

A photograph of a busy Wellington street. In the foreground, a white car is driving towards the camera. To its left, a grey car is also visible. In the middle ground, a green bus with 'Dunedin Park' on its destination sign is moving away. The background shows a hillside covered in colorful houses, with a large green hill in the distance under a clear sky.

TN15 - WELLINGTON TRANSPORT ANALYTICAL TOOLS 2019-21 UPDATE – WPTM UPDATE

PREPARED FOR GREATER WELLINGTON REGIONAL COUNCIL

July 2023

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Greater Wellington Regional Council

TN15 - Wellington Transport Analytical Tools 2019-21 update – WPTM Update

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APPENDICES

Appendix A Comments and Responses

Appendix B Addendum – Revised WPTM for new 2018 WTSM

- B.1 Introduction
- B.2 Changes made to WPTM
- B.3 Validation
- B.4 Forecasted growth comparison

1. Introduction

1.1 Project Overview

This technical note is part of a series documenting the 2019-2021 update of components of the Wellington Regional Transportation Planning Analytical Tools ("Analytical Tools", "Tools"). The higher-level Analytical Tools are maintained and operated by Greater Wellington Regional Council (GWRC), who are the client for this project. This project is being primarily delivered by Stantec and Jacobs, supported by GWRC transport planners.

1.2 Purpose of this Report

This report details the update and validation of the current 2013-based Wellington Public Transport Model (WPTM) to March 2018. It is organised into the following sections:

- Background of this model update
- Description of the data sources used
- Methodology for the update of the demand matrices for each mode
- Methodology for the update of other model components, including network, land use, input parameters and scripts, and
- Model validation

2. Background

The WPTM was originally developed based on 2011 bus electronic ticketing machine (ETM) data and an extensive programme of on-board surveys for rail and bus. As a result, the demand matrices in this model are fully based on observed data and provide a more accurate representation of public transport demand than the synthetic matrices produced by the Wellington Transport Strategy Model (WTSM). It also includes a finer zonal resolution (780 zones instead of 225 zones in WTSM) and a better representation of access to public transport including park-and-ride and kiss-and-ride. A comprehensive description of the WPTM is detailed in a number of technical notes from the 2011 model development.

The model was updated in 2013 as part of the update of the Analytical Tools to 2013 census data¹. However due to the short two-year period since the model development and the fact that no major changes had occurred in terms of both transport supply or demand, this was a limited exercise with minor sector-based adjustments applied to rail matrices based on observed changes in patronage and no changes to bus demand.

The model originally only represented AM and Inter Peak periods (respectively 7-9am and a 2-hr average of 9am-3pm). A PM peak period (4-6pm) was subsequently added². Due to the absence of ETM or on-board survey data for the PM peak, a simplified approach was adopted, drawing on a combination of transposed and adjusted trip patterns from the AM peak, limited observed PM data and some input from the WTSM.

As part of the update of the Analytical Tools to 2018 census, this report describes the update of the WPTM to 2018. The update includes the following changes to the model:

- The WPTM originally represented annual weekday average transport demand and conditions. This has now been changed to March weekday average for consistency with WTSM;
- The number of internal zones in WPTM has been increased from 780 to 813, consistent with the new zone system that will be used in the revised version of WTSM developed during Stage 2 of this project;
- Demand matrices have been updated to March 2018, using different approaches for each PT mode depending on the data available to support it;

¹ TN9 - WPTM 2013 Validation v4.docx, July 2015

² 13938 160815 Rep WPTM PM Peak Model v4).docx, August 2016

- The network has been updated to reflect changes in supply since 2013, the new zone system, and other refinements carried over from WTSM.
- Various input and parameters into the models have been updated to 2018, including zonal land use, economic parameters (value of time, PT fares), car availability, and rail park-and-ride capacities.
- Time periods have been kept identical to earlier versions of the model (and as a result will be different from the new WTSM developed as part of Stage 2).

More detail on the update of these components is provided in the next sections of this report.

It must be noted that the validation of WPTM presented in this document is based on road travel times extracted from the current "interim" 2018 version of WTSM. Results will need to be updated and the model potentially adjusted once the newly rebuilt WTSM is available.

3. Data Sources

This section describes the main datasets used for the model update and validation. Whenever possible, data from March 2018 was used. When not available, data from other years or months was factored based on high level patronage data.

3.1 CBD Cordon Survey

Every year GWRC carries out a survey on a weekday in March, counting inbound PT patronage to the CBD during the AM peak (some years have also included Inter peak or outbound PM peak). This includes bus numbers and occupancy at each crossing of the CBD cordon, patronage on Wellington Harbour ferries and the cable car, and number of pedestrians out of the railway station. The latter however includes people potentially walking through the station but not arriving by train so is not a perfectly accurate count of rail passengers.

More details on this survey and results can be found in 'TN4 - Wellington Analytical Tools 2019-21 Update - Data Analysis'.

3.2 Metlink Patronage Data

Network wide statistics including monthly patronage by PT mode (and separately by line for rail) were downloaded from the Metlink website, with additional data provided by GWRC. This includes historical patronage since 2006, both annual and per month, as well as peak and off-peak.

3.3 Bus Electronic Ticketing

All buses in the Wellington regional area use the 'Snapper' card system, with the exception of the Flyer (route 91) that services the airport. Electronic ticketing machine (ETM) data was provided by GWRC for all bus transactions in March 2019, including Snapper card, cash, and a number of other fare products, amounting to circa 2.4 million records. The reason for using March 2019 data is explained in Section 4.1.

This data was extensively used for the development of the new bus matrices.

3.4 General Transit Feed Specification

The General Transit Feed Specification (GTFS) was provided for the same March 2019 period as ETM data, which includes all information on services, schedules and stopping sequences. This information was combined with ETM data to produce the bus matrices.

3.5 Rail Automated Door Counts

Train carriages on the Wellington railway network are equipped with Automatic Passenger counts (APC) on all doors, which count number of passengers boarding and alighting at each station. APC data for November 2019 was provided by GWRC and factored to March 2018 using Metlink data on patronage per line.

3.6 Kiwirail High Counts

These (also called 'guard counts') are manual counts of the maximum load of passengers on each train, i.e. counts of passengers directly before entering Wellington station for inbound services or after leaving the station for outbound services.

Data for November 2019 was provided by GWRC.

3.7 2017 Park-and-Ride Survey and APC

A survey of access to rail and park-and-ride use was commissioned in June 2017 by GWRC³. Processed data from this survey, including 2017 APC data that was used to expand it was provided and used to check modelled mode access to rail. The 2017 APC was also used to check consistency with 2019 APC data.

4. Bus Demand Update

4.1 Summary of Approach

Bus matrices in WPTM were originally developed using a 2011 dataset of a month worth of ETM transactions on the Metlink bus network.

Trips from the ETM data were converted from stop-to-stop to zone-to-zone, and allocated a purpose (work, education, other or child) based on intercept survey data. The full description of the ETM data cleaning and bus matrices development is contained in 'TN3 ETM Data Cleaning FINAL' and 'TN7 PT Matrix Development FINAL' from the 2011 development of the model.

For the 2013 update, because of only 2 years having passed since the model build as well as the absence of new ETM data, simple checks were made looking at aggregated demand. These showed that no significant change had occurred and the bus matrices were left untouched.

For this 2018 update, the initial approach was to use new ETM data to undertake a more sophisticated approach than simple sector-based factoring. It was not suggested to go the full length of fully replacing the original 2011 matrices, as this would involve completely replicating the methodology carried out during the model development. This would be outside the scope of this project, especially without having new intercept surveys available or most of the processes that were used then.

However, given that a full new month of detailed ETM data was provided, this provided a valuable opportunity to effectively replace the original matrices with more up-to-date trip patterns. This was especially beneficial given the changes to the bus network following the new Public Transport Operating Model. It also enabled the production of more robust demand matrices for the PM peak, rather than transposed and adjusted AM peak matrices.

Ultimately, the adopted approach was to completely rebuild the stop-to-stop matrices based on the new ETM data. These were then converted to zone-to-zone matrices and split by purpose by reapplying the factors from the 2011 model, modified to apply to the new 813 zone system. These factors themselves were not recalibrated in the absence of a new intercept survey.

The Python-based Pandas data analysis library was used for the building of bus matrices, including cleaning of the ETM data. Compared with the multitude of spreadsheets and Access databases used for the 2011 model development, this ensures that the whole process is traceable and reproducible, should new ETM data be available for a future model update.

It must be noted that although the updated modelling suite is intended to represent average weekday conditions for March 2018, bus data and network for March 2019 were used for the WPTM update. The reason for this is that following the new Public Transport Operating Model the bus network changed significantly, resulting in likely changes in trip patterns as well. This would present an issue with scenario testing or forecasting with the model, as the representation of bus demand and supply would essentially already be out of date, therefore data post introduction of the new network was used. While this introduces some inconsistencies with other modes which are based on March 2018, the impact of this was deemed to be minor and outweighed by the benefits of resulting forecasts being more consistent with the bus network that is now in operation.

³ <http://www.gw.govt.nz/assets/2017-Rail-Survey-report20-07-2017.pdf>

The methodology to create the new bus matrices is detailed in the remainder of this section.

4.2 ETM Data Cleaning

The ETM data provided for March 2019 contains 2,382,524 transactions, including Snapper card, cash, and other fare products. Information on fare type used is however not included in the dataset.

A number of records were removed from the dataset, as follows:

- 240 records had boarding type = alighting
- 1,890 records had boarding type = cancel
- 179,429 records from school buses, which are not included in WPTM and neither is their associated demand
- 299,330 records for weekend days
- 773 records which had no matching bus stops in the GTFS

As a result, 1,900,862 records were left in the dataset.

4.3 Missing Alighting Stop Allocation

While all records in the ETM dataset include information on the boarding stop, 21% of transaction (402,335 records) lack information on the alighting stop. This can be caused by a number of reasons but in most cases will be due to fare not being paid for with a Snapper card but through another fare product (most likely cash) which does not include 'tagging off' when alighting the bus. Analysis of the data shows that 20% of all records have no Snapper card ID number, but this increases to 97% for trips with no alight stop.

This 21% proportion is however a marked decrease from the 2011 model development where 43% of records did not have information on alight stop. This drop is caused by an uptake in Snapper card payment since, and also the fact that some bus operators in 2011 used a separate payment card which only recorded the boarding stop.

While the reduction of these incomplete records compared with 2011 will lead to better observed matrices, the 21% remaining had to be processed to assign them an alight stop, following a 5-step approach. This approach was broadly in line with the methodology developed for the 2011 development of the WPTM and described in detail in 'TN7 PT Matrix Development FINAL', but was implemented in the main ETM processing python script and with some modification to account for changes in the nature of the data.

The following sections summarise the various steps and their outcome.

4.3.1 Step 1 – Reverse Direction Match

The first step involves assigning the alight stop based on the board stop for a matching reverse trip, being defined as valid if it has:

- Same card ID number
- Same date
- Same number of zone fares travelled
- Alight stop of reverse trip is near original trip board stop
- Potential alight stop is near reverse board stop

The following figure is extracted from 'TN7 PT Matrix Development FINAL' and illustrates this process. The only notable difference is that stops equivalence per direction was not used, with eligible bus stops being identified based on distance instead.

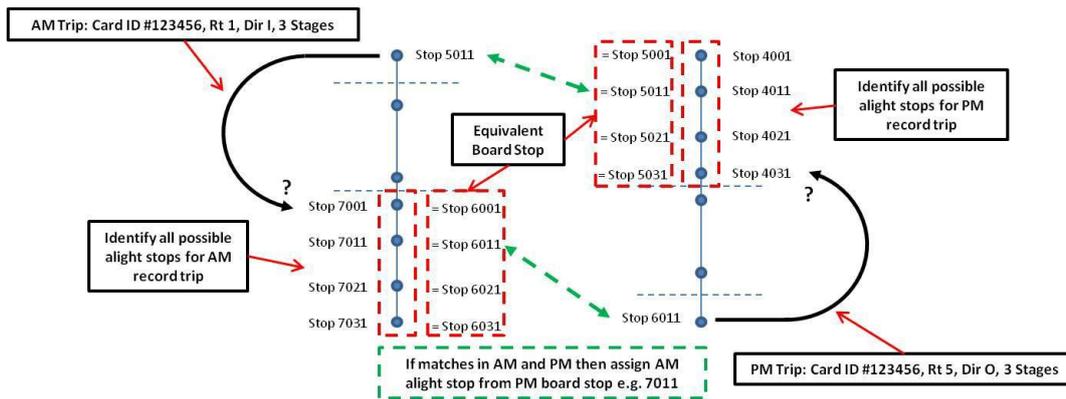


Figure 4-1: Alight Stop Allocation – Step 1

This step led to only 52 records being allocated an alight stop, compared with an 8% success rate in 2011. This is caused by the fact that compared with the 2011 dataset most records with no alights do not have Card ID information to allow linking them to the reverse trip.

4.3.2 Step 2 - Alighting Patterns of Other Travellers, with Fare Zones Constraint

The next step applies only to records which have information on the number of zones travelled.

Stops are assigned from a pool of alight stops for trips with the following attributes:

- Same bus route
- Same direction
- Same board stop
- Same fare zones travelled

The proportion calculated as a number between 0 and 1 of passengers using stop within a pool was calculated, and a random number between 0 and 1 was generated for each incomplete record to select an alight stop.

The following figure from 'TN7 PT Matrix Development FINAL' illustrates this process.

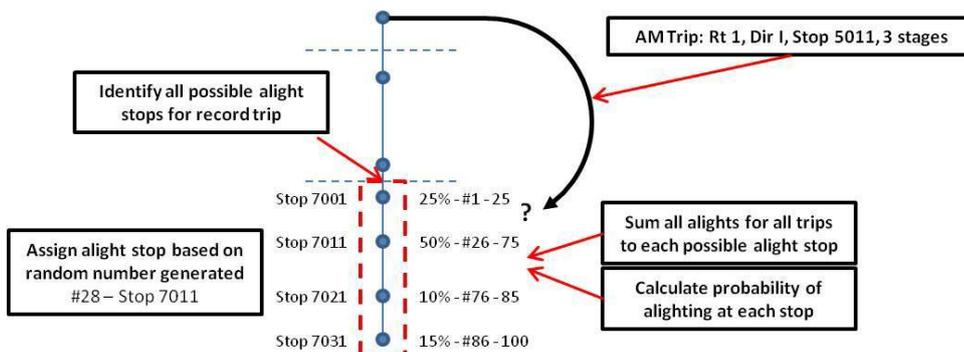


Figure 4-2: Alight Stop Allocation – Step 2

This step was more efficient and led to 168,360 records or about 42% being assigned an alight stop, with 233,932 records remaining.

4.3.3 Step 3 - Boarding Patterns of Reverse Travellers, with Fare Zones Constraint

This step also applies only to records with information on the number of zones travelled. It is similar to Step 2 but uses patterns from reverse trips, with the following attributes:

- Same bus route
- Reverse direction
- Same fare zones travelled

- Board stop and alight stop of reverse trip near respectively potential alight and board stop of incomplete record

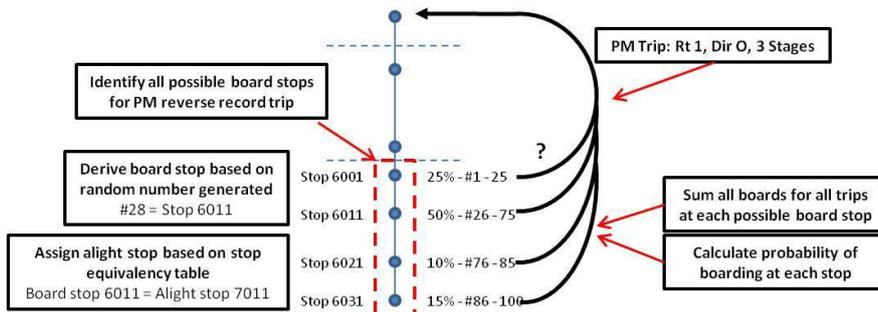


Figure 4-3: Alight Stop Allocation – Step 3

Again, the proportion of passengers for reverse trips boarding at each stop in a selected pool was calculated, and a random number generated to allocate the alight stop.

This step led to only 260 records being successfully completed, compared with 23% in 2011. Again this points to the nature of incomplete records being different in the more recent dataset, with most records that could be filled using Step 3 having already been successfully processed through Step 2.

4.3.4 Step 4 - Alighting Patterns of Other Travellers, No Fare Zones Constraint

This is the same as Step 2 but applies to trips which do not have information on fare zone, and therefore does not include the constraint of matching trips having the same number of fare zones travelled.

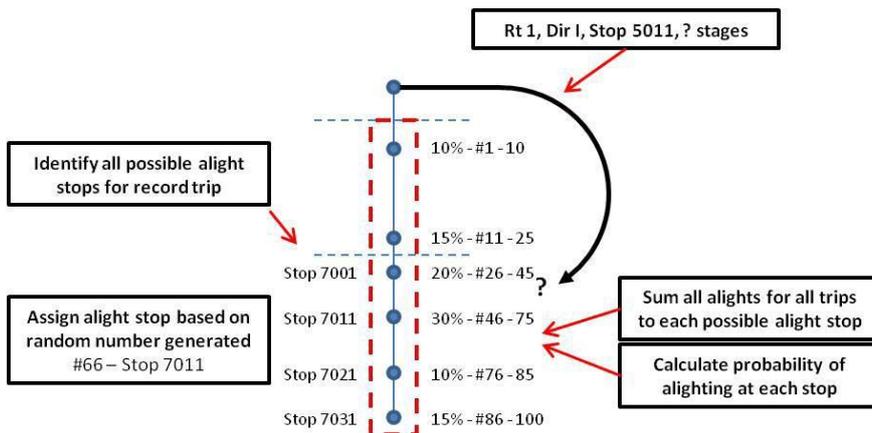


Figure 4-4: Alight Stop Allocation – Step 4

This step led to 209,345 records being successfully processed, or about 52% of all incomplete records.

4.3.5 Step 5 - Boarding Patterns of Reverse Travellers, No Fare Zones Constraint

Finally, this step is identical to Step 3 but again without constraint on number of zones travelled.

As per Step 3, it only leads to 336 records being successfully allocated an alight stop, as Step 4 has already allocated one to most of the records.

4.3.6 Results

Following these 5 steps, 94% of records with no alighting stop information have been allocated an alight stop, with 6% remaining which is the same proportion as during the 2011 matrices development. This amounts to about 1% of all records in the dataset, which were then discarded.

To check the accuracy of this process and validate the allocation of alight stops, a test was carried out with alight stop information randomly removed for 3% of the complete records (this proportion was used as it left a large enough data sample to "train" the algorithm on, while leading to enough records to test it). The 5 steps were then run and the allocated stops for these records were then compared with the original, observed ones.

Results show that the process used led to just above 30% of alight stops being correctly allocated, and a median distance between allocated stops and observed stops of 320 meters for those that were incorrectly allocated, or about 2 stops in average. The following figure shows the distribution of distance between allocated and observed stops.

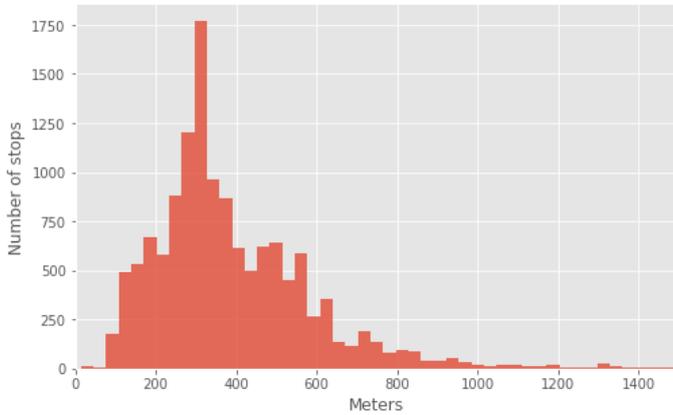


Figure 4-5: Distance Between Allocated and Observed Bus Stops

The Pearson correlation coefficient for the resulting number of alightings per stops is 0.985, indicating a very high correlation between modelled and observed. The same calculation was carried out for each individual route, with 84% of routes returning a Pearson correlation coefficient over 0.85 which is considered the accepted threshold. Routes that did not match this threshold were in all cases routes with very few records and night buses.

The following figures present a comparison of observed and allocated alight stops for a sample of number of routes and directions. The bar plots show a comparison of total alightings at each stop along a bus routes, whereas the heat maps show amounts of trips between each pair of boarding and alighting stops along the route, for both observed and allocated.

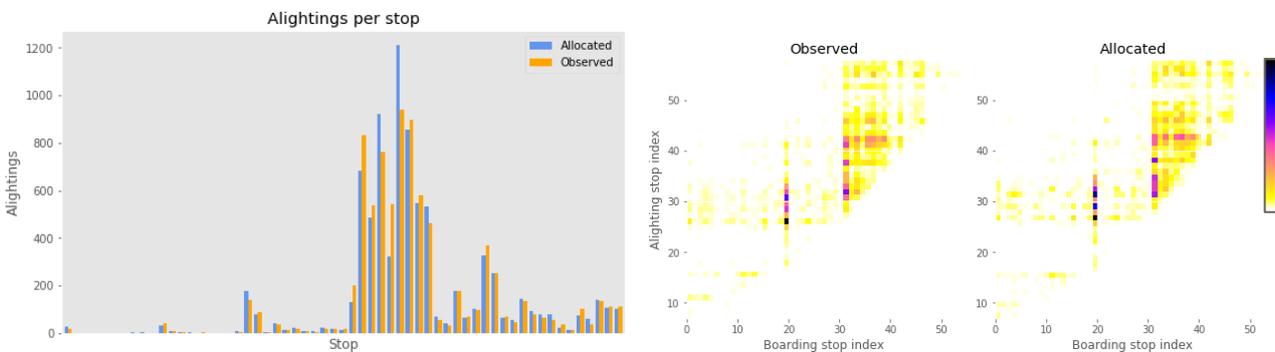


Figure 4-6: Alight Stop Observed vs Allocated – Route 1, Direction 1

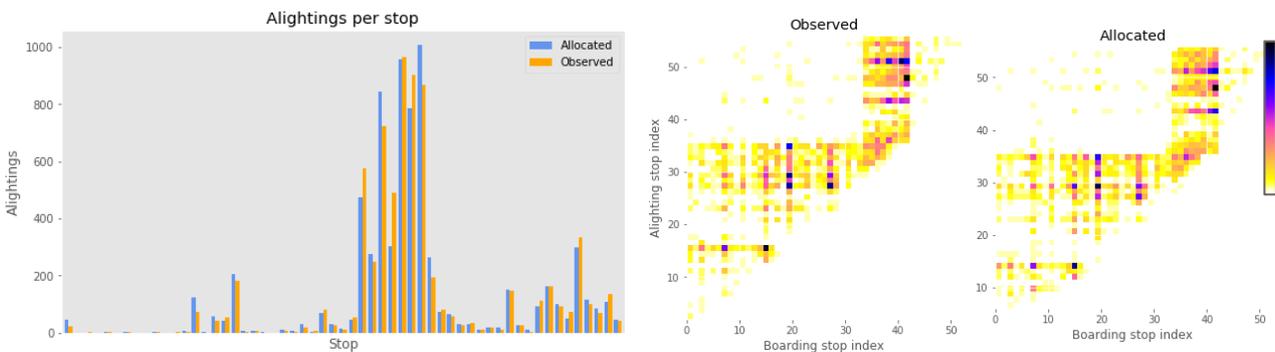


Figure 4-7: Alight Stop Observed vs Allocated – Route 2, Direction 0

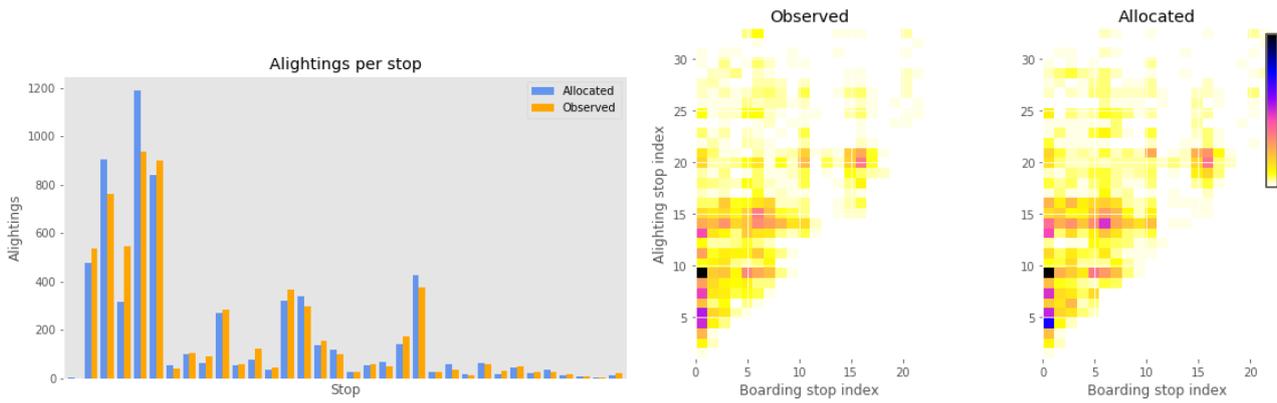


Figure 4-8: Alight Stop Observed vs Allocated – Route 3, Direction 0

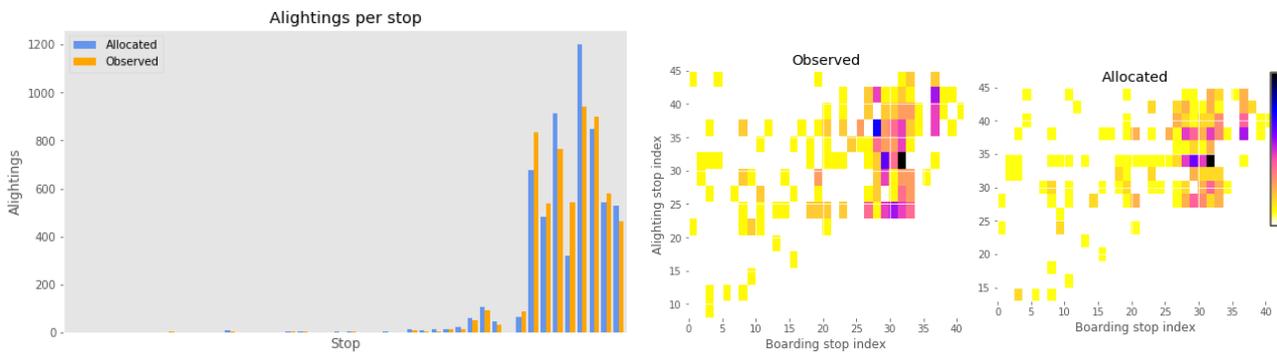


Figure 4-9: Alight Stop Observed vs Allocated – Route 81, Direction 1

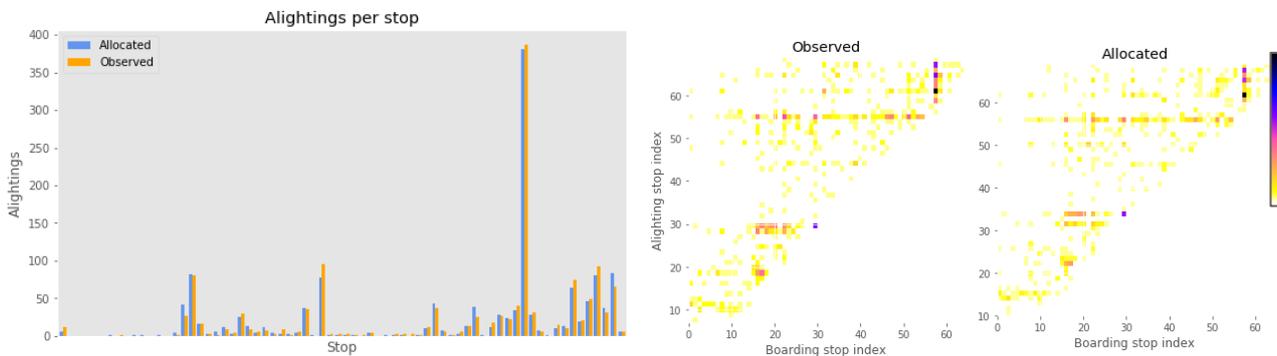


Figure 4-10: Alight Stop Observed vs Allocated – Route 110, Direction 1

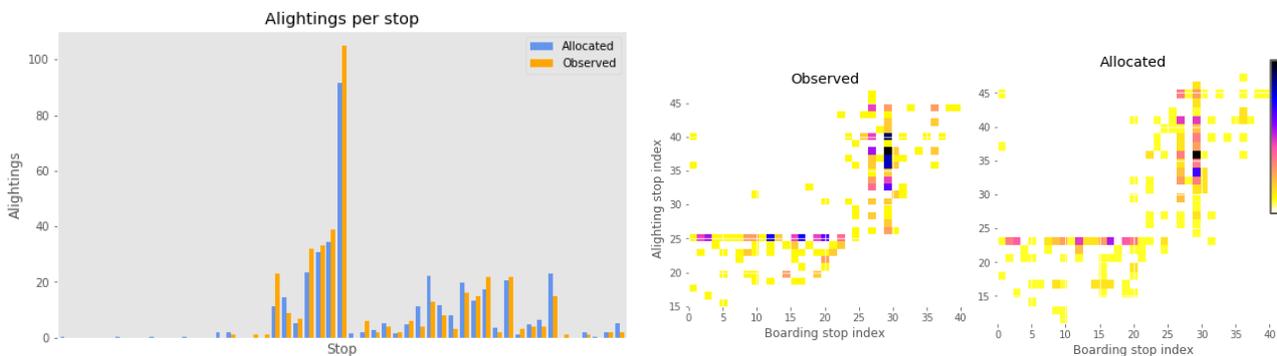


Figure 4-11: Alight Stop Observed vs Allocated – Route 220, Direction 0

As can be observed, the allocated alight stops are generally a good match with actual ones, with the resulting alighting profiles being very close to observed.

4.4 Bus Matrices Development

4.4.1 Trip Legs to Trips

The next step of the ETM processing was the conversion of transaction records into trips, by merging trip legs into full trips for records flagged as including more than one leg i.e. involving transfers.

The following table shows the distribution of trips per number of trip legs.

Table 4-1: Trip Legs Distribution

Number of Legs	Number of Trips	%
1	1,650,505	93.6%
2	106,151	6%
3	5445	0.3%
4	644	0.0%
5	109	0.0%

Multi-leg trips were merged with only information relating to the boarding of the first leg and alighting of the last leg retained, with the exception of fare zones travelled which were summed up along the whole trip.

The following plots shows location and daily number of transfers on the bus network. As can be seen, most of the transfers occur at expected hubs in the region, including Porirua, Lower Hutt and Johnsonville CBDs. In Wellington most transfers occur along the Golden Mile in the CBD, especially at both ends (Bus station and Courtenay Place), as well as in suburb hubs such as Newtown, Kilbirnie and Miramar.

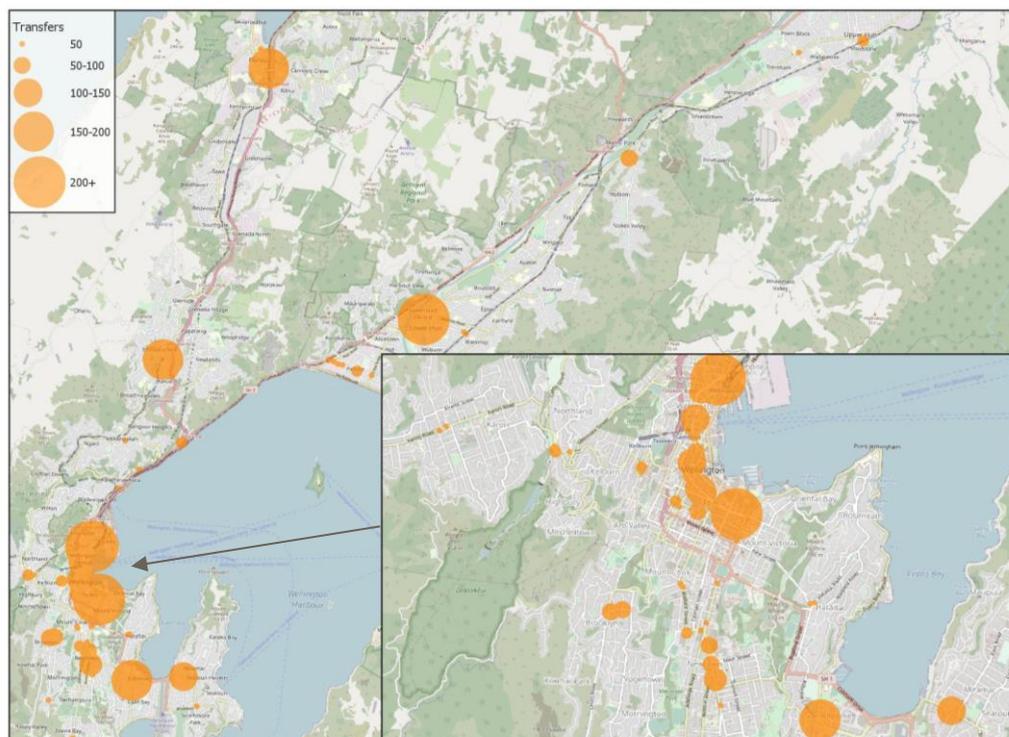


Figure 4-12: Daily Bus to Bus Transfers

The merging of trip legs led to 1,762,853 full trips remaining.

4.4.2 Stop-to-stop Weekday Trips by Time Periods and Passenger Types

Trips were then allocated a time period, based on the first boarding time (consistent with the 2011 WPTM approach) as follows:

- AM Peak: between 7 and 9AM
- Inter peak: between 9AM and 3PM
- PM peak: between 4 and 6PM

The passenger category 'adult' or 'child' was also added, with 'child' allocated to ETM passenger type 'Child' and 'Under-5', and 'adult' allocated to all other types.

All trips were then aggregated by boarding stop, alighting stop, passenger type, time period and route number. The resulting number of trips was also divided by the number of weekdays in March 2019 (21) to derive weekday average.

The following table shows the resulting weekday average trips per time period and passenger category.

Table 4-2: Weekday Average Trips

	AM Peak	Inter Peak	PM Peak
Adult Trips	17,554	23,468	15,765
Child Trips	3,755	1,965	1,970

4.4.3 Trip Purposes

Further disaggregation is then needed to separate 'Adult' demand into the 3 trip purposes used in WPTM: Work (commuting and business), Education and Other. 'Child' demand is represented as the 4th purpose.

The 2011 model build extensively used bus intercept surveys carried out at the time specifically for the development of the model to derive trip purposes. First, employment and education data was used to categorise bus stops depending on the land use in the WPTM zones around the bus stop, leading to the following categories:

- Employment: high, medium or low
- Education: true (within 500m of an educational institute for 17+ year old) or false

Responses from the intercept surveys were used to derive the trip purpose split for each land use category, and these factors were then allocated to all bus stops depending on the employment and education category of their area. For the AM peak, factors were then applied to trips based on the alighting stop as most AM trips have the home close to the boarding stop and the 'activity' close to the alighting stop. For the Inter peak, both boarding and alighting stops were used.

For this WPTM update, no new intercept survey was available. In addition, employment and educational categories were deemed unlikely to have significantly changed since 2011. For this reason the same factors as 2011 were used. A number of bus stops in the 2019 GTFS did not exist in 2011, trip purpose factors for those were manually allocated based on nearby bus stops with similar characteristics.

For the new PM peak period, which was not included in the original model, the reversed approach from the AM Peak was used and trip purpose factors were based on the boarding stop, which was deemed likely to reflect the activity in most cases.

This methodology led to the following number of weekday trips per purpose and time period.

Table 4-3: Weekday Average Trips Per Purpose

	Work	Education	Other	Child
AM	13,244	2,646	1,663	3,755
IP	6,240	5,503	11,727	1,965
PM	12,037	2,211	1,518	1,970

The following figures show the resulting number of alightings and proportion per trip purpose for each time period.

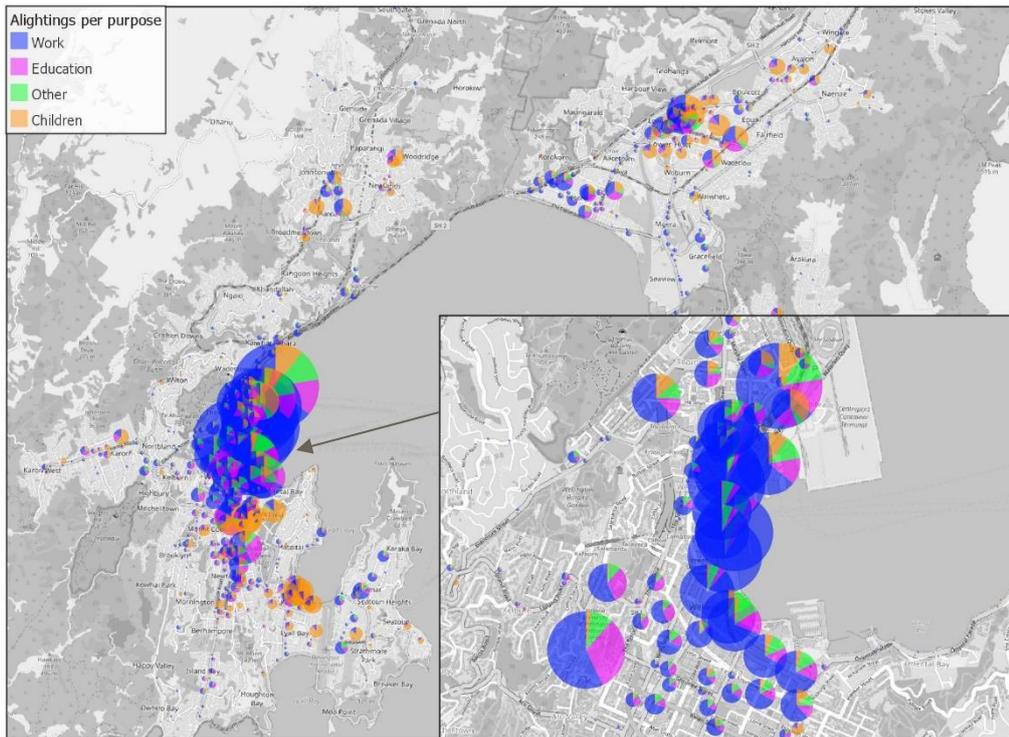


Figure 4-13: Alightings Per Trip Purpose – AM Peak

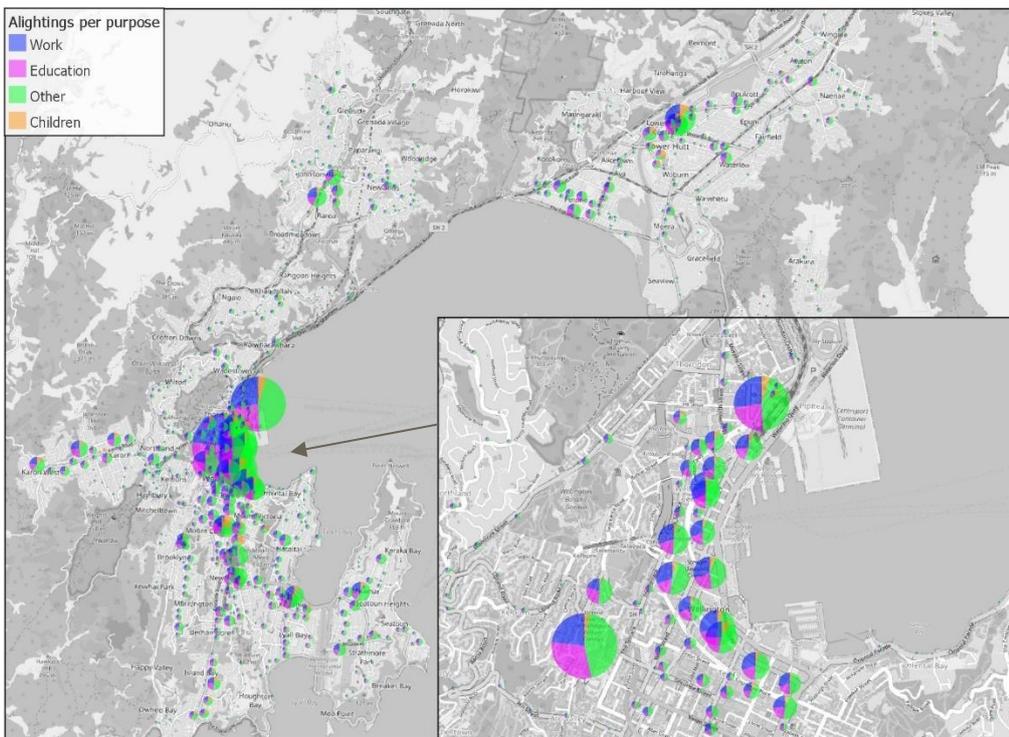


Figure 4-14: Alightings Per Trip Purpose – Inter Peak

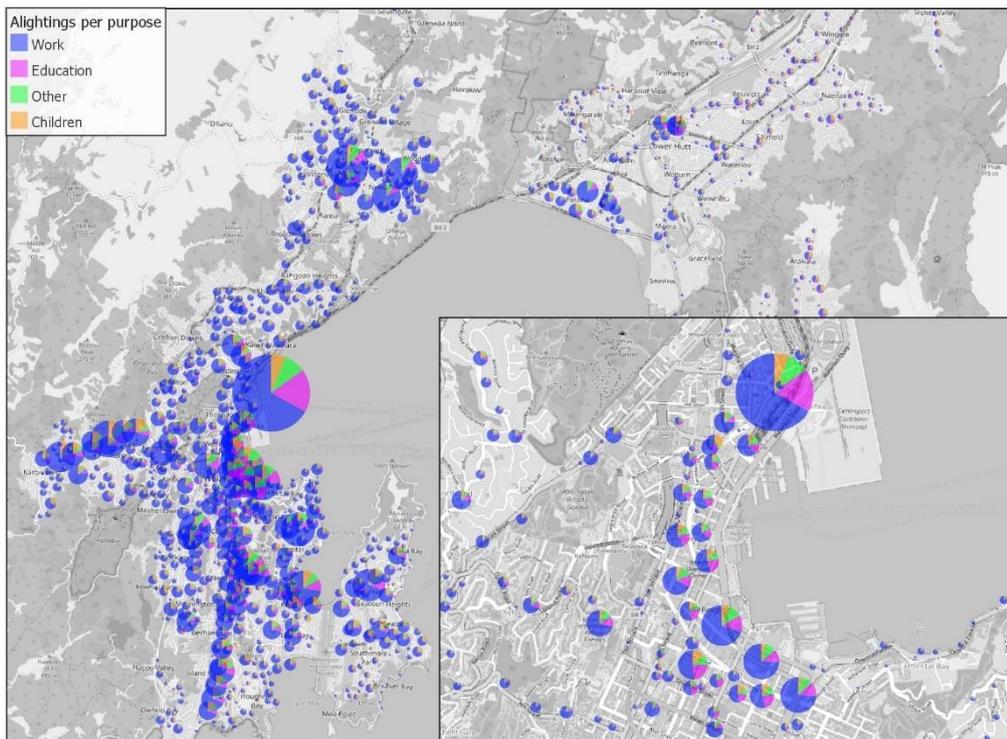


Figure 4-15: Alightings Per Trip Purpose – PM Peak

A number of observations can be made from these plots:

- By far most of the AM peak trips are inbound to Wellington CBD.
- As expected, most trips in the AM and PM peak are work related, especially for trips alighting in the CBD.
- Suburban areas also show a sizable proportions of 'children' trips to school.
- During the Inter Peak, 'other' purpose is the most prevalent.
- Outside the CBD, Victoria University stands out as a major attractor, especially for 'Education' related trips.
- A lot of alighting can also be seen at the bus station, including for the PM peak, some of which are likely to transfer to rail to journey onward.

4.4.4 Stop to Zones

The last step of this process involves converting stop-to-stop trips to zone-to-zone trips and aggregating all trips by zone pairs to form demand matrices for input into the model.

For the 2011 development of the model, stop to zone allocation was carried out through a gravity model using a special version of the EMME WPTM databank with each stop represented as a zone, in addition to the 780 actual model zones. A gravity model was calibrated, taking into account trip generation/attraction potential for each zone (based on different land use information such as population, resident full time employees or students, jobs or school roll, depending on trip purpose and access or egress leg) and a decay function of walking time. Due to the low numbers of car access/egress to bus, all bus trips were categorised as walk-access.

The gravity model was calibrated using data from the intercept survey, with different parameters for the decay function for each trip purpose. This led to a table of allocation factors for each bus stops to surrounding zones, differing per trip purpose, time period and access or egress leg.

For this 2018 update, the same factors from 2011 were used for the same reasons as trip purpose allocation (no new intercept survey, no major changes in land use and recalibrating the gravity models being out of the scope of this update).

Again, factors for new bus stops were manually allocated based on nearby bus stops with similar characteristics.

The factors developed for 780 zones however had to be adjusted for the new 813-zone system, including zones being merged, split and in some cases a combination of both. For merged zones, factors were simply added. For split zones, factors for each new zone were split based on the ratio of population and/or employment in the new zone, depending on trip purpose, time period and access/egress.

The following figures show Wellington and Lower Hutt AM peak 'work' trip purpose per bus stops, and the resulting allocation to zones. Figure 4-16 shows boardings per stops while Figure 4-17 shows alightings per stop

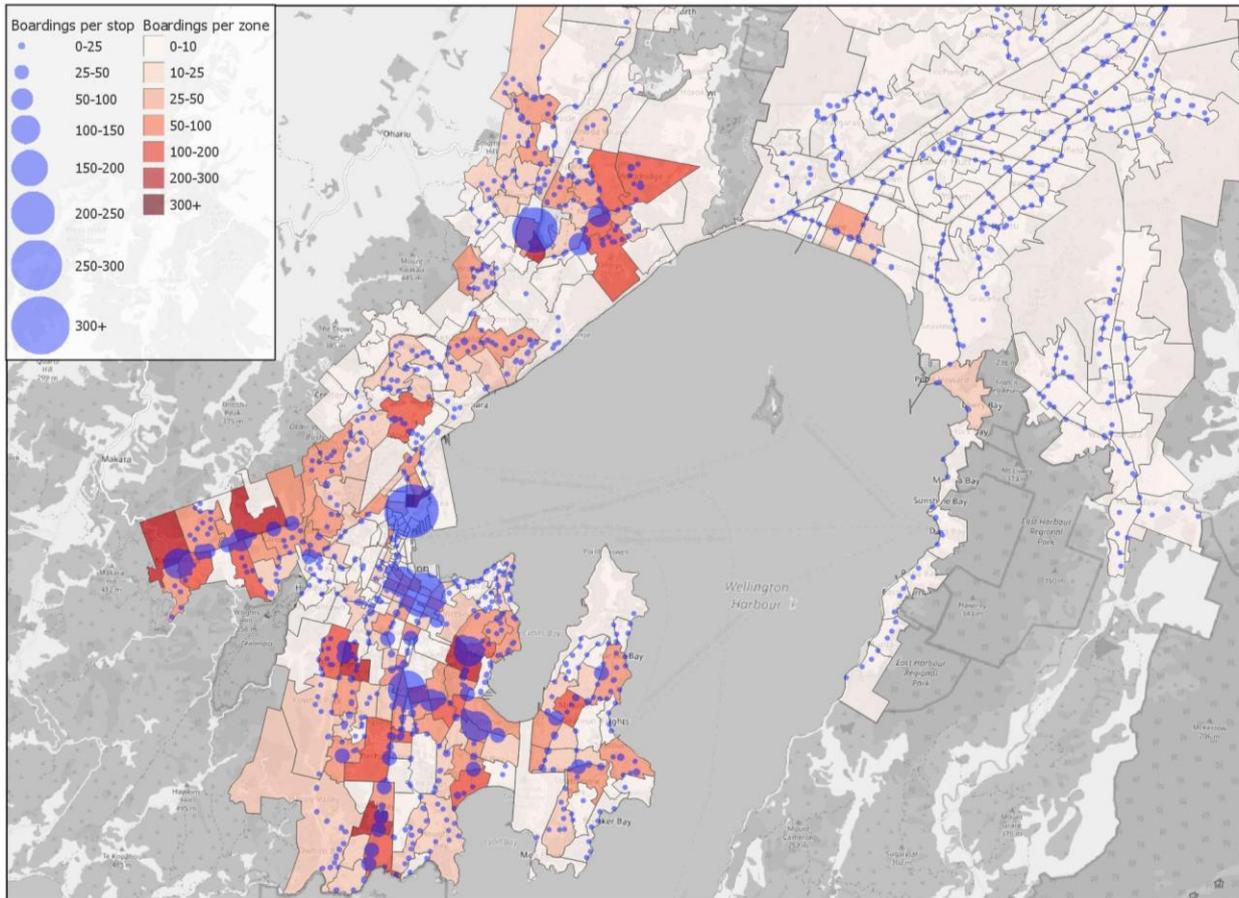


Figure 4-16: Boardings Per Stop and Zone – AM Peak

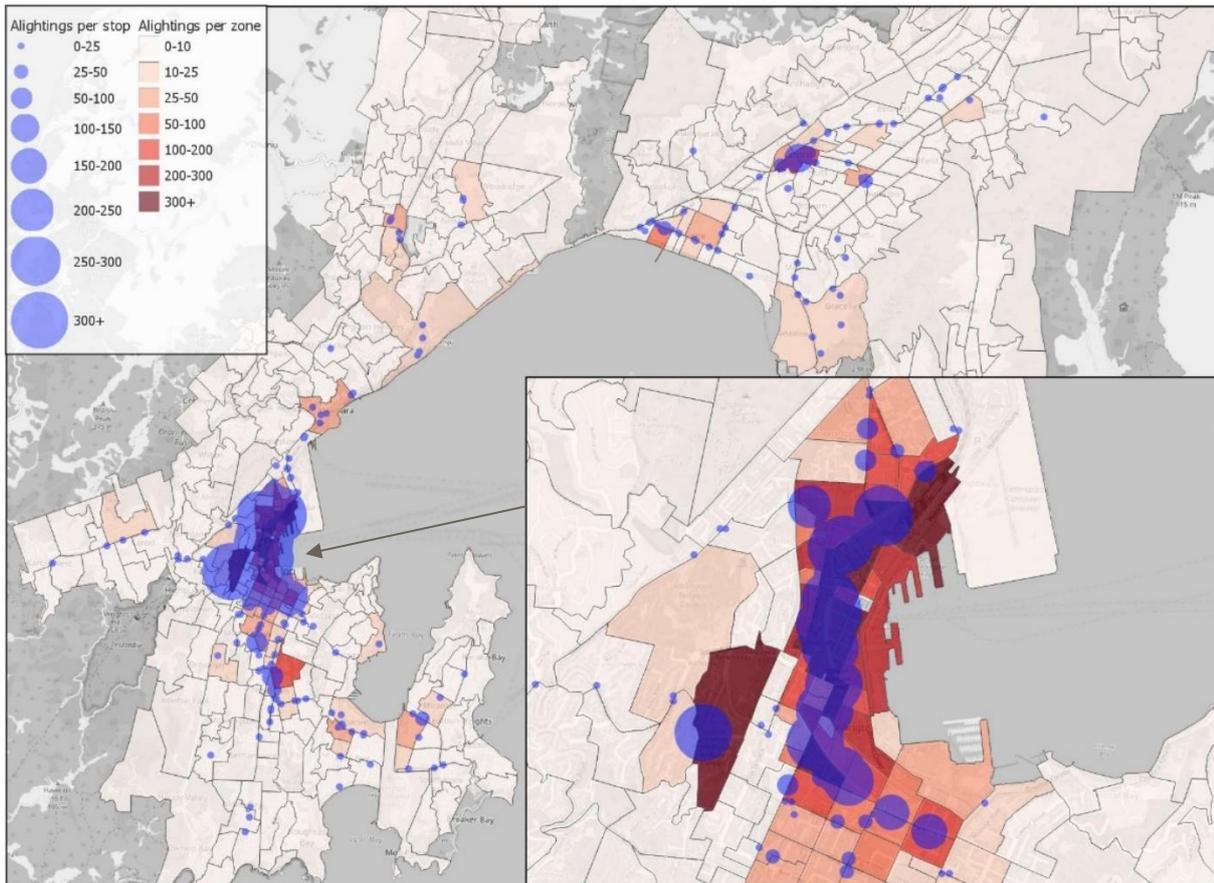


Figure 4-17: Alightings Per Stop and Zone – AM Peak

These plots show that boardings for 'work' related trips are quite spread in the Wellington City area, although the main bus corridors (Karori, Island Bay, Miramar/Kilbirnie and Johnsonville) can clearly be seen. Most trips are bound to the CBD. The bus station stands out for both alightings and boardings, partly due to transfers between bus and rail.

The resulting zone-to-zone trip tables, which at this stage still include separate records for each trip were then aggregated to form zone to zone demand matrices. The Inter Peak matrices were also divided by 3 to obtain the average 2hr demand.

Finally, the matrices were formatted and output in the format required by WPTM.

4.4.5 Airport Bus Demand

Unlike the 2011 model development, bus services to and from the airport (route 91, or 'Airport Flyer') are not part of the Metlink network anymore, and therefore are not included in the ETM dataset. No patronage information for these services was available.

Matrices from the new airport module developed as part of the WTSM 2018 update (see 'TN10 - Wellington Analytical Tools 2019-21 Update - Airport Model_v2') were therefore imported and converted from the WTSM 225-zone system to the WPTM 813-zone system, using the standard WPTM disaggregation process. These matrices were then added to total bus demand for each time period.

A number of limitations apply to the development of these airport bus demand matrices, as documented in TN10, and these also apply to their use in WPTM. Should the WTSM airport module be updated based on more comprehensive data, the new matrices should also be imported in WPTM.

However, this approach leads to consistency between both models, and appropriate levels of base year airport-related demand being included in WPTM.

5. Rail Demand Update

5.1 Summary of Approach

Rail matrices in the original WPTM were developed from an extensive programme of boarding and alighting surveys, as well as intercept surveys. This process is developed in 'TN7 PT Matrix Development FINAL' from the 2011 development of the model.

For the 2013 update, only minor sector-based adjustments were applied to rail matrices based on observed changes in demand from high counts and Metlink aggregated data.

No new survey was carried out for 2018 rail patronage, and unlike bus demand with ETM data, no recent detailed information was available. Only more aggregate metrics such as high counts, Metlink patronage and APC door counts were provided, as detailed in Section 3.

For this 2018 update, annual average matrices were first converted to March average weekday and factored up to take into account demographic growth. A similar approach to 2013 was then applied where aggregated sector-based demand was compared against observed patronage growth to determine if factors needed to be applied to represent additional growth on the rail network.

5.2 Data Analysis

Data used to derive 2011-2018 growth factors to apply to the 2011 demand, or validation metrics include:

- 2011 rail passenger surveys carried out for the development of WPTM
- 2017 park-and-ride study survey and report
- 2017 and 2019 automated door counts and high counts
- Metlink patronage data

The following section highlights the main findings from analysis of these data sources. One difficulty encountered throughout this analysis was that the different datasets were not always consistent and could occasionally lead to very different conclusions. In some cases, this could be explained by differing definitions (March weekday only vs annual, peak only vs all day) but in other cases some datasets had to be discarded or adjusted for consistency.

5.2.1 Overall Patronage

Metlink patronage data⁴ was used to estimate the overall growth on the network, for both peak and off-peak periods, as shown in the following table. Annual figures were used at first, but patronage for March only was also used for comparison (with March 2018 values adjusted to account for 1 less weekday than March 2011).

Table 5-1: Overall Rail Patronage Increase 2011-2018

Time Period	2011	2018	% increase
Annual Total	11,242,812	13,552,866	21%
Annual Total Peak	7,432,766	8,890,514	20%
Annual Total Off Peak	3,810,046	4,662,352	22%
March weekdays	1,134,923	1,320,002	16%

Results show that there has been a 21% increase in rail patronage between 2011 and 2018, with a slightly higher increase off-peak than during the peak. March figures however show only a 16% increase. This is caused by March 2011 patronage representing a higher proportion of the annual figure than March 2018.

5.2.2 Patronage Per Line

Patronage per line was also provided by GWRC, for both Annual and March weekday as shown in the following table.

⁴ https://www.metlink.org.nz/our-metlink-journey/performance-of-our-network/#Accordion_2801

Table 5-2: Rail Patronage Increase Per Line 2011-2018

	Total - Annual			Total - March		
	2011	2018	% increase	2011	2018	% increase
JVL	1,158,517	1,514,230	31%	110,239	147,962	34%
KPL	4,521,359	5,744,809	27%	444,495	543,697	22%
HVL	5,801,181	6,578,474	13%	580,189	628,343	8%
Total	11,481,057	13,837,513	21%	1,134,923	1,320,002	16%

Note: Annual figures are slightly different from values in **Error! Reference source not found.** but the trend is identical.

This shows the highest increase in patronage having occurred on the Johnsonville line (JVL), followed by the Kapiti line (KPL) and with the Hutt Valley Line (HVL, also including Wairarapa and Melling services) having experienced the least growth.

5.2.3 Automated Door Counts and High Counts

Raw automated door counts were obtained for March 2019. Door counts from 2017 (already processed) were also obtained for consistency checks. Following discussions with GWRC, it is understood that these counts are not overly accurate both in terms of number of passengers counted and categorisation of boardings vs alightings, with some carriages having been found to report alightings and boardings the wrong way around. They are however the only available data to estimate growth in patronage per station.

High counts were also provided for March 2019, i.e. manual counts of passengers directly before entering Wellington station for inbound services or after leaving the station for outbound services.

The following plots present respectively a comparison of AM Peak boardings and alightings at each station along the Kapiti line as an example, from the 2011 survey and 2017 and 2019 door counts (Wellington station is not included in the alighting plot as it would dominate all other stations).

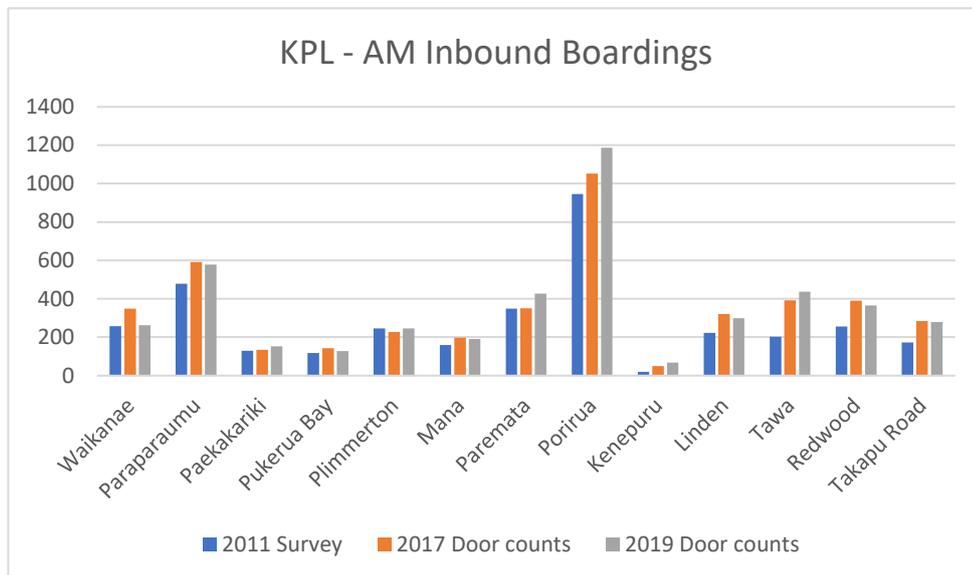


Figure 5-1: Kapiti Line Boardings – AM Peak

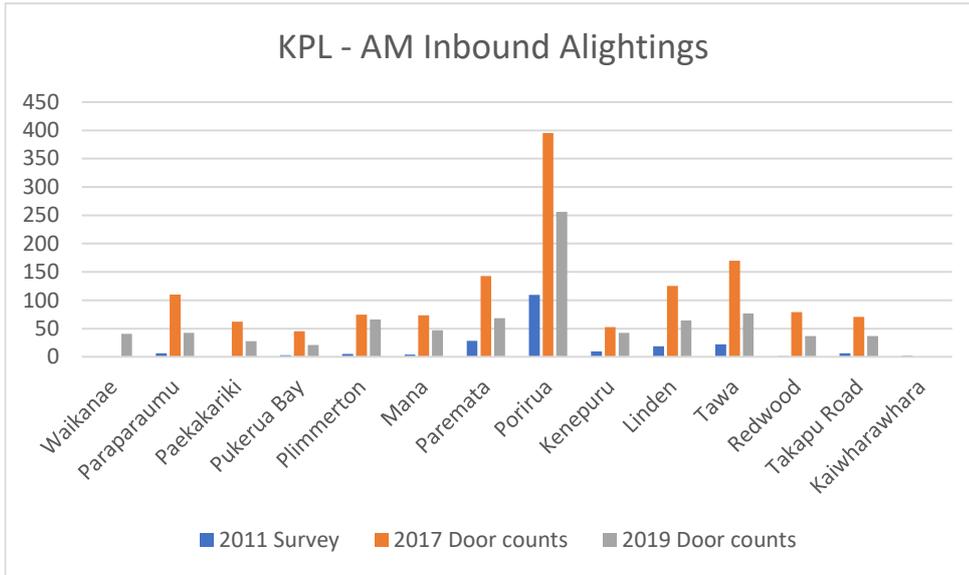


Figure 5-2: Kapiti Line Alightings – AM Peak

Comparison of the three datasets show that boardings are reasonably consistent. However it is not possible to understand how much of the difference is due to door counts inaccuracy and how much is due to actual changes in demand. In particular, boardings at Waikanae and Paraparaumu show little to no increase compared with the 2011 survey, whereas anecdotal evidence indicates that these two stations have experienced large growth in patronage, based on an increase in Park-and-Ride capacities and occupancies.

Alightings however show very different patterns, with much more alightings along the route from the automated door counts than in the original 2011 survey. Given that a large majority of rail passengers travel to and from the Wellington CBD, the more recent door counts appear intuitively incorrect.

The same issues were observed on other routes, time periods and direction.

A comparison was also undertaken between the manual 'high counts' and high counts derived from automated door counts. For automated door data, this was estimated by adding all boardings for inbound services minus all alightings except Wellington station itself. For outbound services this was the other way around with all alightings added, minus all boardings except Wellington Station.

Results are shown in Figure 5-3.

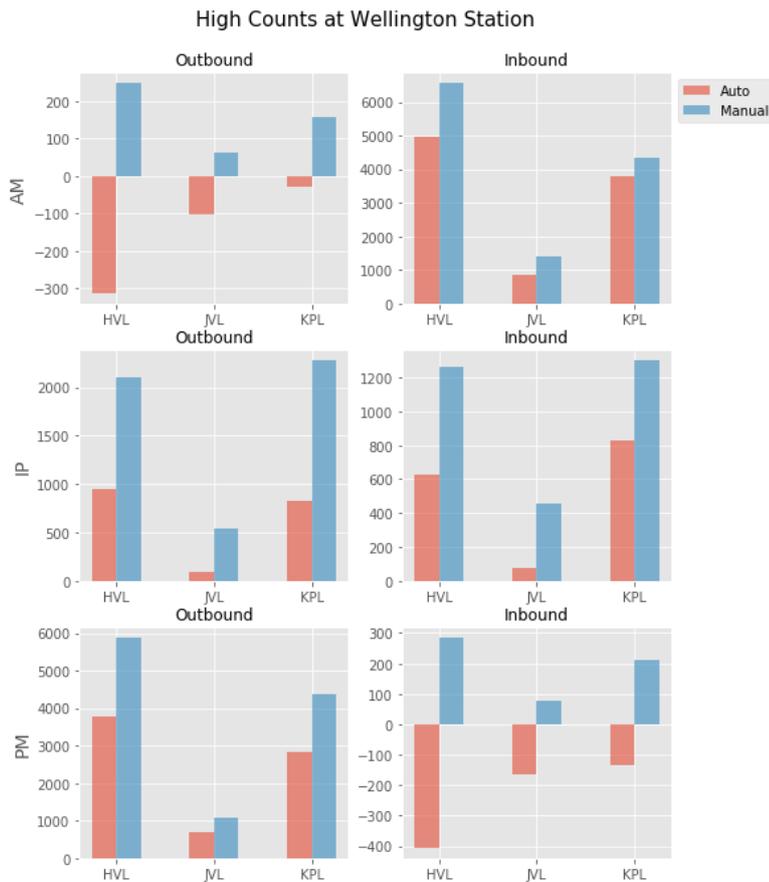


Figure 5-3: High Counts Comparison Auto vs Manual

Results show that in the peak direction (AM inbound and PM outbound), automated door counts consistently under-estimate the number of passengers in and out of Wellington station. During the inter peak, this trend is even more apparent, and in the counter-peak direction estimating high counts using automated door data actually leads to negative values (meaning that in the AM peak outbound direction more boardings than alightings were recorded, excluding Wellington station).

Following discussions with GWRC, it was understood that some door counters were faulty and incorrectly separated boardings from alightings.

5.2.4 Access Mode to Rail

Finally changes in access mode per line between 2011 and 2017 was extracted from the 2017 Park-and-Ride study report, showing results for both years. It must be noted that the 2011 numbers quoted in the report come from the surveys that were carried out specifically for the development of WPTM and are therefore consistent with the original model. 2017 results are based on a survey sample that was expanded based on automated door counts.

The table below shows the percentage of access mode by car (including park-and-ride and kiss-and-ride) for each line during the AM Peak.

Table 5-3: AM Peak Car Modal Access to Rail Stations

	2011	2017
JVL	44%	16%
KPL	55%	60%
HVL	49%	47%
Total	51%	49%

Results show that by 2017, there is an increase in proportion of car access on the Kapiti Line and slight decrease on the Hutt Valley line.

2017 results for the Johnsonville line are however markedly lower than 2011. The park-and-ride survey data report⁵ notes the following:

The Johnsonville line shows some inconsistencies: the high car share in 2011 seems questionable, while the 2017 car share seems rather low. This may be partially explained by the fact that the Johnsonville line results are based on relatively small numbers. For example, only 5 people in the 2017 survey were passengers in cars.

2011 and 2017 observed mode shares were also compared per station, using the 2011 WPTM and 2017 Park-and-Ride surveys. Results are shown in the following three plots.

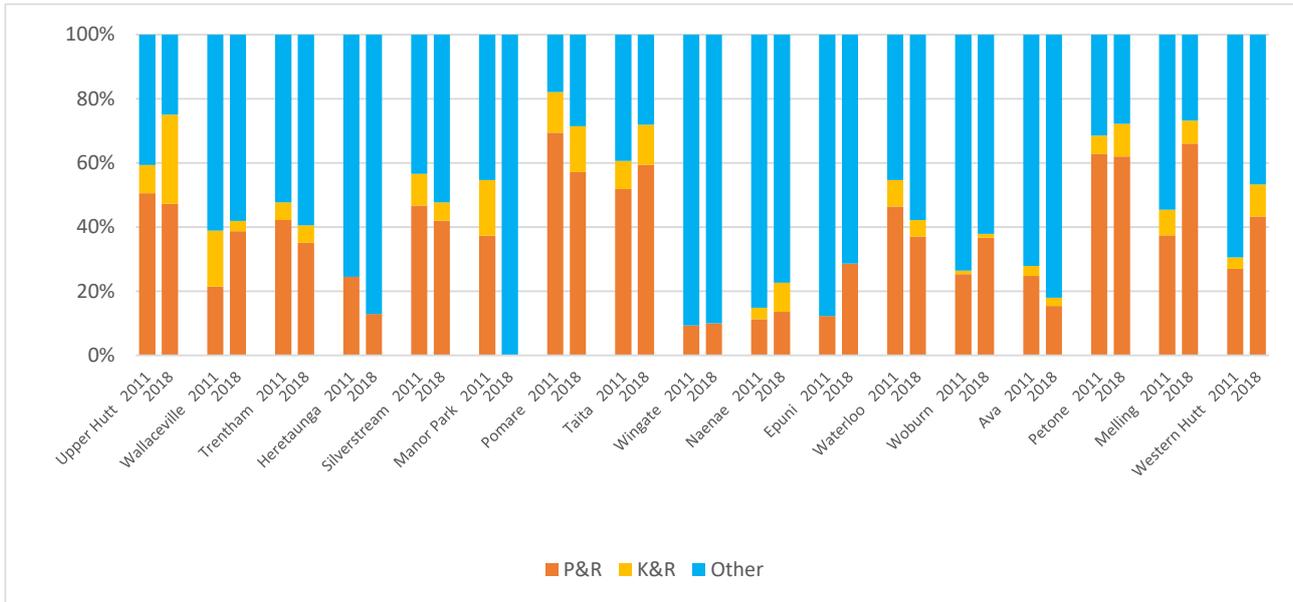


Figure 5-4: AM peak Station Access Mode – Hutt Valley Line Inbound

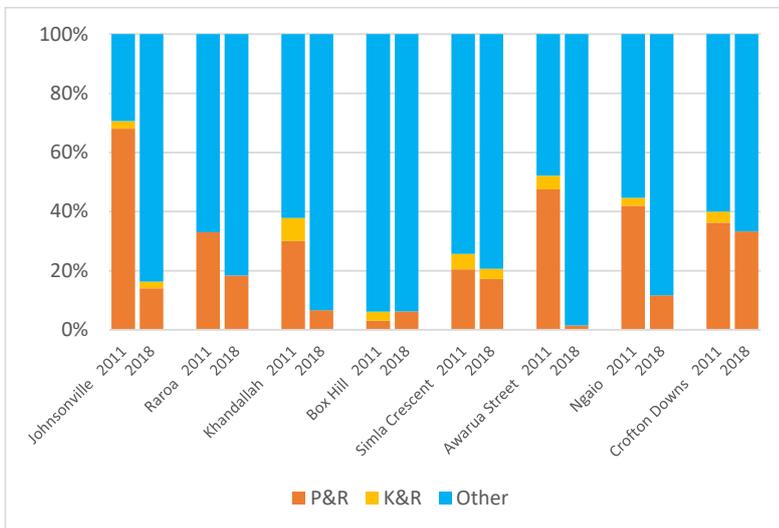


Figure 5-5: AM Peak Station Access Mode – Johnsonville Line Inbound

⁵ <http://www.gw.govt.nz/assets/Transport/Regional-transport/Regional-Transport-Analysis/Rail-Survey-2017-PR-data-Note.pdf>

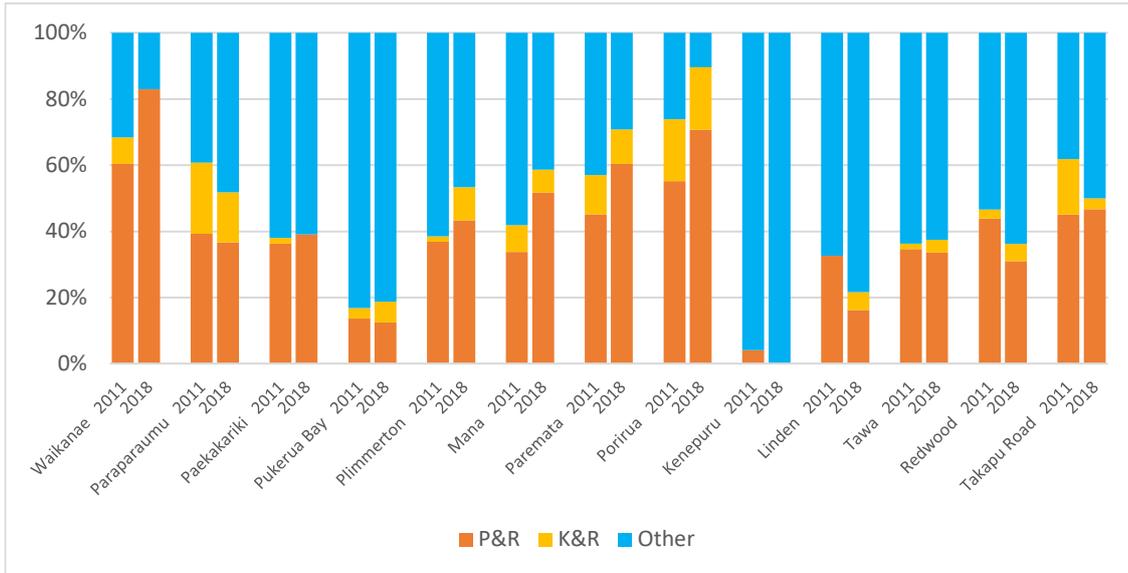


Figure 5-6: AM Peak Station Access Mode – Kapiti Line Inbound

Similarly as boardings per station, access per station vary between the 2011 and 2017 datasets, but it is difficult to understand how much is caused by actual changes and how much is caused by different survey methodology and sampling error. Results for the Johnsonville Line however appear quite different in 2017 from 2011, confirming the issue observed in Table 5-3.

Discussions with GWRC, along with parking capacities along this line (including informal parking) indicates that the share of car access to the Johnsonville line has likely been over-estimated in the 2011 surveys, and therefore in the development of WPTM. Impact of this on the model validation is discussed in section 7.7.

5.2.5 Conclusions

Based on the above analysis, it was found that the data available would not enable observed changes in patronage to be derived at a disaggregate level, i.e. per station or direction, due to accuracy issues with some datasets and inconsistencies between them. This applies both to adjustments factors to apply to the rail matrices, and to observed metrics used for validation.

One approach initially tested was to use 2019 total number of passengers at each station from APC but apply the 2011 split between boardings and alightings to the total. However, it was found during validation of the model that using this approach to estimate 2011-2018 observed changes in patronage per station still led to overall trends per line that were counter-intuitive and did not match the increase in patronage per line shown in Table 5-2. For example, the resulting growth in patronage from 2011 on the Hutt Valley Line from using door counts was much higher than observed through Metlink data or manual high counts, whereas it was the other way around for the Kapiti line.

Ultimately, for the data used for validation it was decided to continue to use the 2011 observed boardings and lightings per station, factored up using Metlink overall patronage data for each line, similarly as for the 2013 update. This means that patronage increases for some stations having experienced more intense growth since 2011 may not be fully reflected in the data used for validation, and it is recommended that the model is checked against more recent patronage data should it become available.

Regarding access mode choice, while a full update of the access choice model was not part of this project, the data available would not allow this recalibration to be carried out in any case. However, the WPTM access mode choice will react to changes in demography, car ownership, parking supply and network congestion. Therefore 2018 modelled access mode share will be compared against the initial 2011 WPTM survey, as well as the 2017 Park-and-Ride survey and high level observed changes since for sense-checking.

5.3 Rail Matrices Development

5.3.1 Change to New Zone System

The rail demand matrices from the original 2011 WPTM (AM peak and Inter peak only) were first converted from the 780 zones to the new 813-zone system. For merged zones, trips were simply added. For split zones, trips were divided based on the ratio of land use in the new zone over land use in the original zone, using either population, employment or education depending on trip purpose and time period. For the AM peak, demand was split based on population for the origin zone and employment for the destination zone (education for the 'Education' purpose). For Inter peak matrices, the average of population and employment was used.

This was not applied to PM Peak matrices that were not originally part of the 2011 model. The approach for this time period is detailed in section 5.3.4.

5.3.2 Factoring from Annual to March Average

AM Peak and Inter Peak rail demand matrices from the original 2011 WPTM are representative of average annual weekday conditions, whereas the updated 2018 model will represent average March weekday demand. March usually shows higher PT patronage in the Wellington region, matrices were therefore first factored up by applying Annual to March factors derived from patronage data, for each line and peak vs off-peak.

The factors to uplift demand to March are shown in the following table.

Table 5-4: Annual to March Factor

	Peak	Off Peak
Johnsonville Line	1.11	1.13
Hutt Valley Line	1.07	1.15
Wairarapa Line	1.08	1.11
Kapiti Line	1.07	1.11

5.3.3 Factoring for Population Growth

2011-2018 population increase per zone was then applied to the demand matrices, to account for increase in demand caused by demographic growth.

For the AM peak, this growth factor was applied based on the origin zone, as most trips during this period are starting from home. For the Inter peak it was based on the origin zones for trips from the region to the CBD, and on the destination zone for outbound trips from the CBD to the rest of the region. Trips not from or to the CBD represent a minority of rail trips and for those the average of origin factor and destination factor was applied.

Factors were calculated at the 225 WTSM zone system as no 2011 land use information was available with the new zone system. This level of aggregation would also smooth out potential large relative changes in demography which could result in unrealistically large changes in demand.

Although separate factors were derived for each zone, the following table presents the total population increase for each Territorial Authority (TA) in the Wellington region, as well as the resulting increase in trips.

Table 5-5: Population and Resulting Trip Increase per TA

TA	Population			Trips		
	2011	2018	Increase	2011	2018	Increase
Wellington City	191,236	201,657	5%	3,307	3,475	5%
Porirua City	51,443	57,645	12%	2,785	3,057	10%
Kapiti Coast District	49,085	53,676	9%	1,320	1,437	9%
Upper Hutt City	40,188	43,983	9%	1,186	1,320	11%
Lower Hutt City	99,678	104,532	5%	4,429	4,764	7%
Wairarapa	39,430	26,205	15%	952	1,116	17%
Total	471,060	506,823	8%	13,980	15,168	8%

The increase in the number of trips at a TA level is generally consistent with the increase in population. Some slight differences can be observed, showing that in some cases such as in the Hutt Valley the increase in population occurs in zones that are more likely to use rail, whereas in other cases such as Porirua it is the opposite.

It is acknowledged that this approach is somewhat coarse as it does not account for potential changes in population characteristics (age, income, employment status) which would impact on trip rates and mode choice, but in the absence of more detailed data it allows to account for a representation of population-driven increase in patronage.

5.3.4 PM Peak Demand

As mentioned previously, the PM peak was not originally included in WPTM and was added subsequently based on a simplified approach, with the resulting matrices being essentially based on the AM peak matrices transposed and adjusted using sector-based factors.

For this update, the model was run with the new AM peak matrices and the adjustments factors were updated to better reflect observed PM patronage. Whereas no detailed patronage data per station was available previously, the PM peak 2019 door counts were used for validation although the same limitations on this dataset as described in section 5.2.3 apply.

The resulting updated factors, together with the previous factors in the 2013 model are shown in the following table.

Table 5-6: AM to PM Peak Factors

Origin – Destination	2013 Factors	2018 Factors
CBD to Johnsonville	0.78	0.9
CBD to Porirua and Kapiti	0.8	0.9
CBD to Lower Hutt	0.85	0.95
CBD to Upper Hutt and Wairarapa	0.85	1.1
Johnsonville to CBD	1.39	1.39
Porirua and Kapiti to CBD	1.43	1.43
Hutt Valley and Wairarapa to CBD	1.34	1.34

6. Ferry and Cable Car Demand Update

No origin or destination surveys were carried out in 2011 for Wellington Harbour ferries and the cable car and a simple approach was adopted. Total number of passengers were obtained from the CBD cordon survey. These trips were then allocated based on population to a limited number of plausible zones on the production end and based on employment on the attraction end (to zones within 1km crow-fly distance in the CBD).

While this method is approximate, it was considered appropriate given the lack of more detailed data and the small number of passengers on these modes.

For this 2018 update, the cable car and ferry matrices were simply factored up based respectively on CBD cordon survey and GWRC patronage data and modified to match the new 813-zone system using the same approach as the rail matrices (see section 5.3.1)

For the cable car, only the AM peak was available for the cordon survey and the same growth factor was applied to the Inter peak. For the ferry, both peak and off-peak were available.

The growth factors and resulting number of trips are shown in the following table.

Table 6-1: Ferry and Cable Car Growth

Mode	Period	Growth	2011	2018
Cable Car	AM	5%	101	106
	IP	5%	50	52
Ferry	AM	7%	247	263
	IP	8%	59	64

7. Update of Other Components

7.1 2018 Network

WPTM receives its networks from WTSM. Networks for all time periods, which include congested travel times, are imported into WPTM, the centroids and connectors for the 225-zone system are deleted and those for the 780-zone system added in.

One outcome of this project will be that both models will eventually share the same 813-zone system (See 'TN3 - Wellington Analytical Tools 2019-21 Update - Zoning V2' for more detail). For WTSM this will be carried out as part of Stage 2, but WPTM has been converted to the new zone system as part of this update.

Most of the network changes, including the new PT network are therefore part of the WTSM update and covered in a separate document (see TN16 – Interim WTSM 2018 Validation). For WPTM itself the only change was updating the network change files that implement the centroids and connectors for the 813-zone system, which will still be used until WTSM is upgraded to the new zones.

All 'partitions' (or 'ensembles') used in the model, i.e. groups of zones, were also updated to match the new 813-zone system.

7.2 2018 Land Use

Land use information is used in WPTM to disaggregate the WTSM demand matrices into the WPTM zone system. While this will not be necessitated once WTSM is based on the new 813-zone system, it is still required with the interim 2018 WTSM and was therefore updated with new 2018 census and school roll data. The land use categories for disaggregating each demand depending on trip purpose and access vs egress were as per the original model:

- Resident Population
- Resident Full Time And Part Time Employees
- Resident Full Time And Part Time Students
- Total Employment
- School Enrolment 17+ Years Old And Tertiary
- School enrolment 11-16 Years Old

7.3 Value of Time and Vehicle Operating Costs

The update of values of time and vehicle operating costs to 2018 is detailed in 'TN9 - Wellington Analytical Tools 2019-21 Update - Model Input Parameters v2'.

7.4 PT Fares

2018 proportions of fare product used for bus and rail were provided by GWRC and compared against 2011 values. The various products were aggregated into a reduced number of categories and the resulting proportions are shown in the figures below, respectively for bus and rail.

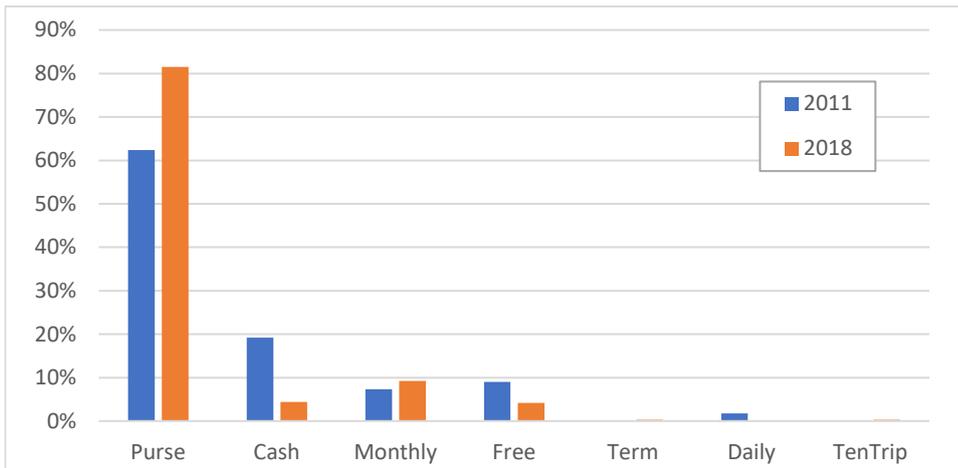


Figure 7-1: Bus Fare Product Proportions

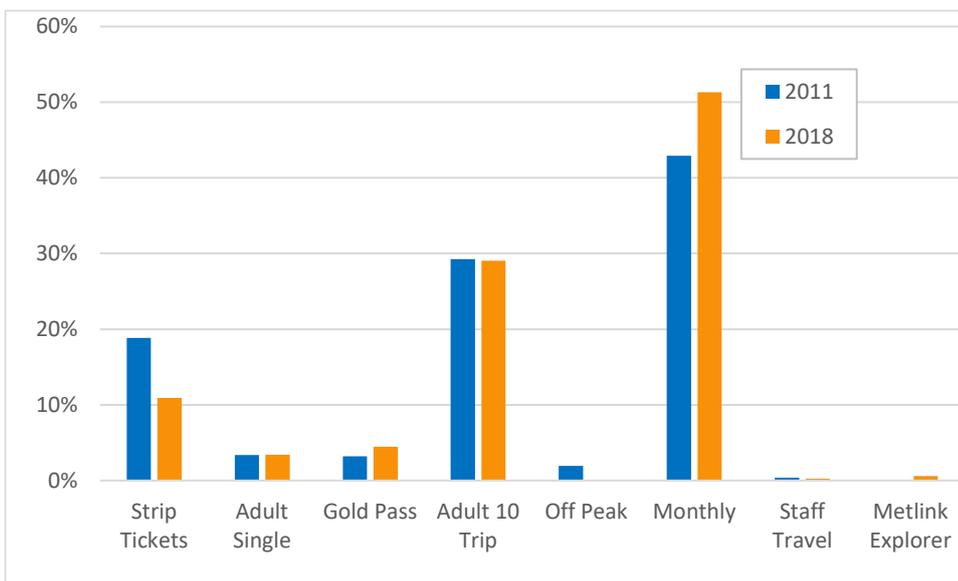


Figure 7-2: Rail Fare Product Proportions

As can be observed, there has been an increase in 'Purse' use for bus, i.e. Snapper card, and a marked decrease in cash fares. For rail, use of strip ticket has decreased with a stronger uptake of monthly fares.

The fares per mode used in WPTM therefore had to be updated to account for the resulting decrease in average prices, due to Snapper card and rail monthly fares being discounted. In addition a 25% discount now applies to Inter peak fares for bus purse and rail 10-trip.

Another change is that the route 91 to the airport ('Flyer') is not part of the Metlink fare structure anymore. The average extra cost for Flyer trips compared with Metlink services across the same number of fare zones were calculated, and applied to fares for this service, resulting in approximately a doubling in fare.

Finally, PT fares have increased slightly for some zones since 2011. However, once adjusted for inflation, there is not a significant change in fares in real dollars overall. Therefore, to update the PT fares for WPTM, the 2011 values were adjusted to 2018 \$ using CPI (as was used for the last update) and no other changes were made, resulting in a circa 9% increase.

The resulting updated PT fares are shown in the following table, along with the original 2011 values.

Table 7-1: PT Fares

	Mode	2011			2018		
		Flagfall Line	Flagfall Node	Boundary	Flagfall Line	Flagfall Node	Boundary
AM Adult	Bus	0	1.89		0	1.98	
	Flyer	2.18	1.89		4.68	1.98	
	Rail	1.89		0.01	2.02		0.01
	Ferry	8.39			9.12		
AM Child	Bus	0	1.28		0	1.34	
	Flyer	1.88	1.28		4.03	1.34	
	Rail	0.99			1.06		
	Ferry	8.39			9.12		
IP Adult	Bus	0	1.57		0	1.29	
	Flyer	2.50	1.57		5.00	1.29	
	Rail	1.96		0.13	1.73		0.12
	Ferry	8.39			9.12		
IP Child	Bus	0	1.29		0	1.29	
	Flyer	1.87	1.29		3.71	1.06	
	Rail	0.9			0.68		
	Ferry	8.39			9.12		

PT fares for the PM peak are the same as for the AM peak, are per earlier version of the model.

7.5 Park-and-Ride Capacity

Rail station parking capacities for 2018 were sourced from Metlink and compared with 2011 values in WPTM. The latter include some informal parking whereas capacities provided by Metlink only included formal parking, and as a result some of the 2018 values were lower than 2011. Only numbers that showed an increase were therefore updated. The resulting updated parking capacities are shown in the following table, along with the 2011 values.

Table 7-2: Park-and-Ride Capacity

Rail Station	WPTM 2011	WPTM 2018	Rail Station	WPTM 2011	WPTM 2018
Upper Hutt	334	349	Crofton Downs	54	54
Wallaceville	132	132	Waikanae	321	470
Trentham	124	127	Paraparaumu	492	527
Heretaunga	0	0	Paekakariki	100	100
Silverstream	136	136	Pukerua Bay	25	30
Manor Park	36	55	Plimmerton	84	157
Pomare	43	87	Mana	71	147
Taita	136	136	Paremata	202	222
Wingate	0	0	Porirua	898	898
Naenae	21	24	Kenepuru	0	0
Epunī	18	18	Linden	80	80
Waterloo	679	679	Tawa	91	214
Woburn	179	179	Redwood	166	166
Ava	0	54	Takapu Road	82	175
Petone	319	478	Melling	195	212
Ngauranga	0	0	Western Hutt	0	0

Rail Station	WPTM 2011	WPTM 2018	Rail Station	WPTM 2011	WPTM 2018
Kaiwharawhara	0	0	Otaki	40	40
Wellington	0	0	Masterton	76	87
Johnsonville	200	200	Renall Street	0	0
Raroa	10	45	Solway	54	87
Khandallah	14	14	Carterton	95	144
Box Hill	0	0	Matarawa	12	12
Simla Crescent	41	41	Maymorn	5	5
Awarua Street	20	20	Woodside	92	98
Ngaio	58	58	Featherston	149	149

7.6 Car Availability

Car availability is specified in the model for each trip purpose and for the AM and Inter peak. Data series of average car ownership for the Wellington region were sourced from the Ministry of Transport website⁶ to derive the 2011-2018 growth, as shown in the following table.

Table 7-3: Car Ownership Increase

	2011	2018	% Change
Car ownership per capita	0.62	0.67	8%

All car availability values in the model were therefore uplifted by 8%.

7.7 Access Choice Model - Johnsonville Line ASC

Analysis of initial results from the 2018 WPTM highlighted an issue with representation of bus versus rail demand between Johnsonville and the Wellington CBD, and car versus walk access to rail for the Johnsonville line.

This corridor is the most susceptible to experience modal shift between rail and bus in the region as travel times and accessibility are generally comparable between both modes. As a result, it has generally been the most sensitive to any changes in generalised costs.

2011 validation of the model showed that a broadly correct balance of demand between bus and rail was achieved, and the model also replicated well the observed share of car access vs other access to the Johnsonville rail line overall (46% by car and 54% other, i.e. mostly walk).

However, it was found during the current update of WPTM to 2018 that some distances were incorrect on a few locations on the network, including State Highway 1 at Ngauranga, resulting in longer bus travel times. In addition, the introduction of the Davidson curves in the car volume-delay functions⁷ also leads to an increase in travel time. Although this is an improvement in terms of representation of observed congestion, it has resulted in a shift from bus to rail on the Johnsonville corridor in the WPTM updated to 2018. Comparison against observed patronage shows rail being overestimated by about 40% and bus underestimated by the same amount in the AM peak.

In addition, the more recent park-and-ride surveys carried out in 2017 have returned a much lower share of car access to rail on the Johnsonville line than observed in 2011, with car access amounting to 24% vs 46% in 2011. It is unlikely that this share has changed significantly between 2011 and 2017, and discussion with GWRC along with parking capacities along this line indicates that the share of car access may have been over-estimated in surveys carried out from the original model.

Analysis of the demand along this line, both total and by access mode, showed that the modelled amount of non-car access passengers is broadly correct, but the amount of car access passengers is indeed too high when comparing against 2017 data.

While a recalibration of the access model was not anticipated and could involve a significant amount of work, a simple adjustment of the model for the Johnsonville line was investigated.

⁶ <https://www.transport.govt.nz/statistics-and-insights/road-transport/sheet/vehicle-ownership>

⁷ TN5 - Wellington Analytical Tools 2019-21 Update - Improve Delay Representation

A modified alternative specific constant for car access (ASCca in the model) was tested for zones in the Johnsonville line catchment only, with lower values resulting in more penalty for this rail line. This leads to a shift both to non-car access to rail, and away from rail altogether to bus.

This adjustment was implemented for the AM peak only. The calibrated value of 0.28 in the AM peak was first replaced by the Inter Peak value of -0.6. This led to a significant improvement for both rail vs bus demand and car vs non-car access to rail. Other values were tested and -1.2 was found to return the best results. Comparison of access mode share with both the original value and the revised -1.2 are shown below for the initial validation.

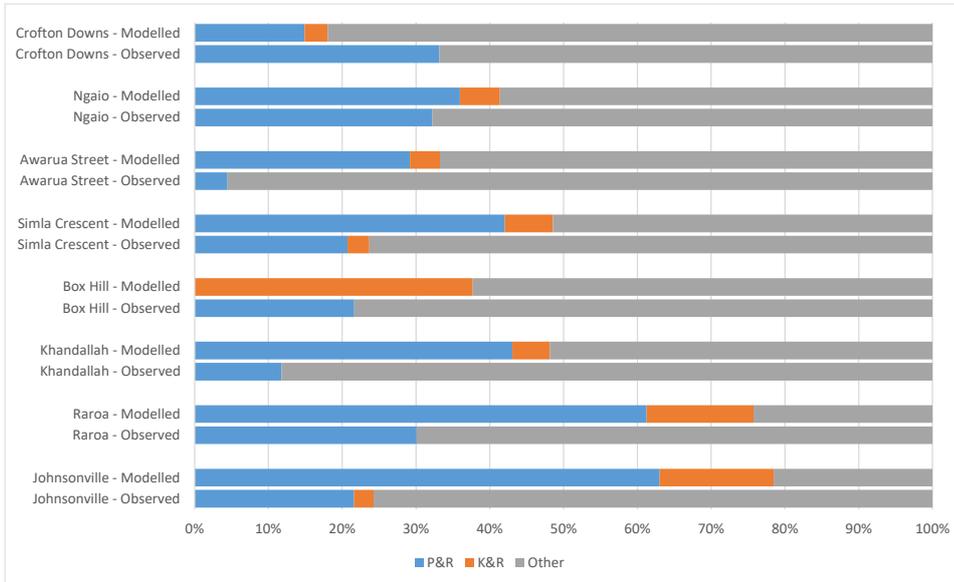


Figure 7-3: Johnsonville Line Access Mode Share – Original ASC

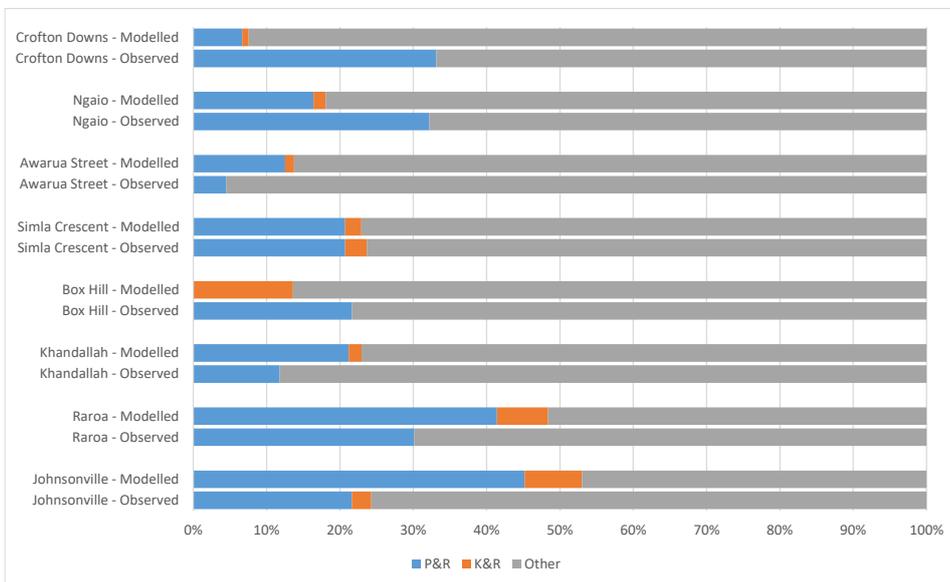


Figure 7-4: Johnsonville Line Access Mode Share – Revised ASC

This also largely addressed the imbalance between rail and bus from Johnsonville.

Adopting a different value for ASCca for the Johnsonville line could be justified by the fact that this line is different to the Hutt Valley and Kapiti lines, servicing a smaller area and being generally slower, in essence closer to a bus service than a suburban railway line as was noted by GWRC.

The adjusted ASC for car access to the Johnsonville line was therefore adopted for the AM peak to improve the representation of public transport demand in the Johnsonville catchment.

7.8 Runtime Improvements

The WPTM was initially developed using the EMME proprietary “macro” scripting language. Following introduction of the python-based Modeller API with EMME 4, it was then converted to Modeller, with matrix calculations and other operations using the dedicated Modeller “tools”.

While these tools are generally well optimized in terms of calculation run times, some matrix operations are more time-consuming and can potentially be more efficiently carried out directly in python, particularly using the scientific computing NumPy library. This library is included as part of the distribution of Python 2.7 installed with EMME and therefore runs “out-of-the-box” without the need to be installed separately by model users.

The potential for replacing some of the EMME-based calculations with python computations to reduce the WPTM run time was investigated, resulting in a number of targeted modifications of the model’s scripts that significantly improve run times while having no discernible impact on results. The changes made were as follows:

- **In “choice.py”, separating matrices into access and rail leg:** this was originally based on the ‘Matrix Triple-Index Operation’ tool with each calculation (for best stations 1 to 3, for both Park-and-Ride and Kiss-and-Ride) taking over 20 seconds per demand segment. The calculations are now python-based and carried out in a new function called ‘matrix_convolutions’ that runs in under a second.
- **In “choice.py”, ranking the 5 best stations:** this was based on the ‘Matrix Calculator’ tool, iterated over 25 times to rank the best stations, with the whole process running in over 17 seconds for each demand segment. It is now replaced by a single python-based operation in a new function called ‘stations_ranking’ and running under 5 seconds.
- **In “pm_peak_egress.py”:** the script to separate matrices into rail and egress legs matrices was modified, similarly as in choice.py for the AM and Inter peak and using the same ‘matrix_convolutions’ function with comparable gains in run time.

The resulting model run times (using the same computer specification), compared with the original WPTM are shown in the following table.

Table 7-4: Model Runtimes Comparison

Tim Period	2013 WPTM	2018 WPTM
AM Peak	0:33:10	0:14:49
Inter Peak	0:31:53	0:13:41
PM Peak	0:22:22	0:05:50
Full Run	1:27:25	0:34:20

As can be observed, run times for the new version of WPTM have decreased by over 60% compared with the original version.

Of the two modifications implemented in the model, the conversion of separating matrices into access and rail legs (or rail and egress for the PM peak) to python has absolutely no impact on the results, with the model returning exactly the same matrices and assigned volumes. Changing the process for ranking of stations leads to very small changes, which were deemed to be inconsequential with the maximum volume difference being less than 1, and only on a small portion of the network.

The following observations can also be made, which may be of importance for the development of the next version of WTSM in Python/Modeller:

- Other matrix and triple-index calculations were also converted to test impact on run times but none showed any significant improvements, many of them actually resulting in longer run times than EMME tools. This indicates that not all matrix calculations would benefit from being converted to NumPy as EMME algorithms are generally efficient. The exceptions include complex operations which necessitate looping through a number of EMME matrix calculator runs but can be replaced with a single NumPy operation. The other main exceptions are triple matrix operations which, although in most cases will be at least as efficient using the dedicated EMME tool, can in some cases run much faster in NumPy.
- Which approach is best therefore seems to be a case by case decision although Numpy will likely be a better choice when it can replace multiple calls to the matrix calculation tool, or when its broadcasting abilities can significantly improve efficiency for triple indexing.

- Although this can be more subjective, another benefit of using python and NumPy for matrix operations is that the resulting scripts tend to be more economical and readable than using EMME tools.

8. 2018 Validation

This section presents the validation of the updated 2018 WPTM against a range of observed metrics. Similar to the 2013 update, it was not intended to replicate all validation checks that were presented in the validation report from the 2011 development of WPTM ("TN19 – WPTM Calibration and Validation"), for the following reasons:

- The validation for the 2011 WPTM was reported for all steps of the development of the model (base input matrices development, access choice model, full model with final assignment) to "give the reader an understanding of the process and level of validation at each given step". In the present case however, This report documents a more limited update and as a result only the final validation for the full model is reported.
- In addition, a lot of the data that was used in the calibration / validation of the 2011 WPTM was collected specifically for the development of the model, including extensive rail and bus on-board surveys and rail platform surveys. No such data has been collected since, so some components of the model could not be checked against more recent data.

The following table details the validation criteria from the 2011 WPTM validation report, whether they were used for this 2018 update, and if not the reason why they were omitted.

Table 8-1: Validation Criteria

Criteria	Description	Target
PT network supply	Omitted: shared with WTSM and reported in the WTSM documentation	-
Bus travel time comparison	Omitted: shared with WTSM and reported in the WTSM documentation	-
Trip purpose, car availability and age split	Omitted: not resurveyed for 2018	-
Access and egress trip length distribution	Omitted: not resurveyed for 2018	-
Bus vs walk from Wellington rail station	Omitted: not resurveyed for 2018	-
Assigned route	Omitted: the underlying road network is virtually identical to the 2011 model with mostly bus routes having changed and transit time functions unchanged. CBD cordon survey validation and boardings per lines are deemed to be a sufficient check.	-
Metlink patronage	Comparison against GWRC monthly patronage per PT mode, converted to patronage per time period	No defined target
CBD cordon – all modes	Total patronage per PT mode entering the CBD	+/-15%
CBD cordon – bus patronage per location	Modelled and observed patronage through each crossing of the CBD cordon	+/-15%
CBD inbound rail volumes	High (or "guard") counts before entering or after leaving Wellington station, per line (Johnsonville, Kapiti and Hutt Valley lines)	No defined target
Rail demand by access mode and station	Number of boardings per access mode (walk, park-and-ride, kiss-and-ride) for each station	+/-20%
Bus and rail volumes at screenlines	Modelled vs observed patronage across screenlines	+/-15%

Criteria	Description	Target
Scattergram of bus boardings by route	Scatter plot of modelled vs observed boardings per bus route	$R^2 > 0.85$

In addition, the more recent criteria from the Waka Kotahi Transport Model Development Guideline⁸ have also been included, detailed in the following table. This uses the GEH statistics to compare modelled and observed volumes for count locations and across screenlines as well as the resulting slope line of best fit and coefficient of determination R^2 .

Table 8-2: TMDG Validation Criteria

GEH	% of Screenlines (per direction)	% of Passenger Counts (per direction)
GEH <5	>60%	>50%
GEH <7.5	>70%	>60%
GEH <10	>80%	>70%
GEH <12	>90%	>85%
Line of best fit	$y=0.9x$ to $1.1x$	$y=0.85x$ to $1.15x$
R^2	>0.85	>0.80

The remainder of this section presents validation outcomes for all adopted metrics.

8.1 Metlink Patronage

The first source of data used for the validation of WPTM is the Metlink monthly patronage counts, showing the total number of boardings per month separately for rail and bus. 2018 figures were obtained from the Metlink website and the same methodology as in previous update was used to convert these to weekday 2-hour values, with monthly counts converted to time periods using the following formula:

$$\begin{aligned} \text{AM / IP / PM trips} &= \text{Monthly total trips} \\ &\quad * \text{weekday trips as \% of weekly trips} \\ &\quad \div \text{Average weekdays in month} \\ &\quad * \text{\% of weekday trips in the AM / IP / PM period} \end{aligned}$$

Percentage of weekday bus trips per period were updated for bus based on ETM data and also calculated for the new PM peak.

The resulting values are shown in the table below. These are not meant to represent exact observed volumes but rather should be taken as an indication of magnitude. In this respect, modelled numbers appear to be in the right range. The main exception is for rail trips in the Inter peak, which is a consistent pattern with earlier versions of the model, although lessened in this updated version (compared with -16% in the 2011 version and -34% in the 2013 version.).

Table 8-3: GWRC Monthly Passenger Counts Validation

Mode	Observed Average Monthly total	AM Peak			Inter Peak			PM Peak		
		Obs	Mod	Diff	Obs	Mod	Diff	Obs	Mod	Diff
Rail	1,262,611	16,657	15,454	-7%	2,445	2,162	-12%	-	-	-
Bus	2,290,227	22,940	23,700	3%	9,219	8,660	-6%	19,148	18,948	-1%
Total	3,552,838	39,597	39,154	-1%	11,664	10,822	-7%	-	-	-

⁸ <https://www.nzta.govt.nz/assets/resources/transport-model-development-guidelines/docs/tmd.pdf>

8.2 CBD Cordon

The total number of PT users entering the CBD during the AM peak was compared with the Annual CBD cordon survey, carried out in March 2018. For bus patronage, data from 2019 was however used for consistency with the post PT Operating Model network and ETM data.

Two adjustments were made to the data:

- The March 2019 bus CBD cordon survey was carried out on a Tuesday and data was factored to average weekday, by applying a factor of 0.98 derived from ETM data.
- As mentioned in Section 3.1, counts at Wellington railway station include non-rail passengers walking through the station. The same factor of 0.79 as in 2011 was used to factor survey total to rail passengers only.

Outbound bus patronage for the PM Peak was also surveyed in March 2017 and has been factored to 2019 for comparison with modelled volumes.

Table 8-4: CBD Cordon Validation

Mode	Cordon Count	Modelled	Difference
Rail - AM	13,383	13,345	0%
Bus - AM	11,774	11,265	-4%
Ferry - AM	215	234	9%
Cable Car - AM	99	8	-92%
Total - AM	25,471	24,852	-2%
Bus - PM	9,777	9,896	1%

Results by mode and overall show a good fit and are well within the validation criterion used for the development of WPTM of +/-15%. The only exception is the cable car, which only carries a very small number of passengers and is largely used by tourists, therefore not driven by time and costs considerations as other users of the public transport network.

8.3 Bus Screenlines

This section presents a comparison of observed and modelled bus passenger volumes across a number of screenlines in the region. These are a subset of the screenlines used for the WTSM validation with screenlines not applying to PT having been removed and are shown in the following figure. Screenlines K1 and P1 are not used for bus validation but are used later on for rail validation.

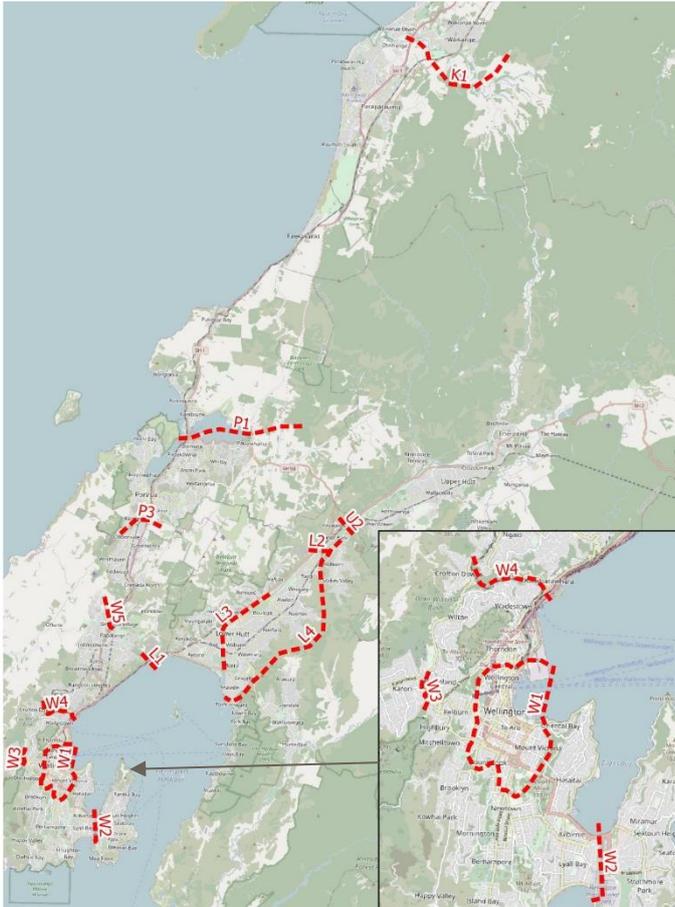


Figure 8-1: Screenlines for Validation

Observed bus volumes were obtained in two ways:

- A tool was developed to extract volumes passing through each bus stop from the ETM data and GTFS bus sequences. Resulting values were checked against the CBD cordon survey locations to verify the tool accuracy. Results were found to be a good match and it was therefore used to inform observed bus patronage at most count locations on the screenlines.
- For some locations, results could not easily be extracted from the ETM tool. These were mostly locations on the State Highway network or on main arterials where a high number of bus routes converge but with no nearby bus stop. For those, a similar approach to the 2011 model development was used where a “reference assignment” was carried out, with the raw bus matrices assigned onto the bus network only. As a result the matrices do not go through trip purpose allocation, mode change and other model process and are a true representation of bus demand. Due to the absence of alternative routes for most of these locations, they represent a reliable proxy for observed bus volumes.

This approach represents an improvement from the 2011 model validation which relied entirely on this “reference assignment”. However, just as for the 2011 model, it is important to note that the ETM data used for the validation is the same that was used for the development of the matrices and is therefore not truly independent. This exercise can therefore be seen more as a check that the various model steps (especially mode choice and assignment) result in bus demand that is in line with observed matrices for the base year and scenario. Other metrics are used in the rest of this section for validation against independent observed data.

Validation results are shown in the following table which shows the observed and modelled volumes, as well as the percentage difference and the GEH, a standard empirical measure used to compare modelled flows against observed volumes. Modelled volumes associated with the ‘Flyer’ bus services to/from the airport have been removed for consistency as they are not included in the ETM data.

Table 8-5: Bus Passenger Screenlines Validation

Screenline	AM				IP				PM			
	ID	Obs	Mod	Diff %	GEH	Obs	Mod	Diff %	GEH	Obs	Mod	Diff %
W1 – I/b	5,618	5,416	-4%	2.7	1,065	1,101	3%	1.1	752	1,008	34%	8.6
W1 – O/b	572	762	33%	7.4	772	839	9%	2.3	4,890	4,772	-2%	1.7
W2 – N/b	87	93	7%	0.6	102	111	9%	0.9	439	451	3%	0.5
W2 – S/b	678	691	2%	0.5	115	122	6%	0.7	99	101	2%	0.2
W3 – N/b	39	42	10%	0.6	94	96	3%	0.3	563	573	2%	0.4
W3 – S/b	678	691	2%	0.5	133	136	2%	0.2	67	68	1%	0.1
W4 – N/b	70	93	32%	2.5	158	178	13%	1.5	1,215	1,243	2%	0.8
W4 – S/b	1,505	1,260	-16%	6.6	210	182	-13%	2.0	105	92	-13%	1.3
W5 – N/b	32	29	-7%	0.4	13	15	14%	0.5	30	16	-47%	3.0
W5 – S/b	42	25	-39%	2.8	14	14	0%	0.0	18	16	-15%	0.6
L1 – N/b	87	87	0%	0.0	59	98	67%	4.4	222	56	-75%	14.1
L1 – S/b	234	62	-73%	14.1	73	101	39%	3.0	97	76	-22%	2.3
L2 – N/b	28	49	77%	3.5	53	60	13%	0.9	108	163	50%	4.7
L2 – S/b	155	198	28%	3.2	47	52	12%	0.8	24	37	51%	2.3
L3 – N/b	366	276	-22%	4.4	182	210	16%	2.0	158	149	-6%	0.8
L3 – S/b	224	263	18%	2.5	203	241	18%	2.5	377	341	-10%	1.9
L4 – E/b	323	385	19%	3.3	77	99	29%	2.4	32	32	0%	0.0
L4 – W/b	25	45	76%	3.3	68	93	37%	2.8	224	286	28%	3.9
U2 – N/b	61	82	35%	2.5	35	35	0%	0.0	55	73	32%	2.2
U2 – S/b	67	62	-8%	0.7	32	31	-4%	0.2	28	41	47%	2.2
P3 – N/b	33	47	41%	2.1	15	27	85%	2.7	19	10	-46%	2.3
P3 – S/b	85	27	-68%	7.6	15	15	5%	0.2	16	11	-34%	1.5
Total	11,008	10,686	-3%		3,534	3,855	9%		9,541	9,613	1%	

The model achieves a good level of validation, being largely a very good match with observed.

The main discrepancy occurs on screenline L1 in the peak direction, where the Hutt Valley rail line is by far the main PT mode with much higher demand than bus. This issue is therefore likely caused by the additional delays on the State Highway due to the introduction of new vehicle delay function on road links, leading to some shift from bus to rail. The absolute difference is minor, however this issue will need to be considered when the final validation of the WPTM running on road travel times from the rebuilt WTSM is carried out.

The following table shows the resulting validation for screenlines and count locations.

Table 8-6: Screenlines and Counts Validation

Time Period	Screenlines			Counts		
	AM	IP	PM	AM	IP	PM
GEH < 5	77%	100%	91%	89%	94%	90%
GEH < 7.5	91%	100%	91%	95%	100%	92%
GEH < 10	95%	100%	95%	97%	100%	92%
GEH < 12	95%	100%	95%	98%	100%	98%
Line of best fit	0.96	1.06	0.99	0.93	1.07	1.01
R ²	0.99	0.99	0.99	0.98	0.96	0.98

Figure 8-2 to Figure 8-4 show scatterplots of observed vs modelled patronage by screenline.

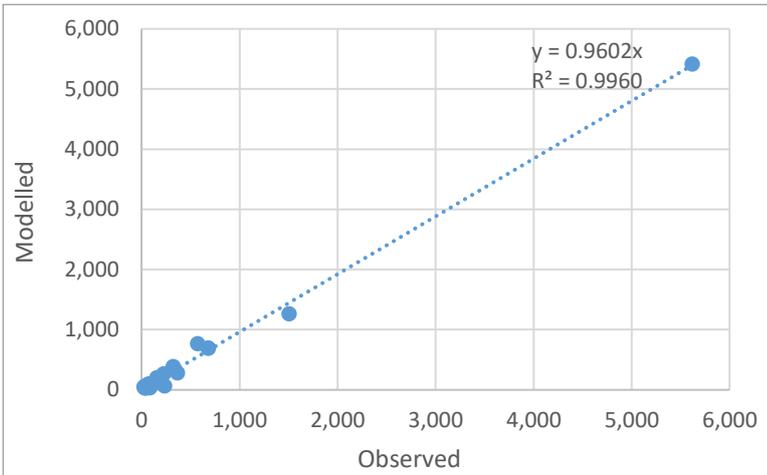


Figure 8-2: Bus Screenline Modelled vs Observed – AM Peak

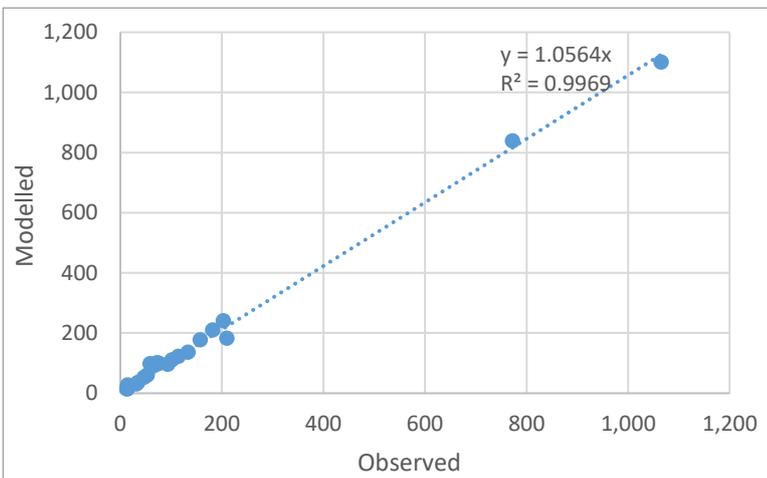


Figure 8-3: Bus Screenline Modelled vs Observed – Inter Peak

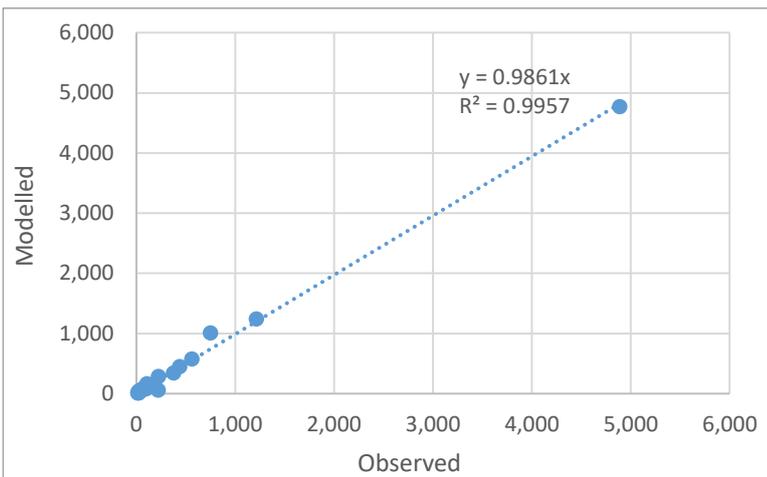


Figure 8-4: Bus Screenline Modelled vs Observed – PM Peak

Figure 8-5 to Figure 8-7 show scatterplots of observed vs modelled patronage by count location.

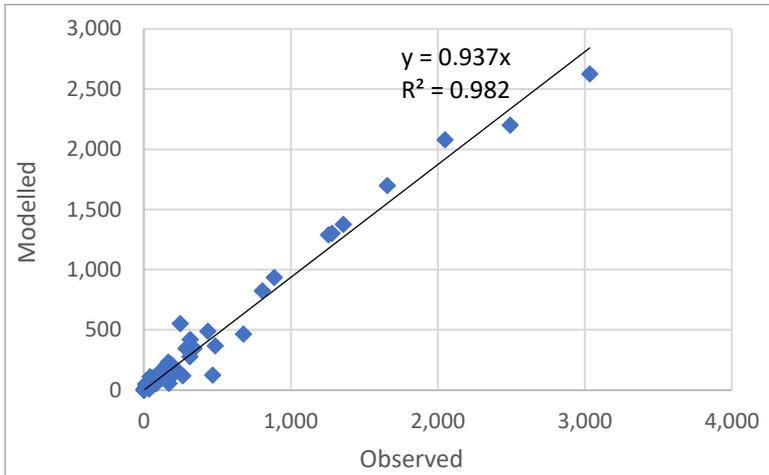


Figure 8-5: Bus Counts Modelled vs Observed – AM Peak

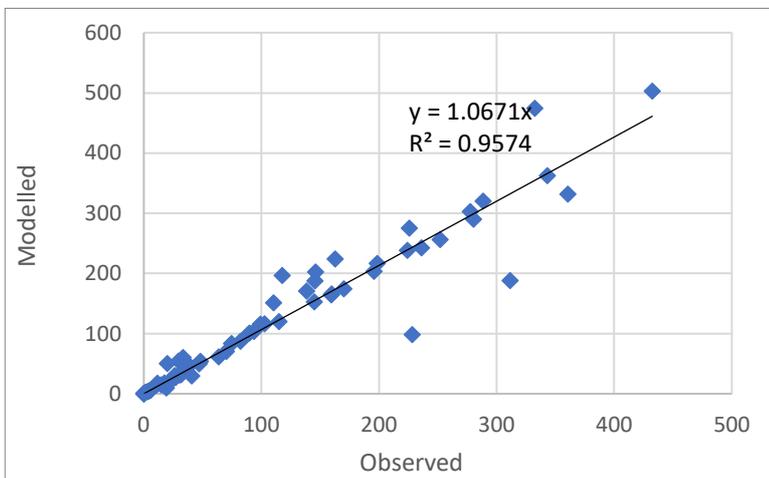


Figure 8-6: Bus Counts Modelled vs Observed – Inter Peak

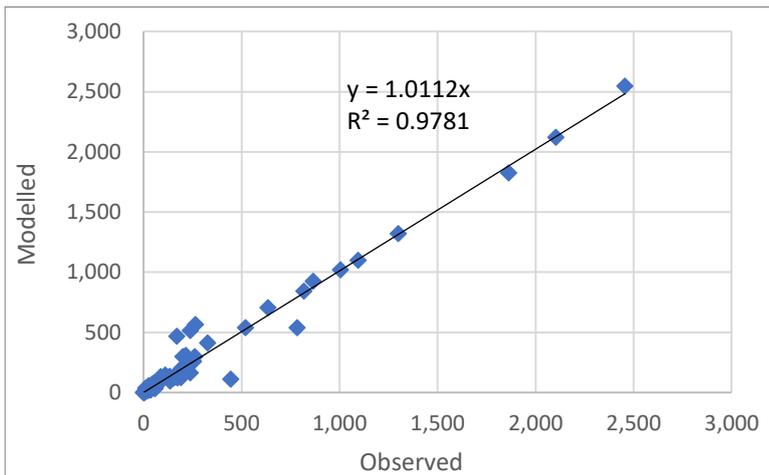


Figure 8-7: Bus Counts Modelled vs Observed – PM Peak

Table 8-6 shows that the model easily matches the TMDG targets for both screenlines and individual counts, for GEH, line of best fit and R^2 .

The criteria defined for the 2011 development of the WPTM for modelled volumes across screenlines being within 15% of observed is only achieved for 36% of screenlines in the AM peak, but 68% in the Inter peak, and 73% in the PM peak. Results from the 2011 model were similar (except for the PM peak which was not included), although the validation report concluded that screenline validation was acceptable.

Many of the screenlines have low volumes of bus patronage, leading to large percentages differences even for small absolute difference. For this reason, the more recent guidelines from the TMDG using the GEH statistics are more appropriate. With the model matching these criteria and leading to a good representation of the main volumes of bus patronage, the validation is considered suitable.

8.4 Bus CBD Cordon Count

The following table shows modelled AM peak inbound bus volumes across all locations on the CBD cordon, along with March 2019 observed patronage.

PM Peak outbound patronage from 2017 was also used, and the same adjustments detailed in section 8.2 were applied. Although the bus network has changed after 2017 and some fluctuations between routes is to be expected, this still provides a useful check of the PM peak bus matrix overall.

Table 8-7: CBD Bus Cordon Validation

Links of CBD Cordon	Observed	Modelled	Difference
AM Peak - Inbound			
Oriental Parade	471	347	-26%
Cambridge Terrace	1,664	1,696	2%
Elizabeth Street	2,237	2,292	2%
Willis Street	899	934	4%
Taranaki Street	1,060	878	-17%
Hawker Street	26	1	-96%
Tinakori Road	1,395	1,375	-1%
Kelburn Parade	919	644	-30%
Murphy Street	497	473	-5%
Thorndon Quay	2,607	2,625	1%
Total	11,774	11,265	-4%
PM Peak - Outbound			
Oriental Parade	397	263	-34%
Kent Terrace	1,573	1,320	-16%
Elizabeth Street	1,572	2,044	30%
Victoria Street	822	925	13%
Taranaki Street	697	538	-23%
Hawker Street	98	6	-94%
Tinakori Road	1,109	1,137	2%
Kelburn Parade	560	561	0%
Molesworth Street	832	554	-33%
Thorndon Quay	2,118	2,548	20%
Total	9,777	9,896	1%

AM Peak results are generally a good match, and the main differences (Oriental Parade, Taranaki Street and Kelburn Parade) are consistent with results from the 2011 model. As noted at the time, these are likely due to short bus trips being assigned as walk trips, and to difference in time period between the cordon counts based on passengers crossing the count locations between 7 and 9am, and WPTM demand which is based on boarding times.

Results are not as good for the new PM peak demand, although as noted previously these are based on 2017 counts when the bus network was different. They are however in the right range and overall demand is a good match.

8.5 Bus Boardings Per Route

This section presents a comparison of the number of boardings per bus route, both observed and modelled. Again, observed values are extracted from the ETM (before transfer trips were removed) and this is not a true independent check of the model as a whole, but it is a useful validation of the assignment process.

When a service had a number of subvariants with alternative routes and start/finish points, there were aggregated.

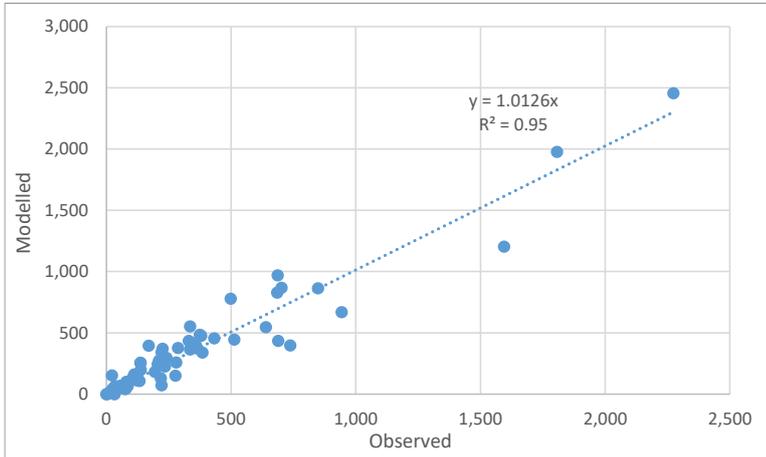


Figure 8-8: Bus Boarding Per Route Validation – AM Peak

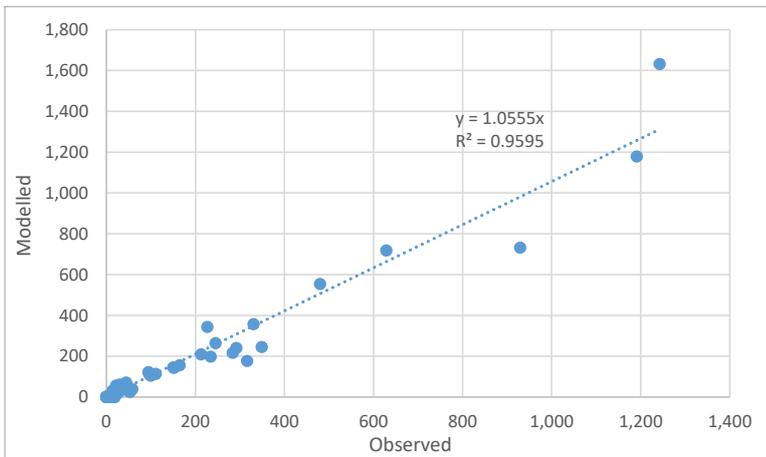


Figure 8-9: Bus Boarding Per Route Validation – Inter Peak

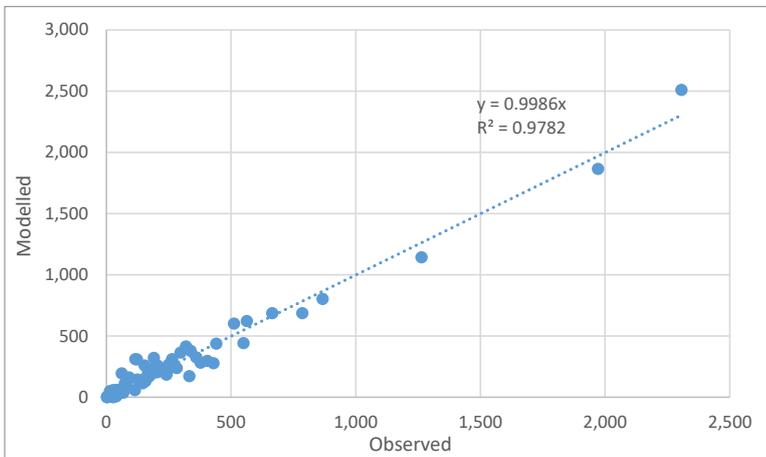


Figure 8-10: Bus Boarding Per Route Validation – PM Peak

Both the r^2 and line of best fit slope achieve the criteria for this metric.

8.6 Rail High Counts – Volumes at Wellington Station

Modelled rail volumes at Wellington station were compared against rail high (or guard) counts obtained from Kiwirail, separately for each railway line. In addition to the AM peak inbound volumes that were used for previous model versions, PM outbound high counts were also available and used for validating the PM peak matrices.

Table 8-8: Rail High Count Validation

Line	High count	Modelled	Difference
AM Peak Inbound			
JVL	1,404	1,719	22%
HVL / MEL / WRL	6,562	6,377	-3%
KPL	4,330	5,249	21%
Total	12,296	13,345	9%
PM Peak outbound			
JVL	1,087	877	-19%
HVL / MEL / WRL	5,868	6,258	7%
KPL	4,372	4,429	1%
Total	11,327	11,564	2%

Although results are generally acceptable, they show that modelled inbound AM volumes on the Kapiti line appear high compared with observed. However, analysis of high counts time series show that observed 2018 values are lower than both 2013 and 2011, which does not match with Metlink patronage data showing a 17% increase since 2011 in the peak period. It is highly unlikely that patronage on this line would have increased overall while AM peak volumes to the CBD would have decreased.

A test was carried out applying overall Metlink patronage growth per line to 2011 high counts, which leads to the following results for the AM peak (2011 PM peak data was not available).

Table 8-9: Rail High Count Validation

Line	High Count	Modelled	Difference
AM Peak Inbound			
JVL	1,399	1,719	23%
HVL / MEL / WRL	5,823	6,377	10%
KPL	5,319	5,249	-1%
Total	12,541	13,345	6%

Results are much closer for the Kapiti line, while the Hutt Valley Line that was too low is now too high, but still within a 10% threshold. Total volumes are also closer at 6%.

Although no target was defined for this criteria, using a target of +/-15%, consistent with other criteria, would lead to the Hutt Valley Line, Kapiti Line and overall demand to all match the target.

Using both approaches, patronage for the Johnsonville line is 22% too high in the AM peak, which again is likely a result from the additional delays on the road network associated with new delay functions. This will need to be considered in the final version of WPTM running with the rebuilt WTSM.

8.7 Rail Screenlines

This section presents a comparison of observed and modelled rail passenger volumes across the screenlines applying to the rail network, using the same metrics as for bus.

For observed demand APC door counts were not used for the AM Peak and Inter peak due to the accuracy issues mentioned previously. Observed was therefore based on boardings and alightings from the 2011 platform surveys, factored up using Metlink patronage data.

The PM peak however was not surveyed as it was not originally included in the model. 2018 APC data was therefore used for boardings, while alightings (which were too unreliable to use) were based on AM peak boardings at the same station, factored to match PM boardings on the whole route.

Table 8-10: Rail Passenger Screenline Validation

Screenline	AM				IP				PM			
ID	Obs	Mod	Diff %	GEH	Obs	Mod	Diff %	GEH	Obs	Mod	Diff %	GEH
W4 – Nb	365	368	1%	0.1	575	395	-31%	8.2	12,193	11,845	-3%	3.2
W4 – Sb	13,905	13,600	-2%	2.6	1,061	920	-13%	4.5	405	493	22%	4.1
L1 – Nb	210	199	-5%	0.7	206	166	-20%	3.0	5,807	6,262	8%	5.9
L1 – Sb	6,338	6,404	1%	0.8	370	361	-3%	0.5	223	198	-11%	1.7
L2 – Nb	311	237	-24%	4.5	56	66	18%	1.3	2,184	2,405	10%	4.6
L2 – Sb	2,202	2,318	5%	2.4	126	150	19%	2.0	204	223	9%	1.3
L3 – Eb	165	147	-11%	1.4	171	166	-3%	0.4	5,064	5,035	-1%	0.4
L3 – Wb	5,271	5,182	-2%	1.2	333	336	1%	0.1	120	143	19%	2.0
U2 – Nb	318	239	-25%	4.7	58	67	16%	1.2	2,159	2,392	11%	4.9
U2 – Sb	2,161	2,303	7%	3.0	122	145	19%	2.0	204	225	10%	1.4
P1 – Nb	36	36	1%	0.1	133	129	-3%	0.4	1,989	1,915	-4%	1.7
P1 – Sb	2,251	2,112	-6%	3.0	282	270	-4%	0.7	117	30	-74%	10.2
P3 – Nb	140	95	-32%	4.1	236	199	-16%	2.5	3,965	3,761	-5%	3.3
P3 – Sb	4,323	4,322	0%	0.0	409	349	-15%	3.1	171	149	-13%	1.7
K1 – Nb	34	32	-7%	0.4	86	87	1%	0.1	366	568	55%	9.3
K1 – Sb	560	624	11%	2.6	121	123	2%	0.2	83	22	-73%	8.4
Total	38,590	38,218	-1%	1.9	4,346	3,929	-10%	6.5	35,254	35,666	1%	2.2

The following table shows the summary of screenline validation. Individual counts are not shown as almost all screenlines only include one rail count location and results would be almost identical.

Table 8-11: Rail Screenline Validation

Time Period	Screenlines		
	AM	IP	PM
GEH < 5	100%	94%	75%
GEH < 7.5	100%	94%	81%
GEH < 10	100%	100%	94%
GEH < 12	100%	100%	10%
Line of best fit	0.99	0.86	0.99
R ²	0.99	0.99	0.99

The following figures show scatterplots of modelled against observed volumes across screenlines.

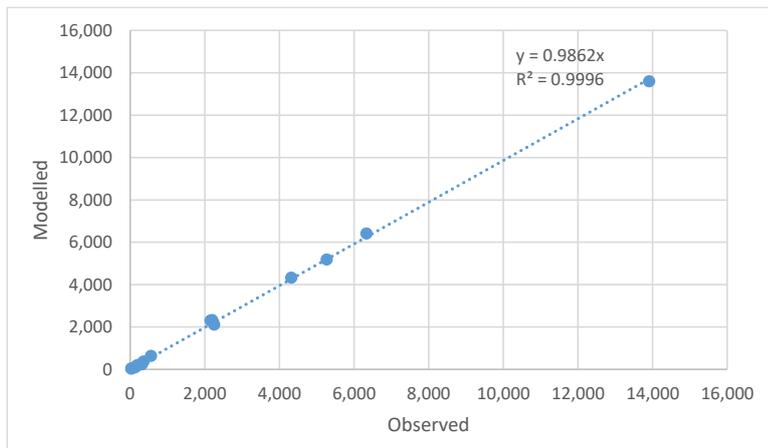


Figure 8-11: Rail Screenline Modelled vs Observed – AM Peak

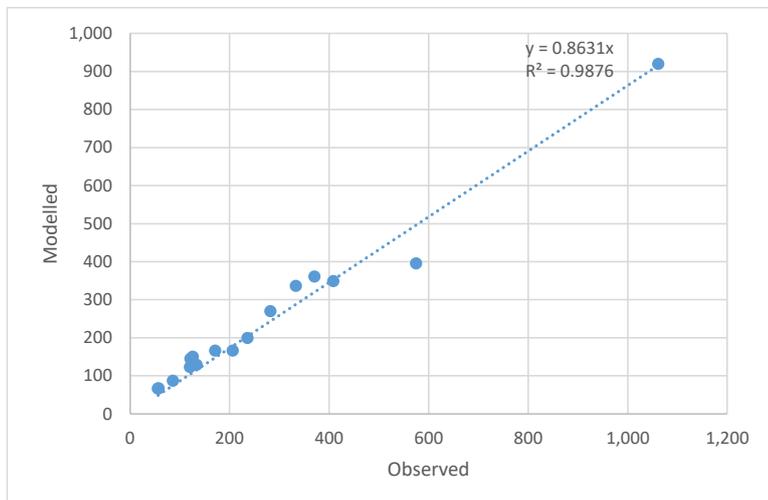


Figure 8-12: Rail Screenline Modelled vs Observed – Inter Peak

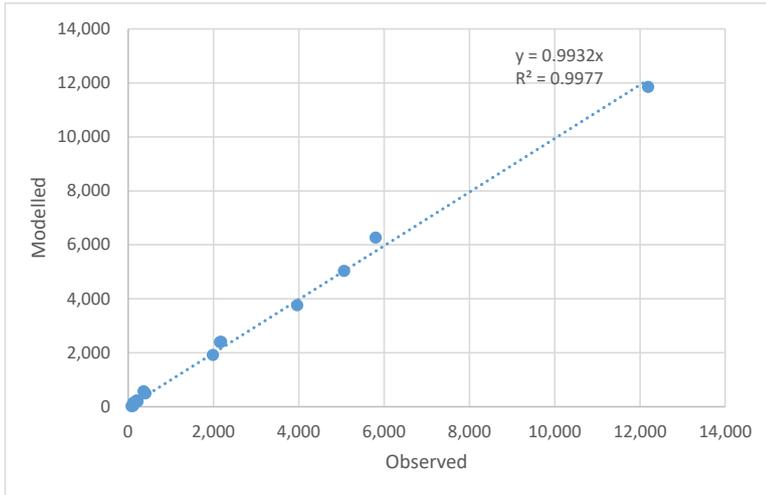


Figure 8-13: Rail Screenline Modelled vs Observed – PM Peak

Validation is generally close to the 2011 model and shows a good match to observed volumes. The same issue with Inter peak flows being too low overall that was noted during the 2011 development of WPTM is still present although lessened (-10% compared with -23% in 2011).

However, the validation criterion used during the development of WPTM of screenlines being within +/-15% of observed is satisfied, and the TMDG criteria are also achieved.

8.8 Rail Lines Profiles

The following plots compare modelled and observed boardings and alightings for each railway line (with Melling and Wairarapa lines combined with the Hutt Valley line), direction and time period, and show the resulting patronage profiles. Observed is based on the same data as the screenlines, i.e. 2011 factored up using Metlink patronage for AM and Inter peaks, and adjusted 2018 APC counts for the PM peak.

Consistently with the original 2011 model, results are generally good for the AM peak inbound (and the new PM peak outbound validation), which are by far the services with most patronage. Validation for counter peak direction and Inter peak services is not as good, although it must be noted that these have much fewer passengers and are on a very different scale.

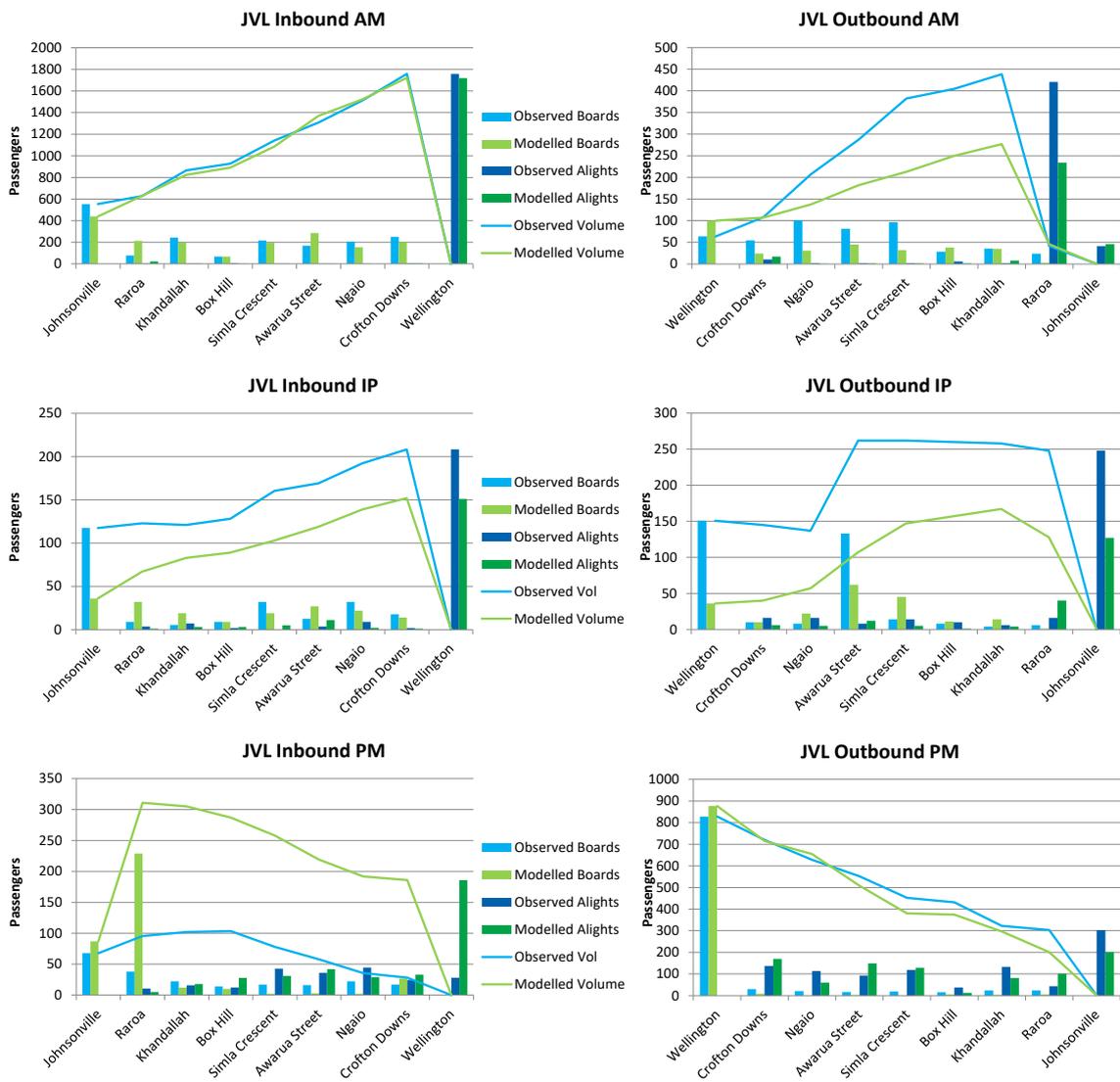


Figure 8-14: Boardings, Alightings and Profiles – Johnsonville Line

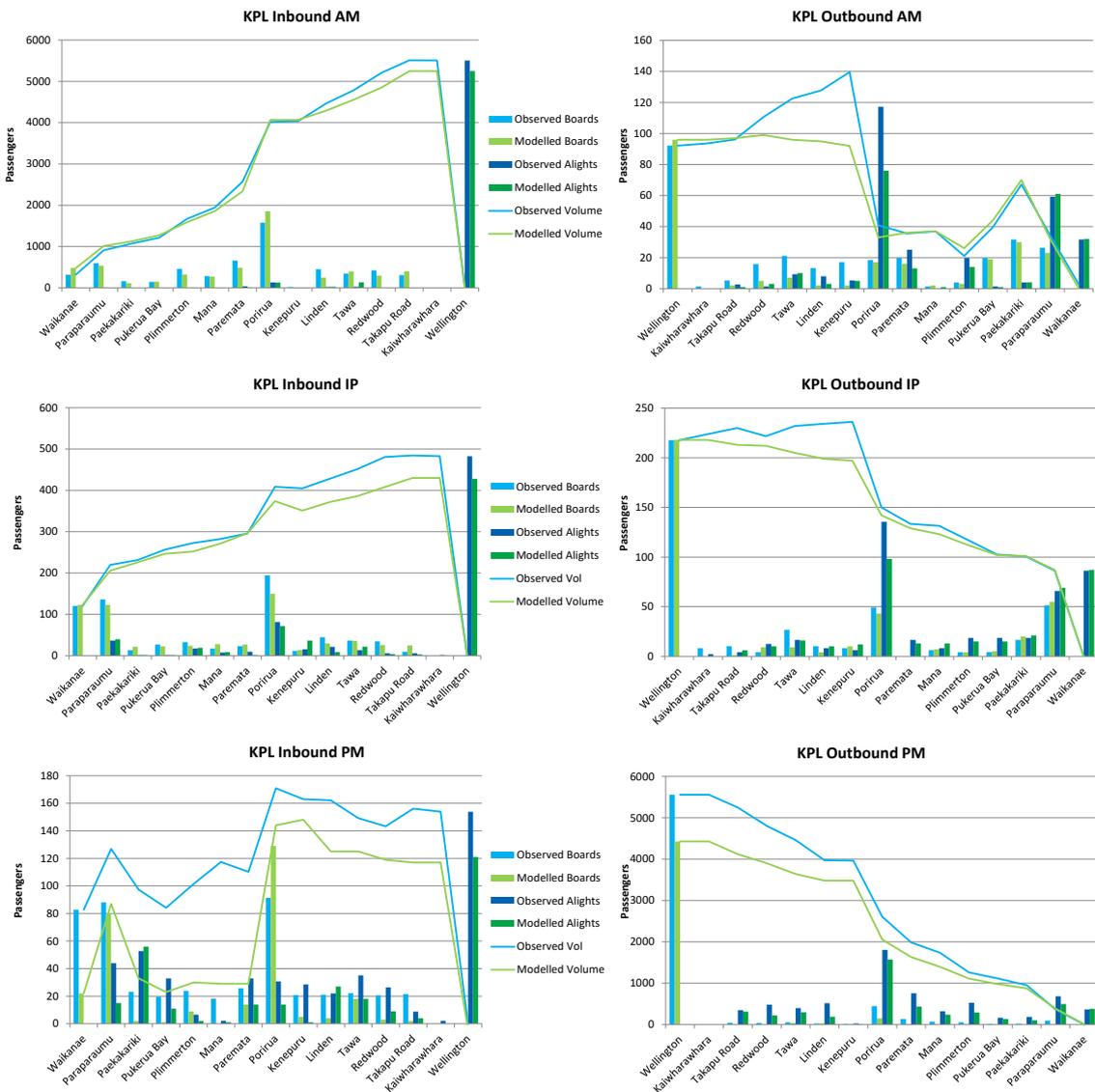


Figure 8-15: Boardings, Alightings and Profiles – Kapiti Line

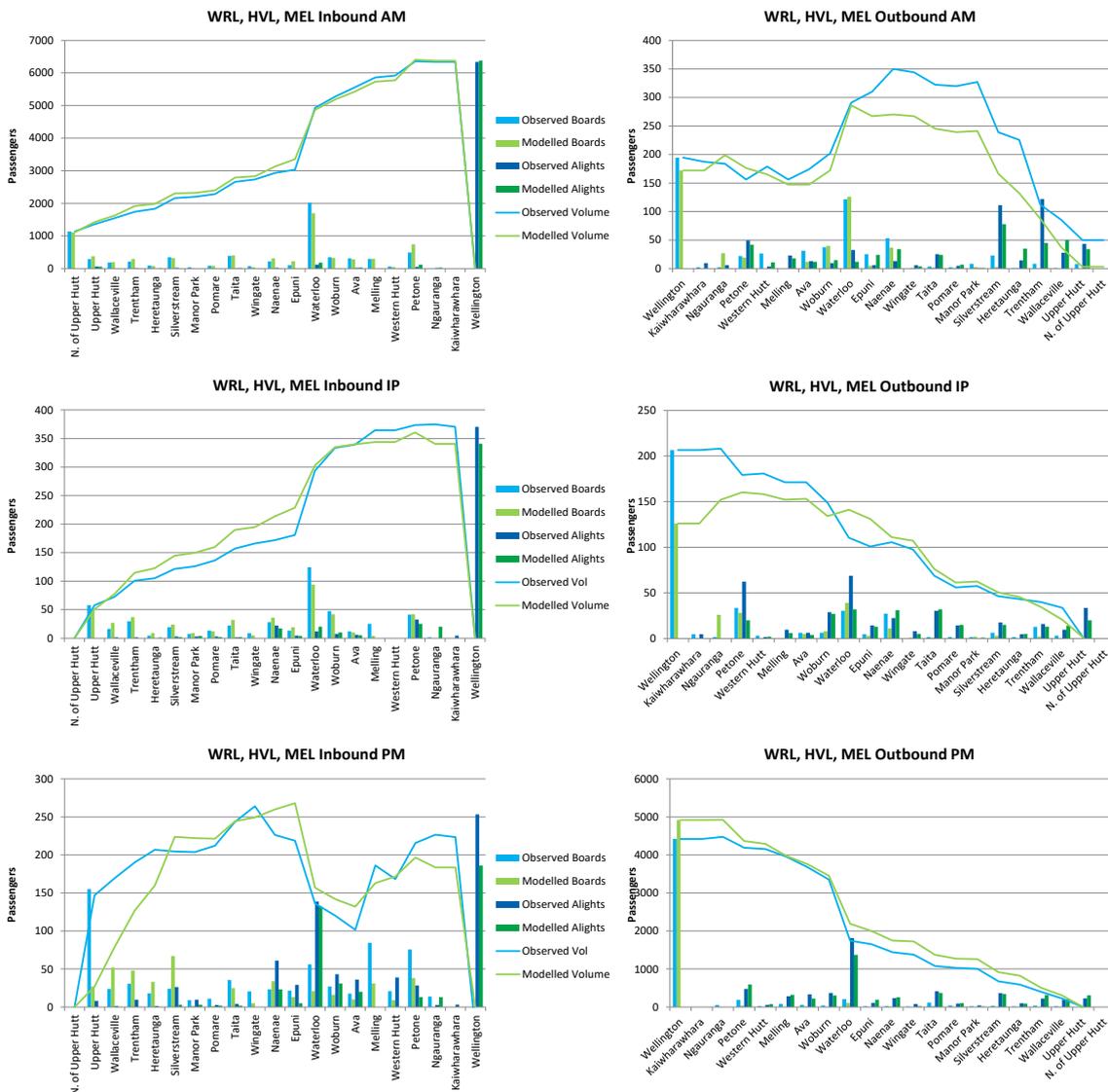


Figure 8-16: Boardings, Alightings and Profiles – Hutt Valley Line

For context regarding the level of validation to be reasonably expected from the WPTM, the technical note covering validation for the original 2011 WPTM ('TN19 WPTM Calibration and Validation') makes the following comments:

"The paucity of data in the Inter peak is such that it could not be calibrated independently from the AM peak model. Instead the IP calibration was a variant of the AM peak, with only the major constants and parameters adjusted."

"Because different stations will have subtly different characteristics, access mode split and catchment areas, it is impossible to accurately replicate the observed boardings and mode split across all stations using a 'one size fits all' approach, whereby the same set of parameters applies to all stations. What is satisfying, however, is that the model accurately replicates observed trends and patterns and that the major stations validate well."

Whilst calibrating station specific parameters would probably result in a superior level of validation, this could be interpreted as 'fixing' the results. Should a new P&R site be proposed and tested in the future, it would be difficult for the user to pick an appropriate set of parameters to be used at such a site as all existing parameters would be station specific."

Therefore the chosen approach results in a choice model that validates well and that can be used, with confidence, for future forecasting and option testing."

Results from the 2018 WPTM are largely consistent with 2011 results and given the limitations of the dataset used for validation, performance of the model is deemed suitable.

8.9 Access to Rail Mode Share

This section presents a comparison of observed versus modelled modal access to rail, including park-and-ride, kiss-and-ride, and other (mostly walk) for the AM peak.

It must be noted that the original 2011 WPTM was validated against extensive rail passenger survey data that was collected for the development of the model. For this 2018 update, observed data was sourced from the 2017 rail survey which had a different purpose and methodology, including using APC data to expand the sample. Validation is therefore not expected to be as close as the 2011 model, partly due to observed modal share for some station being quite different in both surveys.

This comparison is however provided as a high level check that the changes in demand and parameters in the model lead to results that are broadly in line with the most up-to-date observed data.

The table below shows a comparison of access for each station, as well as the resulting car versus other split. Results are also shown for each rail line as a whole.

The mode split is also shown in graphical form in the following Figure 8-17 to Figure 8-19, for the Johnsonville line, Kapiti line, and Hutt Valley line respectively.

Table 8-12: Rail Station Access Mode

Line / Station	Observed			Modelled			Car Split		Other Split	
	P&R	K&R	Other	P&R	K&R	Other	Obs	Mod	Obs	Mod
Hutt Valley Line										
Upper Hutt	283	104	179	137	33	208	68%	45%	32%	55%
Wallaceville	113	24	177	78	19	102	44%	49%	56%	51%
Trentham	110	13	220	139	32	123	36%	58%	64%	42%
Heretaunga	43	0	149	0	13	67	22%	16%	78%	84%
Silverstream	286	25	172	135	28	161	64%	50%	36%	50%
Manor Park	6	0	39	4	1	13	13%	28%	87%	72%
Pomare	105	16	41	57	12	17	75%	80%	25%	20%
Taita	194	37	133	152	33	223	63%	45%	37%	55%
Wingate	9	0	98	0	3	37	8%	7%	92%	93%
Naenae	44	25	183	93	24	234	27%	33%	73%	67%
Epuni	33	5	92	52	13	165	29%	28%	71%	72%
Waterloo	776	133	1030	894	188	738	47%	59%	53%	41%
Woburn	241	13	348	102	21	241	42%	34%	58%	66%
Ava	62	8	310	66	12	214	18%	27%	82%	73%
Petone	554	74	214	389	89	285	75%	63%	25%	37%
Melling	256	24	113	112	32	155	71%	48%	29%	52%
Western Hutt	47	7	63	0	14	33	46%	30%	54%	70%
Subtotal	3162	508	3561	2410	567	3017	51%	50%	49%	50%
Johnsonville Line										
Johnsonville	73	9	256	198	34	208	24%	53%	76%	47%
Raroa	65	0	151	89	15	112	30%	48%	70%	52%
Khandallah	18	0	135	50	4	179	12%	23%	88%	77%
Box Hill	16	0	58	0	14	91	22%	13%	78%	87%
Simla Crescent	35	5	129	47	5	176	24%	23%	76%	77%
Awarua Street	7	0	150	41	4	285	4%	14%	96%	86%
Ngaio	56	0	118	30	3	151	32%	18%	68%	82%
Crofton Downs	60	0	121	16	2	210	33%	8%	67%	92%

Line / Station	Observed			Modelled			Car Split		Other Split	
	P&R	K&R	Other	P&R	K&R	Other	Obs	Mod	Obs	Mod
Subtotal	330	14	1118	471	81	1412	24%	28%	76%	72%
Kapiti Line										
Waikanae	444	26	130	232	70	279	78%	52%	22%	48%
Paraparaumu	456	103	353	273	71	328	61%	51%	39%	49%
Paekakariki	59	4	89	45	12	88	41%	39%	59%	61%
Pukerua Bay	18	6	135	44	9	116	15%	31%	85%	69%
Plimmerton	102	27	142	98	28	198	48%	39%	52%	61%
Mana	109	13	103	118	29	127	54%	54%	46%	46%
Paremata	270	28	145	182	49	274	67%	46%	33%	54%
Porirua	890	198	133	854	255	763	89%	59%	11%	41%
Kenepuru	10	0	41	0	7	7	20%	50%	80%	50%
Linden	59	15	292	80	21	152	20%	40%	80%	60%
Tawa	181	29	188	168	47	192	53%	53%	47%	47%
Redwood	134	18	244	119	33	149	38%	50%	62%	50%
Takapu Road	143	0	152	245	65	95	48%	77%	52%	23%
Subtotal	2875	467	2147	2458	696	2768	61%	53%	39%	47%
TOTAL	6367	989	6826	5339	1344	7197	52%	48%	48%	52%

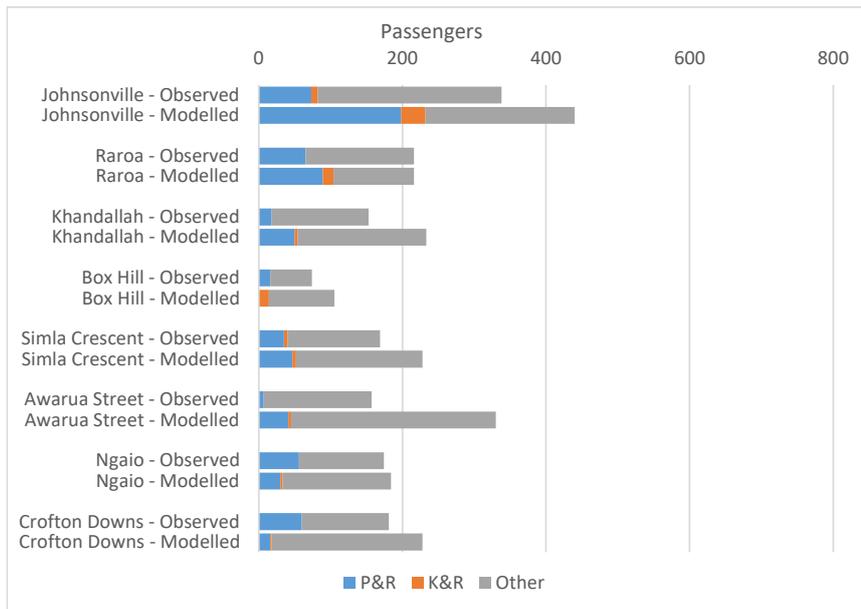


Figure 8-17: Access Per Station AM Peak – Johnsonville Line

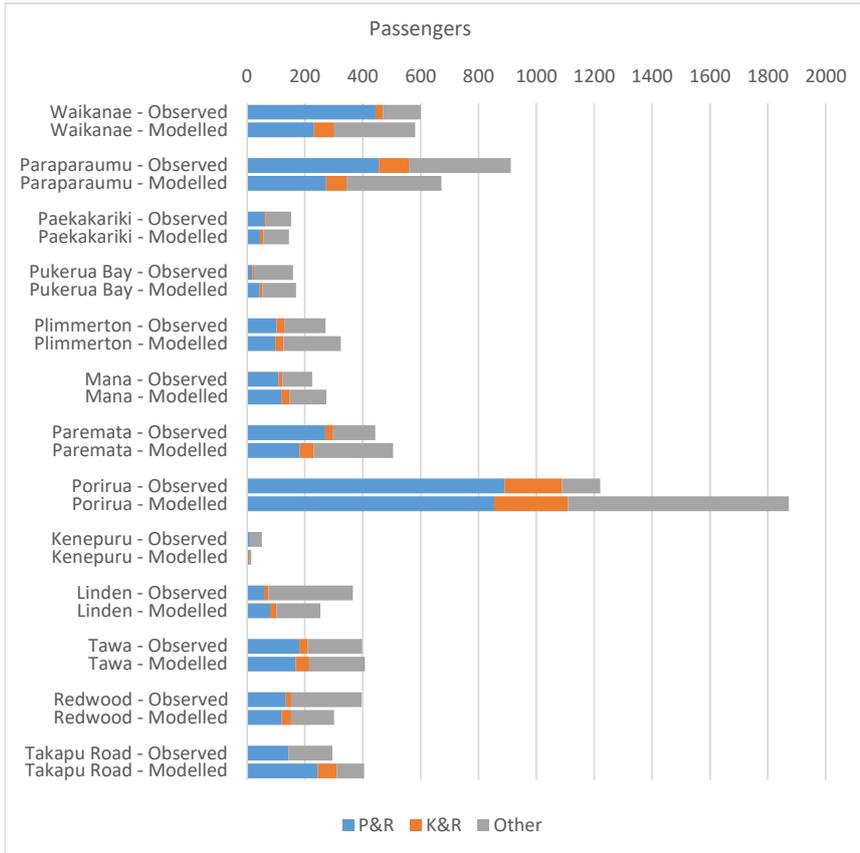


Figure 8-18: Access Per Station AM Peak – Kapiti Line

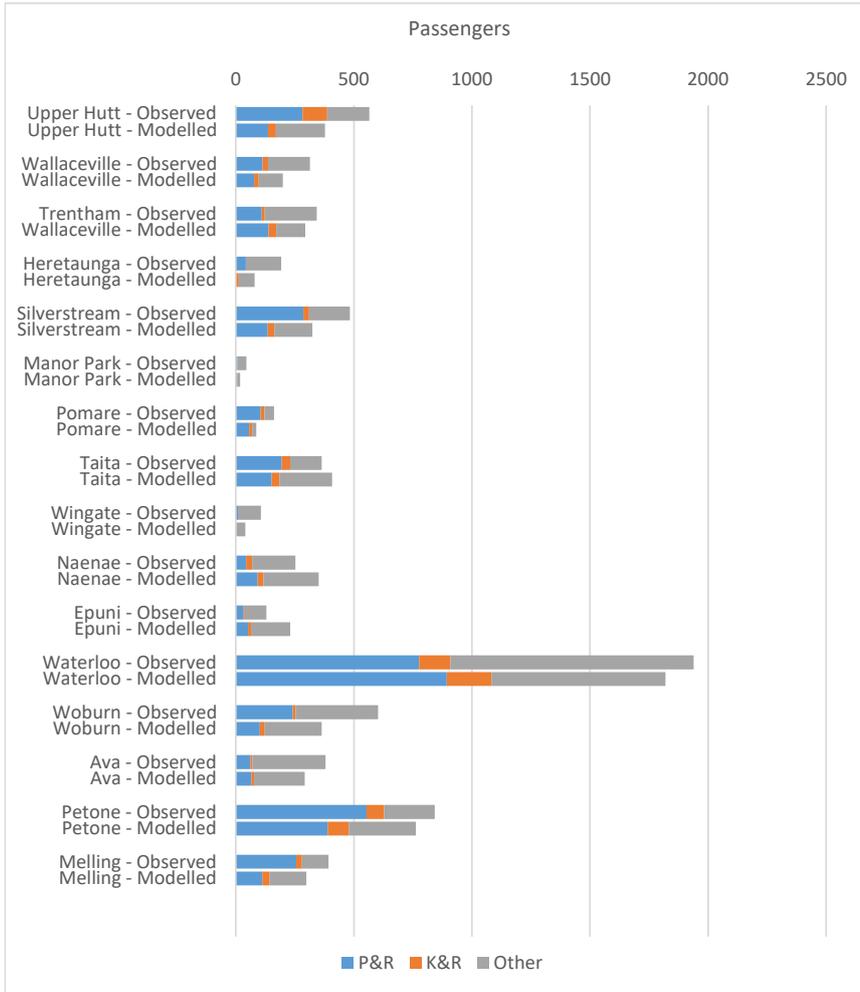


Figure 8-19: Access Per Station AM Peak – Hutt Valley Line

As expected, validation outcome is somewhat different from the 2011 WPTM, but modelled patronage per station and mode are reasonably close to observed.

It must be noted that the target of modelled patronage per mode and station being within +/-20% of observed does not seem to have been used in the 2011 model validation, with more than half modelled figures being over the threshold. The 2011 validation report notes that due to the limitations noted previously (see section 8.8), the choice model validation is “as good as can reasonably be expected”.

For this 2018 update and compared with 2011, just over 50% of stations show a better match to observed in terms of car vs non-car split, but it is hard to interpret this due to the difference in survey data.

The stations showing the most difference are Johnsonville and Porirua but in both cases observed totals are lower than they were in 2011, indicating issues with application of 2017 APC counts for expansion.

Looking at car vs non-car mode split over the whole lines, the Hutt Valley and Johnsonville lines are a good match with observed. Modelled car access on the Johnsonville line has decreased from 51% in the 2011 model to 28%, due to the new ASC for this rail line specifically.

Modelled car access is too high on the Kapiti line (61% vs 53% observed), although this was already the case in the 2011 model (respectively 55 and 49%).

9. Validation Summary

The following table summarises the validation outcomes for each criteria set out in Table 8-1. In addition, brief comment is made regarding the confidence for each observed dataset.

Table 9-1: Validation Criteria

Criteria	Target	Outcome	Confidence
Metlink Patronage	No defined target	✓ Bus and rail patronage within +/-15%	Medium: simple assumptions made to convert monthly to period patronage.
CBD cordon – all modes	+/-15%	✓	High for bus / Medium for rail: Observed counts, although single day surveyed annually. Factor to convert pedestrians at Wellington station to rail passengers to be verified if new data becomes available.
CBD cordon – bus patronage per location	+/-15%	✓ Validation suitable for most locations. Some locations poorer, likely due to trips assigned to walk and different time definition in observed and modelled.	High for AM: Observed counts, although single day surveyed annually. Medium for PM, as different year used.
CBD inbound rail volumes	No defined target	✓ Within +/-15% for Kapiti and Hutt Valley line. Johnsonville line to be re-checked once new WTSM is developed with updated bus travel times.	High: Observed guard counts
Rail demand by access mode and station	+/-20%	✗ Not achieved, but consistent with 2011 WPTM which did not use this criteria. Results are however considered suitable as the model replicates well overall patterns and demand at main stations.	Low: Survey from different year (2017) and with different methodology, expanded using APC data.
Bus and rail volumes at screenlines	+/-15%	✗ Achieved for all periods for rail and IP and PM for bus. Bus AM has only 36% of screenlines within target. This criteria deemed less suitable than using GEH.	High for bus as based on ETM. Medium for rail as based on 2011 surveyed data, factored using Metlink patronage by line.
Scatterplot of bus boardings by route	$R^2 > 0.85$	✓	High: based on ETM
TMDG screenlines and counts GEH, line of best fit and R^2		✓	High for bus as based on ETM. Medium for rail as based on 2011 surveyed, factored using Metlink patronage by line.

10. Conclusion

This technical note has detailed the update of the Wellington Public Transport model to 2018, including:

- Development Of New Bus Demand Matrices Based On ETM Data, Including For The PM Peak Which Until Now Was Based On The AM Peak Matrices Transposed And Factored.
- Update Of Matrices For Rail, Ferry And Cable Car Based On A Range Of Observed Patterns.
- Update Of Other Model Components Such As Network, Land Use, Economic Input Parameters, and
- Scripts improvements for accelerated runtimes.

Various data sources were used for the demand update and the model validation, which had to be processed, sense-checked and in some cases adjusted for consistency.

Validation of the new 2018 model was then undertaken against a whole range of metrics and validated to appropriate industry standards, while also comparing with earlier versions of the model. Overall the model was found to perform as well as earlier versions achieving a high standard of validation, and the more recent PM peak has now been validated to the same level as other time periods.

Validation of this new 2018 WPTM will need to be verified once the redeveloped 2018 WTSM is completed, as the new strategic model will run with the same zone system as WPTM, new time periods, entirely new demand matrices and adjusted road travel times, which could all potentially impact on the WPTM validation and operation.

Appendix A Comments and Responses

Please note that the comments below have been paraphrased in some places.

Comment / question from Client

Could we have a simple table that summarise the different components (bus demand, rail demand, bus validation, rail validation) and provides some indication of the confidence that we have in the data and thus the overall validation; for example, we have more confidence in the bus ETM data than rail demand data, there is some uncertainty about conflicting rail validation data etc

Response from Consultant

Added in Table 9 in validation summary.

Comment / question from Client

It would be useful for the AM peak and PM peak to report the % of rail trips where Wellington Station is neither an origin or destination; can this be compared against guard count or APC data to understand if we have the correct relativity between Wellington and non-Wellington trips?

Response from Consultant

This metric as modelled can be easily extracted from the model (results show circa 10% of rail trips not being from or to the Wellington station both in the AM and PM peak). However the observed proportions cannot be determined from the available data: the APC data for 2018 has been found to be too unreliable, and high counts can only show how many trips are arriving or departing the Wellington station in the peak direction, but not how many trips occurred on the rest of the network. The closest approximation (for the AM peak only) is to use the proportion of trips in high counts divided by the estimated total number of rail patronage from Metlink data (this number being itself based on a number of assumptions as detailed in section 8.1). This estimate leads to a proportion of 15% of inbound trips not headed to Wellington station.

Comment / question from Client

The main area of concern relates to rail demand into Wellington Station in the AM peak; I appreciate and understand the challenges highlighted with different data sources providing different (and often contradictory numbers) however I still have a concern that the 13,300 arrivals into Wellington in the AM peak (7am to 9am) are on the low side. The factor of 0.79 that is used to convert from all persons exiting the station to rail passengers exiting the station appears relatively high – this implies over 3,000 people walking “through” the station in the AM peak which, for comparison, is greater than the number of people who alight from buses at Wellington bus interchange in the AM peak; I don't suggest doing anything now to rectify – one approach would be to extend the March cordon survey in 2022 to count persons exiting and entering the station to see if we can update this factor, whilst also working further with Metlink to understand what other data they may have to verify this assumption (accepting that it could just give us another different answer)

Response from Consultant

This validation target for rail passengers out of Wellington station can be updated if more data is available. As it is, modelled rail volumes against this criterion are very close to observed and as a result, the observed volumes could be reduced by up to 10% with the model still meeting the validation criteria. Alternatively, if the volumes were found to need adjustments higher than 10%, adjusting the rail matrices to match it may lead to other validation criteria not being met anymore, due to the issues noted in the report with inconsistency in observed data.

Comment / question from Client

We have validated to a 2018 situation that has some residual crowding – what we have observed and modelled is already constrained by crowding - so if we were to add crowding into the 2018 WTSM / WPTM without changing anything else then demand would drop as the perceived cost would increase.

I suppose crowding would work in different ways in both models – WTSM would reflect crowding in terms of changes in demand / mode shift, whilst WPTM would reflect crowding more in terms of route / service choice.

Response from Consultant

This is correct for WTSM. For WPTM it might mostly lead to a shift between bus and rail on corridors for which there is competition and congestion on bus and/or rail. For most of Wellington TA where bus is the only PT mode, it would have a limited impact, potentially more bus users walking for short trips or the first/last section of their journeys. Route choice is limited, and for service choice it is expected this would improve results from the model, with less services overcrowded.

This would need to be addressed when confirming validation of the WPTM upon completion of WTSM.

Comment / question from Peer Reviewer

Are there any complexities that need to be worked through with WPTM now covering different (shorter) time periods than WTSM?

Response from Consultant

The WTSM matrices (both for validated base and forecast scenario) are passed on to WPTM to “pivot” on the observed WPTM matrices. Depending on growth type, for each OD either the absolute relative growth is used, absolute growth, or a combination of both. As a result, WTSM matrices will need to be factored down to the current WPTM time periods. A similar approach will be used as the approach to convert the “whole” period into smaller period (e.g. peak of the peak) for assignment in the new WTSM.

Comment / question from Peer Reviewer

The technical note acknowledges the resulting challenges in taking data from different years, but are there any obvious areas where the different sets of data do not sit well together (eg rail data from year x, not matching with bus data for year y, where, say, a feeder bus service to a rail station was only introduced in 2019)?

Response from Consultant

Because of the rail and bus datasets being largely separate, using different years has not created any such issues. Most of the issues relate to rail and are caused by inconsistencies in data that is mostly from 2018.

Comment / question from Peer Reviewer

It appears from the numbers being quoted (eg Section 4.2) that data from Monday to Friday is being used. Does this create complexities around achievable accuracy - noting that many models only take data for “neutral weekdays”, ie Tuesday to Thursday?

Response from Consultant

The same approach was used as in the original WPTM and 2013 update, with volumes being representative of an average weekday, i.e. average of Monday to Friday. This is also consistent with WTSM.

Comment / question from Peer Reviewer

The vast majority of trips in Figures 5-4 onwards relate to “other” – do we not have any breakdown of these other figures?

Response from Consultant

From the surveys carried out for WPTM, a very large majority (90%+) of these “other” access were walk, the rest being cycle and bus.

Comment / question from Peer Reviewer

Section 7-5 indicates that only locations where parking at stations has increased (between 2011 and 2018) have been updated. Presumably there could be locations where parking has legitimately reduced over time, which needs to be taken into account. Also, the text refers to the inclusion of "some" informal parking – maybe greater clarification could be provided, as it is quite likely that informal parking areas could contribute a significant proportion of total parking. Also, I forget if the model has a facility to not allow parking areas to be overfull.

Response from Consultant

No parking facilities have experienced a reduction in formal capacity. To clarify, comparing values from Metlink that are not inclusive of formal parking to model input values which are inclusive of them led in a few instances of apparent reductions and these were not applied.

Regarding informal parking, it does indeed represent a significant proportion of overall parking capacity at some locations. Unfortunately, little detail was provided in the original documentation for WPTM, and no updated data is available.

WPTM does not currently have the functionality to apply a cap or increase costs to reflect capacity constraints.

Comment / question from Peer Reviewer

Section 8 sets out the validation criteria, then the results, and it is good to see that the earlier criteria have been supplemented with those now included in the Transport Model Development Guidelines. Presumably the calibration has developed purely synthetic matrices, but is there any part of the process where some data has been used to assist the calibration stage and then re-used at the validation stage?

Response from Consultant

WPTM is based on observed data and therefore does not use synthetic matrices, although the demand does go through some processes to calculate access/route/station choice. The main issue relating to this comment is for ETM data, which is the primary source of information for building the new bus matrices, but ETM has also been used to produce some of the validation targets (bus screenlines, boardings per route). These checks still allow verifying that the intermediate processes in the model lead to the correct PT mode and route choice being output. Any such instance where ETM data was used to produce validation criteria is commented on in the report.

Comment / question from Peer Reviewer

The validation checks do not include travel times (by bus or rail). Is this being covered elsewhere?

Response from Consultant

Rail travel times in WPTM are based on timetables. For buses, however it is suggested that bus travel time validation will be reported in the new WTSM validation as vehicle-delay functions (shared with WPTM) will be re-estimated. A separate memo was produced that identified issues with obtaining reliable bus journey times, and potential inconsistencies with modelled travel times compared with the small sample of observed times provided. This memo will be made available separately as part of the suite of model documentation.

Comment / question from Peer Reviewer

The CBD cordon validation in Table 8-4 seems very good, apart from the modelled demand for the cable car. The numbers involved are clearly very low, and I accept that the cable car's contribution to PT in Wellington is also clearly very minor.

Response from Consultant

Yes, this is provided for consistency with earlier validation but the cable car is largely inconsequential as a transport mode.

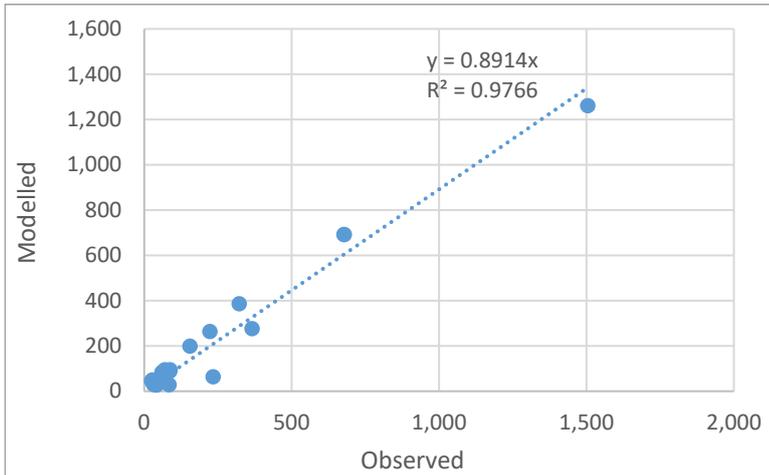
Comment / question from Peer Reviewer

Figures 8-2 to 8-4 look very good, but I wonder if they would still look so good if the single high number for the CBD cordon, within each Figure, was excluded.

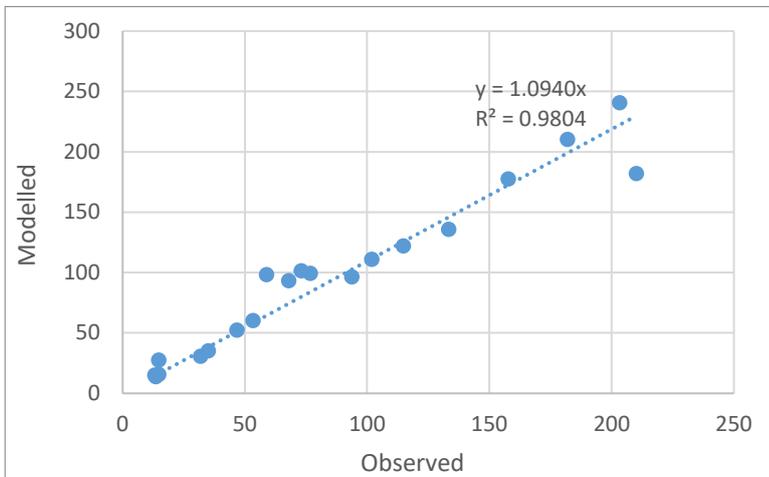
Response from Consultant

Scatterplots with the CBD screenlines removed are shown below. While most results deteriorate slightly, they are still largely within validation thresholds.

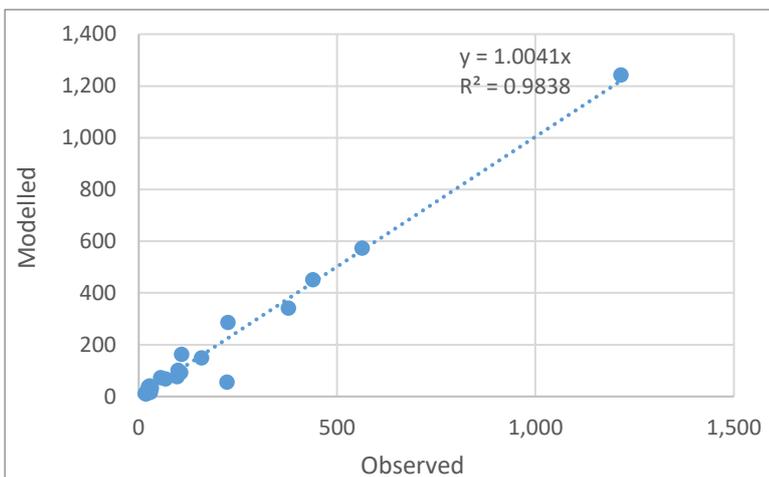
Bus Screenline Validation – AM Peak



Bus Screenline Validation – Inter Peak



Bus Screenline Validation – PM Peak



Comment / question from Peer Reviewer

The conclusion also highlights data which seems questionable, making validation challenging – and I agree that a simple table to highlight which data needs to be awarded higher and lower confidence would be useful. The technical note also concludes that the validation of WPTM will need to be verified once the redeveloped 2018 WTSM is completed.

Response from Consultant

Comment on confidence in data added in Table 9 in validation summary.

Appendix B Addendum – Revised WPTM for new 2018 WTSM

B.1 Introduction

As noted in the introduction of this report, the 2018 WPTM was updated using demand matrices and networks from the “interim” version of the strategic model WTSM updated as part of Stage 1 of this project.

Following the completion of the newly rebuilt WTSM as part of Stage 2, the WPTM had to be adjusted in order to be operational with the new strategic model. This section summarises the changes implemented, presents the validation of the revised WPTM and checks of the “pivoting” process used to apply forecasted growth.

B.2 Changes made to WPTM

The new version of WTSM developed as part of Stage 2 of this project is significantly different from the previous version, including:

- A new zone system with 819 zones (813 internal zones, 2 externals and special generators for the port, ferry terminals and airport) which is the same as now used in WPTM so that both models operate on the same zone system.
- New networks and road assignment using the JCAT module for improved representation of intersection delay. This impacts public transport as well as the bus travel times are calculated as a function of background traffic congestion.
- New public transport assignment with different transit time functions, cost, penalties and parameters for auxiliary, waiting, boarding times, etc.
- Demand segmentation is also different, with the same trip purposes as before but separate representation of bus, rail, rail park-and-ride and rail kiss-and-ride demand. Car availability at the household level is also changed from 'captive', 'competition' and 'choice' to 'car available' versus 'no car available'.

As a result, the following changes were implemented in the revised 2018 WPTM:

- The passing of matrices from WTSM to WPTM has been changed to reflect the new demand segmentation in WTSM. Matrices for all PT modes are summed up to total PT and output for 'car available' and 'no car available' segments. Due to the much larger matrices as a result of increased number of zones, the '.omx' open matrix format is used as it leads to significantly reduced file size.
- The passing of network has also been changed with the adjustments that were needed due to the different zone systems between both models now removed. The WTSM transit time functions are however now imported, and the auxiliary speed is reset to 5kph (the perception factor of 1.8 is directly applied to the speed in WTSM to allow different perception for walk vs car, whereas it is applied in the assignment in WPTM).
- The PT assignment has been changed so that it is more in line with WTSM. It had to be changed as previous transit time function were based on superseded car travel times calculations (with intersections delays added at a link level whereas they are now added to the turn due to the new JCAT module). The new WTSM functions are now used instead. Most other parameters from WTSM are also used, for improved consistency between both models. This also simplifies operation of the models greatly in terms of not having separate coding and parameters. It must be noted that the new WPTM assignment is not entirely the same as WTSM however, as not using journey levels and mixed modes. The original WPTM fare calculation has also been retained.
- Finally, the WTSM matrices were originally based on a coarser zone system and needed to be disaggregated to the WPTM zone system before carrying out the “pivot” process to apply WTSM forecasted growth to observed demand. As both models now use the same 819 zones, this step is not required anymore.

B.3 Validation

The following section presents the validation for the revised WPTM coupled with the new 2018 WTSM. Results can be compared with Section 8 in the main body of this report, that presented validation results of WPTM with demand and networks from the interim 2018 WTSM.

Metlink Patronage

The following table shows a comparison with Metlink monthly patronage counts, factored down to patronage by weekday time periods.

Table B-1: GWRC Monthly Passenger Counts Validation

Mode	Observed Average Monthly total	AM Peak			Inter Peak			PM Peak		
		Obs	Mod	Diff	Obs	Mod	Diff	Obs	Mod	Diff
Rail	1,262,611	16,657	15,164	-9%	2,445	2,090	-15%	-	-	-
Bus	2,290,227	22,940	23,842	4%	9,219	8,759	-5%	19,148	18,954	-1%
Total	3,552,838	39,597	39,006	-1%	11,664	10,750	-8%	-	-	-

Results are similar to the interim model, with the exception of rail in the Inter Peak being lower.

CBD Cordon

The table below shows validation results against the annual CBD cordon survey.

Table B-2: CBD Cordon Validation

Mode	Cordon Count	Modelled	Difference
Rail - AM	13,383	13,380	0%
Bus - AM	11,774	11,564	-2%
Ferry - AM	215	266	24%
Cable Car - AM	99	3	-97%
Total - AM	25,471	25,213	-1%
Bus - PM	9,777	10,037	3%

No significant change can be observed compared with the interim model.

Bus screenlines

The following tables respectively shows validation for bus screenlines, and a summary against Transport Model Design Guidelines criteria.

Table B-3: Bus Passenger Screenlines Validation

Screenline	AM				IP				PM			
	Obs	Mod	Diff %	GEH	Obs	Mod	Diff %	GEH	Obs	Mod	Diff %	GEH
W1 – I/b	5,618	5,619	0%	0.0	1,065	1,177	11%	3.4	752	1,172	56%	13.6
W1 – O/b	572	875	53%	11.3	772	848	10%	2.6	4,890	4,819	-1%	1.0
W2 – N/b	87	95	9%	0.8	102	112	10%	1.0	439	447	2%	0.4
W2 – S/b	678	691	2%	0.5	115	122	6%	0.7	99	101	2%	0.2
W3 – N/b	39	42	10%	0.6	94	96	3%	0.3	563	571	1%	0.3
W3 – S/b	678	691	2%	0.5	133	136	2%	0.2	67	68	2%	0.2
W4 – N/b	70	109	55%	4.1	158	181	14%	1.7	1,215	1,302	7%	2.4
W4 – S/b	1,505	1,407	-6%	2.6	210	223	6%	0.9	105	124	17%	1.7
W5 – N/b	32	31	-1%	0.1	13	15	15%	0.5	30	16	-47%	2.9
W5 – S/b	42	27	-35%	2.5	14	14	0%	0.0	18	16	-14%	0.6
L1 – N/b	87	111	28%	2.5	59	106	81%	5.2	222	115	-48%	8.2
L1 – S/b	234	10	-96%	20.3	73	109	50%	3.8	97	74	-24%	2.5

Screenline	AM				IP				PM			
	ID	Obs	Mod	Diff %	GEH	Obs	Mod	Diff %	GEH	Obs	Mod	Diff %
L2 – N/b	28	51	82%	3.6	53	66	24%	1.7	108	147	36%	3.5
L2 – S/b	155	201	30%	3.4	47	62	32%	2.0	24	44	84%	3.5
L3 – N/b	366	245	-33%	6.9	182	224	23%	2.9	158	140	-12%	1.5
L3 – S/b	224	265	18%	2.6	203	270	33%	4.3	377	454	20%	3.8
L4 – E/b	323	384	19%	3.2	77	100	30%	2.5	32	27	-16%	0.9
L4 – W/b	25	51	101%	4.2	68	96	41%	3.1	224	319	42%	5.7
U2 – N/b	61	83	37%	2.6	35	41	17%	1.0	55	57	4%	0.3
U2 – S/b	67	58	-13%	1.1	32	40	25%	1.3	28	48	75%	3.4
P3 – N/b	33	41	24%	1.3	15	26	77%	2.5	19	8	-58%	3.0
P3 – S/b	85	23	-72%	8.4	15	12	-21%	0.9	16	10	-41%	1.9
Total	11,008	11,111	1%		3,534	4,075	15%		9,541	10,080	6%	

Table B-4: Screenlines and Counts Validation

Time Period	Screenlines			Counts		
	AM	IP	PM	AM	IP	PM
GEH < 5	82%	100%	86%	80%	95%	85%
GEH < 7.5	86%	100%	91%	92%	98%	89%
GEH < 10	91%	100%	95%	97%	100%	94%
GEH < 12	95%	100%	95%	97%	100%	98%
Line of best fit	1.00	1.06	1.03	0.98	1.12	1.02
R ²	1.00	0.99	0.99	0.98	0.95	0.97

Results are generally similar to the interim WPTM. It must be noted that bus volumes are very low between the Hutt Valley and Wellington in the peak direction. This was already the case in the previous model but is more marked now. Observed volumes are however quite small as well.

Bus CBD cordon counts

The following table shows modelled AM peak inbound and PM peak outbound bus volumes across all locations on the CBD cordon, along with observed patronage.

Table B-5: CBD Bus Cordon Validation

Links of CBD Cordon	Observed	Modelled	Difference
AM Peak - Inbound			
Oriental Parade	471	346	-27%
Cambridge Terrace	1664	1,670	0%
Elizabeth Street	2237	2,375	6%
Willis Street	899	982	9%
Taranaki Street	1060	857	-19%
Hawker Street	26	0	-100%
Tinakori Road	1395	1,299	-7%
Kelburn Parade	919	756	-18%
Murphy Street	497	393.3	-21%
Thorndon Quay	2607	2,886	11%
Total	11,774	11,564	-2%

Links of CBD Cordon	Observed	Modelled	Difference
PM Peak - Outbound			
Oriental Parade	397	324	-18%
Kent Terrace	1573	1,247	-21%
Elizabeth Street	1572	1,851	18%
Victoria Street	822	876	7%
Taranaki Street	697	679	-3%
Hawker Street	98	6	-94%
Tinakori Road	1109	1,133	2%
Kelburn Parade	560	573	2%
Molesworth Street	832	652	-22%
Thorndon Quay	2118	2,696	27%
Total	9,777	10,037	3%

Results are overall similar to the WPTM coupled with the interim WTSM.

Bus boardings per route

This section presents a comparison of the number of boardings per bus route, both observed and modelled.

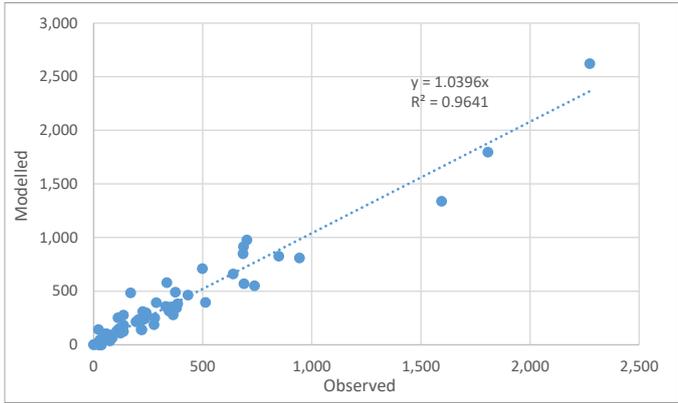


Figure B-1: Bus Boarding Per Route Validation – AM Peak

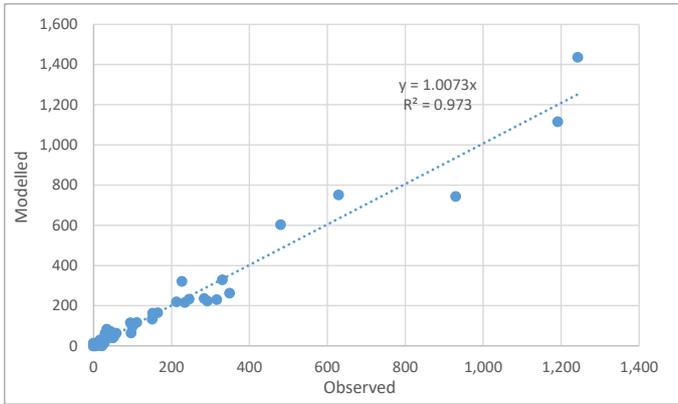


Figure B-2: Bus Boarding Per Route Validation – Inter Peak

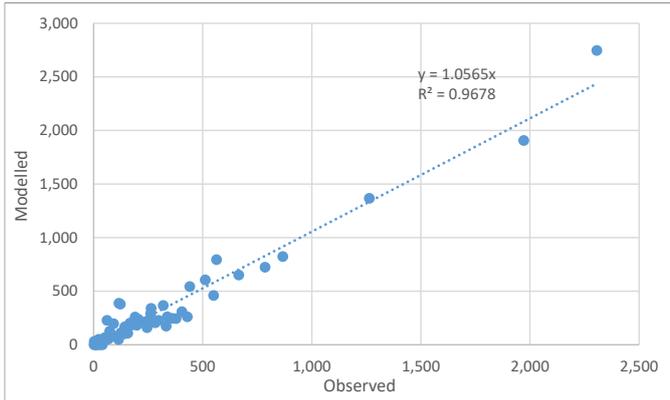


Figure B-3: Bus Boarding Per Route Validation – PM Peak

Results are very similar to the interim WPTM.

Rail high counts – Volumes at Wellington station

The following table presents a comparison of modelled rail volumes at Wellington station against rail high (or guard) counts obtained from Kiwirail, separately for each railway line. The second table shows comparison against volumes derived from Metlink patronage growth per line applied to 2011 high counts as an additional check as it was found that 2018 high counts for the Kapiti line were lower than 2011 and 2013.

Table B-6: Rail High Count Validation

Line	High count	Modelled	Difference
AM Peak Inbound			
JVL	1,404	1,236	-12%
HVL / MEL / WRL	6,562	6,461	-2%
KPL	4,330	5,683	31%
Total	12,296	13,380	9%
PM Peak outbound			
JVL	1,087	969	-11%
HVL / MEL / WRL	5,868	6,049	3%
KPL	4,372	5,027	15%
Total	11,327	12,045	6%

Table B-7: Rail High Count Validation –Metlink observed growth applied to 2011 high counts

Line	High Count	Modelled	Difference
AM Peak Inbound			
JVL	1,399	1,236	-12%
HVL / MEL / WRL	5,823	6,461	11%
KPL	5,319	5,683	7%
Total	12,541	13,380	7%

Results are generally similar to the interim model, with the main exception being patronage for the Johnsonville line that was too high and is now slightly too low.

Rail screenlines

The following tables respectively shows validation for rail screenlines, and a summary against TMDG criteria.

Table B-8: Rail Passenger Screenline Validation

Screenline	AM				IP				PM			
	ID	Obs	Mod	Diff %	GEH	Obs	Mod	Diff %	GEH	Obs	Mod	Diff %
W4 – Nb	365	311	-15%	3.0	575	367	-36%	9.6	12,193	12,045	-1%	1.3
W4 – Sb	13,905	13,380	-4%	4.5	1,061	824	-22%	7.7	405	325	-20%	4.2
L1 – Nb	210	164	-22%	3.3	206	154	-25%	3.9	5,807	6,071	5%	3.4
L1 – Sb	6,338	6,494	2%	2.0	370	344	-7%	1.4	223	135	-40%	6.6
L2 – Nb	311	235	-24%	4.6	56	54	-4%	0.3	2,184	2,287	5%	2.2
L2 – Sb	2,202	2,328	6%	2.6	126	131	4%	0.4	204	116	-43%	6.9
L3 – Eb	165	129	-22%	3.0	171	151	-12%	1.6	5,064	5,088	0%	0.3
L3 – Wb	5,271	5,304	1%	0.4	333	308	-8%	1.4	120	96	-20%	2.3
U2 – Nb	318	237	-25%	4.9	58	55	-5%	0.3	2,159	2,267	5%	2.3
U2 – Sb	2,161	2,306	7%	3.1	122	125	3%	0.3	204	118	-42%	6.8
P1 – Nb	36	36	1%	0.1	133	126	-6%	0.7	1,989	1,669	-16%	7.5
P1 – Sb	2,251	2,031	-10%	4.7	282	266	-6%	1.0	117	26	-78%	10.8
P3 – Nb	140	107	-23%	2.9	236	199	-16%	2.5	3,965	3,849	-3%	1.8
P3 – Sb	4,323	4,291	-1%	0.5	409	355	-13%	2.7	171	114	-33%	4.8
K1 – Nb	34	32	-7%	0.4	86	82	-5%	0.5	366	454	24%	4.3
K1 – Sb	560	616	10%	2.3	121	120	-1%	0.1	83	20	-76%	8.8
Total	38,590	38,001	-2%	3.0	4,346	3,661	-16%	10.8	35,254	34,680	-2%	3.1

Table B-9: Rail Screenline Validation

Time Period	Screenlines		
	AM	IP	PM
GEH < 5	100%	88%	63%
GEH < 7.5	100%	88%	69%
GEH < 10	100%	100%	94%
GEH < 12	100%	100%	10%
Line of best fit	0.98	0.80	1.00
R ²	1.00	0.99	1.00

Results are generally close to the interim WPTM. More screenlines have a GEH above 5 in the PM peak, however this is mostly for the counterpeak direction with GEH in the 6 to 8 range and is therefore not considered critical.

Access to rail mode share

Finally the following table shows the validation of mode share for access to rail, for each railway line.

Table B-10: Rail Station Access Mode

Line		P&R	K&R	Other
JVL	Observed	23%	1%	76%
	Modelled	35%	7%	58%
KPL	Observed	52%	9%	39%
	Modelled	41%	11%	48%
HVL	Observed	44%	7%	49%
	Modelled	39%	9%	52%
Total	Observed	45%	7%	48%
	Modelled	39%	10%	51%

Results are in line with the interim WPTM for the Kapiti and Hutt Valley lines, but have deteriorated for the Johnsonville line with less non-car based access than observed.

This issue was investigated and the ASC that was introduced for the Johnsonville line was amended to improve on this access mode share. This was found to have an adverse impact on the share of rail versus bus from Johnsonville however so a compromise was sought between access to rail mode share and bus/rail split.

Validation summary

The following table presents a summary of the validation of the revised WPTM coupled with the new 2018 WTSM.

Table B-11: Validation Criteria

Criteria	Target	Outcome	Confidence
Metlink Patronage	No defined target	✓ Bus and rail patronage within +/-15%	Medium: simple assumptions made to convert monthly to period patronage.
CBD cordon – all modes	+/-15%	✓	High for bus / Medium for rail: Observed counts, although single day surveyed annually. Factor to convert pedestrians at Wellington station to rail passengers to be verified if new data becomes available.
CBD cordon – bus patronage per location	+/-15%	✓ Validation suitable for most locations. Some locations poorer, likely due to trips assigned to walk and different time definition in observed and modelled.	High for AM: Observed counts, although single day surveyed annually. Medium for PM, as different year used.
CBD inbound rail volumes	No defined target	✓ Within +/-15%	High: Observed guard counts
Rail demand by access mode and station	+/-20%	✗ Not achieved, but consistent with 2011 WPTM which did not use this criteria. Results are still considered suitable but the Johnsonville line has deteriorated compared with earlier results.	Low: Survey from different year (2017) and with different methodology, expanded using APC data.
Bus and rail volumes at screenlines	+/-15%	✗ Similar results to interim model. This criteria deemed less suitable than using GEH.	High for bus as based on ETM. Medium for rail as based on 2011 surveyed data, factored using Metlink patronage by line.
Scatterplot of bus boardings by route	$R^2 > 0.85$	✓	High: based on ETM
TMDG screenlines and counts GEH, line of best fit and R^2		✗ Passed for all criteria except rail IP (line of best fit) and PM ($GEH < 5$ and $GEH < 7.5$).	High for bus as based on ETM. Medium for rail as based on 2011 surveyed, factored using Metlink patronage by line.

Validation for the revised WPTM coupled with the new 2018 WTSM is overall similar to the previous version that was updated based on 2018 interim WTSM demand matrices and networks. The main differences include:

- A reduction in bus demand between the Hutt Valley and Wellington. This was already the case before but modelled volumes are now very low.

- A reduction in rail patronage on the Johnsonville line. This was however over-estimated previously and the resulting demand is now a better match with observed.
- Validation of access to rail on the Johnsonville line has deteriorated to some extent with less non-car access than observed.
- The counter peak direction in the PM peak is generally lower than observed for rail. This is not considered critical however due to the low patronage in this direction.

B.4 Forecasted growth comparison

As noted previously, the pivoting process used to apply WTSM forecasted growth to the observed base year matrices in the WPTM was modified to account for the new 819-zone system used in both model. As a result the disaggregation of the WTSM matrices is not required anymore and this step has been removed.

A number of testing scenarios were run in both WTSM and WPTM, and the resulting levels of growth in each model were compared to check that the WPTM forecasting process was not impacted by the changes made. These scenarios include:

- 2018 base year
- 2038 land use
- 2053 land use and network, including PT modal enhancements
- 2053 land use, network and parameters including increase in vehicle operating costs, values of time, CBD parking costs and a cap on number of car trips to the CBD.

It must be noted that these scenarios were not based on any realistic forecasts but were simply indicative scenarios set up for testing the WPTM pivoting process.

Results were first compared looking at the number of public transport boardings, in total and separately for each mode. The following table presents the forecasting growth in WTSM and WPTM for each scenario. When comparing absolute numbers, it must be kept in mind that the modelled time periods are different in both models (for the AM/PM peaks the modelled periods are 3hrs for WTSM and 2hrs for WPTM, and for the Interpeak respectively 6 and 2hrs). The percentage growth however should be similar in both models.

Table B-12: Forecasted growth per mode

Boardings per mode	Time Period	WTSM							
		2018	2038	% Diff	2053	% Diff	2053 + Params	% Diff	
Bus	AM	30,432	33,450	10%	37,818	24%	51,103	68%	
	IP	28,606	31,552	10%	39,959	40%	54,035	89%	
	PM	35,356	38,532	9%	45,079	28%	62,691	77%	
Rail	AM	20,930	26,006	24%	36,411	74%	49,800	138%	
	IP	6,230	7,861	26%	11,631	87%	18,635	199%	
	PM	19,386	23,779	23%	33,033	70%	46,564	140%	
Enhanced PT	AM				7,906	-	16,615	-	
	IP				5,011	-	10,755	-	
	PM				7,753	-	16,168	-	
Total	AM	51,362	59,456	16%	82,135	60%	117,518	129%	
	IP	34,836	39,413	13%	56,601	62%	83,425	139%	
	PM	54,742	62,311	14%	85,865	57%	125,423	129%	
Boardings per mode	Time Period	WPTM							
		2018	2038	% Diff	2053	% Diff	2053 + Params	% Diff	
Bus	AM	24,701	26,702	8%	30,232	22%	37,597	52%	

Boardings per mode	Time Period	WTSM						
		2018	2038	% Diff	2053	% Diff	2053 + Params	% Diff
	IP	9,270	10,099	9%	12,119	31%	15,181	64%
	PM	20,024	22,098	10%	26,416	32%	32,955	65%
Rail	AM	15,164	18,518	22%	25,355	67%	31,933	111%
	IP	1,990	2,670	34%	3,652	84%	5,342	168%
	PM	13,540	16,602	23%	23,406	73%	29,817	120%
Enhanced PT	AM				5,766	-	10,808	-
	IP				1,513	-	2,998	-
	PM				5,127	-	9,832	-
Total	AM	39,865	45,220	13%	61,353	54%	80,338	102%
	IP	11,260	12,769	13%	17,284	53%	23,521	109%
	PM	33,564	38,700	15%	54,949	64%	72,604	116%

Overall the 2038 to 2018 growth is quite close in both models. This matches the test reported in the original WPTM forecasting report which also tested forecasting at a 20-year horizon.

For the 2053 tests which include a much higher growth however, the WPTM consistently forecasts a lower growth than WTSM. In the absence of similar test in the original model documentation, it is not possible to tell if this was already the case previously, although experience on use of the model has shown levels of growth being generally lower in WPTM than WTSM.

The respective patterns by time periods or modes are however consistent in both models apart from the less marked response from WPTM.

Reassuringly forecasted patronage on the new 'Enhanced PT' mode, a completely new mode in the 2053 scenarios, is very close in both models once the different periods duration are accounted for.

The following tables then show sectorised growth by Territorial Authority (TA), to ensure that the spatial distribution of growth in WPTM broadly replicates WTSM forecasts. Results are shown for the AM peak period.

Table B-13: Forecasted growth per TA – AM peak

	2018 - 2038		2018 - 2053		2018 - 2053 + Parameters	
TA	WTSM					
	From	To	From	To	From	To
Wellington	10%	12%	40%	51%	94%	112%
Porirua	22%	29%	60%	63%	106%	74%
Kapiti	52%	40%	96%	61%	173%	91%
Lower Hutt	9%	35%	45%	73%	90%	85%
Upper Hutt	15%	47%	62%	74%	109%	80%
Wairarapa	56%	24%	189%	61%	285%	90%
Total	16%	16%	54%	54%	108%	108%
TA	WPTM					
	From	To	From	To	From	To
Wellington	12%	14%	40%	51%	87%	98%
Porirua	27%	15%	66%	35%	95%	44%

	2018 - 2038		2018 - 2053		2018 - 2053 + Parameters	
TA	WTSM					
	From	To	From	To	From	To
Kapiti	38%	44%	79%	64%	153%	97%
Lower Hutt	5%	21%	33%	47%	57%	55%
Upper Hutt	6%	24%	45%	36%	72%	41%
Wairarapa	56%	0%	201%	17%	307%	109%
Total	15%	15%	50%	50%	92%	92%

The modelled growth by TA is overall a good match between the two models. Results fluctuate more in the “to” direction, but it must be noted that in the AM peak the large majority of trips are to the Wellington City area and trips to other TAs are numerically much smaller.

It must be noted that the significant growth observed on the Wairarapa line in both models is simply a consequence of the indicative population and employment input used for these tests.

As a result of this comparison, it appears that the pivoting process in WPTM replicates well forecasted growth from WTSM for shorter term forecasts or lower levels of growth, but generally returns lower patronage increase for longer term forecasts or with higher growth. Although this is not a result of the changes documented in this addendum but a feature of the pivoting process itself, this should be considered for project analysis when forecasting at farther out horizons.

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