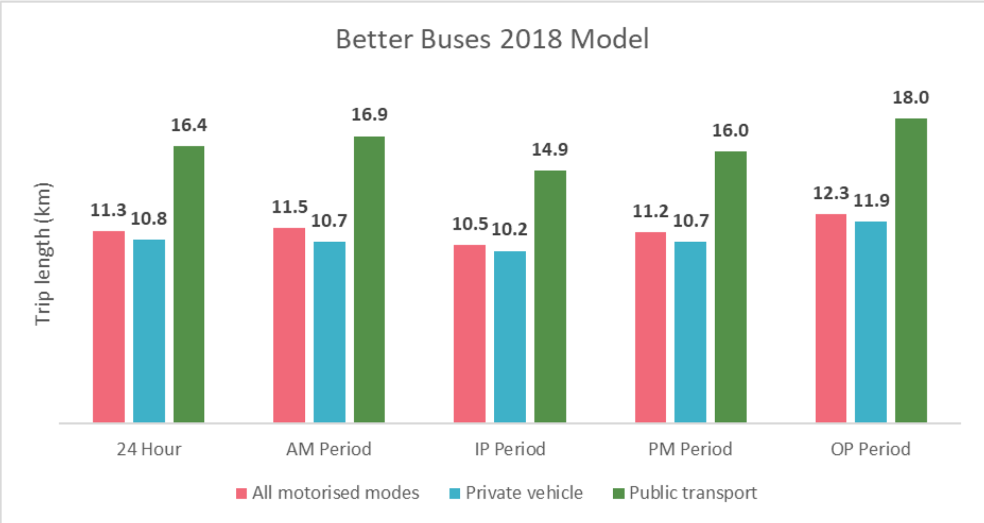


Figure 5-13 Average trip lengths by mode, Better Buses model

5.4 RESPONSE VALIDATION

To have confidence in the Better Buses base model's response to different types of bus reform, we have also undertaken a response validation to test the demand response to changes in services that are likely to form part of key reform packages. Key sensitivity tests examined using the Better Buses base model were:

— A system-wide increase in service frequencies of 20 per cent

— A reduction in in-vehicle time of 10 per cent as a proxy for increased service speeds[2]

— A reduction in peak boarding penalties from 12 to 11 (~9 per cent reduction).

The results of these sensitivity tests, the implied demand elasticities, and the extent to which the elasticities fit with guidance, literature and case studies has been summarised in Table 5-14, with further analysis provided in the sections below.

[2] This was implemented by reducing the transit time for buses by 10 per cent

Table 5-14 Model response validation summary

REFORM	DESCRIPTION	PROXY VITM OUTPUT MEASURE	GUIDANCE RANGE AND SOURCE	GUIDANCE RANGE	IMPLIED VITM ELASTICITY
Operational reform	Adjusted frequency, Longer operating hours, Better integration between buses and other modes	Bus boardings vs. service frequency	DoT	0.2 to 0.6	0.42 (✓)
			ATAP	0.2 to 0.7	
			Currie and Wallis (2008)	Case studies suggest demand could grow up to 200% in response to a frequency increase of 100%.	
Network redesign	More direct bus network, Realignment of existing routes, Introduction of new routes	Bus boardings vs. in-vehicle time	DoT	-0.1 to -0.5	Implied elasticity varies considerably between LGAs, but average elasticities are: Daily: -1.07, AM: -1.08, PM: -1.04 (x)
			DfT (UK)	-0.6	
			ATAP	-0.1 to -0.7	
Bus priority lanes	Through bus lanes (focus on inner and middle parts of Melbourne)		Transport Research Laboratory	-0.4 to -0.7	
Bus Rapid Transit	Selection of routes and corridors to become BRT	Bus boardings vs. bus boarding penalty[3]	Currie (2005)	'Lack of primary evidence' on penalties for BRT systems. Initial research suggests BRT systems would perform well compared relative to other public transport modes	AM: -0.95 PM: -0.70 E.g., a 1-minute reduction in penalty causes an 8.6% increase in AM peak boardings (N/A)

[3] A boarding penalty is a parameter applied to capture, all else being equal, a preference by travellers to use one mode over another from reasons that are not explicitly observed in VITM. This includes the availability of timetable and service information, service reliability and comfort on board.

5.4.1 FREQUENCY

We tested VITM's response to increasing service frequencies by applying a system-wide increase of 20 per cent. VITM's implied demand elasticity of 0.42 is consistent with guidance, the global elasticity and elasticities across metropolitan Melbourne LGAs all falling within the range indicated in ATAP and DoT dynamic validation guidance (Figure 5-14). This elasticity means that a 20 per cent increase in frequency results in an 8 per cent increase in bus boardings per day.

Figure 5-14 Bus boardings vs. service frequency elasticities

5.4.2 IN-VEHICLE TIME

As a proxy for increased service speeds, we reduced VITM's in-vehicle time by 10 per cent to understand how bus boardings responded. VITM's implied global elasticity fell outside of the recommended guidance range, sitting at over -1.0, meaning a 10 per cent reduction in travel time resulted in an increase in daily boardings of 12 per cent.

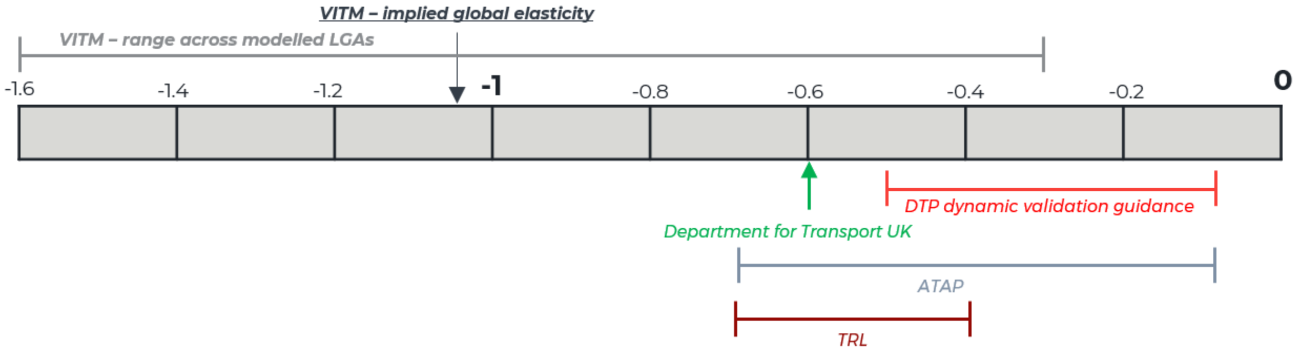


Figure 5-15 Bus boardings vs. in-vehicle time elasticities

Unlike with frequency elasticities, there was a high level of variability in the demand response to lower in-vehicle times across different LGAs. Elasticities ranged from -0.3 (in the Monash LGA) to -1.6 (Boroondara and Stonnington). Generally, LGAs in the inner and middle parts of Melbourne showed higher sensitivity to reduce in-vehicle times, while outer LGAs had a lower sensitivity (see Figure 5-16). This suggests that, where congestion levels are higher and opportunities to travel by public transport are greater, the model predicts a higher propensity for travellers to switch modes in response to more competitive travel times from an alternate mode.

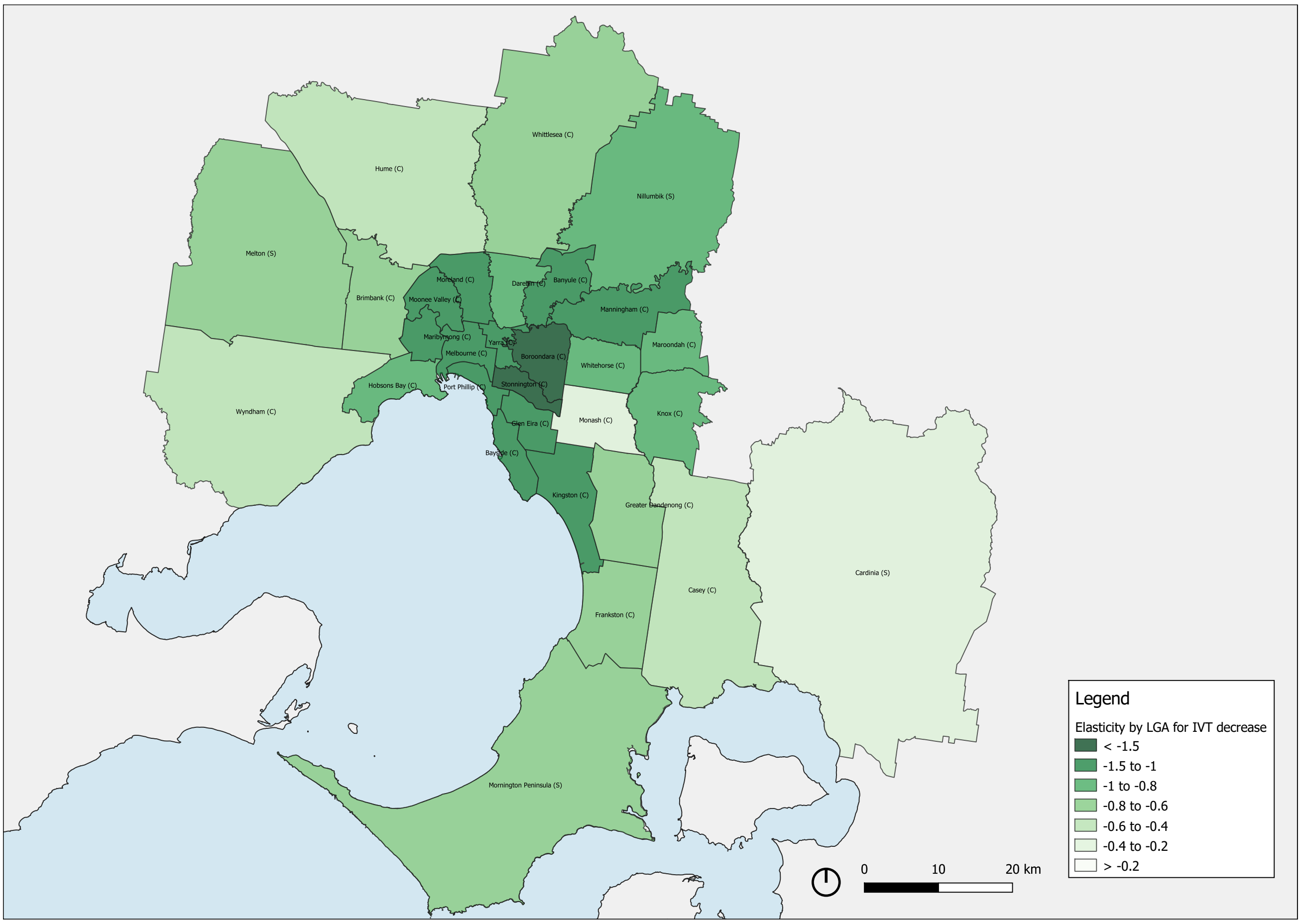


Figure 5-16 In-vehicle time demand elasticity by LGA

Note that using in-vehicle time to understand demand response to speed improvements is a proxy for the impacts of reforms that improve bus travel times, like bus lanes. As described in an earlier section, in-vehicle travel time for buses is a function of highway link time and link distance to replicate the various source of delays (acceleration / deceleration, congestion delays, traffic interactions, junction delays, dwell times etc.). In applying an adjustment to in-vehicle time, we are assuming an improvement across all of these sources of delay, as well as improved ‘perception’ of in-vehicle time on bus services. While this may realistically occur where a reform involves materially improvements (for example towards Bus Rapid Transit-style system), many of the more incremental reforms being tested in the Better Buses project will only address some of these types of delay (for example, reducing the impact of traffic congestion on buses).

Given that we are not intending to change in-vehicle time as part of implementing any reform scenarios, this higher-than-expected sensitivity may not impact the realism of the modelled scenarios and we do not think it compromises the model’s usefulness in informing the likely impact of reform scenarios that improve the speed of bus service in Melbourne. However, the test has alerted us to the potential that the model could overestimate an increase in bus patronage under such conditions. We will check the results of each scenario in detail, particularly along corridors where bus priority has been implemented or where bus routes have been rationalised, to ensure that the demand uplift is reasonable.

5.4.3 BOARDING PENALTIES

VITM’s bus demand is also quite sensitive to changes in bus boarding penalties, with a 1-minute reduction in penalty causing an 8.6 per cent increase in AM peak boardings. While there is no explicit modelling guidance on an appropriate level of sensitivity to mode penalties, this type of variable is an important way to reflect the impact of higher passenger perceptions of the BRT ‘brand’ compared to other buses. Research by Currie (2005) indicated that there could be an argument to assume that BRT services may attract penalties comparable to other public transport modes, suggesting that there may be a case to use the same penalties for BRT as for trams and trains.

However, sensitivity testing indicated that this approach would result in a substantial increase in bus demand, with the further 3-minute reduction in boarding penalties (to match 8 minutes boarding penalties trams and trains) resulting in an increase in modelled bus boardings of approximately 25 per cent. Table 5-15 shows the original and Better Buses boarding penalties by mode.

Table 5-15 Boarding penalties by mode and time period, original base and Better Buses 2018 model

TIME PERIOD / MODE	BUS AND SMARTBUS		TRAM / RAIL
	ORIGINAL BASE	BETTER BUSES[4]	ORIGINAL BASE AND BETTER BUSES
Peak	12	11	8
Off-peak	8	8	5

[4] In the Better Buses model, the boarding penalties for standard and SmartBus services were reduced by 1 minute in both the peak (from 12 to 11 minutes) and off peak (from 9 to 8 minutes) periods, to address the underestimation of bus boardings in outer LGAs.

6 CONCLUSIONS

Overall, we have made considerable improvements to the representation of bus demand in VITM. Highlights include:

— Better geographic representation of bus demands, with a significantly higher percentage of modelled LGA bus boardings falling within 25 per cent of observed by time period, or 15 per cent across the day.

— A strong improvement in the representation of bus demand by route, improving the validation rating from 'indicative' to 'good' with 70 per cent of validation elements hitting the target criteria

— Better representation of activity centre and corridor bus boardings, with an increase in the percentage of areas with boardings within 25 per cent of observed compared with the original 2018 base year. However, note that confidence levels in the observed boarding data at this level of geographic detail are relatively low.

Based on these improvements and given the focus of bus reform modelling will be on the relative impacts of each type of reform rather than the absolute bus demand forecast in each scenario, we recommend using the Better Buses 2018 model to support the Better Buses project. There are, however, several residual limitations in the model.

Despite the range of activities undertaken to improve VITM with the Better Buses project objectives in mind, there are several residual limitations. These include:

— High bus boardings in the Melbourne, Yarra and Port Phillip LGAs (noting that material improvement has been achieved compared with our starting point). The Yarra Ranges LGA remains low compared to observed.

— High sensitivity of bus boardings to changes in bus in-vehicle time

— Uncertainty in the level of validation achieved in corridors/activity centres and for transfers between rail and buses/trams due to the limited availability of robust observed data

— Testing of the model's sensitivity to changes in bus in-vehicle time resulted in unexpectedly high addition bus boardings, which suggests an overestimation of the effects of congestion on travel speeds. This has implications when interpreting modelling results based on bus reforms affecting the speed of bus services including priority measures. Where the modelled demand response is higher than seems reasonable for these types of reforms, we will undertake out-of-model adjustments to develop more realistic bus demands for those scenarios using the guidance elasticities as a reference.

<table>
<tr><th>MODELLED OUTPUTS</th><th>VALIDATION METRIC</th><th>VALIDATION RATING</th><th>RECOMMENDED FORECASTING APPROACH</th></tr>
<tr><td>Model-wide boardings</td><td>Model-wide bus boardings</td><td>Very good</td><td>Forecasts from the model scenarios can generally be used without adjustments.</td></tr>
<tr><td rowspan="5">Bus boardings by LGA</td><td>Bus boardings by LGA</td><td>Good</td><td rowspan="5">— Forecasts from model scenarios can generally be used without adjustments.
— Where the focus of a scenario is on the absolute bus boardings by LGA, we recommend adjusting base year observed data using growth forecast by the model, particularly within the Melbourne, Yarra and Port Phillip and Yarra Ranges LGAs.</td></tr>
<tr><td>Bus boardings by LGA (excluding Melbourne LGA)</td><td>Very good</td></tr>
<tr><td rowspan="3">Total bus boardings by LGA (within 25% by time period, 15% daily)</td><td>AM and IP: Satisfactory</td></tr>
<tr><td>PM: Good</td></tr>
<tr><td>OP and daily: Indicative</td></tr>
<tr><td rowspan="2">Bus boardings by route</td><td>Bus boardings by route (scatterplot)</td><td>Good</td><td rowspan="2">— Forecasts from model scenarios can generally be used without adjustments, particularly along busy bus routes and</td></tr>
<tr><td>Bus boardings by route (GEH)</td><td>Very good</td></tr>
</table>

MODELLED OUTPUTS	VALIDATION METRIC	VALIDATION RATING	RECOMMENDED FORECASTING APPROACH
	Bus boardings by route, within 25% of observed	Indicative	where multiple bus routes are grouped together for the purpose of analysis — Caution should be exercised in using forecasts for routes with low passenger numbers. Where absolutely necessary, we recommend adjusting base year observed data using growth forecast by the model for these routes.
Boardings by activity centre and corridor	Bus boardings by activity centre and corridor within 25%	Indicative	There is uncertainty in the appropriateness of observed data at the level of geographic detail required for these metrics. Caution should be exercised when using forecasts from model scenario. Due to limitations in the data, we do not suggest any out of model adjustments specific to this metric. However, if adjustments are made at an LGA-level, we can apply a similar adjustment to corridors and activity centre within that LGA.
	Bus boardings by activity centre and corridor (scatterplot)	Indicative	
	Bus boardings by activity centre and corridor (scatterplot, excluding Melbourne LGA)	Satisfactory	
Bus transfers	Transfers	Poor	While the is model almost certainly over-estimating transfers at City Loop stations, the quality of the observed data is unclear. VITM is still useful to understand general transfer trends because of bus reform, for example overall growth in transfers and key transfer hubs on the network. However, we recommend caution in using absolute transfer numbers, particularly at specific locations on the network.
Bus travel times	Bus travel times	Poor	Bus travel times are slow compared to observed by around 20 per cent. While this does not appear to substantially impact the model's ability to reasonably reflect observed bus travel, we may consider making out of model adjustments to develop a 'range' of travel times for routes / corridors where required.
Global travel demand	Public transport boardings / mode share	Very good	Forecasts from the model scenarios can be used without adjustments.
	Traffic demand	Very good	

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APPENDIX A

ADDITIONAL VALIDATION OUTPUTS FOR THE BETTER BUSES 2018 MODEL

A1 BUS BOARDINGS BY LGA

Table A.1 Bus boardings by LGA, daily (target ±15%)

BUS BOARDINGS BY LGA - DAILY (24H)	OBSERVED	MODELLED	+/-	%	CRITERIA
Banyule (C)	11,864	8,901	-2,963	-25%	Not Satisfied
Bayside (C)	5,999	7,512	1,514	25%	Not Satisfied
Boroondara (C)	9,351	9,753	402	4%	Satisfied
Brimbank (C)	15,393	12,336	-3,057	-20%	Not Satisfied
Cardinia (S)	1,900	1,551	-350	-18%	Not Satisfied
Casey (C)	19,366	10,900	-8,466	-44%	Not Satisfied
Darebin (C)	19,552	15,934	-3,619	-19%	Not Satisfied
Frankston (C)	10,737	5,847	-4,890	-46%	Not Satisfied
Glen Eira (C)	10,783	10,508	-275	-3%	Satisfied
Greater Dandenong (C)	18,739	12,819	-5,921	-32%	Not Satisfied
Hobsons Bay (C)	6,006	5,210	-796	-13%	Not Satisfied
Hume (C)	15,171	14,192	-979	-6%	Satisfied
Kingston (C)	11,905	10,251	-1,653	-14%	Satisfied
Knox (C)	11,571	9,887	-1,684	-15%	Satisfied
Manningham (C)	16,192	15,611	-581	-4%	Satisfied
Maribyrnong (C)	13,131	16,800	3,669	28%	Not Satisfied
Maroondah (C)	10,657	7,583	-3,075	-29%	Not Satisfied
Melbourne (C)	25,160	76,377	51,217	204%	Not Satisfied
Melton (S)	4,719	5,889	1,170	25%	Not Satisfied
Monash (C)	43,906	53,878	9,972	23%	Not Satisfied
Moonee Valley (C)	10,722	10,258	-464	-4%	Satisfied
Moreland (C)	11,896	11,782	-114	-1%	Satisfied
Mornington Peninsula (S)	3,913	2,452	-1,462	-37%	Not Satisfied
Nillumbik (S)	2,854	2,610	-245	-9%	Satisfied
Port Phillip (C)	3,894	8,999	5,105	131%	Not Satisfied
Stonnington (C)	6,534	8,691	2,157	33%	Not Satisfied
Whitehorse (C)	28,541	30,825	2,284	8%	Satisfied
Whittlesea (C)	14,780	9,830	-4,950	-33%	Not Satisfied
Wyndham (C)	21,142	19,111	-2,031	-10%	Satisfied
Yarra (C)	6,455	16,298	9,843	152%	Not Satisfied
Yarra Ranges (S)	9,262	3,297	-5,965	-64%	Not Satisfied
Total	*402,097*	*435,892*	*33,795*	8%	Satisfied

Table A.2 Bus boardings by LGA, AM peak 2hr (target ±25%)

BUS BOARDINGS BY LGA - DAILY (AM-2H)	OBSERVED	MODELLED	+/-	%	CRITERIA
Banyule (C)	3,083	1,721	-1,363	-44%	Not Satisfied
Bayside (C)	1,693	1,908	215	13%	Satisfied
Boroondara (C)	3,380	2,692	-688	-20%	Satisfied
Brimbank (C)	3,250	2,176	-1,074	-33%	Not Satisfied
Cardinia (S)	607	365	-242	-40%	Not Satisfied
Casey (C)	5,133	2,499	-2,634	-51%	Not Satisfied
Darebin (C)	3,629	2,965	-664	-18%	Satisfied
Frankston (C)	2,325	1,200	-1,125	-48%	Not Satisfied
Glen Eira (C)	2,983	2,696	-287	-10%	Satisfied
Greater Dandenong (C)	3,900	2,954	-946	-24%	Satisfied
Hobsons Bay (C)	1,458	1,191	-267	-18%	Satisfied
Hume (C)	3,760	2,467	-1,293	-34%	Not Satisfied
Kingston (C)	3,063	1,986	-1,076	-35%	Not Satisfied
Knox (C)	3,770	2,517	-1,253	-33%	Not Satisfied
Manningham (C)	5,943	4,491	-1,452	-24%	Satisfied
Maribyrnong (C)	2,843	2,789	-54	-2%	Satisfied
Maroondah (C)	2,897	1,721	-1,176	-41%	Not Satisfied
Melbourne (C)	4,076	12,366	8,289	203%	Not Satisfied
Melton (S)	1,474	1,634	160	11%	Satisfied
Monash (C)	8,258	12,060	3,802	46%	Not Satisfied
Moonee Valley (C)	2,798	2,453	-346	-12%	Satisfied
Moreland (C)	2,808	2,326	-482	-17%	Satisfied
Mornington Peninsula (S)	1,116	514	-602	-54%	Not Satisfied
Nillumbik (S)	1,105	786	-319	-29%	Not Satisfied
Port Phillip (C)	1,114	2,320	1,206	108%	Not Satisfied
Stonnington (C)	806	1,783	977	121%	Not Satisfied
Whitehorse (C)	6,723	7,079	356	5%	Satisfied
Whittlesea (C)	3,583	2,146	-1,437	-40%	Not Satisfied
Wyndham (C)	5,613	4,455	-1,158	-21%	Satisfied
Yarra (C)	1,527	3,277	1,750	115%	Not Satisfied
Yarra Ranges (S)	2,824	856	-1,968	-70%	Not Satisfied
Total	*97,542*	*92,393*	*-5,149*	-5%	Satisfied

Table A.3 Bus boardings by LGA, IP 2hr (target ±25%)

BUS BOARDINGS BY LGA - DAILY (IP-2H)	OBSERVED	MODELLED	+/-	%	CRITERIA
Banyule (C)	1,287	868	-419	-33%	Not Satisfied
Bayside (C)	561	726	165	29%	Not Satisfied
Boroondara (C)	843	1,079	235	28%	Not Satisfied
Brimbank (C)	1,965	1,115	-850	-43%	Not Satisfied
Cardinia (S)	157	131	-26	-16%	Satisfied
Casey (C)	1,896	1,045	-850	-45%	Not Satisfied
Darebin (C)	2,788	1,757	-1,032	-37%	Not Satisfied
Frankston (C)	1,189	620	-569	-48%	Not Satisfied
Glen Eira (C)	1,114	1,135	20	2%	Satisfied
Greater Dandenong (C)	2,301	1,189	-1,113	-48%	Not Satisfied
Hobsons Bay (C)	708	486	-222	-31%	Not Satisfied
Hume (C)	1,753	1,630	-123	-7%	Satisfied
Kingston (C)	1,229	929	-300	-24%	Satisfied
Knox (C)	1,060	890	-170	-16%	Not Satisfied
Manningham (C)	1,521	1,660	138	9%	Satisfied
Maribyrnong (C)	1,704	2,263	559	33%	Not Satisfied
Maroondah (C)	810	643	-168	-21%	Satisfied
Melbourne (C)	2,239	7,321	5,082	227%	Not Satisfied
Melton (S)	544	600	57	10%	Satisfied
Monash (C)	4,950	5,303	354	7%	Satisfied
Moonee Valley (C)	986	1,017	31	3%	Satisfied
Moreland (C)	1,521	1,266	-255	-17%	Satisfied
Mornington Peninsula (S)	369	281	-88	-24%	Satisfied
Nillumbik (S)	247	209	-38	-15%	Satisfied
Port Phillip (C)	398	937	539	135%	Not Satisfied
Stonnington (C)	721	985	264	37%	Not Satisfied
Whitehorse (C)	2,858	3,023	165	6%	Satisfied
Whittlesea (C)	1,681	981	-699	-42%	Not Satisfied
Wyndham (C)	2,002	1,630	-372	-19%	Satisfied
Yarra (C)	661	1,860	1,198	181%	Not Satisfied
Yarra Ranges (S)	726	290	-435	-60%	Not Satisfied
Total	1,287	868	-419	-33%	Not Satisfied

Table A.4 Bus boardings by LGA, PM peak 2hr (target ±25%)

BUS BOARDINGS BY LGA - DAILY (PM-2H)	OBSERVED	MODELLED	+/-	%	CRITERIA
Banyule (C)	2,375	1,897	-478	-20%	Satisfied
Bayside (C)	1,216	1,428	212	17%	Satisfied
Boroondara (C)	1,778	1,661	-116	-7%	Satisfied
Brimbank (C)	2,747	2,854	106	4%	Satisfied
Cardinia (S)	397	385	-13	-3%	Satisfied
Casey (C)	4,006	2,480	-1,526	-38%	Not Satisfied
Darebin (C)	3,531	3,188	-343	-10%	Satisfied
Frankston (C)	2,354	1,245	-1,109	-47%	Not Satisfied
Glen Eira (C)	1,968	1,712	-256	-13%	Satisfied
Greater Dandenong (C)	3,512	2,565	-947	-27%	Not Satisfied
Hobsons Bay (C)	1,040	1,016	-24	-2%	Satisfied
Hume (C)	2,788	2,995	208	7%	Satisfied
Kingston (C)	2,465	2,414	-51	-2%	Satisfied
Knox (C)	2,223	2,016	-207	-9%	Satisfied
Manningham (C)	2,521	2,482	-39	-2%	Satisfied
Maribyrnong (C)	2,165	2,395	230	11%	Satisfied
Maroondah (C)	2,714	1,651	-1,063	-39%	Not Satisfied
Melbourne (C)	5,957	15,564	9,607	161%	Not Satisfied
Melton (S)	699	1,022	323	46%	Not Satisfied
Monash (C)	9,589	11,534	1,945	20%	Satisfied
Moonee Valley (C)	2,377	1,940	-437	-18%	Satisfied
Moreland (C)	1,978	2,048	70	4%	Satisfied
Mornington Peninsula (S)	899	477	-423	-47%	Not Satisfied
Nillumbik (S)	492	501	9	2%	Satisfied
Port Phillip (C)	631	1,322	690	109%	Not Satisfied
Stonnington (C)	1,527	1,621	94	6%	Satisfied
Whitehorse (C)	5,874	6,240	366	6%	Satisfied
Whittlesea (C)	2,419	2,153	-266	-11%	Satisfied
Wyndham (C)	3,972	3,953	-19	0%	Satisfied
Yarra (C)	1,224	2,566	1,342	110%	Not Satisfied
Yarra Ranges (S)	2,329	669	-1,660	-71%	Not Satisfied
Total	*79,769*	*85,994*	*6,225*	8%	Satisfied

Table A.5 Bus boardings by LGA, OP 2hr (target ±25%)

BUS BOARDINGS BY LGA - DAILY (OP-2H)	OBSERVED	MODELLED	+/-	%	CRITERIA
Banyule (C)	453	577	124	27%	Not Satisfied
Bayside (C)	267	428	162	61%	Not Satisfied
Boroondara (C)	258	444	186	72%	Not Satisfied
Brimbank (C)	709	845	136	19%	Satisfied
Cardinia (S)	75	72	-4	-5%	Satisfied
Casey (C)	846	515	-331	-39%	Not Satisfied
Darebin (C)	754	972	218	29%	Not Satisfied
Frankston (C)	437	306	-131	-30%	Not Satisfied
Glen Eira (C)	502	614	112	22%	Satisfied
Greater Dandenong (C)	889	817	-72	-8%	Satisfied
Hobsons Bay (C)	289	346	58	20%	Satisfied
Hume (C)	657	781	124	19%	Satisfied
Kingston (C)	486	619	133	27%	Not Satisfied
Knox (C)	429	559	130	30%	Not Satisfied
Manningham (C)	635	806	171	27%	Not Satisfied
Maribyrnong (C)	642	1,210	568	88%	Not Satisfied
Maroondah (C)	419	486	67	16%	Satisfied
Melbourne (C)	1,811	6,234	4,423	244%	Not Satisfied
Melton (S)	189	307	118	63%	Not Satisfied
Monash (C)	2,138	2,869	731	34%	Not Satisfied
Moonee Valley (C)	466	615	148	32%	Not Satisfied
Moreland (C)	519	862	343	66%	Not Satisfied
Mornington Peninsula (S)	114	126	12	11%	Satisfied
Nillumbik (S)	90	149	58	65%	Not Satisfied
Port Phillip (C)	213	628	415	195%	Not Satisfied
Stonnington (C)	425	507	82	19%	Satisfied
Whitehorse (C)	1,478	1,772	295	20%	Satisfied
Whittlesea (C)	842	503	-339	-40%	Not Satisfied
Wyndham (C)	1,188	1,279	91	8%	Satisfied
Yarra (C)	369	1,198	829	225%	Not Satisfied
Yarra Ranges (S)	256	189	-67	-26%	Not Satisfied
Total	453	577	124	27%	Not Satisfied

A2 BUS BOARDINGS BY CORRIDOR AND ACTIVITY CENTRE

Table A.6 Bus boardings by corridor and activity centre, daily (target ±25%)

BUS BOARDINGS BY CORDON DAILY - (24HR)	OBSERVED	MODELLED	+/-	%	CRITERIA
City Cordon	14,855	44,054	29,199	197%	Not Satisfied
Box Hill Cordon	9,226	7,100	-2,126	-23%	Satisfied
Broadmeadows Cordon	2,709	2,206	-502	-19%	Satisfied
Chadstone Cordon	3,787	2,131	-1,656	-44%	Not Satisfied
Cranbourne Cordon	3,153	1,181	-1,972	-63%	Not Satisfied
Dandenong Cordon	8,084	3,658	-4,426	-55%	Not Satisfied
Doncaster Cordon	3,253	2,254	-998	-31%	Not Satisfied
Epping Cordon	2,649	1,531	-1,117	-42%	Not Satisfied
Essendon Cordon	2,143	2,156	13	1%	Satisfied
Fishermans Bend Cordon	2,017	4,082	2,064	102%	Not Satisfied
Footscray Cordon	5,620	6,763	1,143	20%	Satisfied
Fountain Gate Cordon	2,595	1,053	-1,542	-59%	Not Satisfied
Frankston Cordon	4,002	2,428	-1,574	-39%	Not Satisfied
Glen Waverley Cordon	4,128	3,072	-1,056	-26%	Not Satisfied
Greensborough Cordon	2,080	1,229	-851	-41%	Not Satisfied
Knox City Shopping Centre Cordon	1,896	1,013	-882	-47%	Not Satisfied
La Trobe Cordon	3,459	2,958	-501	-14%	Satisfied
Melton Cordon	3,162	2,922	-240	-8%	Satisfied
Monash Cordon	9,049	12,570	3,521	39%	Not Satisfied
Parkville Cordon	1,621	7,344	5,723	353%	Not Satisfied
Reservoir Cordon	3,291	1,532	-1,759	-53%	Not Satisfied
Ringwood Cordon	3,020	2,320	-700	-23%	Satisfied
Sunshine Cordon	4,854	2,955	-1,899	-39%	Not Satisfied
Werribee Cordon	3,443	1,659	-1,784	-52%	Not Satisfied
Hoddle Street Corridor, NB	779	1,985	1,206	155%	Not Satisfied
Hoddle Street Corridor, SB	1,049	3,198	2,149	205%	Not Satisfied
N/S Armadale Corridor, NB	935	1,483	548	59%	Not Satisfied
N/S Armadale Corridor, SB	546	790	243	45%	Not Satisfied
Warrigal Road Corridor, NB	1,958	3,309	1,351	69%	Not Satisfied
Warrigal Road Corridor, SB	1,792	2,111	318	18%	Satisfied
N/S Hoppers Crossing Corridor, NB	1,146	1,484	338	29%	Not Satisfied
N/S Hoppers Crossing Corridor, SB	1,427	2,607	1,180	83%	Not Satisfied
Bell Street Corridor, EB	2,745	3,388	643	23%	Satisfied

BUS BOARDINGS BY CORDON DAILY - (24HR)	OBSERVED	MODELLED	+/-	%	CRITERIA
Bell Street Corridor, WB	2,608	3,163	556	21%	Satisfied
North Road Corridor, EB	1,899	1,096	-803	-42%	Not Satisfied
North Road Corridor, WB	1,060	598	-462	-44%	Not Satisfied
Doncaster Road Corridor, EB	1,437	787	-649	-45%	Not Satisfied
Doncaster Road Corridor, WB	1,934	2,253	319	16%	Satisfied
Victoria Parade Corridor, EB	1,194	2,178	984	82%	Not Satisfied
Victoria Parade Corridor, WB	410	3,606	3,196	780%	Not Satisfied

Table A.7 Bus boardings by corridor and activity centre, AM peak 2hr (target ±25%)

BUS BOARDINGS BY CORDON DAILY - AM PERIOD (2HR)	OBSERVED	MODELLED	+/-	%	CRITERIA
City Cordon	1,819	7,075	5,257	289%	Not Satisfied
Box Hill Cordon	1,474	1,391	-83	-6%	Satisfied
Broadmeadows Cordon	429	408	-21	-5%	Satisfied
Chadstone Cordon	364	153	-211	-58%	Not Satisfied
Cranbourne Cordon	443	150	-293	-66%	Not Satisfied
Dandenong Cordon	1,427	930	-497	-35%	Not Satisfied
Doncaster Cordon	687	182	-505	-73%	Not Satisfied
Epping Cordon	298	249	-49	-16%	Satisfied
Essendon Cordon	404	274	-130	-32%	Not Satisfied
Fishermans Bend Cordon	417	473	56	13%	Satisfied
Footscray Cordon	808	846	38	5%	Satisfied
Fountain Gate Cordon	442	147	-295	-67%	Not Satisfied
Frankston Cordon	788	374	-414	-53%	Not Satisfied
Glen Waverley Cordon	548	521	-27	-5%	Satisfied
Greensborough Cordon	382	144	-239	-62%	Not Satisfied
Knox City Shopping Centre Cordon	321	228	-94	-29%	Not Satisfied
La Trobe Cordon	241	241	0	0%	Satisfied
Melton Cordon	751	652	-98	-13%	Satisfied
Monash Cordon	342	450	108	32%	Not Satisfied
Parkville Cordon	57	877	820	1433%	Not Satisfied
Reservoir Cordon	690	305	-384	-56%	Not Satisfied
Ringwood Cordon	502	349	-153	-31%	Not Satisfied
Sunshine Cordon	842	510	-332	-39%	Not Satisfied
Werribee Cordon	424	217	-207	-49%	Not Satisfied
Hoddle Street Corridor, NB	129	284	155	121%	Not Satisfied
Hoddle Street Corridor, SB	367	827	460	125%	Not Satisfied
N/S Armadale Corridor, NB	229	526	296	129%	Not Satisfied
N/S Armadale Corridor, SB	112	136	24	22%	Satisfied

BUS BOARDINGS BY CORDON DAILY - AM PERIOD (2HR)	OBSERVED	MODELLED	+/-	%	CRITERIA
Warrigal Road Corridor, NB	499	746	247	49%	Not Satisfied
Warrigal Road Corridor, SB	482	415	-67	-14%	Satisfied
N/S Hoppers Crossing Corridor, NB	378	468	89	24%	Satisfied
N/S Hoppers Crossing Corridor, SB	499	554	55	11%	Satisfied
Bell Street Corridor, EB	634	630	-5	-1%	Satisfied
Bell Street Corridor, WB	376	483	106	28%	Not Satisfied
North Road Corridor, EB	440	305	-135	-31%	Not Satisfied
North Road Corridor, WB	569	168	-401	-71%	Not Satisfied
Doncaster Road Corridor, EB	226	135	-91	-40%	Not Satisfied
Doncaster Road Corridor, WB	754	445	-309	-41%	Not Satisfied
Victoria Parade Corridor, EB	96	136	39	41%	Not Satisfied
Victoria Parade Corridor, WB	96	863	767	798%	Not Satisfied

Table A.8 Bus boardings by corridor and activity centre, IP 6hr (target ±25%)

BUS BOARDINGS BY CORDON DAILY - IP PERIOD (6HR)	OBSERVED	MODELLED	+/-	%	CRITERIA
City Cordon	3,185	12,815	9,630	302%	Not Satisfied
Box Hill Cordon	2,818	1,821	-997	-35%	Not Satisfied
Broadmeadows Cordon	1,101	755	-346	-31%	Not Satisfied
Chadstone Cordon	1,225	861	-364	-30%	Not Satisfied
Cranbourne Cordon	900	341	-558	-62%	Not Satisfied
Dandenong Cordon	2,900	1,063	-1,836	-63%	Not Satisfied
Doncaster Cordon	1,067	758	-309	-29%	Not Satisfied
Epping Cordon	912	387	-525	-58%	Not Satisfied
Essendon Cordon	392	434	42	11%	Satisfied
Fishermans Bend Cordon	424	771	347	82%	Not Satisfied
Footscray Cordon	2,070	2,916	846	41%	Not Satisfied
Fountain Gate Cordon	799	322	-478	-60%	Not Satisfied
Frankston Cordon	1,210	798	-412	-34%	Not Satisfied
Glen Waverley Cordon	1,045	766	-280	-27%	Not Satisfied
Greensborough Cordon	637	278	-359	-56%	Not Satisfied
Knox City Shopping Centre Cordon	673	281	-393	-58%	Not Satisfied
La Trobe Cordon	1,248	961	-286	-23%	Satisfied
Melton Cordon	943	821	-122	-13%	Satisfied
Monash Cordon	2,728	3,282	553	20%	Satisfied
Parkville Cordon	398	2,347	1,949	490%	Not Satisfied
Reservoir Cordon	1,627	545	-1,083	-67%	Not Satisfied
Ringwood Cordon	810	553	-257	-32%	Not Satisfied
Sunshine Cordon	1,757	716	-1,041	-59%	Not Satisfied

BUS BOARDINGS BY CORDON DAILY - IP PERIOD (6HR)	OBSERVED	MODELLED	+/-	%	CRITERIA
Werribee Cordon	960	333	-627	-65%	Not Satisfied
Hoddle Street Corridor, NB	161	434	273	170%	Not Satisfied
Hoddle Street Corridor, SB	308	1,127	820	266%	Not Satisfied
N/S Armadale Corridor, NB	256	461	205	80%	Not Satisfied
N/S Armadale Corridor, SB	193	186	-7	-4%	Satisfied
Warrigal Road Corridor, NB	635	922	288	45%	Not Satisfied
Warrigal Road Corridor, SB	436	526	89	20%	Satisfied
N/S Hoppers Crossing Corridor, NB	338	512	174	52%	Not Satisfied
N/S Hoppers Crossing Corridor, SB	468	633	166	35%	Not Satisfied
Bell Street Corridor, EB	951	1,000	49	5%	Satisfied
Bell Street Corridor, WB	879	847	-32	-4%	Satisfied
North Road Corridor, EB	561	282	-279	-50%	Not Satisfied
North Road Corridor, WB	172	156	-16	-9%	Satisfied
Doncaster Road Corridor, EB	379	183	-196	-52%	Not Satisfied
Doncaster Road Corridor, WB	591	742	152	26%	Not Satisfied
Victoria Parade Corridor, EB	302	400	99	33%	Not Satisfied
Victoria Parade Corridor, WB	147	1,406	1,260	860%	Not Satisfied

Table A.9 Bus boardings by corridor and activity centre, PM peak 3hr (target ±25%)

BUS BOARDINGS BY CORDON DAILY - PM PERIOD (3HR)	OBSERVED	MODELLED	+/-	%	CRITERIA
City Cordon	5,569	12,537	6,968	125%	Not Satisfied
Box Hill Cordon	3,091	2,441	-649	-21%	Satisfied
Broadmeadows Cordon	808	682	-125	-15%	Satisfied
Chadstone Cordon	1,381	762	-619	-45%	Not Satisfied
Cranbourne Cordon	1,288	491	-797	-62%	Not Satisfied
Dandenong Cordon	2,423	989	-1,434	-59%	Not Satisfied
Doncaster Cordon	1,005	879	-126	-13%	Satisfied
Epping Cordon	898	660	-238	-26%	Not Satisfied
Essendon Cordon	907	944	37	4%	Satisfied
Fishermans Bend Cordon	902	1,668	767	85%	Not Satisfied
Footscray Cordon	1,596	1,261	-335	-21%	Satisfied
Fountain Gate Cordon	927	400	-526	-57%	Not Satisfied
Frankston Cordon	1,320	852	-468	-35%	Not Satisfied
Glen Waverley Cordon	1,606	1,144	-462	-29%	Not Satisfied
Greensborough Cordon	729	478	-251	-34%	Not Satisfied
Knox City Shopping Centre Cordon	654	335	-319	-49%	Not Satisfied
La Trobe Cordon	1,533	1,297	-236	-15%	Satisfied
Melton Cordon	1,001	932	-69	-7%	Satisfied

BUS BOARDINGS BY CORDON DAILY - PM PERIOD (3HR)	OBSERVED	MODELLED	+/-	%	CRITERIA
Monash Cordon	4,255	7,223	2,968	70%	Not Satisfied
Parkville Cordon	774	2,807	2,032	262%	Not Satisfied
Reservoir Cordon	586	375	-211	-36%	Not Satisfied
Ringwood Cordon	1,130	920	-211	-19%	Satisfied
Sunshine Cordon	1,433	1,114	-320	-22%	Satisfied
Werribee Cordon	1,582	692	-890	-56%	Not Satisfied
Hoddle Street Corridor, NB	291	741	450	155%	Not Satisfied
Hoddle Street Corridor, SB	206	621	415	202%	Not Satisfied
N/S Armadale Corridor, NB	274	251	-23	-9%	Satisfied
N/S Armadale Corridor, SB	148	348	200	135%	Not Satisfied
Warrigal Road Corridor, NB	531	930	398	75%	Not Satisfied
Warrigal Road Corridor, SB	474	685	211	44%	Not Satisfied
N/S Hoppers Crossing Corridor, NB	260	305	45	17%	Satisfied
N/S Hoppers Crossing Corridor, SB	258	806	548	212%	Not Satisfied
Bell Street Corridor, EB	729	980	251	34%	Not Satisfied
Bell Street Corridor, WB	873	1,051	179	20%	Satisfied
North Road Corridor, EB	634	327	-308	-49%	Not Satisfied
North Road Corridor, WB	202	193	-9	-4%	Satisfied
Doncaster Road Corridor, EB	639	341	-298	-47%	Not Satisfied
Doncaster Road Corridor, WB	344	680	336	98%	Not Satisfied
Victoria Parade Corridor, EB	516	854	338	66%	Not Satisfied
Victoria Parade Corridor, WB	100	617	516	514%	Not Satisfied

Table A.10 Bus boardings by corridor and activity centre, OP 13hr (target ±25%)

BUS BOARDINGS BY CORDON DAILY - OP PERIOD (13HR)	OBSERVED	MODELLED	+/-	%	CRITERIA
City Cordon	4,282	11,627	7,344	172%	Not Satisfied
Box Hill Cordon	1,843	1,447	-396	-22%	Satisfied
Broadmeadows Cordon	371	361	-10	-3%	Satisfied
Chadstone Cordon	817	356	-461	-56%	Not Satisfied
Cranbourne Cordon	523	199	-324	-62%	Not Satisfied
Dandenong Cordon	1,335	676	-659	-49%	Not Satisfied
Doncaster Cordon	494	436	-58	-12%	Satisfied
Epping Cordon	540	234	-306	-57%	Not Satisfied
Essendon Cordon	440	504	64	15%	Satisfied
Fishermans Bend Cordon	274	1,169	895	326%	Not Satisfied
Footscray Cordon	1,146	1,741	594	52%	Not Satisfied
Fountain Gate Cordon	427	184	-243	-57%	Not Satisfied
Frankston Cordon	684	404	-280	-41%	Not Satisfied

BUS BOARDINGS BY CORDON DAILY - OP PERIOD (13HR)	OBSERVED	MODELLED	+/-	%	CRITERIA
Glen Waverley Cordon	928	641	-287	-31%	Not Satisfied
Greensborough Cordon	331	330	-2	-1%	Satisfied
Knox City Shopping Centre Cordon	247	170	-77	-31%	Not Satisfied
La Trobe Cordon	437	458	21	5%	Satisfied
Melton Cordon	467	515	49	10%	Satisfied
Monash Cordon	1,724	1,615	-109	-6%	Satisfied
Parkville Cordon	391	1,313	922	236%	Not Satisfied
Reservoir Cordon	388	307	-81	-21%	Satisfied
Ringwood Cordon	578	498	-79	-14%	Satisfied
Sunshine Cordon	823	616	-207	-25%	Not Satisfied
Werribee Cordon	477	417	-60	-13%	Satisfied
Hoddle Street Corridor, NB	199	526	328	165%	Not Satisfied
Hoddle Street Corridor, SB	169	622	454	269%	Not Satisfied
N/S Armadale Corridor, NB	176	246	70	40%	Not Satisfied
N/S Armadale Corridor, SB	94	120	27	28%	Not Satisfied
Warrigal Road Corridor, NB	294	711	418	142%	Not Satisfied
Warrigal Road Corridor, SB	400	485	85	21%	Satisfied
N/S Hoppers Crossing Corridor, NB	171	199	29	17%	Satisfied
N/S Hoppers Crossing Corridor, SB	202	613	411	203%	Not Satisfied
Bell Street Corridor, EB	431	778	347	81%	Not Satisfied
Bell Street Corridor, WB	480	782	303	63%	Not Satisfied
North Road Corridor, EB	264	183	-81	-31%	Not Satisfied
North Road Corridor, WB	117	82	-35	-30%	Not Satisfied
Doncaster Road Corridor, EB	193	129	-64	-33%	Not Satisfied
Doncaster Road Corridor, WB	245	386	140	57%	Not Satisfied
Victoria Parade Corridor, EB	280	787	507	181%	Not Satisfied
Victoria Parade Corridor, WB	67	719	653	981%	Not Satisfied

A3 TRAIN BOARDINGS

Table A.11 Train Station Entries by Line, Daily 24hr (target ±15%)

DAILY (24HR) - STATION ENTRIES BY LINE (EXCLUDES RAIL-RAIL TRANSFERS)	OBSERVED	MODELLED	+/-	%	CRITERIA
Williamstown	2,513	3,455	943	38%	Not Satisfied
Werribee	22,533	25,605	3,072	14%	Satisfied
Newport	10,606	12,006	1,400	13%	Satisfied
Sunbury	33,934	32,159	-1,775	-5%	Satisfied

DAILY (24HR) - STATION ENTRIES BY LINE (EXCLUDES RAIL-RAIL TRANSFERS)	OBSERVED	MODELLED	+/-	%	CRITERIA
Footscray	19,735	13,017	-6,719	-34%	Not Satisfied
Craigieburn	37,109	43,385	6,276	17%	Not Satisfied
Upfield	15,881	20,095	4,213	27%	Not Satisfied
Mernda	10,714	7,530	-3,184	-30%	Not Satisfied
Epping	23,646	24,398	753	3%	Satisfied
Hurstbridge	25,854	32,166	6,313	24%	Not Satisfied
Clifton Hill	12,491	19,533	7,042	56%	Not Satisfied
Lilydale	9,815	10,419	604	6%	Satisfied
Belgrave	9,932	10,371	439	4%	Satisfied
Ringwood	42,618	44,955	2,337	5%	Satisfied
Alamein	4,827	5,100	273	6%	Satisfied
Camberwell	22,221	18,398	-3,823	-17%	Not Satisfied
Glen Waverley	25,184	29,642	4,458	18%	Not Satisfied
Burnley	5,101	5,906	805	16%	Not Satisfied
Pakenham	14,099	12,511	-1,588	-11%	Satisfied
Cranbourne	6,218	5,821	-396	-6%	Satisfied
Dandenong	48,986	52,960	3,974	8%	Satisfied
Frankston	40,223	42,071	1,848	5%	Satisfied
Caulfield	23,126	23,078	-48	0%	Satisfied
Sandringham	31,586	30,408	-1,178	-4%	Satisfied
South Yarra	15,519	9,434	-6,086	-39%	Not Satisfied
West Melbourne (Old Nth Melb)	4,613	5,006	393	9%	Satisfied
City Loop	298,456	289,796	-8,660	-3%	Satisfied
Jolimont	2,608	6,084	3,476	133%	Not Satisfied
Richmond	11,404	13,987	2,583	23%	Not Satisfied

Table A.12 Train Station Entries by Line, AM 2hr (target ±15%)

AM (2HR) - STATION ENTRIES BY LINE (EXCLUDES RAIL-RAIL TRANSFERS)	OBSERVED	MODELLED	+/-	%	CRITERIA
Williamstown	1,043	954	-89	-9%	Satisfied
Werribee	10,873	11,543	670	6%	Satisfied
Newport	5,189	4,935	-254	-5%	Satisfied
Sunbury	14,367	13,078	-1,290	-9%	Satisfied
Footscray	5,222	3,181	-2,040	-39%	Not Satisfied
Craigieburn	16,735	16,839	104	1%	Satisfied
Upfield	5,714	5,725	11	0%	Satisfied
Mernda	4,548	3,181	-1,367	-30%	Not Satisfied
Epping	9,583	9,510	-73	-1%	Satisfied

AM (2HR) - STATION ENTRIES BY LINE (EXCLUDES RAIL-RAIL TRANSFERS)	OBSERVED	MODELLED	+/-	%	CRITERIA
Hurstbridge	12,479	13,272	793	6%	Satisfied
Clifton Hill	2,967	4,672	1,705	57%	Not Satisfied
Lilydale	4,805	5,203	398	8%	Satisfied
Belgrave	4,850	5,000	150	3%	Satisfied
Ringwood	17,052	16,606	-446	-3%	Satisfied
Alamein	2,797	2,472	-325	-12%	Satisfied
Camberwell	5,175	4,095	-1,080	-21%	Not Satisfied
Glen Waverley	11,135	11,399	264	2%	Satisfied
Burnley	1,246	845	-401	-32%	Not Satisfied
Pakenham	5,633	5,193	-440	-8%	Satisfied
Cranbourne	3,004	2,823	-181	-6%	Satisfied
Dandenong	15,756	17,162	1,406	9%	Satisfied
Frankston	16,270	16,450	180	1%	Satisfied
Caulfield	5,898	5,557	-341	-6%	Satisfied
Sandringham	12,852	11,366	-1,486	-12%	Satisfied
South Yarra	3,773	1,948	-1,825	-48%	Not Satisfied
West Melbourne (Old Nth Melb)	571	454	-117	-20%	Not Satisfied
City Loop	11,501	12,013	511	4%	Satisfied
Jolimont	184	685	501	272%	Not Satisfied
Richmond	1,445	1,541	95	7%	Satisfied

Table A.13 Train Station Entries by Line, IP 2hr (target ±15%)

IP (2HR) - STATION ENTRIES BY LINE (EXCLUDES RAIL-RAIL TRANSFERS)	OBSERVED	MODELLED	+/-	%	CRITERIA
Williamstown	231	381	150	65%	Not Satisfied
Werribee	1,803	2,720	917	51%	Not Satisfied
Newport	901	1,370	469	52%	Not Satisfied
Sunbury	3,062	3,762	701	23%	Not Satisfied
Footscray	1,945	1,235	-710	-36%	Not Satisfied
Craigieburn	3,118	4,495	1,377	44%	Not Satisfied
Upfield	1,482	2,179	698	47%	Not Satisfied
Mernda	747	782	34	5%	Satisfied
Epping	2,096	2,522	426	20%	Not Satisfied
Hurstbridge	1,835	3,220	1,384	75%	Not Satisfied
Clifton Hill	1,020	1,544	524	51%	Not Satisfied
Lilydale	677	808	131	19%	Not Satisfied
Belgrave	655	824	169	26%	Not Satisfied
Ringwood	3,597	4,393	795	22%	Not Satisfied
Alamein	316	433	117	37%	Not Satisfied

IP (2HR) - STATION ENTRIES BY LINE (EXCLUDES RAIL-RAIL TRANSFERS)	OBSERVED	MODELLED	+/-	%	CRITERIA
Camberwell	1,889	1,767	-122	-6%	Satisfied
Glen Waverley	1,983	3,178	1,195	60%	Not Satisfied
Burnley	302	430	128	42%	Not Satisfied
Pakenham	974	1,094	120	12%	Satisfied
Cranbourne	460	506	47	10%	Satisfied
Dandenong	4,595	5,126	531	12%	Satisfied
Frankston	3,427	3,926	499	15%	Satisfied
Caulfield	2,071	2,119	48	2%	Satisfied
Sandringham	2,523	2,469	-54	-2%	Satisfied
South Yarra	1,327	694	-633	-48%	Not Satisfied
West Melbourne (Old Nth Melb)	323	237	-86	-27%	Not Satisfied
City Loop	16,317	12,360	-3,956	-24%	Not Satisfied
Jolimont	137	340	203	148%	Not Satisfied
Richmond	617	756	140	23%	Not Satisfied

Table A.14 Train Station Entries by Line, PM 2hr (target ±15%)

PM (2HR) - STATION ENTRIES BY LINE (EXCLUDES RAIL-RAIL TRANSFERS)	OBSERVED	MODELLED	+/-	%	CRITERIA
Williamstown	293	479	186	64%	Not Satisfied
Werribee	1,608	1,516	-91	-6%	Satisfied
Newport	813	844	31	4%	Satisfied
Sunbury	2,961	2,586	-375	-13%	Satisfied
Footscray	3,621	2,132	-1,490	-41%	Not Satisfied
Craigieburn	3,436	4,427	991	29%	Not Satisfied
Upfield	2,084	2,390	306	15%	Satisfied
Mernda	911	748	-163	-18%	Not Satisfied
Epping	2,456	2,654	198	8%	Satisfied
Hurstbridge	2,435	3,113	678	28%	Not Satisfied
Clifton Hill	2,718	3,918	1,200	44%	Not Satisfied
Lilydale	790	679	-111	-14%	Satisfied
Belgrave	867	813	-53	-6%	Satisfied
Ringwood	5,591	5,527	-64	-1%	Satisfied
Alamein	436	536	100	23%	Not Satisfied
Camberwell	5,014	3,843	-1,171	-23%	Not Satisfied
Glen Waverley	2,880	3,095	215	7%	Satisfied
Burnley	1,343	1,568	225	17%	Not Satisfied
Pakenham	1,245	1,180	-65	-5%	Satisfied
Cranbourne	278	363	84	30%	Not Satisfied
Dandenong	7,262	7,804	542	7%	Satisfied

PM (2HR) - STATION ENTRIES BY LINE (EXCLUDES RAIL-RAIL TRANSFERS)	OBSERVED	MODELLED	+/-	%	CRITERIA
Frankston	4,581	4,745	164	4%	Satisfied
Caulfield	3,936	4,313	377	10%	Satisfied
Sandringham	4,121	4,379	258	6%	Satisfied
South Yarra	3,121	2,372	-749	-24%	Not Satisfied
West Melbourne (Old Nth Melb)	1,393	1,721	328	24%	Not Satisfied
City Loop	100,448	96,469	-3,978	-4%	Satisfied
Jolimont	733	1,687	955	130%	Not Satisfied
Richmond	2,476	4,195	1,719	69%	Not Satisfied

Table A.15 Train Station Entries by Line, OP 2hr (target ±15%)

OP (2HR) - STATION ENTRIES BY LINE (EXCLUDES RAIL-RAIL TRANSFERS)	OBSERVED	MODELLED	+/-	%	CRITERIA
Williamstown	112	213	101	90%	Not Satisfied
Werribee	1,280	1,209	-71	-6%	Satisfied
Newport	498	565	66	13%	Satisfied
Sunbury	1,980	1,305	-675	-34%	Not Satisfied
Footscray	1,082	977	-105	-10%	Satisfied
Craigieburn	1,956	2,140	184	9%	Satisfied
Upfield	865	1,415	550	64%	Not Satisfied
Mernda	852	294	-559	-66%	Not Satisfied
Epping	1,363	1,114	-249	-18%	Not Satisfied
Hurstbridge	1,405	1,522	117	8%	Satisfied
Clifton Hill	796	1,451	655	82%	Not Satisfied
Lilydale	599	591	-7	-1%	Satisfied
Belgrave	606	559	-46	-8%	Satisfied
Ringwood	2,129	2,294	164	8%	Satisfied
Alamein	143	175	32	22%	Not Satisfied
Camberwell	1,286	1,080	-207	-16%	Not Satisfied
Glen Waverley	1,261	1,356	95	8%	Satisfied
Burnley	311	473	162	52%	Not Satisfied
Pakenham	1,226	755	-471	-38%	Not Satisfied
Cranbourne	472	312	-161	-34%	Not Satisfied
Dandenong	2,850	2,905	54	2%	Satisfied
Frankston	2,267	2,242	-25	-1%	Satisfied
Caulfield	1,704	1,565	-139	-8%	Satisfied
Sandringham	1,662	1,689	27	2%	Satisfied
South Yarra	1,027	615	-412	-40%	Not Satisfied
West Melbourne (Old Nth Melb)	328	420	92	28%	Not Satisfied
City Loop	29,111	32,000	2,889	10%	Satisfied

OP (2HR) - STATION ENTRIES BY LINE (EXCLUDES RAIL-RAIL TRANSFERS)	OBSERVED	MODELLED	+/-	%	CRITERIA
Jolimont	305	616	311	102%	Not Satisfied
Richmond	1,465	1,295	-170	-12%	Satisfied

A4 TRAM BOARDINGS

Table A.16 Tram boardings by route, daily 24hr (target ±15%)

TRAM BOARDINGS BY ROUTE (DAILY, 24HR)	OBSERVED	MODELLED	+/-	%	CRITERIA
1	35,842	31,423	-4,419	-12%	Satisfied
3	20,619	20,847	228	1%	Satisfied
5	19,754	15,799	-3,955	-20%	Not Satisfied
6	40,788	35,419	-5,369	-13%	Satisfied
11	41,281	29,577	-11,704	-28%	Not Satisfied
12	25,659	35,124	9,465	37%	Not Satisfied
16	29,082	28,956	-126	0%	Satisfied
19	39,584	36,572	-3,012	-8%	Satisfied
30	4,689	11,173	6,484	138%	Not Satisfied
48	27,640	21,765	-5,875	-21%	Not Satisfied
57	16,616	25,379	8,763	53%	Not Satisfied
59	31,748	32,093	345	1%	Satisfied
64	22,162	20,094	-2,068	-9%	Satisfied
67	25,923	23,308	-2,615	-10%	Satisfied
70	23,000	15,461	-7,539	-33%	Not Satisfied
72	22,415	24,259	1,844	8%	Satisfied
75	34,014	32,142	-1,872	-6%	Satisfied
78	7,842	10,909	3,067	39%	Not Satisfied
82	5,015	4,356	-659	-13%	Satisfied
86	49,784	56,911	7,127	14%	Satisfied
96	56,722	57,770	1,048	2%	Satisfied
109	49,062	46,602	-2,460	-5%	Satisfied

A5 OTHER MODEL-WIDE VALIDATION OUTPUTS

The full suite of standard VITM validation outputs have been provided alongside this report.

— ValidationReporting_VITM21_v220815_BLANK_Y2018_RUN18_(CalibratedBaseYear)

- DetailedPTReporting_VITM21_v210430_RUN18_(Calibrated2018)
- Better Buses – Pilot Dashboard_RUN18