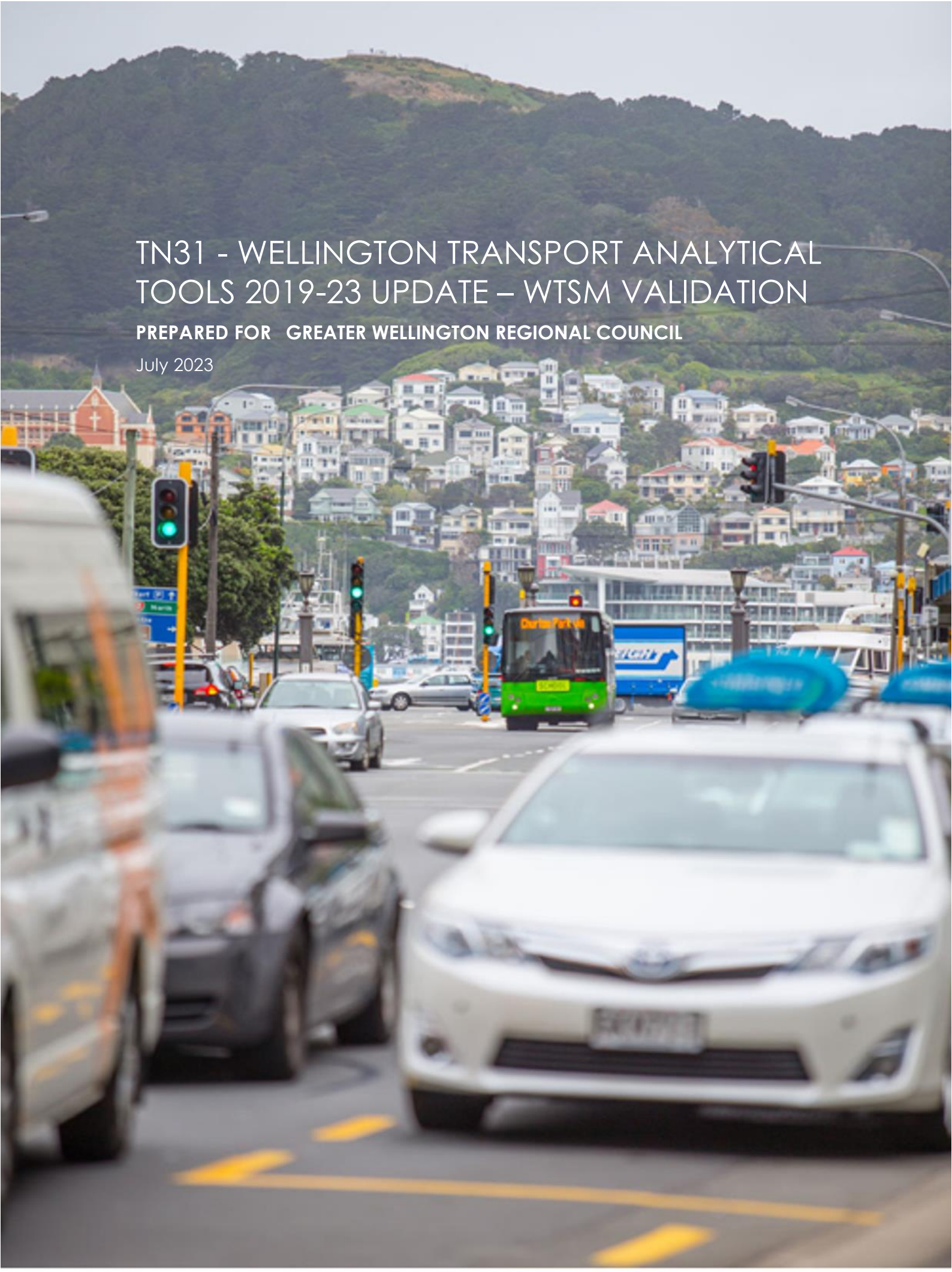

TN31 - WELLINGTON TRANSPORT ANALYTICAL TOOLS 2019-23 UPDATE – WTSM VALIDATION

PREPARED FOR GREATER WELLINGTON REGIONAL COUNCIL

July 2023

Stantec | JACOBS

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1. Introduction

This technical note is part of a series documenting the 2019-2023 update of the Wellington Regional Transportation Planning Analytical Tools. The higher-level Analytical Tools are maintained and operated by Greater Wellington Regional Council (GWRC), who is the client for this project. This project is being delivered by Stantec and Jacobs, supported by GWRC transport modellers.

This note details the validation of the Wellington Transport Strategy Model (WTSM), which aims to demonstrate that the model is a good representation of transport patterns in the base year 2018, by comparing output against a range of observed data:

- Traffic counts and screenlines volumes for light and heavy/medium vehicles
- Traffic travel times
- Bus passengers ticketing information and CBD cordon counts
- Bus travel times
- Rail counts and loading profiles
- Active mode counts

Convergence of the demand model assignment is also reported to demonstrate that the WTSM converges satisfactorily.Convergence of the model in terms of iterative calculation of demand through to assignment is also reported to demonstrate that the WTSM converges satisfactorily.

The criteria used for the model validation are mostly based on the Transport Model Development Guidelines (TMDG), developed by Waka Kotahi. Under the TMDG definition, WTSM is a model of category A, or 'Regional' and criteria for this model category was used.

'TN4 – Data Analysis' details the data that has been used for the validation and how it has been processed.

2. Road assignment validation

2.1 Screenlines and criteria

The 16 screenlines used for the validation of the previous version of the WTSM, comprising a total of 66 counts, were adopted for this new model. However, data for an additional 12 screenlines and 41 counts was also collected which were added to the validation dataset. Description of the screenlines and traffic counts is included in TN4, and their locations are shown in the following figures.

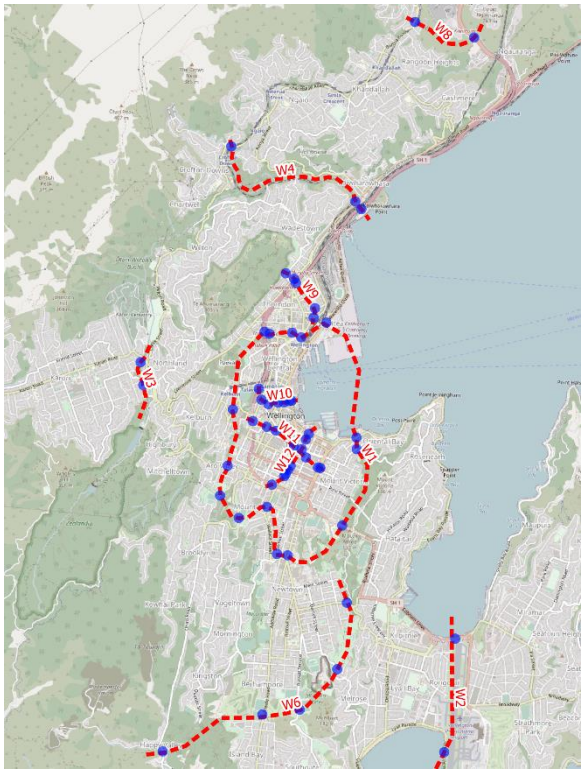


Figure 2.1: Screenlines Wellington

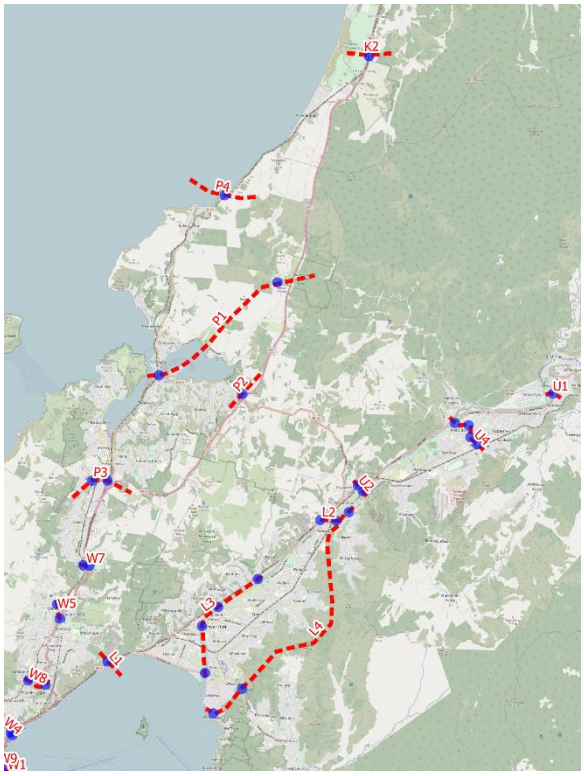


Figure 2.2: Screenlines Hutt Valley and Porirua

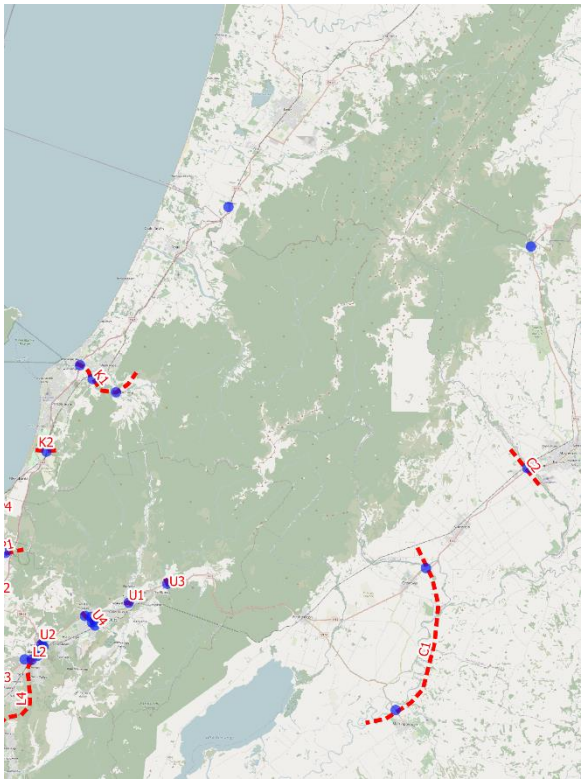


Figure 2.3: Screenlines rest of region

Validation criteria for traffic counts and screenlines is based on the TMDG appropriate for this regional model. The following table shows the criteria for the GEH statistics, used to compare observed and modelled counts.

Table 2.1: Hourly GEH comparison criteria for road traffic count validation

GEH	% of screenlines (per direction)	% of traffic counts (per direction)
GEH <5	>60%	>65%
GEH <7.5	>75%	>75%
GEH <10	>90%	>85%
GEH <12	N/A	>95%

The targets for the GEH statistic are based on hourly volumes, but the modelled periods in WTSM are longer than a single hour. The method employed in previous updates of WTSM was to divide the 2-hour observed and modelled flows by two to generate an "average hour" flow. The same approach was applied for the 3-hour AM and PM peak periods in the new model, as well as for the 6-hour Inter-peak period. For the 12-hour Overnight period however, a factor of seven was used to divide observed and modelled flows, as many hours during this period have very low volumes which would make the GEH look artificially better.

In addition to the GEH comparison, the TMDG specifies the following criteria:

- Screenline hourly count bands:
  - >70% within 10%
  - >80% within 15%
- Link hourly counts bands:
  - For links with directional volumes less than 700 vph (vehicles per hour): >70% within 100vph
  - For links with directional volumes between 700 and 2700 vph: >70% within 15%
  - For links with directional volumes above 2700 vph: >70% within 400vph
- Scatterplots of modelled vs observed for all traffic counts, line of best fit with:
  - R^2 greater than 0.85

- Slope line of best fit (forced through zero) between 0.9 and 1.1

- RMSE (root mean squared error) for all counts:
  - Acceptable: less than 30%
  - Requires clarification: between 30% and 40%
  - Unlikely to be appropriate: greater than 40%

Turning movements are not validated, as this is not required or appropriate for a strategic model of category A.

Validation was carried out separately for light vehicles, and medium and heavy vehicles combined (called 'heavy vehicle' in the rest of this note for simplicity).

2.2 Screenline validation – Light vehicles

The following table shows a summary of the light vehicles' validation against observed volumes (average hour) across screenlines. Results are also presented in scatterplot format, where flows for the modelled period are plotted.

Values shaded in grey in the validation tables throughout this note are values that do not meet TMDG criteria.

Table 2.2: Screenline validation – light vehicles

Criteria		AM	IP	PM	ON
GEH	>60% with GEH<5	69%	70%	73%	69%
	>75% with GEH<7.5	83%	81%	83%	86%
	>90% with GEH<10	91%	91%	91%	94%
% Difference	70% with difference <10%	50%	58%	59%	42%
	80% with difference <20%	79%	77%	82%	65%

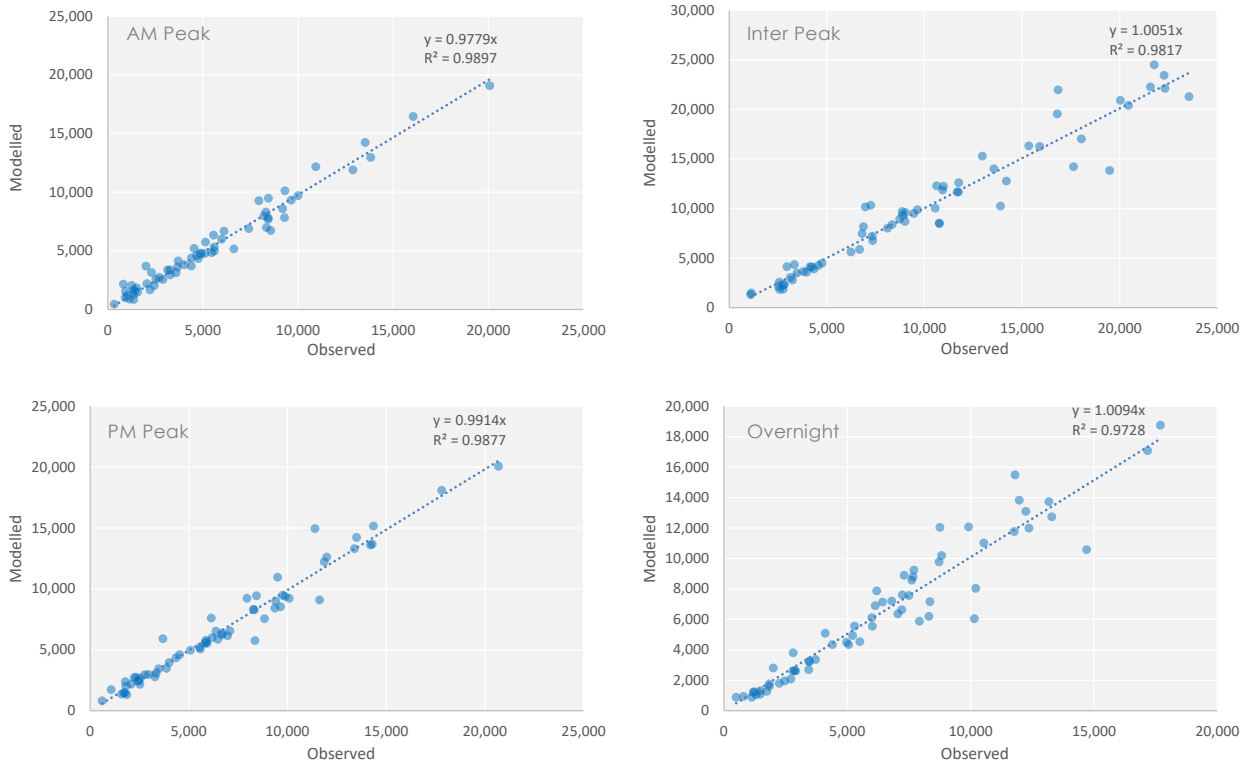


Figure 2.4: Screenline validation scatterplots – Light vehicles (period flows)

At an aggregate level, results show that all of the GEH criteria are met. In most cases, the model performs largely above the TMDG criteria.

Looking at percentage difference with observed, the model does not meet any of the TMDG guidelines. It is generally well below the first criteria, and slightly under the second one. This is consistent with our experience with other strategic models for which achieving these thresholds appears very difficult even if all other metrics are met.

Looking at detailed results per screenline (which are included in Appendix A), the following comments can be made:

- Screenline W1 was broken down in 4 sections (W1A to W1D) to separate movements from the East, South, West and North to the CBD. Most movements show a GEH under 5 for all time periods. The worst performing is the CBD South (W1A) outbound in the PM peak, with a GEH of 10.
- The CBD cordon screenline as a whole (W1) shows GEH of respectively 1 and 4 for the critical AM inbound and PM outbound movements, showing that the model is a good representation of peak direction trips to and from the CBD.
- Two of the newly added screenlines within the CBD (W11 and W12) show low levels of validation, consistently under-predicting traffic volumes. This is unsurprising due to a strategic model such as WTSM having limitations in representing central city patterns, with trips allocated to their destination zone and not parking zone, and parking circulation not represented. This must be taken into consideration when interpreting results from the model however.
- Outside of the CBD, the main outliers are screenlines Lower Hutt East and Lower Hutt Central (respectively L4 and L3) with GEH up to 18. The model generally overestimates by 25%-30% traffic from/to the East of Lower Hutt through L4, which then also impacts L3 to a lesser extent. Peak direction traffic is however a better match with respectively 17% and 12% (GEH 8 and 6) in the AM and PM peak periods.
- The Karori screenline (W3) also shows a 25-30% overestimation from the model, although GEH are mostly between 5 and 10 due to the lower volumes.
- The screenline U3 which includes a single count on the SH2 Rimutaka Hill Rd shows a significant difference with modelled volumes being higher than observed, especially in the peak direction. However, both nearby screenline U1 and a screenline on the other side of the Rimutaka Hill (C1) show the model being a good match with observed, even showing a slight underestimation. The level of landuse activity between U3 and U1 is unlikely to generate the 14,000 daily trips difference between the two screenlines and therefore no further adjustments were made to match this count. It is however recommended that this is investigated should further observed data become available.
- Other strategically important screenlines on the State Highway network such as Miramar (W2), Kaiwharawhara (W4), Churton Park (W5), Lower Hutt North and South (L2 and L1) and Porirua North and South (P1 and P3) all show good performance, with most GEH values under or slightly above 5.

2.3 Individual link validation – Light vehicles

The following table and plots present the validation of light vehicle assignment against observed volumes for individual counts.

Table 2.3: Individual link validation – light vehicles

Criteria	Criteria	AM	IP	PM	ON
GEH	>65% with GEH<5	58%	59%	56%	66%
	>75% with GEH<7.5	78%	79%	80%	81%
	>85% with GEH<10	88%	87%	88%	88%
	>95% with GEH<12	93%	90%	94%	91%
Difference	70% of links with flow<700vph within 100	67%	68%	60%	86%
	70% of links with 700<flow<2700vph within 15%	65%	65%	66%	33%
	70% of links with flow>2700vph within 400	100%	N/A	83%	N/A
Other	r2 > 0.85	0.97	0.96	0.97	0.94
	Slope of trendline between 0.9 and 1.1	0.97	1.02	0.98	1.02
	RMSE <30%	26%	28%	24%	36%

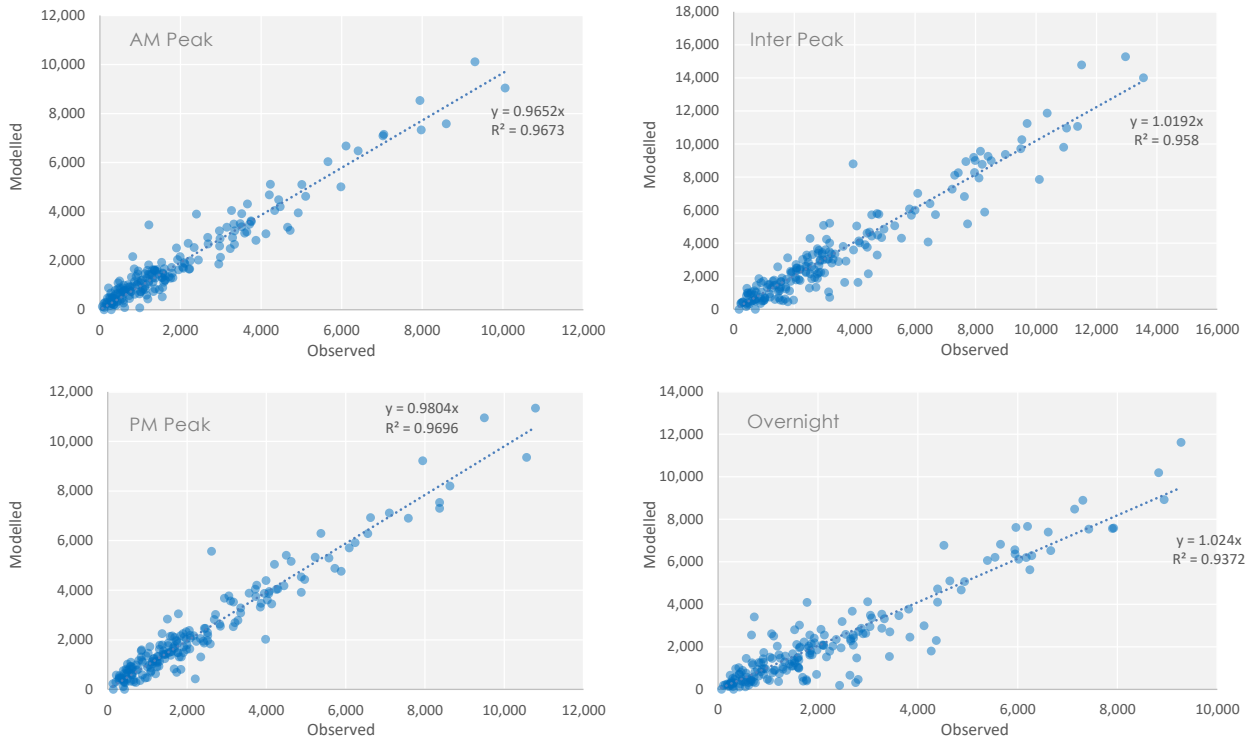


Figure 2.5: Individual link validation scatterplots – Light vehicles (period flows)

The summary of validation for individual links shows that the model fails to match the TMDG criteria for links below GEH 5 and to a lesser extent GEH 12. It achieves criteria for GEH 7.5 and 10 however. Similarly, the model is below the criteria for volume differences in most cases, although generally close. Again, our experience with other strategic models shows that these thresholds are generally difficult to achieve, and results for this version of WTSM, which achieves over half of the GEH criteria, is a significant improvement on previous versions of the model.

For all other metrics the model achieves the TMDG guidelines, with the exception of RMSE for the Overnight period.

In most cases, the main outliers are consistent with screenline results, with counts on L3, L4 and W3 reflecting the over-estimation of volumes over these screenlines, and the model underestimating flows for W11 and W12.

2.4 Screenline validation – Heavy vehicles

The following table shows the heavy vehicles validation against observed volumes across screenlines. Results are also presented in scatterplot format.

Table 2.4: Screenline validation – heavy vehicles

Criteria		AM	IP	PM	ON
GEH	>60% with GEH<5	80%	83%	79%	85%
	>75% with GEH<7.5	92%	95%	91%	95%
	>90% with GEH<10	97%	97%	97%	97%
% Difference	70% with difference <10%	18%	17%	24%	8%
	80% with difference <20%	32%	30%	39%	20%

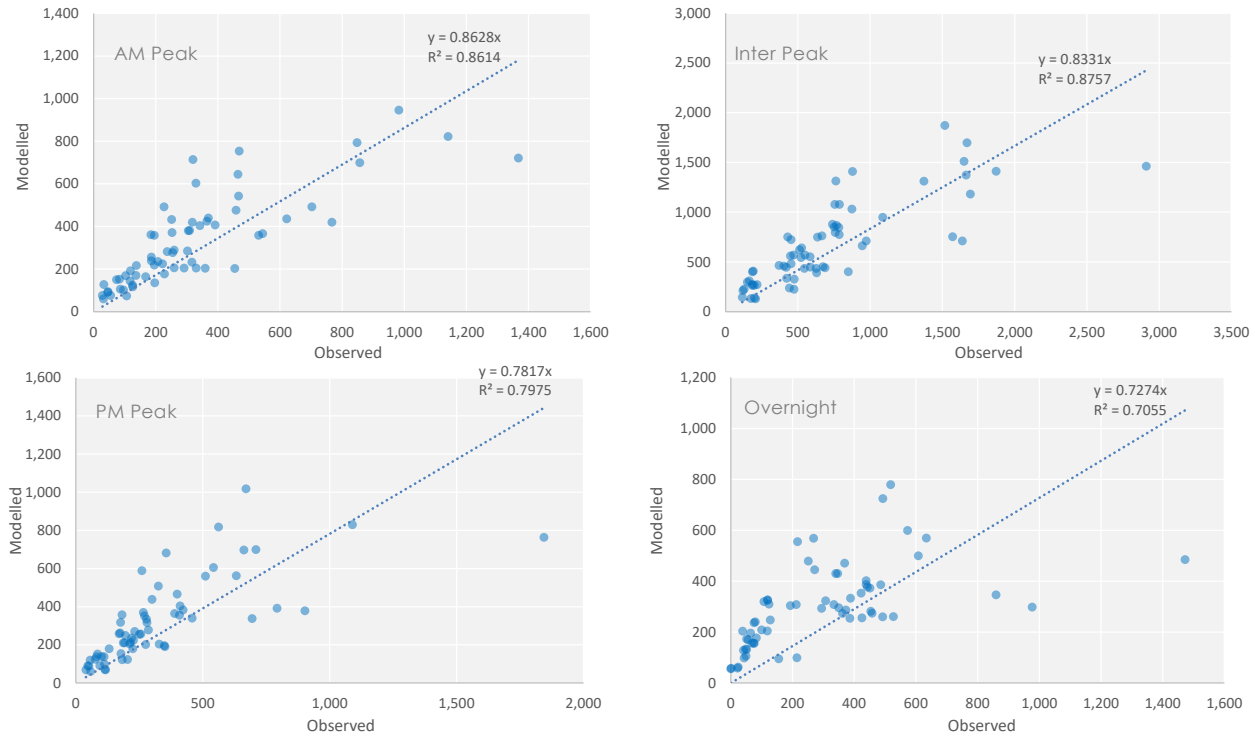


Figure 2.6: Screenline validation Scatterplots – Heavy vehicles (period flows)

The detailed results per screenline are included in Appendix A.

While the GEH criteria are all achieved, this is because the heavy vehicles flows are numerically small and the GEH statistic is tolerant of differences. It is also noted that the targets in the TMDG are not specifically for different vehicle types.

For percentage differences, none of the targets are achieved and the heavy vehicle flows are a long way from the targets. Again, this is a reflection of modelling very small flows. For example, for the average hour in the AM peak, the observed heavy vehicle flows range from zero to 300, with the overall average (simple average across all links) is 37 vehicles.

The scatter plots for the AM, Inter-peak, and PM peak periods shows a reasonable relationship, albeit not as tightly clustered as for light vehicles. The Overnight overestimates at most locations although the flows are relatively small in comparison to the other periods.

2.5 Individual link validation – Heavy vehicles

The following table and plots present the validation of heavy vehicle assignment against observed volumes for individual counts.

Table 2.5: Individual link validation – heavy vehicles

Criteria	Criteria	AM	IP	PM	ON
GEH	>65% with GEH<5	83%	82%	81%	90%
	>75% with GEH<7.5	95%	95%	93%	99%
	>85% with GEH<10	98%	98%	98%	99%
	>95% with GEH<12	99%	99%	99%	99%
Difference	70% of links with flow<700vph within 100	98%	99%	97%	100%
	70% of links with 700<flow<2700vph within 15%	N/A	N/A	N/A	N/A
	70% of links with flow>2700vph within 400	N/A	N/A	N/A	N/A
Other	r2 > 0.85	0.67	0.64	0.54	0.56
	Slope of trendline between 0.9 and 1.1	0.80	0.73	0.63	0.62
	RMSE <30%	90%	91%	114%	118%

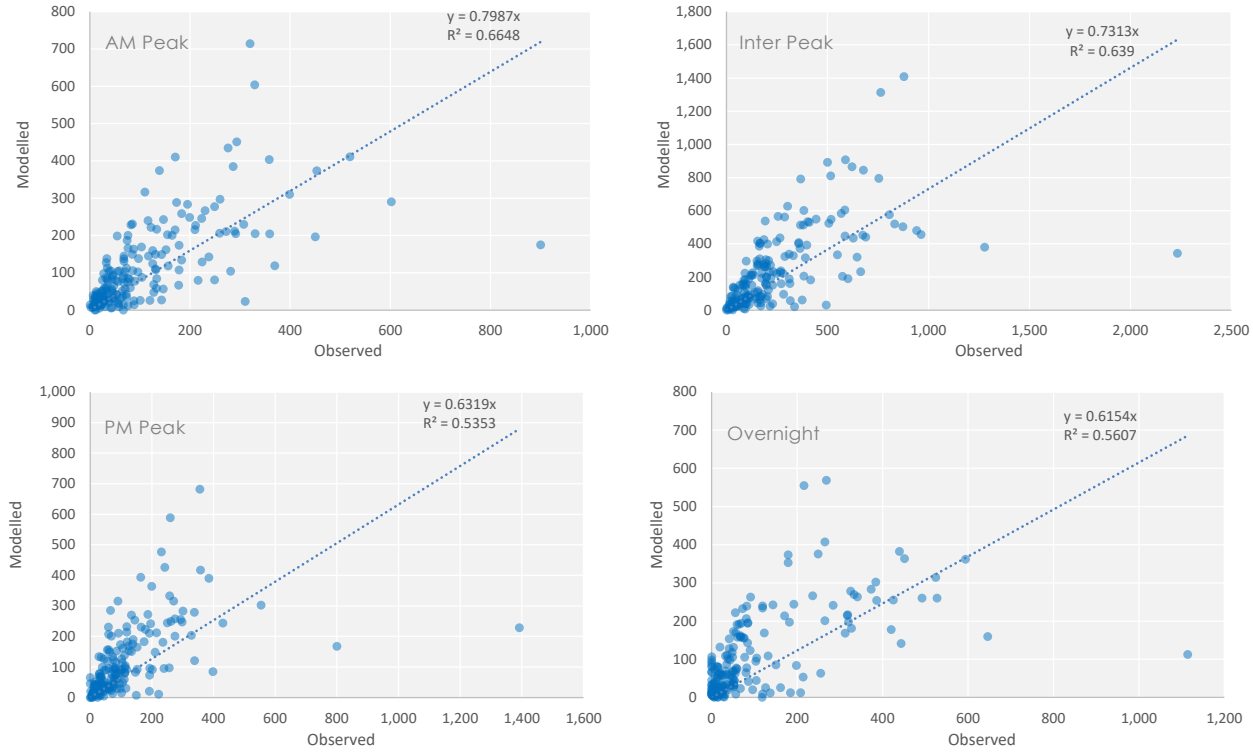


Figure 2.7: Individual link validation Scatterplots – Heavy vehicles (period flows)

Again, while the GEH and the difference targets are all achieved, these are not good metrics for heavy vehicles which are small in magnitude. Similarly, the modelled RMSE values are significantly higher than the target, but RMSE will always be high for low volume roads and so is also not a good measure for heavy vehicle flows.

The r-squared and the slope of the trendline do not meet the targets. The graphs in Figure 2.7 show a relative amount of scatter but also that the flows are small in volume.

While there is notable variation in the heavy vehicle flows, particularly at link level, they are difficult to replicate in a synthetic model and numerically less significant.

2.6 Screenline validation – Total vehicles

Finally, the following table and scatterplots shows results for total vehicles, including light and heavy.

Table 2.6: Screenline validation – total vehicles

Criteria		AM	IP	PM	ON
GEH	>60% with GEH<5	64%	69%	70%	69%
	>75% with GEH<7.5	84%	81%	83%	86%
	>90% with GEH<10	89%	91%	91%	92%
% Difference	70% with difference <10%	50%	59%	59%	42%
	80% with difference <20%	80%	76%	82%	67%

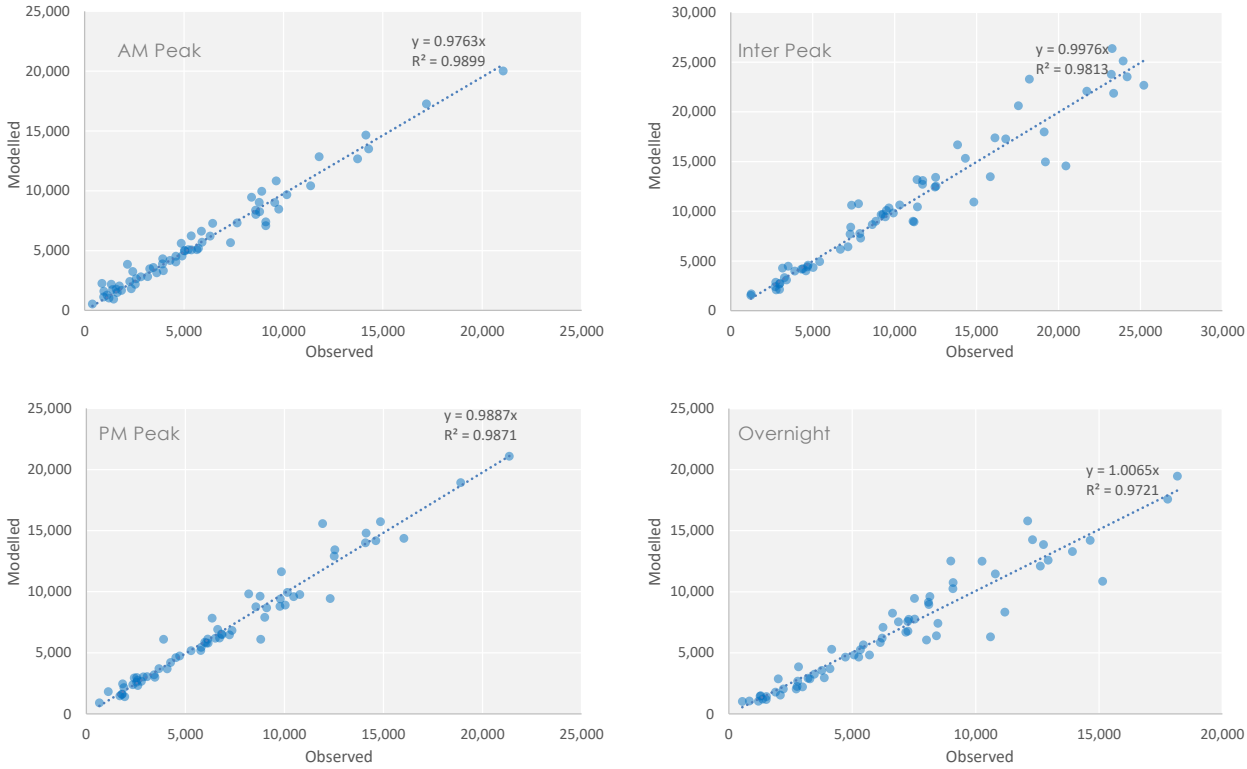


Figure 2.8: Screenline validation scatterplots – Total vehicles (period flows)

Results are overall similar to light vehicles, as these represent the large majority of volumes.

2.7 Individual link validation – Total vehicles

The following table and plots present the validation of total vehicle, including light and heavy, against observed volumes for individual counts.

Table 2.7: Individual link validation – total vehicles

Criteria	Criteria	AM	IP	PM	ON
GEH	>65% with GEH<5	60%	59%	56%	64%
	>75% with GEH<7.5	76%	77%	78%	80%
	>85% with GEH<10	87%	85%	86%	87%
	>95% with GEH<12	91%	89%	92%	90%
Difference	70% of links with flow<700vph within 100	64%	68%	61%	85%
	70% of links with 700<flow<2700vph within 15%	64%	62%	61%	33%
	70% of links with flow>2700vph within 400	80%	N/A	71%	N/A
Other	r2 > 0.85	0.97	0.95	0.97	0.93
	Slope of trendline between 0.9 and 1.1	0.97	1.02	0.98	1.02
	RMSE <30%	26%	30%	25%	37%

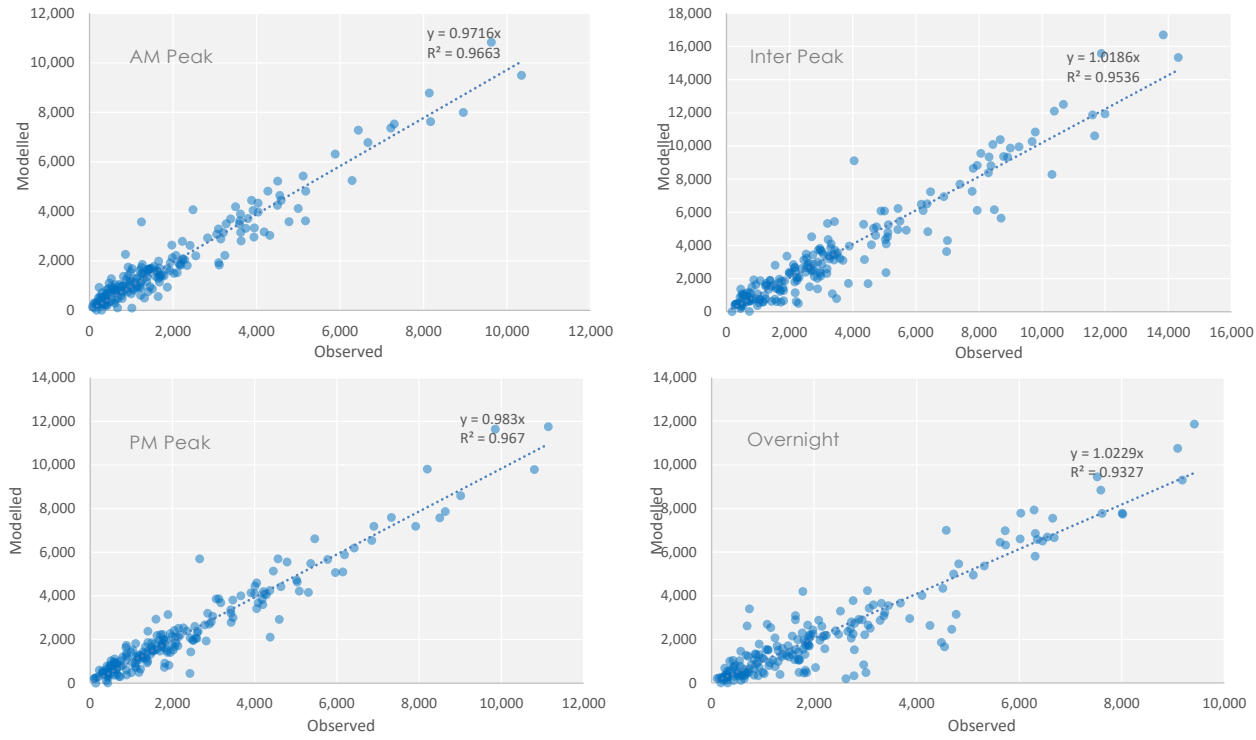


Figure 2.9: Individual link validation scatterplots – Total vehicles (period flows)

Again, results are similar to light vehicles only.

3. Private vehicles travel times

This section details the validation of modelled travel times for light vehicles as calculated through the WTSM traffic assignment, against observed travel times extracted from GPS information. Details of how this data was sourced and processed can be found in 'TN4 – Data Analysis'.

Eight routes were used for the travel times validation:

- Route 1: Masterton to Wellington Airport via SH1 and SH2
- Route 2: Paekakariki to Island Bay via the Waterfront
- Route 3: Centreport to Seaview
- Route 4: Newlands to Wellington Rail Station via Hutt Road
- Route 5: Karori to Miramar via Waterfront and Evans Bay
- Route 6: Waterfront to Airport via Adelaide Rd and Kilbirnie
- Route 7: Seatoun to Wellington Station via Taranaki St and Waterfront
- Route 8: Paremata to Haywards via SH58

These routes are shown in the following figures.

Figure 3.1: Travel time validation routes

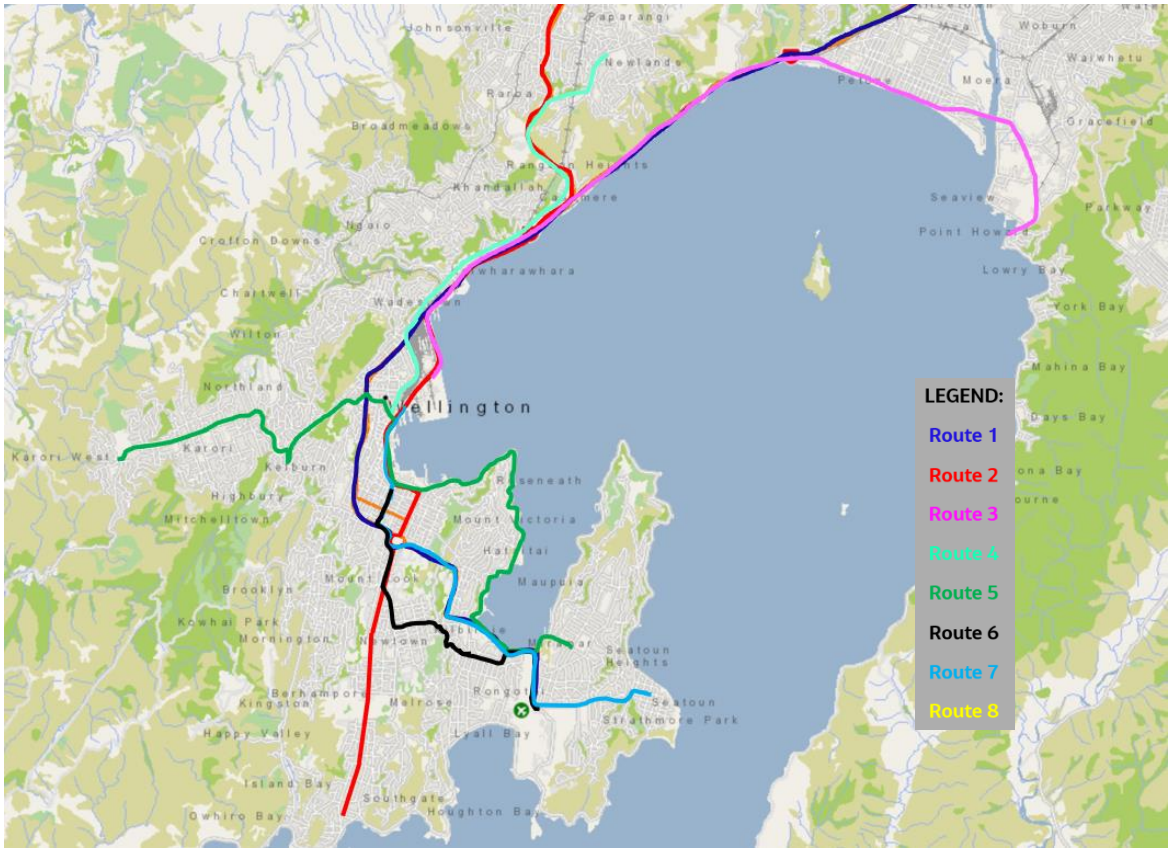


Figure 3.2: Travel time validation routes - Wellington

The TMDG specifies the following criteria:

- 80% of routes within 15% or 1 minute (if higher)
- 85% of routes within 25% or 1.5 minute (if higher)

A summary of the travel time validation is shown in the following table.

A more detailed comparison of observed and modelled travel time profiles for each route and direction is included in Appendix D. Traditionally these graphs show the mean observed travel times, along with the

minimum and maximum. In this case however, due to the travel time data being sourced from GPS information, minimum and maximum times reflect minimums and maximums experienced at each particular point along the route. Summing minimums/maximums over the whole route does not result in a minimum/maximum journey time experienced in reality. The time +/-15% were used as an alternative.

Finally, for the AM and PM peak periods both the peak hour and the shoulder periods are assigned separately in WTSM, however validation is carried out for the peak period as a whole. Modelled and observed travel times were therefore extracted for both peak hour and shoulders, and the weighted average was calculated to produce times for the whole AM and PM peak periods.

Table 3.1: Travel time validation

Route and direction		AM Peak				Inter Peak				PM Peak			
		Obs	Mod	within 15% or 1min	within 25% or 1.5min	Obs	Mod	within 15% or 1min	within 25% or 1.5min	Obs	Mod	within 15% or 1min	within 25% or 1.5min
Route 1	NB	112	107	Y	Y	108	104	Y	Y	124	128	Y	Y
	SB	129	148	Y	Y	113	107	Y	Y	116	117	Y	Y
Route 2A	NB	54	52	Y	Y	53	51	Y	Y	72	68	Y	Y
	SB	69	66	Y	Y	54	51	Y	Y	60	55	Y	Y
Route 3	NB	18	17	Y	Y	19	18	Y	Y	24	31	N	N
	SB	35	43	N	Y	19	18	Y	Y	18	22	N	Y
Route 4	NB	15	13	Y	Y	14	13	Y	Y	15	16	Y	Y
	SB	20	19	Y	Y	14	11	N	Y	15	13	Y	Y
Route 5	EB	32	29	Y	Y	30	26	Y	Y	32	32	Y	Y
	WB	34	31	Y	Y	31	27	Y	Y	39	35	Y	Y
Route 6	EB	18	16	Y	Y	20	15	N	Y	23	20	Y	Y
	WB	19	17	Y	Y	19	15	N	Y	25	17	N	N
Route 7	EB	20	21	Y	Y	21	20	Y	Y	25	25	Y	Y
	WB	28	25	Y	Y	22	21	Y	Y	34	25	N	N
Route 8	EB	14	13	Y	Y	14	13	Y	Y	13	15	Y	Y
	WB	16	18	N	Y	14	13	Y	Y	13	14	Y	Y
Routes within guidelines				88%	100%			81%	100%			75%	81%
Target				80%	85%			80%	85%			80%	85%

Results show that overall, the model tends to slightly under-estimate travel time, being circa 3% too fast in total. This is considered acceptable and the model meets TMDG guidelines for all cases except the 'within 15% or 1 minute' criteria in the PM peak, where it falls short by one route.

The main outliers are:

- Route 3 (Centreport to Seaview) is about 20% too slow southbound in the AM peak and northbound in the PM peak, i.e. in the peak direction. Most of the difference occurs on SH2 between Lower Hutt and Ngauranga which is highly congested.
- Route 6 (Waterfront to Airport) and 7 (Seatoun to Wellington Station) are 25-30% too fast southbound in the PM peak (and Interpeak for route 6).

4. Bus patronage

4.1 Summary

Bus assigned patronage was validated using a subset of the screenlines used for traffic volumes, with some removed as they are not crossed by any bus routes.

The TMDG specifies criteria for the validation of public transport, as shown in the following table.

Table 4.1: Hourly GEH comparison criteria for public transport patronage validation

GEH	% of screenlines (per direction)	% of traffic counts (per direction)
GEH <5	>60%	>50%
GEH <7.5	>70%	>60%
GEH <10	>80%	>70%
GEH <12	>90%	>85%
Line of best fit – slope	y=0.9x to 1.1x	y=0.85x to 1.15x
R^2	>0.85	>0.80

Unlike traffic counts, no observed public transport patronage was available across screenlines. Instead, the same process to extract observed bus volumes as for the validation of the Wellington Public Transport Model (WPTM) was used as detailed in 'TN15 – WPTM validation'. As a summary, a "reference" assignment was carried out, with observed bus matrices derived from electronic ticketing information assigned to the bus network to derive observed volumes. While this approach can potentially lead to some routing error in assigning the observed demand, the topography and absence of alternative routes for most Wellington PT corridors mean that this represents a reliable proxy for observed bus volumes at a screenline level.

The approach used to derive the observed matrices from ticketing data was the same as for WPTM, but based on the longer WTSM time periods.

4.2 Screenline validation

Validation results for screenlines are shown in the following table which shows the GEH, slope of the trendline, and r-squared. 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. Volumes are shown for the whole modelled periods, however, for the GEH calculation period flows were converted to average hour by dividing by the number of hours in each period.

Table 4.2: Screenline validation – bus patronage

Criteria		AM	IP	PM	ON
GEH	>60% with GEH<5	78%	72%	61%	87%
	>70% with GEH<7.5	85%	87%	72%	98%
	>80% with GEH<10	93%	93%	85%	100%
	>90% with GEH<12	100%	98%	91%	100%
Other	Slope of trendline between 0.9 and 1.1	0.92	0.94	0.90	0.93
	r2 > 0.85	97%	93%	97%	92%

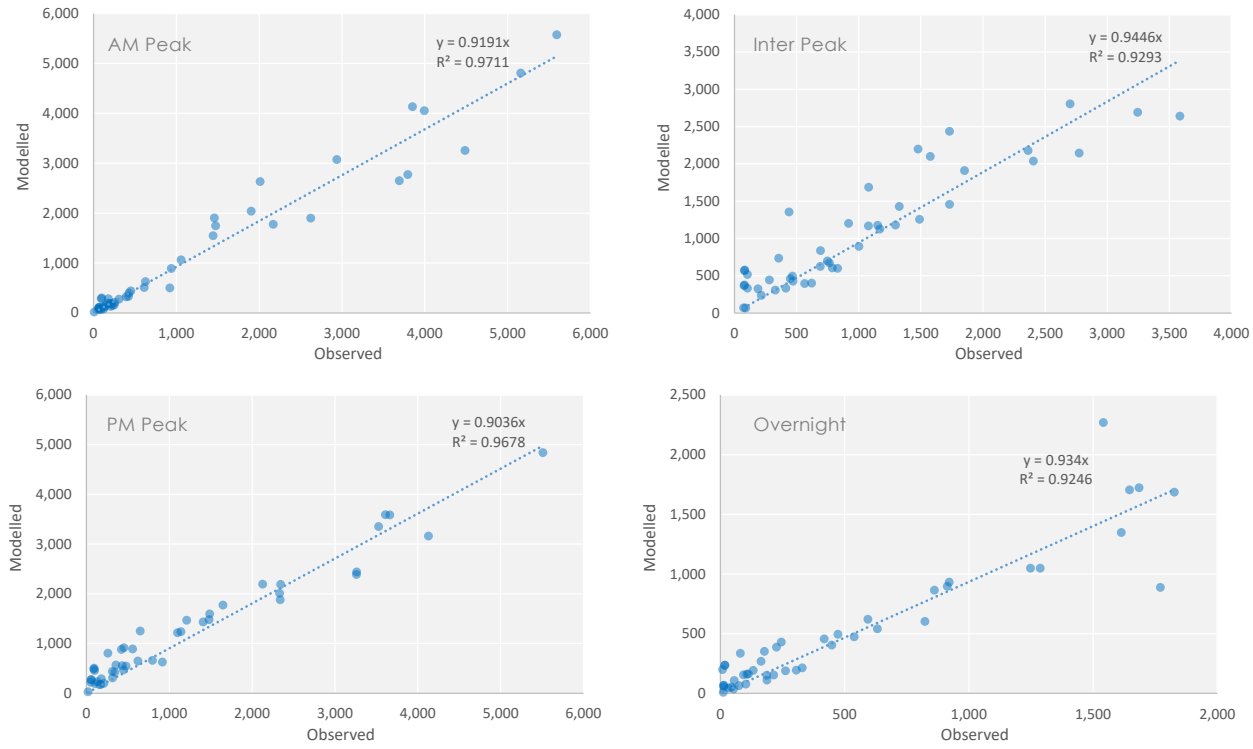


Figure 4.1: Screenline validation scatterplots – Bus patronage (period flows)

Results show that overall the model meets all the TMDG guidelines, with scatterplots also showing a close match between modelled and observed volumes. The slope indicates a slight tendency of the model to underestimate demand, between 5 and 8% depending on the time period.

The detailed results per screenline are included in Appendix B and the following observations can be made:

- The total number of bus passengers from and to the CBD through screenline W1 is a good match with observed, with GEH smaller than 5 for all time periods and both directions.
- Results are also good overall if looking at patronage to/from the CBD on different corridors (W1A to W1D). The main exception is between the CBD and the North, which shows a circa 30% underestimation in the peak direction, with a GEH of 11 in the AM peak.
- The same issue can be seen on screenlines further north (W4) and south (W9) on the same corridor which indicates an underestimation of bus patronage between North Wellington and the CBD. It must however be noted that data from the CBD cordon counts shows lower patronage on this corridor (see section 4.4). It is therefore recommended that this discrepancy is investigated in more detail should appropriate patronage data become available, and that model users take it into consideration in the meantime.
- Results are overall goods in terms of GEH for most other screenlines. In some cases, large relative differences can be observed but these are for corridor, or time period and direction with low volumes resulting in small GEH.

4.3 Individual link validation

The following table and plots present the validation of bus patronage from the public transport assignment against observed volumes for individual locations.

Table 4.3: Individual count validation – bus patronage

Criteria	Criteria	AM	IP	PM	ON
GEH	>50% with GEH<5	84%	88%	75%	94%
	>60% with GEH<7.5	94%	93%	86%	94%
	>70% with GEH<10	98%	97%	96%	94%
	>85% with GEH<12	100%	99%	96%	94%
Other	Slope of trendline between 0.85 and 1.15	0.88	0.97	0.89	0.92
	r2 > 0.8	97%	90%	96%	89%

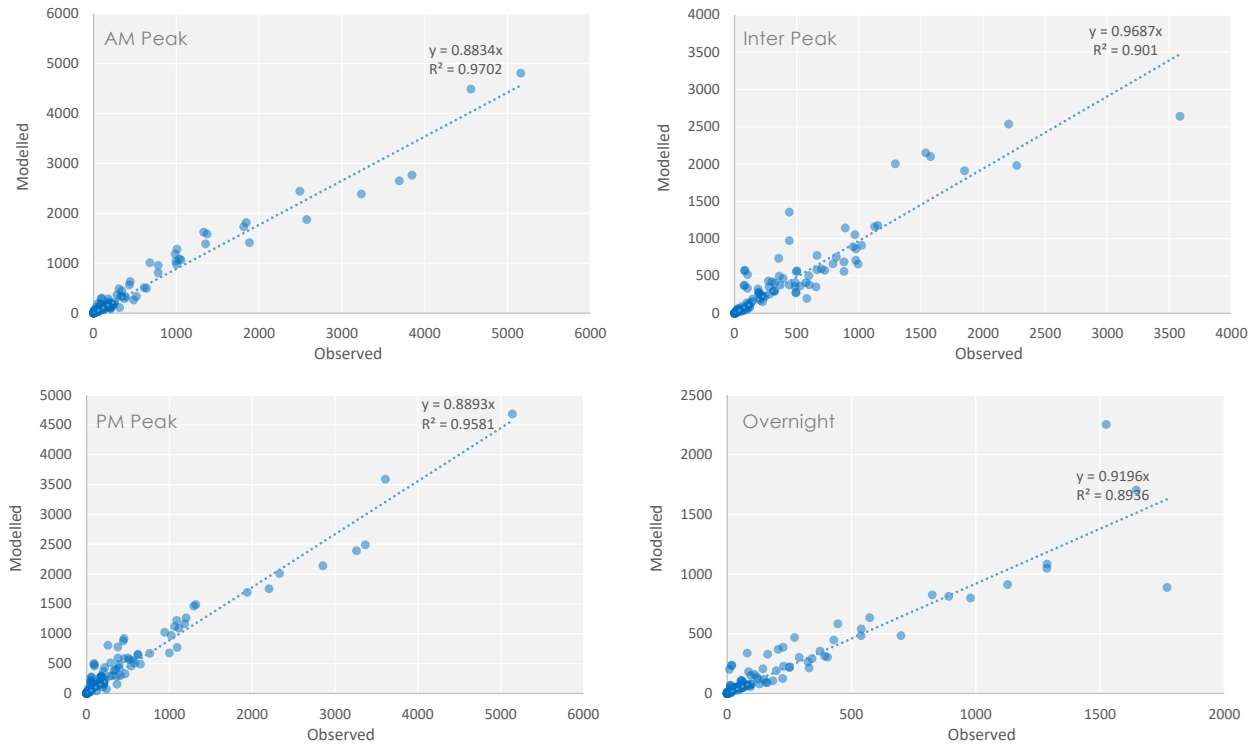


Figure 4.2: Individual counts validation scatterplots – Bus patronage (period flows)

Results for individual links show that overall the model meets all the TMDG guidelines, with scatterplots also showing a close match between modelled and observed volumes.

4.4 Wellington CBD cordon counts

The total number of bus users entering the CBD during the AM peak was compared with the annual CBD cordon survey. Data from March 2019 was used for consistency with the post PT Operating Model network changes and ETM data used.

Necessary 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.
- The CBD cordon surveys cover the 7-9am period, whereas the modelled AM peak period includes 6-9am. Observed volumes were therefore adjusted using factors also derived from ETM data.
- Finally outbound bus patronage for the 4-6pm period was also surveyed but only in March 2017 before network changes from the PT Operating Model were made. These volumes were used, factored up to 2019 and to 3-6pm as it was considered they would still provide a useful check with modelled volumes.

The following table shows modelled bus volumes across all locations on the CBD cordon, along with observed patronage. Again, the GEH was calculated using an average hour flow.

Table 4.4: CBD Cordon bus passenger validation

Links of CBD Cordon	Observed (3 hour)	Modelled (, 3 hour)	Difference	% Difference	GEH
AM Peak - Inbound					
Oriental Parade	515	640	125	24%	3.0
Cambridge Terrace	1,919	1,830	-89	-5%	1.2
Elizabeth Street	2,607	2,590	-17	-1%	0.2
Willis Street	1,072	1,297	225	21%	3.8
Taranaki Street	1,348	1,004	-344	-26%	5.8
Hawker Street	26	5	-21	-81%	3.1
Tinakori Road	1,451	1,655	204	14%	3.0
Kelburn Parade	1,100	1,154	54	5%	0.9
Murphy Street	520	512	-8	-1%	0.2
Thorndon Quay	3,196	2,817	-379	-12%	4.0
Total	**13,756**	**13,504**	**-252**	**-2%**	**1.2**
PM Peak - Outbound					
Oriental Parade	397	528	131	33%	3.5
Kent Terrace	1,945	1,567	-378	-19%	5.2
Elizabeth Street	1,572	1,962	390	25%	5.4
Victoria Street	1,148	1,121	-27	-2%	0.5
Taranaki Street	1,084	804	-280	-26%	5.3
Hawker Street	98	14	-84	-86%	6.5
Tinakori Road	1,421	1,141	-280	-20%	4.5
Kelburn Parade	756	915	159	21%	3.2
Molesworth Street	832	661	-171	-21%	3.6
Thorndon Quay	2,718	2,526	-192	-7%	2.2
Total	**11,970**	**11,239**	**-731**	**-6%**	**3.9**

Results show that the model is a good representation of bus patronage entering the CBD in the AM peak period, with all but one corridor showing a GEH smaller than 5, as does the cordon as a whole. Most relative differences are also small. The main exception is Taranaki with a 26% underestimate leading to a GEH of 6.

As noted previously, while modelled volumes are smaller than observed on Thorndon Quay, the difference is far less than compared against the "observed matrix" built from ETM used in the previous section. Being based on a single weekday, results from the CBD cordon tend to fluctuate but volumes from 2018 and 2017 surveys were found to be consistent with 2019 as well.

Results are not as good in the PM peak, although as noted previously, the observed is based on a 2017 survey before network changes and factored to 2019. The difference in patronage is however unlikely to have been significant and these results provide a useful check, showing that the model still provides a suitable representation of observed volume in this time period.

5. Bus journey times

The detailed comparison of bus journey times estimated by the model against observed data is shown in 'TN29 – PT Assignment' which also describes how the travel time functions for buses were estimated.

Modelled travel times were compared against observed for a sample of 25 routes covering the whole region and were found to be a good fit with observed, achieving all validation targets in terms of slope and r-squared.

The TMDG does not have any specific guidelines for bus travel times, simply stating that comparison would be broadly similar to vehicle comparison with some potential relaxing of guideline target levels depending on the focus and purpose of the model.

The table below shows how the model performs against the TMDG validation criteria for private vehicles. As can be observed, the criteria of 80% of routes within 15% or 1 minute is not achieved. This is unsurprising as modelled bus journey times include some error associated with the background traffic travel times as well as additional error related to time components specific to bus (acceleration/deceleration at bus stops, dwell times, bus lanes, etc) and do not generally validate as well as traffic travel times. The second criteria of 85% of routes within 25% or 1.5 minutes is however achieved for all time periods.

Table 5.1: Bus travel times

Time period	Within 15% or 1 minute	Within 25% or 1.5 minute
AM Peak	70%	85%
Inter peak	71%	90%
PM peak	76%	91%
Overnight	67%	86%

In addition, travel times along the Golden Mile which are critical for correct estimation of modal share in the Wellington CBD were also compared with observed and were found to be a good match for all time periods and both directions.

6. Rail patronage

6.1 Summary

No new survey was carried out for 2018 rail patronage, and unlike bus demand with ETM data, no recent disaggregated information was available. Four main sources of data were investigated to derive observed rail patronage:

- **Rail automated door counts:** train carriages on the Wellington railway network are equipped with Automatic Passenger Counts (APC) on all doors, which count the 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 of patronage per line.
- **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.
- **2017 Park-and-Ride survey and APC:** a survey of access to rail and park-and-ride use was commissioned in June 2017 by GWRC[1]. 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.
- **2011 rail survey:** this is detailed data collated for the development of the 2011 WPTM, based on an extensive survey of rail patronage.

Upon analysis of the APC counts, it was clear that these counts were not overly accurate both in terms of number of passengers counted and categorisation of boardings vs alightings. Results showed that in the peak direction (AM inbound and PM outbound), automated door counts consistently underestimated the number of passengers in and out of Wellington station. During the Inter-peak, this trend was even more apparent, and in the counter-peak direction estimating high counts using automated door data actually led 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.

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. 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

[1] http://www.gw.govt.nz/assets/2017-Rail-Survey-report20-07-2017.pdf

to overall trends per line that were counter-intuitive and did not match the increase in patronage per line observed using the more reliable high counts.

Ultimately, for the data used for individual count validation and loading profiles, it was decided to continue to use the 2011 observed boardings and lightings per station, factored up using overall patronage data for each line.

This approach 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.

6.2 Guard counts

First, modelled peak direction rail volumes at Wellington station were compared against rail high (or guard) counts obtained from KiwiRail, separately for each railway line. Results are shown in the following table, with the GEH calculated based on the average hourly volume.

Table 6.1: Rail high counts validation

Line	Observed (3 Hour)	Modelled (3 Hour)	Difference	% Difference	GEH
AM Peak - Inbound					
Johnsonville	1,632	1,347	-285	-17%	4.3
Hutt Valley / Melling / Wairarapa	8,205	8,392	187	2%	1.2
Kapiti	6,349	7,112	763	12%	5.4
Total	**16,186**	**16,851**	**665**	**4%**	**3.0**
PM Peak - Outbound					
Johnsonville	1,319	1,351	32	2%	0.5
Hutt Valley / Melling / Wairarapa	6,873	6,736	-137	-2%	1.0
Kapiti	5,409	5,832	423	8%	3.3
Total	**13,601**	**13,919**	**318**	**2%**	**1.6**

Results of the comparison show that the model replicates the peak direction patronage well to and from Wellington rail station for each line, with the most notable difference being the Kapiti line in the AM peak with a GEH of 5.

6.3 Individual counts

This section presents a comparison of observed and modelled rail passenger volumes at a number of locations on the rail network. Note that screenline results are not shown as each screenline would effectively be a single count for rail.

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 was not surveyed in 2011, however, as it was not originally included in the WPTM. 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.

No reliable data was available for the Overnight period, which has generally low levels of rail patronage, and this period was not included in the validation.

Results are shown in the following table, and then plotted as scattergrams.

Table 6.2: Individual count validation – rail patronage

Criteria		AM	IP	PM
GEH	>50% with GEH<5	56%	89%	61%
	>60% with GEH<7.5	83%	100%	78%
	>70% with GEH<10	100%	100%	83%
	>85% with GEH<12	100%	100%	100%
Other	Slope of trendline between 0.85 and 1.15	0.96	1.24	1.01
	r2 > 0.8	99%	97%	99%

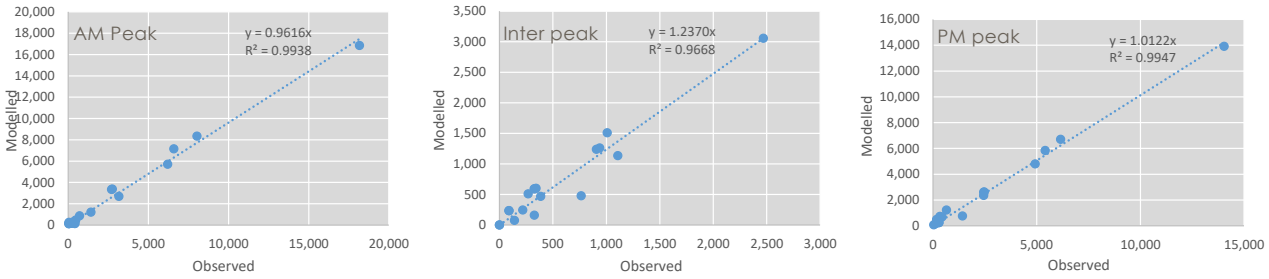


Figure 6.1: Screenline validation scatterplots – Rail patronage (period flows)

Overall results show that the model meets all TMDG guidelines, with the exception of the slope of the trendline for the Inter-peak. This indicates that rail patronage is overestimated in the Inter-peak period. Rail passenger demand is however very low during this period (hourly volumes are less than 10% of the average hour of the peak periods) and this is therefore considered acceptable, as reflected by the good GEH performance. This should however be taken into account if using model output specifically for the Inter-peak.

The detailed results are included in Appendix C, and show the following:

- The main screenline for trips directly arriving to/departing from Wellington station in the CBD (W4) performs well for all time periods and direction, with the exception of the PM inbound with a GEH of 11. This is the counter-peak direction with low volume and is therefore not considered critical.
- In the AM peak, the main discrepancy is for screenlines L2 and U2 (respectively Lower Hutt North and Upper Hutt South) which are located close together and show the same pattern of modelled trips being about 25% higher than observed, with a GEH of 6-7.
- A number of screenlines, especially in the PM peak show the same pattern as W4 with modelled trips being too high in the counter-peak direction, although these all have low volumes.

6.4 Patronage loading 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) in the peak direction, and show the resulting patronage profiles. Observed is based on the same data as the individual counts, i.e. 2011 surveys factored up using Metlink patronage for the AM peak and Inter-peak, and adjusted 2018 APC counts for the PM peak.

As is generally the case for strategic models, patronage profile validation for the counter-peak direction and Inter-peak is not as good, and was not included in this analysis due to the low levels of patronage both observed and modelled (consistent with previous versions of WTSM). In this case however, the comparison would have been made even more difficult due to the data used for comparison being more unreliable.

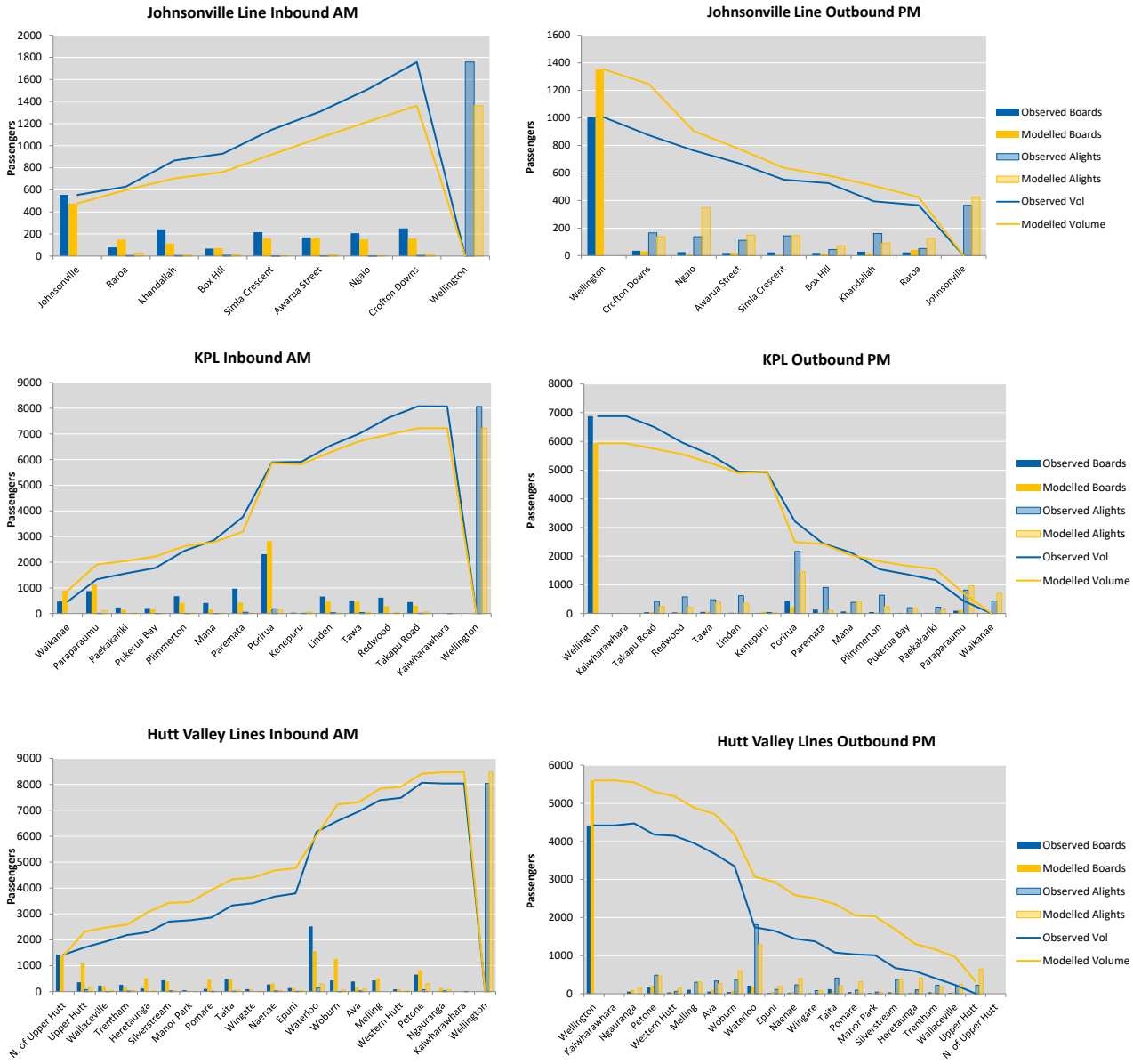


Figure 6.2: Rail loading profiles for peak direction (3-hour)

This comparison shows that the overall "shape" of the modelled loading profile is a good match with observed, with patronage at most stations also being relatively close. However, there are some clear differences, including total boardings at Wellington station in the PM peak for the Johnsonville and Hutt Valley lines which are quite high in the model. This does not tally with guard counts which show the model being much closer to observed, highlighting some of the limitations with the observed data used for comparison as detailed above.

Other differences include the higher modelled boardings at Waikanae and Paraparaumu, for which the 2011 boardings factored up using growth on the whole line likely do not represent the high growth in patronage that is known to have occurred since at these stations.

In order to provide a more reliable comparison, passenger loadings were also produced using the more recent 2019 APC counts and the 2017 park-and-ride survey, but this time looking only at boardings along the route and not taking into account alightings (which were too unreliable in the former and not included in the latter).

Due to the large majority of rail passengers travelling to Wellington station, this was deemed to be a useful comparison despite not considering alightings, and which would account for more recent localised changes in patronage. This analysis was however only possible for AM peak inbound passengers.

Results are shown in the following figures which show the loading profiles based on boardings only for all three main rail lines and for peak period volumes.

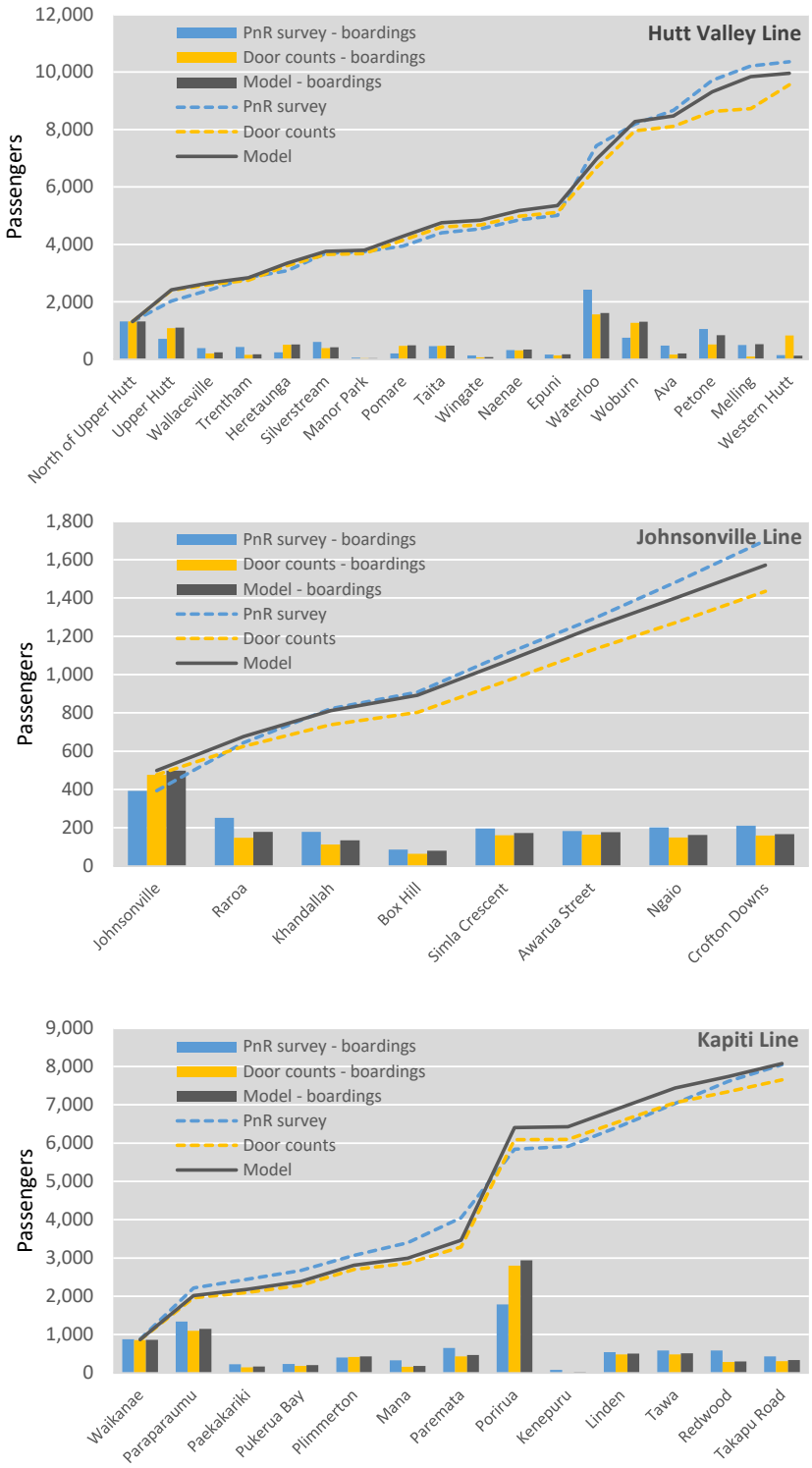


Figure 6.3: Rail loading profiles AM Peak – boardings only (3-hour)

The model clearly performs better compared against these loading profiles based on more recent and accurate datasets, although the limitation that these are based on boardings must be borne in mind.

6.5 Access to rail

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

Observed data was sourced from the 2017 rail survey, which used APC data to expand the sample. This comparison is however provided as a high level check that shares of rail demand by access mode resulting from the mode choice component of WTSM are a good match with the most up-to-date observed data.

The table below shows a comparison of access mode shares for each rail line and overall.

Table 6.3: Access to rail validation

Line	Observed			Modelled		
	Park-and-ride	Kiss-and-ride	Other	Park-and-ride	Kiss-and-ride	Other
Johnsonville	23%	1%	76%	25%	8%	67%
Hutt Valley / Melling / Wairarapa	44%	7%	49%	43%	11%	46%
Kapiti	52%	9%	39%	49%	7%	44%
Total	**46%**	**7%**	**47%**	**44%**	**9%**	**47%**

This comparison shows that the model correctly reproduces modal access to rail overall, with the result per line also being reasonably close. The main difference is for the Johnsonville line with an overestimation of kiss-and-ride access but the difference is deemed acceptable, being circa 100 passengers.

7. Active modes

Active modes including walk and cycle are represented as a single demand segment in WTSM (although an additional module was subsequently added that splits this demand into separate walk and cycle matrices, which is separately described in 'TN23 – Active modes'). This demand is produced as 24hr production-attraction matrices, and is not then factored to origin-destination by time period as are other modes.

In addition, little observed data is available to compare against for active modes, with the only source being the Wellington CBD cordon survey, carried out between 7 and 9am in a single weekday in March.

This data was however used as a coarse check that the model is a suitable match based on the start point of active trips to the CBD. As active modes are not assigned in WTSM, sectored matrices were used instead to aggregate trips to the CBD by production sector.

The different nature of both datasets must be kept in mind for this comparison (2hr AM peak vs daily, origin-destination vs production-attraction), as a result the actual number of trips were very different and only the spatial distribution as a percentage per sector was used.

Results are presented in the following table, with the model reflecting well the broad distribution of observed trips, albeit at a very coarse level.

Table 7.1: Active mode trips to CBD by area

Origin sector	CBD cordon	Model
South-east suburbs	41%	42%
Western suburbs	33%	35%
Northern suburbs and rest of region	27%	23%

8. Model convergence

Finally, convergence of the demand-assignment loops is also reported to ensure that the WTSM is internally consistent, i.e. the demand that is assigned on the network produces delays and generalised costs which are in turn consistent with the demand itself at convergence. This also ensures that the model is stable enough for scenario appraisal.

The WTSM, as a 4-step model, iterates over a number of loops with trip distribution, modal choice and assignment being run in sequence for each iteration until the model converges to a stable outcome. The model convergence is checked after each iteration by undertaking a comparison of current demand with demand from the previous iteration. Two criteria are used:

- the root mean square error (RMSE) of matrices between the current and the previous iteration being less than 0.01.
- Less than 5% of demand matrix non-zero cells showing a change greater than 5% between the current and previous iteration.

The second check was used as RMSE is not always suitable for matrices with low demand and many cells with zero values. This is the case for most PT matrices, which tend to return low RMSE values after a few iterations. Matrices for car and public transport modes and for all time periods need to match these criteria for convergence to be achieved.

For the validated base year 2018 scenario, the model was found to converge after five iterations, with an "initialisation" assignment (i.e. iteration 0) based on observed matrices to generate the first set of generalised costs. The two following plots show the convergence results for both criteria. Note that for clarity not all time periods are shown, with each point on the plot showing the worst-performing time period for each mode and iteration instead.

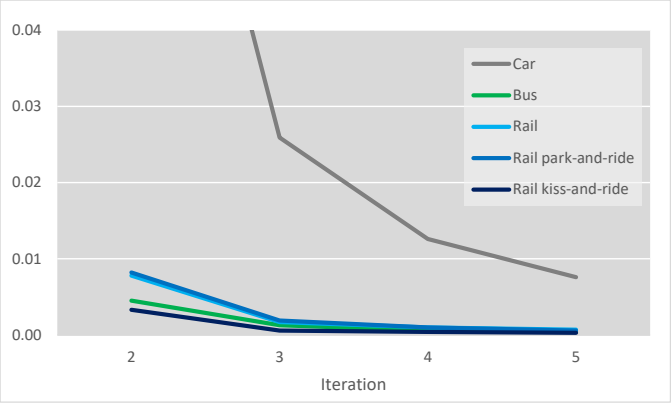


Figure 8.1: Demand convergence – RMSE

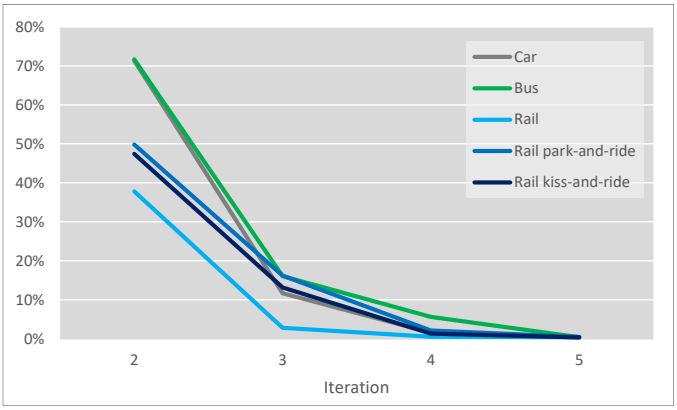


Figure 8.2: Demand convergence – ODs with >5% difference

Looking at forecasting years the model converges after 8 iterations for a standard 2053 forecasting including significant population growth assumption. With the crowded PT assignment functionality turned on, that applies capacity constraints on the PT network, this increased to 10 iterations.

In addition to these demand checks, assignment convergence was also checked to ensure that total vehicle-kilometres and vehicle-hours travelled across the whole network changed by less than 0.1% between the current iteration and the previous one.

Results are presented in the following table which shows the total vehicle-kilometres travelled and vehicle-hours travelled (in 1000s), as well as the percentage change between iterations. Results are for the modelled period in all cases (i.e. not an average hour).

Table 8.1: Assigned VKT and VHT convergence

Iteration	AM Peak		Inter-peak		PM Peak		Overnight	
	veh.km	veh.hr	veh.km	veh.hr	veh.km	veh.hr	veh.km	veh.hr
1	1,685	2678.1	2,924	3944.8	2,038	3339.0	1,803	2197.1
2	1,654	2544.4	2,838	3849.3	2,000	3115.2	1,774	2166.5
	-1.83%	-4.99%	-2.93%	-2.42%	-1.88%	-6.70%	-1.63%	-1.39%
3	1,658	2556.0	2,878	3852.9	2,003	3125.8	1,777	2168.7
	0.21%	0.46%	1.41%	0.09%	0.17%	0.34%	0.17%	0.10%
4	1,659	2558.8	2,879	3854.2	2,004	3127.3	1,778	2169.4
	0.07%	0.11%	0.04%	0.03%	0.05%	0.05%	0.05%	0.03%
5	1,660	2559.5	2,880	3853.1	2,005	3129.4	1,778	2169.7
	0.04%	0.03%	0.02%	-0.03%	0.02%	0.07%	0.02%	0.02%

9. Validation summary

This report has detailed the performance of the new Wellington Transport Strategy Model in reproducing observed multi-modal travel patterns and counts in the Wellington region against a range of metrics. Validation criteria were mostly based on the Transport Model Development Guidelines and criteria for a model type 'A – Regional' were used, consistent with the strategic nature of the WTSM.

For the large majority of criteria, the new WTSM achieves the targets set out in the TMDG, and significantly outperforms the previous version. Results can be summarised as follows:

- **Light vehicles validation:** both screenline and individual count validation show the model performing well, with some caveats that are consistent with limitations seen in strategic models (percentage difference for screenlines, GEH<5 for individual counts, representation of CBD traffic) but that must be considered if looking at detailed model outputs.
- **Heavy vehicles validation:** meets the GEH targets for screenlines and individual links and the absolute difference for links, however, these criteria are not designed for heavy vehicles which are numerically small. At a screenline level, the R-squared values are considered acceptable for all periods albeit with more variation than for light vehicles. At the individual link level, there is more variation between modelled and observed compared with screenlines, which is not unexpected.
- **Private vehicle travel times:** the model performs well in reproducing observed travel times. The main difference can be seen on the SH2 between Lower Hutt and Ngauranga where the model tends to return slow speeds in the peak direction.
- **Bus patronage:** modelled volumes compare well with the assigned reference matrix built from ETM data used to produce "observed" volumes, achieving all TMDG criteria. The main issue appears to be an underestimation of inbound patronage from North Wellington to the CBD in the AM peak, however this is not apparent if looking at comparisons against the CBD cordon survey for which the model validates well. This should be investigated in more detail is further data is available.
- **Bus travel times:** the model is a good representation of bus travel times, including along the Golden Mile in the CBD.
- **Rail patronage:** while availability of recent and accurate disaggregate observed data was an issue for validation, the model overall performs sensibly against a range of data, including the more aggregate but accurate high counts.
- **Active modes:** comparison against observed data was very limited for these modes, but a high level check of sectored distribution of trips to the CBD indicates that the WTSM broadly replicates observed patterns.

Results from this analysis show that the new version of WTSM achieves adequate validation expected from a strategic model.

The model also achieves convergence in base and future years, demonstrating stability of output.

In addition, sensitivity tests were carried out separately to show the model response to changes in input costs and parameters. These are reported in 'TN29 – Trip distribution and mode choice', and it was found that the demand model responses were within expected ranges and elasticity guidelines.

However, and as with all such strategic models, care must be taken when looking at more disaggregate model output, with local validation checks potentially carried out.

Appendices

Appendix A Vehicles screenline validation

A.1 AM Peak

Screenline	Description	Light, 3 Hours					Heavy, 3 Hours				
		Obs	Mode	Diff	% Diff	GEH	Obs	Mode	Diff	% Diff	GEH
W1A	CBD South In	5,984	5,982	-2	0%	0.0	316	234	-82	-26%	2.9
W1A	CBD South Out	3,696	4,139	443	12%	4.1	228	177	-51	-22%	2.1
W1B	CBD North In	16,053	16,451	398	2%	1.8	1,141	822	-319	-28%	5.9
W1B	CBD North Out	9,290	7,824	-1,466	-16%	9.1	465	645	180	39%	4.4
W1C	CBD West In	2,534	2,574	40	2%	0.5	54	77	22	41%	1.6
W1C	CBD West Out	1,374	1,673	299	22%	4.4	28	76	48	172%	3.9
W1D	CBD East In	5,459	4,834	-625	-11%	5.0	186	256	70	38%	2.7
W1D	CBD East Out	4,753	4,328	-425	-9%	3.6	137	217	79	58%	3.4
W2	Miramar Peninsula In	5,599	4,988	-611	-11%	4.8	118	193	74	63%	3.4
W2	Miramar Peninsula Out	4,868	4,806	-62	-1%	0.5	168	165	-3	-2%	0.1
W3	Karori In	2,716	2,731	15	1%	0.2	106	75	-31	-30%	1.9
W3	Karori Out	929	1,538	609	66%	10.0	31	60	29	94%	2.5
W4	Kaiwharawhara In	20,068	19,081	-987	-5%	4.1	983	946	-37	-4%	0.7
W4	Kaiwharawhara Out	8,302	8,293	-9	0%	0.1	468	754	285	61%	6.7
W5	Churton Park In	9,185	8,581	-604	-7%	3.7	369	439	70	19%	2.0
W5	Churton Park Out	4,673	4,605	-68	-1%	0.6	342	404	62	18%	1.9
W6	South Wellington In	4,391	4,390	-1	0%	0.0	197	136	-61	-31%	2.7
W6	South Wellington Out	2,292	3,142	850	37%	9.4	126	118	-8	-6%	0.4
W7	Tawa In	8,429	7,833	-596	-7%	3.8	365	425	60	17%	1.7
W7	Tawa Out	4,536	5,203	667	15%	5.5	318	420	102	32%	3.1
W8	North Wellington In	13,815	12,963	-852	-6%	4.2	467	543	77	16%	2.0
W8	North Wellington Out	5,130	5,737	607	12%	4.8	227	493	266	117%	8.1
W9	Thorndon In	13,523	14,224	701	5%	3.4	621	433	-188	-30%	4.7
W9	Thorndon Out	7,409	6,891	-518	-7%	3.5	251	433	183	73%	5.7
W10	CBD Lambton North	9,994	9,698	-296	-3%	1.7	1,368	722	-646	-47%	11.5
W10	CBD Lambton South	12,880	11,884	-996	-8%	5.2	848	794	-54	-6%	1.1
W11	CBD Te Aro North	5,590	5,318	-272	-5%	2.1	309	382	73	24%	2.3
W11	CBD Te Aro South	6,631	5,166	-1,465	-22%	11.0	703	495	-208	-30%	4.9
W12	CBD Mount Cook East	8,335	6,985	-1,350	-16%	8.9	767	421	-346	-45%	8.2
W12	CBD Mount Cook West	8,560	6,734	-1,826	-21%	12.1	544	361	-183	-34%	5.0
P1	Porirua North In	5,105	4,787	-318	-6%	2.6	254	278	24	9%	0.8
P1	Porirua North Out	2,899	2,545	-354	-12%	3.9	259	289	30	12%	1.1
P2	SH58 In	2,441	2,028	-413	-17%	5.0	103	169	66	64%	3.3
P2	SH58 Out	2,224	1,666	-558	-25%	7.3	117	145	28	24%	1.4
P3	Porirua South In	8,200	7,976	-224	-3%	1.4	391	407	16	4%	0.5
P3	Porirua South Out	4,900	4,709	-191	-4%	1.6	305	380	76	25%	2.4
P4	Pukerua Bay In	3,291	2,942	-349	-11%	3.6	330	205	-125	-38%	4.4
P4	Pukerua Bay Out	1,374	1,294	-80	-6%	1.3	259	206	-53	-21%	2.0
K1	Kapiti North In	3,267	3,361	94	3%	0.9	186	239	54	29%	2.1
K1	Kapiti North Out	2,052	2,188	136	7%	1.7	207	235	28	14%	1.1
K2	Kapiti South In	3,590	3,124	-466	-13%	4.6	359	204	-155	-43%	5.3

Screenline	Description	Light, 3 Hours					Heavy, 3 Hours				
		Obs	Mode	Diff	% Diff	GEH	Obs	Mode	Diff	% Diff	GEH
K2	Kapiti South Out	1,560	1,464	-96	-6%	1.4	291	205	-86	-30%	3.2
L1	Lower Hutt South In	9,305	10,113	808	9%	4.7	320	714	394	123%	10.0
L1	Lower Hutt South Out	6,107	6,672	565	9%	4.1	329	604	275	83%	7.3
L2	Lower Hutt North In	9,638	9,323	-315	-3%	1.9	531	359	-172	-32%	4.7
L2	Lower Hutt North Out	4,028	3,811	-217	-5%	2.0	252	372	119	47%	3.9
L3	Lower Hutt Central In	10,937	12,161	1,224	11%	6.6	857	700	-157	-18%	3.3
L3	Lower Hutt Central Out	8,443	9,477	1,034	12%	6.3	458	477	18	4%	0.5
L4	Lower Hutt East In	7,935	9,267	1,332	17%	8.3	454	203	-251	-55%	8.0
L4	Lower Hutt East Out	2,009	3,690	1,681	84%	18.2	136	170	34	25%	1.6
U1	Upper Hutt North In	3,147	3,366	219	7%	2.2	125	126	0	0%	0.0
U1	Upper Hutt North Out	916	1,004	88	10%	1.6	33	127	95	289%	6.1
U2	Upper Hutt South In	8,424	7,674	-750	-9%	4.8	184	362	178	96%	6.2
U2	Upper Hutt South Out	4,390	3,700	-690	-16%	6.3	195	359	163	84%	5.7
U3	Remutaka In	813	2,162	1,349	166%	20.2	46	95	49	106%	3.3
U3	Remutaka Out	339	445	106	31%	3.1	45	91	46	103%	3.2
U4	Upper Hutt Central In	5,559	6,333	774	14%	5.8	302	285	-17	-6%	0.6
U4	Upper Hutt Central Out	3,669	3,614	-55	-1%	0.5	236	282	46	19%	1.6
C1	Wairarapa South In	1,249	2,044	795	64%	11.3	83	153	70	84%	3.7
C1	Wairarapa South Out	1,137	882	-255	-22%	4.6	73	151	78	106%	4.2
C2	Wairarapa North In	1,022	1,186	164	16%	2.9	96	102	6	7%	0.4
C2	Wairarapa North Out	1,364	848	-516	-38%	9.0	86	106	20	23%	1.2
E	External In	1,522	1,822	300	20%	4.2	222	225	3	1%	0.1
E	External Out	1,379	1,555	176	13%	2.6	195	219	24	12%	1.0

A.2 Inter Peak

Screenline	Description	Light, 6 Hours					Heavy, 6 Hours				
		Obs	Mode	Diff	% Diff	GEH	Obs	Mode	Diff	% Diff	GEH
W1A	CBD South In	10,549	10,045	-504	-5%	2.0	849	399	-450	-53%	7.3
W1A	CBD South Out	8,866	9,699	833	9%	3.5	630	390	-240	-38%	4.3
W1B	CBD North In	22,322	22,116	-206	-1%	0.6	1,872	1,410	-462	-25%	4.7
W1B	CBD North Out	21,571	22,280	709	3%	2.0	1,650	1,510	-140	-8%	1.4
W1C	CBD West In	4,566	4,281	-285	-6%	1.8	115	143	28	24%	1.0
W1C	CBD West Out	4,217	4,093	-124	-3%	0.8	199	137	-62	-31%	2.0
W1D	CBD East In	10,759	8,543	-2,216	-21%	9.2	369	464	95	26%	1.9
W1D	CBD East Out	10,768	8,504	-2,264	-21%	9.4	419	445	26	6%	0.5
W2	Miramar Peninsula In	8,872	9,367	495	6%	2.1	422	334	-88	-21%	1.9
W2	Miramar Peninsula Out	9,457	9,517	60	1%	0.3	475	326	-149	-31%	3.0
W3	Karori In	3,332	4,356	1,024	31%	6.7	175	130	-45	-26%	1.5
W3	Karori Out	2,957	4,155	1,198	41%	8.2	208	129	-79	-38%	2.5
W4	Kaiwharawhara In	22,276	23,430	1,154	5%	3.1	1,671	1,697	26	2%	0.3
W4	Kaiwharawhara Out	21,760	24,493	2,733	13%	7.3	1,518	1,870	353	23%	3.5
W5	Churton Park In	11,742	11,677	-65	-1%	0.2	783	846	63	8%	0.9
W5	Churton Park Out	10,624	12,306	1,682	16%	6.4	739	877	138	19%	2.0
W6	South Wellington In	6,875	8,172	1,297	19%	6.1	442	234	-207	-47%	4.6
W6	South Wellington Out	6,806	7,481	675	10%	3.3	474	225	-249	-53%	5.4
W7	Tawa In	10,971	12,256	1,285	12%	4.9	751	850	99	13%	1.4

Screenline	Description	Light, 6 Hours					Heavy, 6 Hours				
		Obs	Mode	Diff	% Diff	GEH	Obs	Mode	Diff	% Diff	GEH
W7	Tawa Out	10,932	11,863	931	9%	3.6	767	867	100	13%	1.4
W8	North Wellington In	15,902	16,265	363	2%	1.2	874	1,031	157	18%	2.1
W8	North Wellington Out	15,336	16,319	983	6%	3.2	787	1,076	289	37%	3.9
W9	Thorndon In	18,037	17,038	-999	-6%	3.1	1,088	947	-141	-13%	1.8
W9	Thorndon Out	16,797	19,547	2,750	16%	8.3	756	1,077	322	43%	4.3
W10	CBD Lambton North	20,448	20,414	-34	0%	0.1	2,912	1,461	-1,451	-50%	12.7
W10	CBD Lambton South	23,548	21,303	-2,245	-10%	6.1	1,664	1,372	-292	-18%	3.1
W11	CBD Te Aro North	13,886	10,267	-3,619	-26%	13.4	945	662	-283	-30%	4.1
W11	CBD Te Aro South	14,199	12,774	-1,425	-10%	5.0	1,638	709	-929	-57%	11.1
W12	CBD Mount Cook East	17,638	14,224	-3,414	-19%	11.0	1,571	754	-817	-52%	9.8
W12	CBD Mount Cook West	19,478	13,853	-5,625	-29%	17.8	973	717	-256	-26%	3.6
P1	Porirua North In	7,350	6,767	-583	-8%	2.8	584	550	-34	-6%	0.6
P1	Porirua North Out	7,327	7,218	-109	-1%	0.5	550	567	17	3%	0.3
P2	SH58 In	2,528	2,160	-368	-15%	3.1	184	273	89	48%	2.4
P2	SH58 Out	2,568	2,602	34	1%	0.3	186	262	76	41%	2.1
P3	Porirua South In	11,679	11,673	-6	0%	0.0	786	775	-11	-1%	0.2
P3	Porirua South Out	11,751	12,617	866	7%	3.2	758	796	38	5%	0.6
P4	Pukerua Bay In	3,962	3,595	-367	-9%	2.4	627	434	-193	-31%	3.4
P4	Pukerua Bay Out	4,135	4,147	12	0%	0.1	586	446	-140	-24%	2.5
K1	Kapiti North In	6,238	5,627	-611	-10%	3.2	449	560	111	25%	2.0
K1	Kapiti North Out	6,680	5,876	-804	-12%	4.1	470	568	98	21%	1.7
K2	Kapiti South In	4,344	3,910	-434	-10%	2.8	689	440	-249	-36%	4.3
K2	Kapiti South Out	4,755	4,496	-259	-5%	1.6	674	452	-222	-33%	3.8
L1	Lower Hutt South In	13,551	14,017	466	3%	1.6	763	1,313	550	72%	7.0
L1	Lower Hutt South Out	12,961	15,287	2,326	18%	8.0	878	1,409	531	61%	6.4
L2	Lower Hutt North In	9,646	9,890	244	3%	1.0	667	760	93	14%	1.4
L2	Lower Hutt North Out	9,019	9,604	585	6%	2.5	635	749	114	18%	1.8
L3	Lower Hutt Central In	20,038	20,906	868	4%	2.5	1,694	1,183	-511	-30%	5.5
L3	Lower Hutt Central Out	16,848	21,984	5,136	30%	15.0	1,372	1,310	-62	-5%	0.7
L4	Lower Hutt East In	7,253	10,337	3,084	43%	13.4	545	435	-110	-20%	2.0
L4	Lower Hutt East Out	6,968	10,166	3,198	46%	14.1	404	457	54	13%	1.1
U1	Upper Hutt North In	3,240	2,808	-432	-13%	3.2	164	309	145	88%	3.8
U1	Upper Hutt North Out	3,128	3,052	-76	-2%	0.6	150	296	146	97%	4.0
U2	Upper Hutt South In	9,008	8,711	-297	-3%	1.3	430	751	321	75%	5.4
U2	Upper Hutt South Out	8,731	8,943	212	2%	0.9	453	723	270	60%	4.5
U3	Remutaka In	1,100	1,326	226	21%	2.6	129	226	97	75%	3.0
U3	Remutaka Out	1,134	1,495	361	32%	4.1	120	212	92	76%	2.9
U4	Upper Hutt Central In	8,108	8,038	-70	-1%	0.3	526	639	113	22%	1.9
U4	Upper Hutt Central Out	8,338	8,392	54	1%	0.2	512	620	108	21%	1.9
C1	Wairarapa South In	2,775	2,278	-497	-18%	4.0	191	407	216	113%	5.1
C1	Wairarapa South Out	2,825	2,362	-463	-16%	3.7	186	400	214	115%	5.1
C2	Wairarapa North In	2,575	1,854	-721	-28%	6.3	199	264	65	33%	1.7
C2	Wairarapa North Out	2,766	1,876	-890	-32%	7.5	217	271	54	25%	1.4
E	External In	3,461	3,512	51	1%	0.4	453	480	27	6%	0.5
E	External Out	3,798	3,648	-150	-4%	1.0	522	543	21	4%	0.4

A.3 PM Peak

Screenline	Description	Light, 3 Hours					Heavy, 3 Hours				
		Obs	Mode	Diff	% Diff	GEH	Obs	Mode	Diff	% Diff	GEH
W1A	CBD South In	6,173	5,991	-182	-3%	1.3	349	196	-152	-44%	5.3
W1A	CBD South Out	6,132	7,609	1,477	24%	10.3	227	223	-3	-1%	0.1
W1B	CBD North In	11,855	12,218	363	3%	1.9	662	697	35	5%	0.8
W1B	CBD North Out	17,812	18,097	285	2%	1.2	1,090	830	-260	-24%	4.8
W1C	CBD West In	2,541	2,676	135	5%	1.5	40	68	29	73%	2.3
W1C	CBD West Out	2,953	2,977	24	1%	0.3	117	69	-48	-41%	2.9
W1D	CBD East In	5,075	4,956	-119	-2%	1.0	212	205	-7	-3%	0.3
W1D	CBD East Out	6,683	6,216	-467	-7%	3.4	171	258	87	51%	3.4
W2	Miramar Peninsula In	5,883	5,636	-247	-4%	1.9	178	154	-23	-13%	1.0
W2	Miramar Peninsula Out	6,692	6,357	-335	-5%	2.4	131	180	48	37%	2.2
W3	Karori In	1,781	2,393	612	34%	7.7	58	60	3	5%	0.2
W3	Karori Out	2,769	2,958	189	7%	2.0	114	72	-43	-37%	2.6
W4	Kaiwharawhara In	11,988	12,617	629	5%	3.3	562	817	255	45%	5.6
W4	Kaiwharawhara Out	20,688	20,071	-617	-3%	2.5	670	1,018	348	52%	6.9
W5	Churton Park In	6,463	5,854	-609	-9%	4.5	270	352	82	30%	2.7
W5	Churton Park Out	9,393	9,005	-388	-4%	2.3	411	405	-7	-2%	0.2
W6	South Wellington In	4,527	4,606	79	2%	0.7	182	122	-60	-33%	2.8
W6	South Wellington Out	5,582	5,065	-517	-9%	4.1	203	123	-80	-39%	3.6
W7	Tawa In	6,365	6,539	174	3%	1.3	266	369	103	39%	3.3
W7	Tawa Out	9,357	8,410	-947	-10%	5.8	422	383	-39	-9%	1.1
W8	North Wellington In	8,264	8,317	53	1%	0.3	300	438	138	46%	4.1
W8	North Wellington Out	14,291	13,668	-623	-4%	3.0	325	508	183	56%	5.2
W9	Thorndon In	9,753	9,467	-286	-3%	1.7	399	466	67	17%	1.9
W9	Thorndon Out	14,347	15,164	817	6%	3.9	510	560	50	10%	1.2
W10	CBD Lambton North	14,198	13,597	-601	-4%	2.9	1,845	763	-1,081	-59%	17.3
W10	CBD Lambton South	13,390	13,307	-83	-1%	0.4	709	699	-10	-1%	0.2
W11	CBD Te Aro North	8,352	5,755	-2,597	-31%	17.9	458	339	-119	-26%	3.4
W11	CBD Te Aro South	8,317	8,287	-30	0%	0.2	793	392	-401	-51%	9.5
W12	CBD Mount Cook East	9,881	9,393	-488	-5%	2.9	903	379	-524	-58%	12.0
W12	CBD Mount Cook West	11,620	9,095	-2,525	-22%	14.3	695	340	-355	-51%	9.0
P1	Porirua North In	4,006	3,953	-53	-1%	0.5	250	254	4	2%	0.2
P1	Porirua North Out	5,921	5,525	-396	-7%	3.0	232	270	38	16%	1.4
P2	SH58 In	2,431	2,459	28	1%	0.3	111	138	27	24%	1.4
P2	SH58 Out	2,516	2,170	-346	-14%	4.1	85	152	67	78%	3.5
P3	Porirua South In	6,954	6,150	-804	-12%	5.7	280	316	36	13%	1.2
P3	Porirua South Out	9,642	8,536	-1,106	-11%	6.7	408	356	-52	-13%	1.5
P4	Pukerua Bay In	2,077	2,181	104	5%	1.3	275	201	-74	-27%	2.8
P4	Pukerua Bay Out	3,279	2,785	-494	-15%	5.2	192	210	18	10%	0.7
K1	Kapiti North In	3,475	3,445	-30	-1%	0.3	195	249	54	28%	2.1
K1	Kapiti North Out	4,346	4,334	-12	0%	0.1	174	262	88	50%	3.4
K2	Kapiti South In	2,458	2,464	6	0%	0.1	328	203	-125	-38%	4.4
K2	Kapiti South Out	3,867	3,473	-394	-10%	3.8	215	212	-3	-1%	0.1
L1	Lower Hutt South In	7,938	9,225	1,287	16%	8.0	260	589	329	127%	9.2
L1	Lower Hutt South Out	9,495	10,955	1,460	15%	8.3	355	682	326	92%	8.3

Screenline	Description	Light, 3 Hours					Heavy, 3 Hours				
		Obs	Mode	Diff	% Diff	GEH	Obs	Mode	Diff	% Diff	GEH
L2	Lower Hutt North In	5,851	5,776	-75	-1%	0.6	279	335	56	20%	1.8
L2	Lower Hutt North Out	10,080	9,233	-847	-8%	5.0	389	364	-25	-6%	0.7
L3	Lower Hutt Central In	13,492	14,227	735	5%	3.6	632	562	-70	-11%	1.7
L3	Lower Hutt Central Out	11,387	14,958	3,571	31%	18.0	542	606	63	12%	1.5
L4	Lower Hutt East In	3,682	5,921	2,239	61%	18.7	224	180	-45	-20%	1.8
L4	Lower Hutt East Out	8,427	9,433	1,006	12%	6.1	351	190	-161	-46%	5.6
U1	Upper Hutt North In	1,754	1,487	-267	-15%	3.8	56	119	63	112%	3.9
U1	Upper Hutt North Out	3,347	3,079	-268	-8%	2.7	76	124	48	64%	2.8
U2	Upper Hutt South In	5,808	5,538	-270	-5%	2.1	176	318	142	81%	5.2
U2	Upper Hutt South Out	8,831	7,546	-1,285	-15%	8.2	182	358	176	97%	6.2
U3	Remutaka In	608	810	202	33%	4.4	51	89	38	75%	2.6
U3	Remutaka Out	1,059	1,724	665	63%	10.3	47	90	43	92%	3.0
U4	Upper Hutt Central In	5,548	5,190	-358	-6%	2.8	256	257	1	0%	0.0
U4	Upper Hutt Central Out	7,072	6,545	-527	-7%	3.7	286	277	-9	-3%	0.3
C1	Wairarapa South In	1,712	1,453	-259	-15%	3.8	81	137	56	69%	3.1
C1	Wairarapa South Out	1,802	2,008	206	11%	2.7	101	138	37	37%	2.0
C2	Wairarapa North In	1,852	1,311	-541	-29%	7.9	95	91	-3	-3%	0.2
C2	Wairarapa North Out	1,584	1,372	-212	-13%	3.2	113	98	-14	-12%	0.8
E	External In	2,232	2,723	491	22%	5.7	187	210	23	12%	1.0
E	External Out	2,330	2,742	412	18%	4.7	219	236	17	8%	0.7

A.4 Overnight

Screenline	Description	Light, 12 Hours					Heavy, 12 Hours				
		Obs	Mode	Diff	% Diff	GEH	Obs	Mode	Diff	% Diff	GEH
W1A	CBD South In	7,923	5,873	-2,050	-26%	9.3	83	176	93	113%	3.1
W1A	CBD South Out	7,493	7,563	70	1%	0.3	38	203	165	434%	5.7
W1B	CBD North In	12,365	11,987	-378	-3%	1.3	573	599	26	4%	0.4
W1B	CBD North Out	17,174	17,082	-92	-1%	0.3	608	500	-108	-18%	1.7
W1C	CBD West In	2,790	2,622	-168	-6%	1.2	1	57	56	5594%	3.9
W1C	CBD West Out	3,444	3,206	-238	-7%	1.6	22	58	36	163%	2.1
W1D	CBD East In	8,308	6,194	-2,114	-25%	9.4	100	208	108	108%	3.3
W1D	CBD East Out	8,347	7,166	-1,181	-14%	5.1	128	247	119	93%	3.3
W2	Miramar Peninsula In	7,207	6,644	-563	-8%	2.6	48	133	85	176%	3.4
W2	Miramar Peninsula Out	7,225	7,600	375	5%	1.6	68	156	88	129%	3.1
W3	Karori In	2,001	2,812	811	41%	6.2	0	56	56	0%	4.0
W3	Karori Out	2,802	3,798	996	36%	6.6	24	62	38	160%	2.2
W4	Kaiwharawhara In	12,232	13,089	857	7%	2.9	518	779	261	50%	3.9
W4	Kaiwharawhara Out	17,690	18,744	1,054	6%	3.0	493	724	231	47%	3.5
W5	Churton Park In	6,433	7,140	707	11%	3.2	439	401	-38	-9%	0.7
W5	Churton Park Out	7,698	9,240	1,542	20%	6.3	451	372	-79	-17%	1.5
W6	South Wellington In	5,295	5,567	272	5%	1.4	155	95	-60	-39%	2.0
W6	South Wellington Out	5,996	6,111	115	2%	0.6	214	99	-115	-54%	3.5
W7	Tawa In	6,190	7,870	1,680	27%	7.6	439	386	-53	-12%	1.0
W7	Tawa Out	7,615	8,570	955	13%	4.0	486	386	-100	-21%	1.8
W8	North Wellington In	8,712	9,780	1,068	12%	4.2	369	471	102	28%	1.9
W8	North Wellington Out	11,970	13,834	1,864	16%	6.2	340	429	89	26%	1.7

Screenline	Description	Light, 12 Hours					Heavy, 12 Hours				
		Obs	Mode	Diff	% Diff	GEH	Obs	Mode	Diff	% Diff	GEH
W9	Thorndon In	9,913	12,078	2,165	22%	7.8	346	430	84	24%	1.6
W9	Thorndon Out	11,800	15,483	3,683	31%	11.9	307	323	16	5%	0.3
W10	CBD Lambton North	13,171	13,729	558	4%	1.8	1,473	485	-988	-67%	11.9
W10	CBD Lambton South	13,288	12,731	-557	-4%	1.8	634	569	-65	-10%	1.0
W11	CBD Te Aro North	10,144	6,044	-4,100	-40%	17.2	458	274	-184	-40%	3.6
W11	CBD Te Aro South	10,208	8,034	-2,174	-21%	8.6	977	298	-679	-69%	10.2
W12	CBD Mount Cook East	11,762	11,762	0	0%	0.0	860	346	-514	-60%	7.9
W12	CBD Mount Cook West	14,696	10,579	-4,117	-28%	13.8	454	281	-173	-38%	3.4
P1	Porirua North In	3,711	3,366	-345	-9%	2.2	388	333	-55	-14%	1.1
P1	Porirua North Out	4,390	4,342	-48	-1%	0.3	334	308	-26	-8%	0.6
P2	SH58 In	1,464	1,084	-380	-26%	4.0	49	105	56	115%	2.4
P2	SH58 Out	1,477	1,318	-159	-11%	1.6	43	98	55	128%	2.5
P3	Porirua South In	6,801	7,203	402	6%	1.8	443	377	-66	-15%	1.2
P3	Porirua South Out	7,662	8,789	1,127	15%	4.7	422	353	-69	-16%	1.3
P4	Pukerua Bay In	2,233	1,793	-440	-20%	3.7	492	260	-232	-47%	4.5
P4	Pukerua Bay Out	2,902	2,617	-285	-10%	2.0	386	254	-132	-34%	2.8
K1	Kapiti North In	2,858	2,629	-229	-8%	1.7	350	296	-54	-16%	1.1
K1	Kapiti North Out	3,468	3,268	-200	-6%	1.3	294	293	-1	0%	0.0
K2	Kapiti South In	2,460	1,952	-508	-21%	4.1	527	260	-267	-51%	5.1
K2	Kapiti South Out	3,438	2,701	-737	-21%	5.0	425	255	-170	-40%	3.5
L1	Lower Hutt South In	7,305	8,896	1,591	22%	6.7	216	555	339	157%	6.5
L1	Lower Hutt South Out	8,822	10,190	1,368	16%	5.3	268	568	300	112%	5.5
L2	Lower Hutt North In	5,212	4,940	-272	-5%	1.4	119	326	207	174%	5.2
L2	Lower Hutt North Out	7,049	6,368	-681	-10%	3.1	119	325	206	173%	5.2
L3	Lower Hutt Central In	10,530	11,022	492	5%	1.8	272	445	173	64%	3.5
L3	Lower Hutt Central Out	8,747	12,042	3,295	38%	12.2	251	479	227	91%	4.5
L4	Lower Hutt East In	4,105	5,092	987	24%	5.5	64	196	132	207%	4.4
L4	Lower Hutt East Out	6,132	6,896	764	12%	3.6	118	204	86	73%	2.6
U1	Upper Hutt North In	1,835	1,609	-226	-12%	2.1	51	173	122	239%	4.4
U1	Upper Hutt North Out	2,705	2,075	-630	-23%	4.9	56	169	113	202%	4.0
U2	Upper Hutt South In	4,964	4,502	-462	-9%	2.5	107	319	212	198%	5.5
U2	Upper Hutt South Out	6,012	5,540	-472	-8%	2.3	124	310	186	150%	4.8
U3	Remutaka In	492	886	394	80%	5.7	51	131	80	157%	3.2
U3	Remutaka Out	787	939	152	19%	2.0	41	128	87	212%	3.6
U4	Upper Hutt Central In	5,052	4,340	-712	-14%	3.9	212	308	96	45%	2.2
U4	Upper Hutt Central Out	5,503	4,532	-971	-18%	5.2	193	303	110	57%	2.7
C1	Wairarapa South In	1,215	1,248	33	3%	0.4	79	240	161	204%	4.8
C1	Wairarapa South Out	1,191	1,225	34	3%	0.4	75	237	162	216%	4.9
C2	Wairarapa North In	1,293	1,053	-240	-19%	2.7	76	155	79	104%	2.8
C2	Wairarapa North Out	1,123	892	-231	-21%	2.7	74	157	83	112%	2.9
E	External In	1,728	1,271	-457	-26%	4.5	362	273	-89	-25%	1.9
E	External Out	1,830	1,764	-66	-4%	0.6	373	287	-86	-23%	1.8

Appendix B Bus patronage screenline validation

B.1 AM Peak

Screenline	Description	Obs, 3 hours	Mod, 3 hours	Diff	% Diff	GEH
W1	CBD South In	3,850	4,130	279	7%	2.6
W1	CBD South Out	628	626	-1	0%	0.0
W1B	CBD North In	4,486	3,253	-1,234	-38%	11.5
W1B	CBD North Out	428	398	-30	-7%	0.8
W1C	CBD West In	2,012	2,630	618	24%	7.4
W1C	CBD West Out	110	119	9	7%	0.5
W1D	CBD East In	2,937	3,071	134	4%	1.4
W1D	CBD East Out	306	274	-33	-12%	1.1
W2	Miramar Peninsula In	1,444	1,545	101	7%	1.5
W2	Miramar Peninsula Out	207	131	-76	-58%	3.4
W3	Karori In	1,473	1,745	272	16%	3.9
W3	Karori Out	91	66	-25	-38%	1.6
W4	Kaiwharawhara In	3,795	2,771	-1,025	-37%	10.3
W4	Kaiwharawhara Out	211	187	-24	-13%	1.0
W5	Churton Park In	100	299	200	67%	8.2
W5	Churton Park Out	68	110	42	38%	2.6
W6	South Wellington In	1,457	1,899	441	23%	6.2
W6	South Wellington Out	250	158	-92	-58%	3.7
W7	Tawa In	93	280	188	67%	7.9
W7	Tawa Out	68	110	42	38%	2.6
W8	North Wellington In	2,623	1,895	-728	-38%	8.8
W8	North Wellington Out	140	148	8	6%	0.4
W9	Thorndon In	3,693	2,648	-1,045	-39%	10.7
W9	Thorndon Out	256	210	-46	-22%	1.7
W10	CBD Lambton North	5,159	4,803	-356	-7%	2.9
W10	CBD Lambton South	2,169	1,773	-396	-22%	5.2
W11	CBD Te Aro North	3,996	4,051	55	1%	0.5
W11	CBD Te Aro South	1,905	2,036	131	6%	1.7
W12	CBD Mount Cook East	5,594	5,571	-23	0%	0.2
W12	CBD Mount Cook West	1,058	1,063	6	1%	0.1
P3	Porirua South In	178	283	104	37%	4.0
P3	Porirua South Out	68	71	3	4%	0.2
L1	Lower Hutt South In	611	508	-103	-20%	2.5
L1	Lower Hutt South Out	199	191	-8	-4%	0.3
L2	Lower Hutt North In	422	329	-93	-28%	2.8
L2	Lower Hutt North Out	60	73	13	18%	0.9
L3	Lower Hutt Central In	939	889	-50	-6%	0.9
L3	Lower Hutt Central Out	451	439	-12	-3%	0.3
L4	Lower Hutt East In	922	499	-422	-85%	9.1
L4	Lower Hutt East Out	64	100	36	36%	2.3
U1	Upper Hutt North In	134	118	-16	-13%	0.8
U1	Upper Hutt North Out	7	15	8	51%	1.3
U2	Upper Hutt South In	171	192	21	11%	0.9

Screenline	Description	Obs, 3 hours	Mod, 3 hours	Diff	% Diff	GEH
U2	Upper Hutt South Out	124	80	-44	-54%	2.5
U4	Upper Hutt Central In	394	321	-72	-22%	2.2
U4	Upper Hutt Central Out	228	147	-81	-55%	3.4

B.2 Inter-Peak

Screenline	Description	Obs, 6 hours	Mod, 6 hours	Diff	% Diff	GEH
W1	CBD South In	2,406	2,037	-369	-18%	3.2
W1	CBD South Out	1,731	1,458	-273	-19%	2.8
W1B	CBD North In	1,730	2,436	706	29%	6.3
W1B	CBD North Out	1,325	1,430	105	7%	1.2
W1C	CBD West In	1,490	1,256	-234	-19%	2.6
W1C	CBD West Out	763	673	-91	-13%	1.4
W1D	CBD East In	1,170	1,127	-43	-4%	0.5
W1D	CBD East Out	748	699	-49	-7%	0.7
W2	Miramar Peninsula In	691	625	-66	-11%	1.1
W2	Miramar Peninsula Out	620	401	-219	-55%	4.0
W3	Karori In	787	607	-180	-30%	2.8
W3	Karori Out	564	397	-167	-42%	3.1
W4	Kaiwharawhara In	1,477	2,198	722	33%	6.9
W4	Kaiwharawhara Out	1,079	1,169	90	8%	1.1
W5	Churton Park In	82	577	496	86%	11.1
W5	Churton Park Out	79	376	296	79%	8.0
W6	South Wellington In	1,002	894	-108	-12%	1.4
W6	South Wellington Out	829	601	-228	-38%	3.5
W7	Tawa In	80	568	488	86%	11.1
W7	Tawa Out	77	368	291	79%	8.0
W8	North Wellington In	918	1,204	286	24%	3.6
W8	North Wellington Out	691	837	146	17%	2.2
W9	Thorndon In	1,576	2,100	524	25%	5.0
W9	Thorndon Out	1,152	1,179	26	2%	0.3
W10	CBD Lambton North	3,584	2,640	-945	-36%	6.9
W10	CBD Lambton South	2,700	2,806	105	4%	0.8
W11	CBD Te Aro North	2,774	2,146	-628	-29%	5.2
W11	CBD Te Aro South	2,364	2,179	-185	-8%	1.6
W12	CBD Mount Cook East	3,245	2,690	-555	-21%	4.2
W12	CBD Mount Cook West	1,851	1,911	59	3%	0.6
P3	Porirua South In	104	518	414	80%	9.6
P3	Porirua South Out	104	334	230	69%	6.3
L1	Lower Hutt South In	439	1,354	915	68%	12.5
L1	Lower Hutt South Out	355	735	380	52%	6.6
L2	Lower Hutt North In	281	443	162	37%	3.5
L2	Lower Hutt North Out	328	310	-19	-6%	0.4
L3	Lower Hutt Central In	1,080	1,687	608	36%	6.7
L3	Lower Hutt Central Out	1,295	1,179	-115	-10%	1.3
L4	Lower Hutt East In	466	496	29	6%	0.5
L4	Lower Hutt East Out	413	334	-78	-23%	1.7

Screenline	Description	Obs, 6 hours	Mod, 6 hours	Diff	% Diff	GEH
U1	Upper Hutt North In	74	71	-3	-4%	0.1
U1	Upper Hutt North Out	91	68	-23	-34%	1.0
U2	Upper Hutt South In	188	327	138	42%	3.5
U2	Upper Hutt South Out	216	238	23	10%	0.6
U4	Upper Hutt Central In	449	461	12	3%	0.2
U4	Upper Hutt Central Out	471	428	-43	-10%	0.8

B.3 PM Peak

Screenline	Description	Obs, 3 hours	Mod, 3 hours	Diff	% Diff	GEH
W1	CBD South In	1,100	1,216	117	10%	2.0
W1	CBD South Out	3,529	3,352	-177	-5%	1.7
W1B	CBD North In	648	1,252	603	48%	11.3
W1B	CBD North Out	4,130	3,161	-969	-31%	9.3
W1C	CBD West In	798	663	-135	-20%	2.9
W1C	CBD West Out	2,127	2,195	68	3%	0.8
W1D	CBD East In	477	550	72	13%	1.8
W1D	CBD East Out	2,345	2,192	-153	-7%	1.9
W2	Miramar Peninsula In	315	312	-3	-1%	0.1
W2	Miramar Peninsula Out	1,142	1,238	97	8%	1.6
W3	Karori In	210	199	-11	-5%	0.4
W3	Karori Out	1,409	1,435	25	2%	0.4
W4	Kaiwharawhara In	423	883	460	52%	10.4
W4	Kaiwharawhara Out	3,263	2,440	-822	-34%	8.9
W5	Churton Park In	58	276	218	79%	9.7
W5	Churton Park Out	93	504	411	82%	13.7
W6	South Wellington In	342	423	81	19%	2.4
W6	South Wellington Out	1,489	1,597	108	7%	1.6
W7	Tawa In	58	273	215	79%	9.6
W7	Tawa Out	87	486	399	82%	13.6
W8	North Wellington In	357	570	213	37%	5.7
W8	North Wellington Out	2,339	1,882	-458	-24%	5.8
W9	Thorndon In	453	919	466	51%	10.3
W9	Thorndon Out	3,260	2,390	-869	-36%	9.4
W10	CBD Lambton North	2,332	2,010	-322	-16%	4.0
W10	CBD Lambton South	5,510	4,841	-670	-14%	5.4
W11	CBD Te Aro North	1,211	1,469	259	18%	4.1
W11	CBD Te Aro South	3,663	3,587	-76	-2%	0.7
W12	CBD Mount Cook East	1,647	1,773	125	7%	1.8
W12	CBD Mount Cook West	3,610	3,591	-19	-1%	0.2
P3	Porirua South In	54	219	165	75%	8.2
P3	Porirua South Out	98	459	361	79%	12.5
L1	Lower Hutt South In	258	805	547	68%	13.7
L1	Lower Hutt South Out	620	649	29	4%	0.7
L2	Lower Hutt North In	107	197	90	46%	4.2
L2	Lower Hutt North Out	449	470	21	5%	0.6
L3	Lower Hutt Central In	557	890	333	37%	7.1

Screenline	Description	Obs, 3 hours	Mod, 3 hours	Diff	% Diff	GEH
L3	Lower Hutt Central Out	1,481	1,483	2	0%	0.0
L4	Lower Hutt East In	131	235	105	45%	4.5
L4	Lower Hutt East Out	916	627	-289	-46%	6.0
U1	Upper Hutt North In	20	31	12	38%	1.4
U1	Upper Hutt North Out	172	179	8	4%	0.3
U2	Upper Hutt South In	161	180	20	11%	0.9
U2	Upper Hutt South Out	181	293	112	38%	4.2
U4	Upper Hutt Central In	313	442	129	29%	3.8
U4	Upper Hutt Central Out	433	557	123	22%	3.2

B.4 Overnight

Screenline	Description	Obs, 12 hours	Mod, 12 hours	Diff	% Diff	GEH
W1	CBD South In	448	406	-42	-10%	0.8
W1	CBD South Out	1,827	1,687	-140	-8%	1.3
W1B	CBD North In	244	430	185	43%	3.8
W1B	CBD North Out	1,613	1,349	-264	-20%	2.6
W1C	CBD West In	186	153	-33	-22%	1.0
W1C	CBD West Out	913	897	-15	-2%	0.2
W1D	CBD East In	305	195	-110	-56%	2.6
W1D	CBD East Out	920	932	11	1%	0.1
W2	Miramar Peninsula In	187	112	-75	-67%	2.3
W2	Miramar Peninsula Out	472	496	24	5%	0.4
W3	Karori In	102	78	-24	-31%	0.9
W3	Karori Out	631	542	-90	-17%	1.4
W4	Kaiwharawhara In	177	352	175	50%	4.1
W4	Kaiwharawhara Out	1,248	1,049	-198	-19%	2.2
W5	Churton Park In	13	68	56	82%	3.3
W5	Churton Park Out	18	238	219	92%	7.3
W6	South Wellington In	214	154	-60	-39%	1.7
W6	South Wellington Out	593	621	28	4%	0.4
W7	Tawa In	13	67	54	81%	3.2
W7	Tawa Out	17	235	218	93%	7.3
W8	North Wellington In	131	194	62	32%	1.8
W8	North Wellington Out	861	866	5	1%	0.1
W9	Thorndon In	225	388	163	42%	3.5
W9	Thorndon Out	1,287	1,049	-238	-23%	2.6
W10	CBD Lambton North	1,770	888	-882	-99%	9.1
W10	CBD Lambton South	1,541	2,270	729	32%	6.3
W11	CBD Te Aro North	538	475	-63	-13%	1.1
W11	CBD Te Aro South	1,685	1,723	39	2%	0.4
W12	CBD Mount Cook East	822	605	-218	-36%	3.1
W12	CBD Mount Cook West	1,646	1,706	59	3%	0.5
P3	Porirua South In	13	53	39	75%	2.6
P3	Porirua South Out	9	201	193	96%	7.1
L1	Lower Hutt South In	80	337	257	76%	6.7
L1	Lower Hutt South Out	329	214	-115	-54%	2.6

Screenline	Description	Obs, 12 hours	Mod, 12 hours	Diff	% Diff	GEH
L2	Lower Hutt North In	44	54	10	18%	0.5
L2	Lower Hutt North Out	113	163	51	31%	1.6
L3	Lower Hutt Central In	163	270	107	40%	2.8
L3	Lower Hutt Central Out	417	456	39	9%	0.7
L4	Lower Hutt East In	75	66	-9	-13%	0.4
L4	Lower Hutt East Out	262	190	-72	-38%	1.8
U1	Upper Hutt North In	11	10	-1	-8%	0.1
U1	Upper Hutt North Out	52	37	-15	-41%	0.9
U2	Upper Hutt South In	33	45	12	27%	0.8
U2	Upper Hutt South Out	55	109	53	49%	2.2
U4	Upper Hutt Central In	93	156	64	41%	2.2
U4	Upper Hutt Central Out	106	162	56	35%	1.8

Appendix C Rail validation

C.1 AM Peak

Screenline	Description	Obs (3 hours)	Mod (3 hours)	Diff	% Diff	GEH
W4	Kaiwharawhara Out	462	466	4	1%	0.1
	Kaiwharawhara In	18,171	16,851	-1,320	-7%	5.8
L1	Lower Hutt South Out	267	268	1	0%	0.0
	Lower Hutt South In	8,036	8,337	301	4%	1.9
L2	Lower Hutt North Out	403	147	-256	-64%	8.9
	Lower Hutt North In	2,754	3,369	615	22%	6.4
L3	Lower Hutt Central Out	214	165	-49	-23%	2.1
	Lower Hutt Central In	6,591	7,144	553	8%	3.8
U1	Upper Hutt North Out	39	124	85	219%	5.4
	Upper Hutt North In	1,422	1,210	-212	-15%	3.4
U2	Upper Hutt South Out	413	151	-262	-63%	9.0
	Upper Hutt South In	2,702	3,341	639	24%	6.7
P1	Porirua South Out	43	253	210	495%	10.0
	Porirua South In	3,158	2,693	-465	-15%	5.0
P3	Porirua South Out	167	191	24	14%	1.0
	Porirua South In	6,197	5,713	-484	-8%	3.6
K1	Kapiti South Out	41	125	84	205%	5.3
	Kapiti South In	709	859	150	21%	3.1

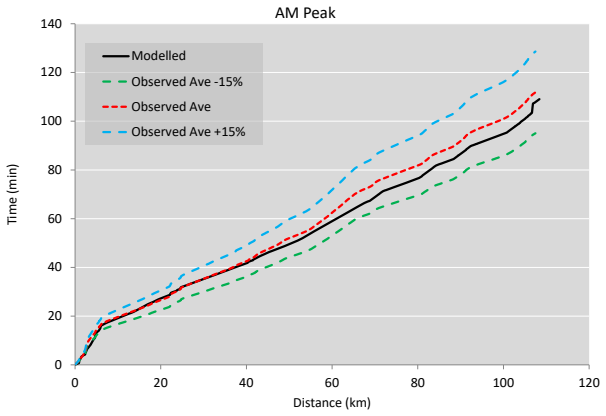
C.2 Inter Peak

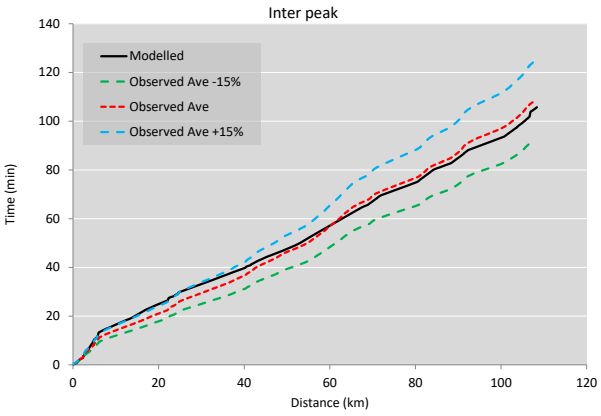
Screenline	Description	Obs (6 hours)	Mod (6 hours)	Diff	% Diff	GEH
W4	Kaiwharawhara Out	938	1,261	323	34%	4.0
	Kaiwharawhara In	2,469	3,055	586	24%	4.6
L1	Lower Hutt South Out	325	590	265	81%	5.1
	Lower Hutt South In	1,008	1,509	501	50%	5.8
L2	Lower Hutt North Out	88	235	147	167%	4.7
	Lower Hutt North In	343	600	257	75%	4.8
L3	Lower Hutt Central Out	269	509	240	89%	5.0
	Lower Hutt Central In	908	1,240	332	37%	4.1
U1	Upper Hutt North Out	0	0	0	0%	0.0
	Upper Hutt North In	0	0	0	0%	0.0
U2	Upper Hutt South Out	90	233	143	158%	4.6
	Upper Hutt South In	331	594	263	80%	5.0
P1	Porirua South Out	218	245	27	12%	0.7
	Porirua South In	764	478	-286	-37%	4.7
P3	Porirua South Out	386	468	82	21%	1.6
	Porirua South In	1,106	1,134	28	2%	0.3
K1	Kapiti South Out	141	74	-67	-47%	2.6
	Kapiti South In	327	160	-167	-51%	4.4

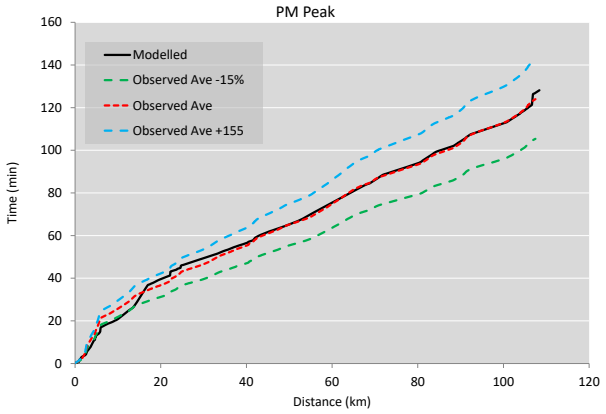
C.3 PM Peak

Screenline	Description	Obs (3 hours)	Mod (3 hours)	Diff	% Diff	GEH
W4	Kaiwharawhara Out	14,036	13,919	-117	-1%	0.6
	Kaiwharawhara In	653	1,232	579	89%	10.9
L1	Lower Hutt South Out	6,154	6,702	548	9%	3.9
	Lower Hutt South In	334	732	398	119%	10.0
L2	Lower Hutt North Out	2,472	2,630	158	6%	1.8
	Lower Hutt North In	288	243	-45	-16%	1.6
L3	Lower Hutt Central Out	5,412	5,837	425	8%	3.3
	Lower Hutt Central In	171	490	319	187%	10.1
U1	Upper Hutt North Out	1,422	756	-666	-47%	11.6
	Upper Hutt North In	39	80	41	106%	3.1
U2	Upper Hutt South Out	2,448	2,605	157	6%	1.8
	Upper Hutt South In	289	249	-40	-14%	1.4
P1	Porirua South Out	2,439	2,352	-87	-4%	1.0
	Porirua South In	188	379	191	102%	6.6
P3	Porirua South Out	4,928	4,807	-121	-2%	1.0
	Porirua South In	273	448	175	64%	5.3
K1	Kapiti South Out	439	682	243	55%	5.9
	Kapiti South In	132	160	28	21%	1.3

Appendix D Vehicle travel times validation







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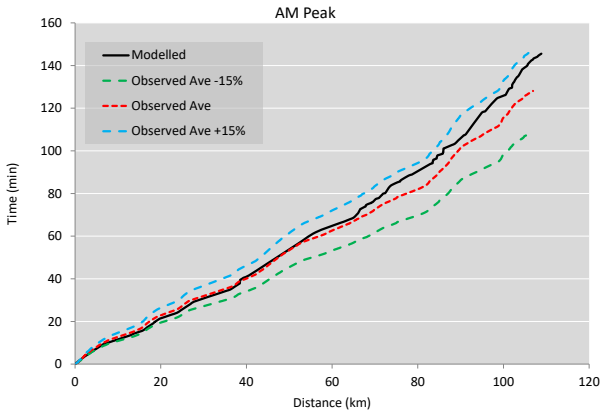

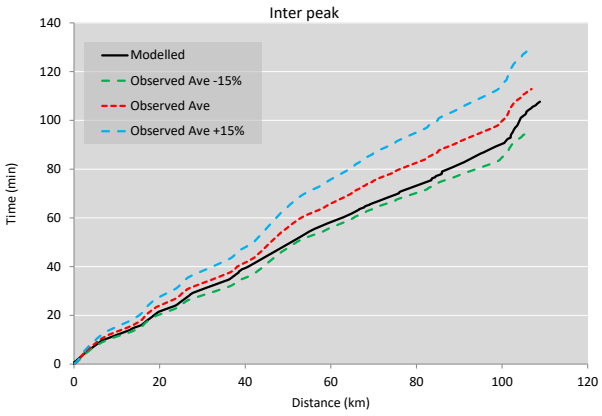

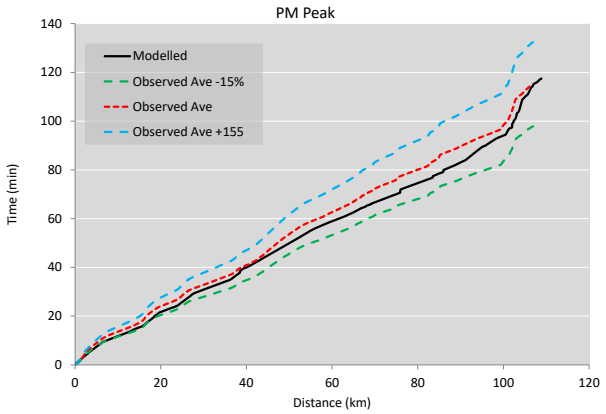

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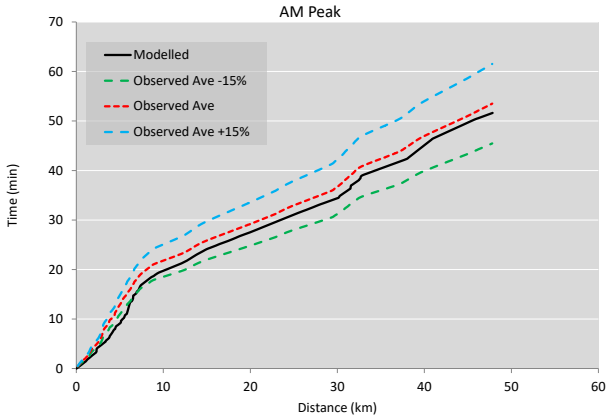

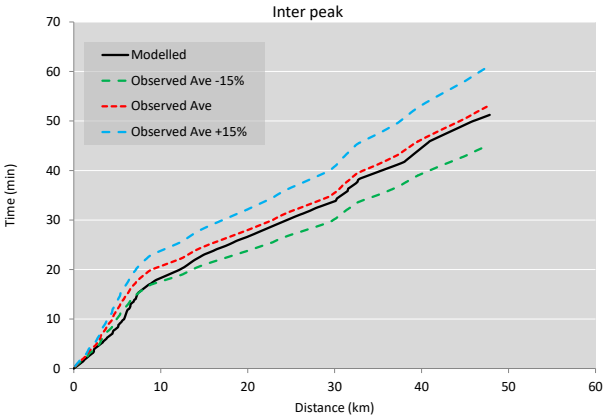

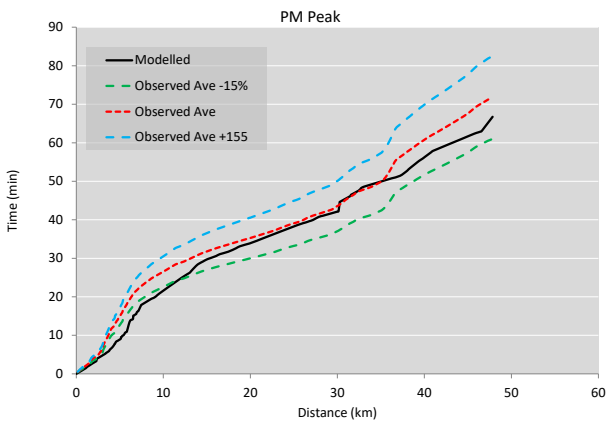

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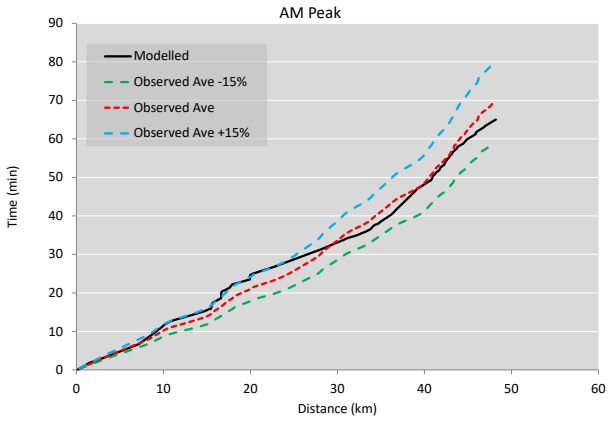

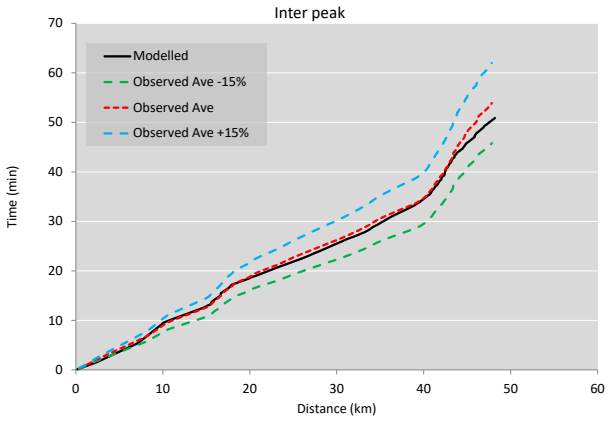

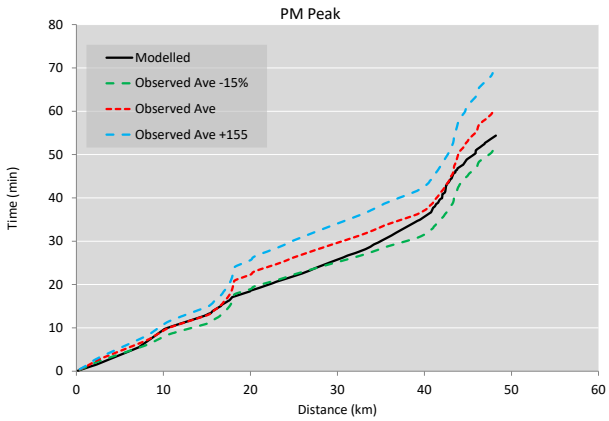

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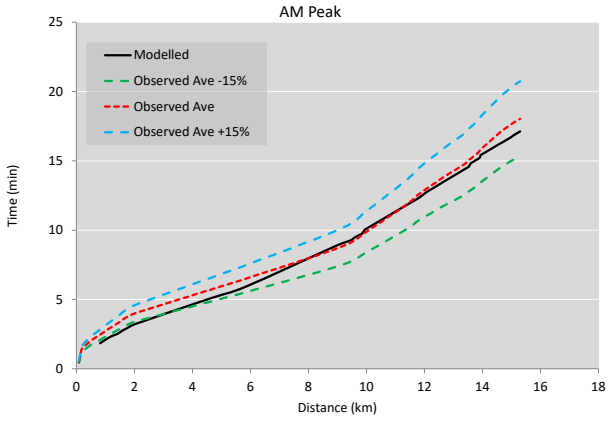

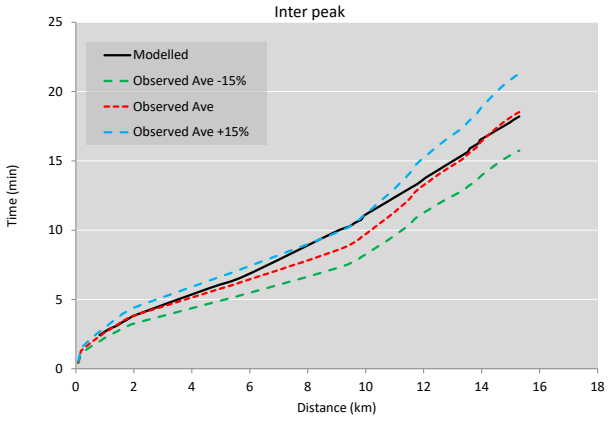

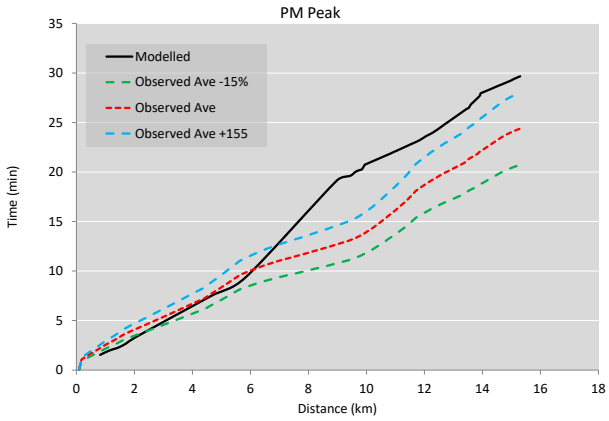

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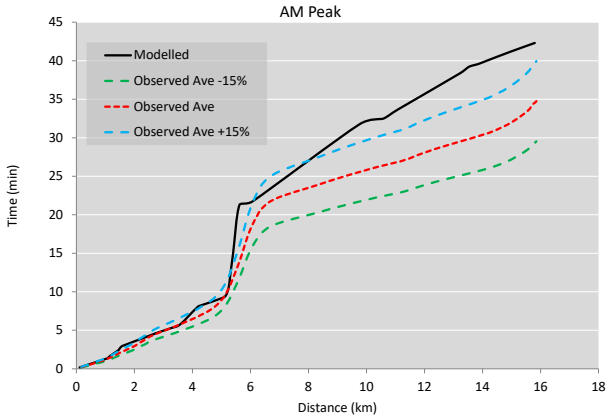

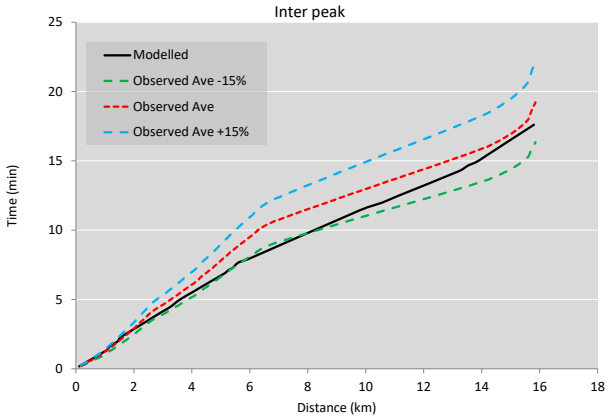

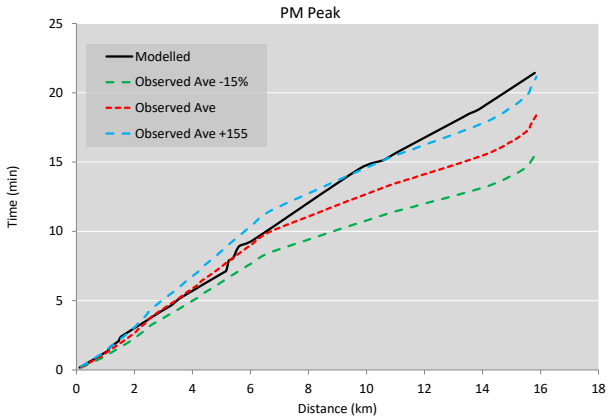

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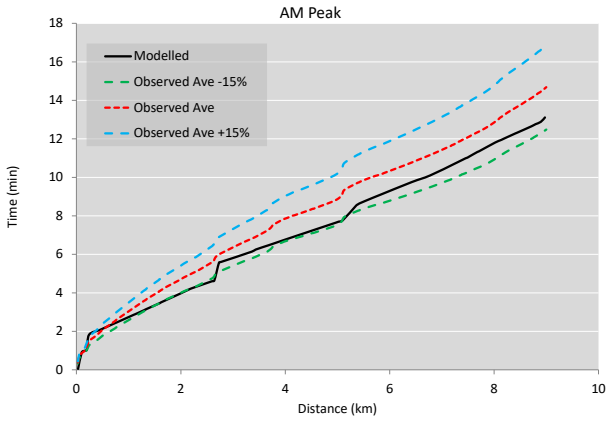

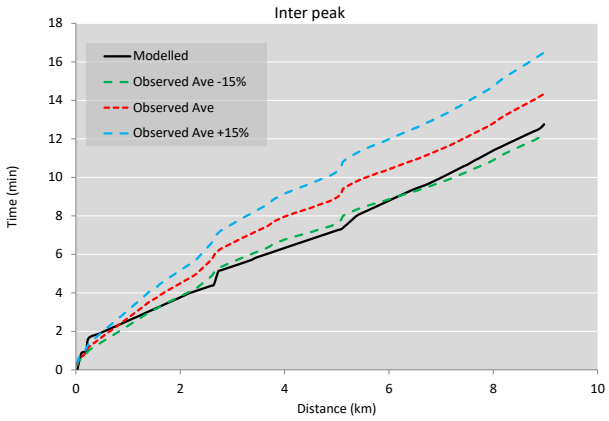

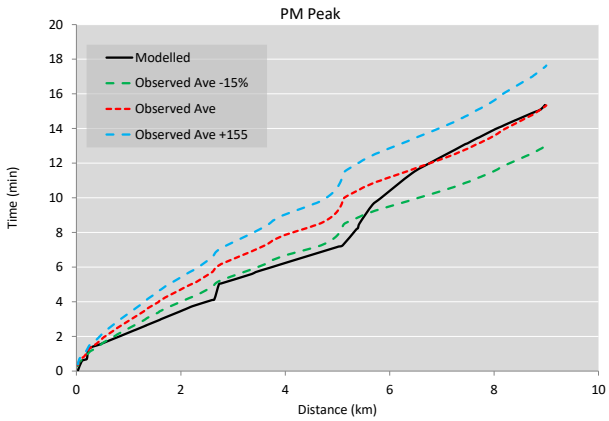

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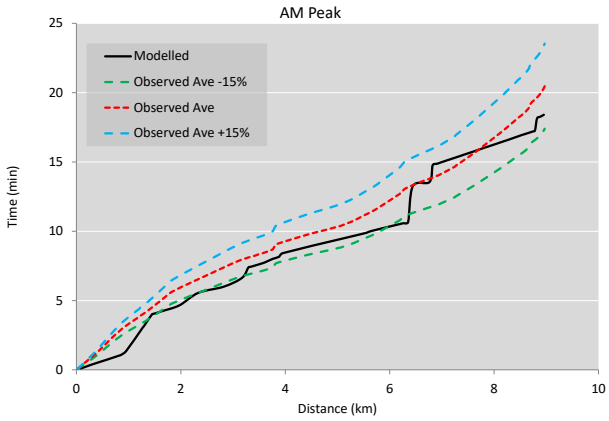

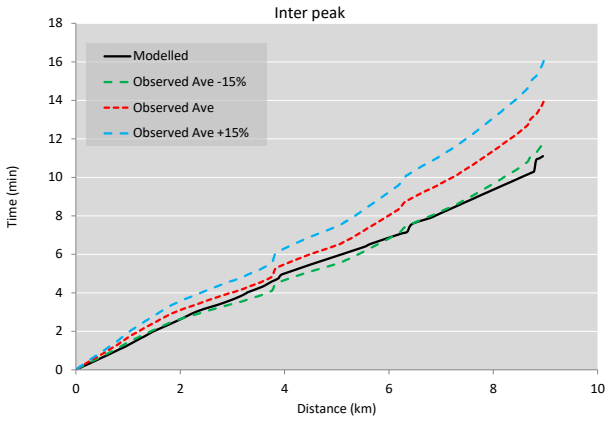

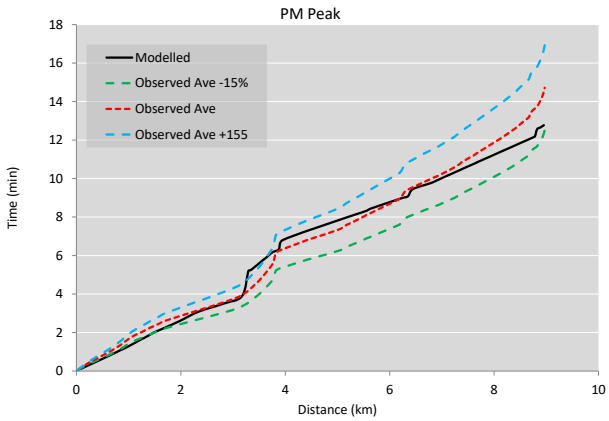

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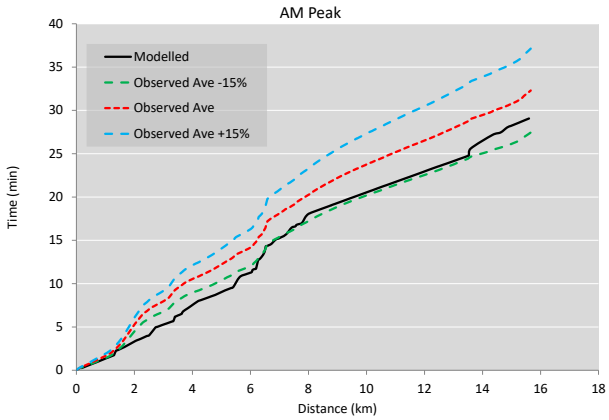

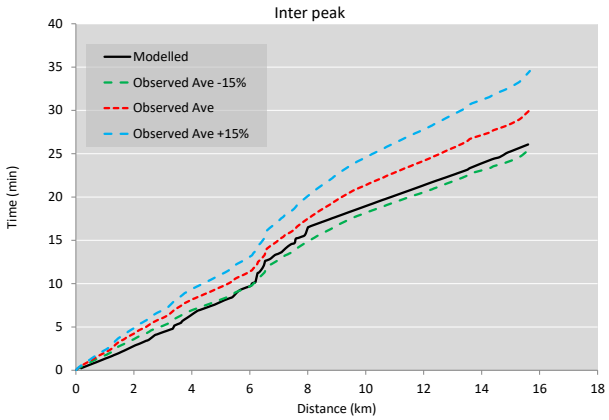

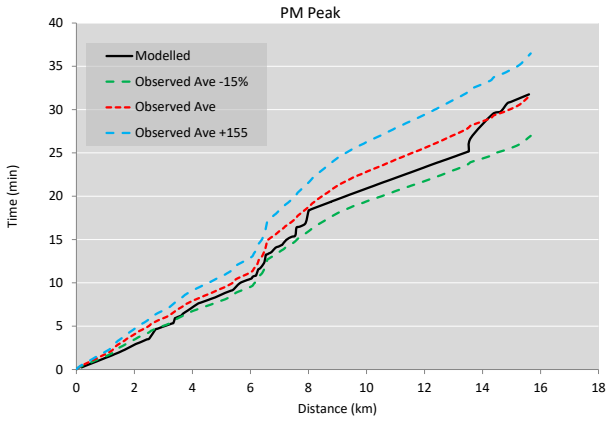

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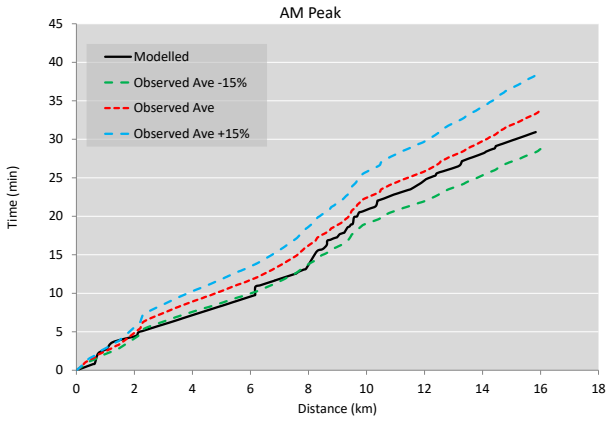
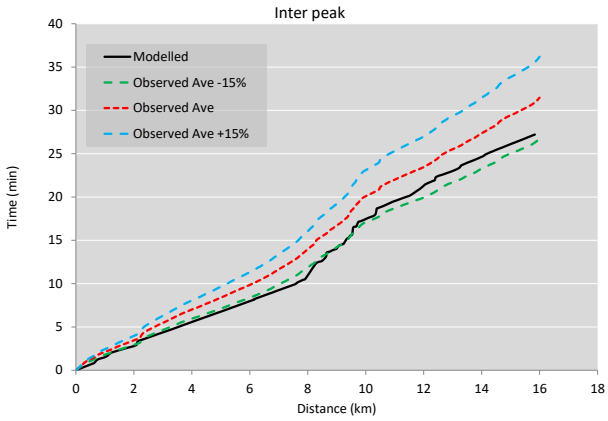
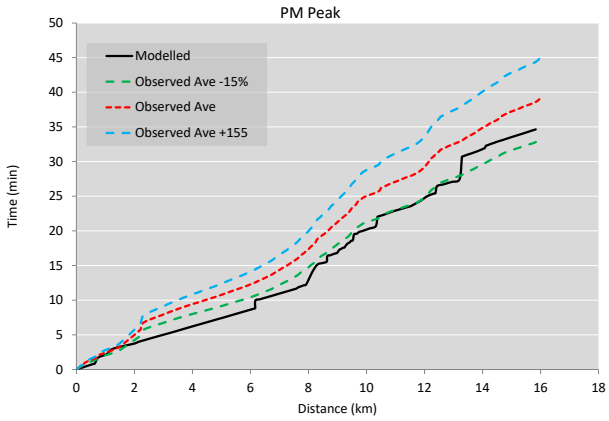
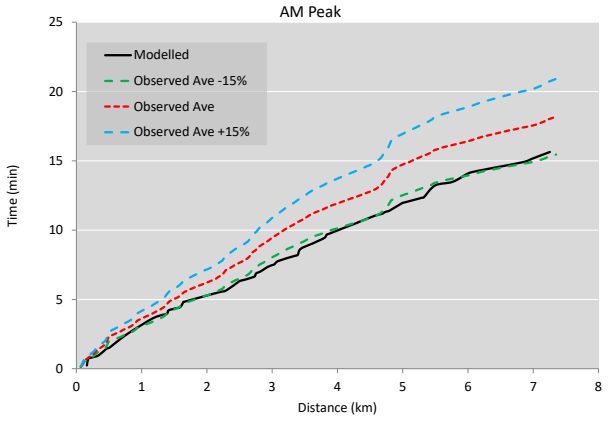
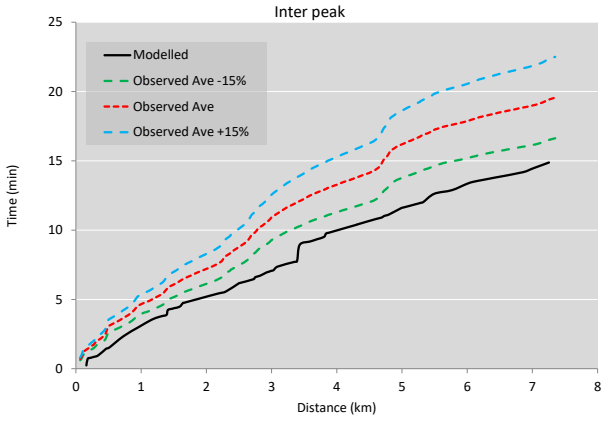


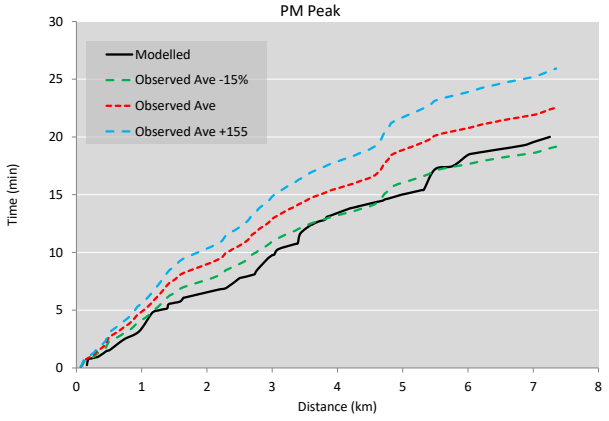




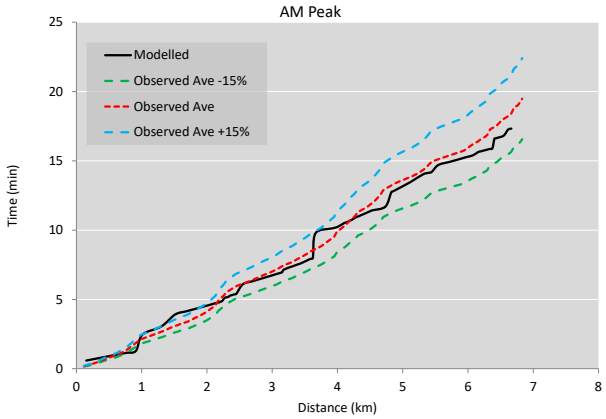
Route 5 – Southbound

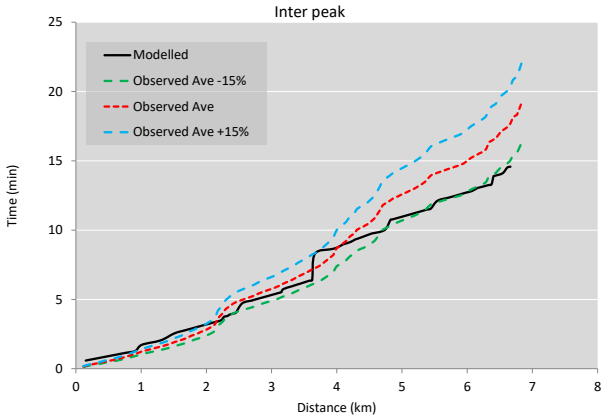


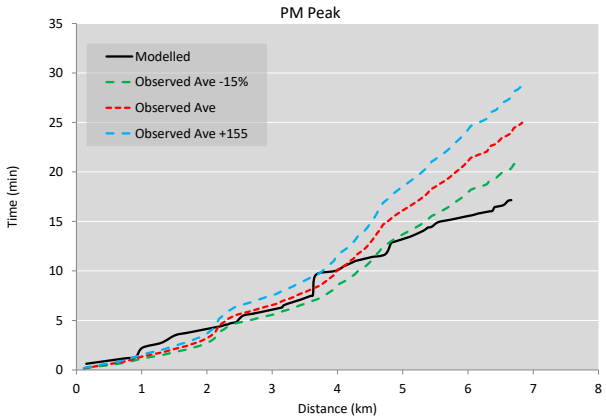




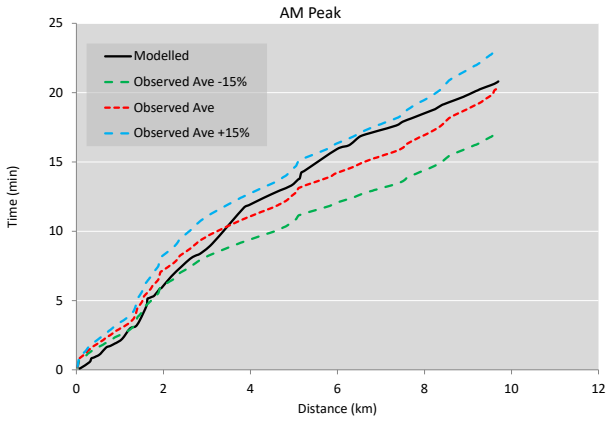
Route 6 – Northbound

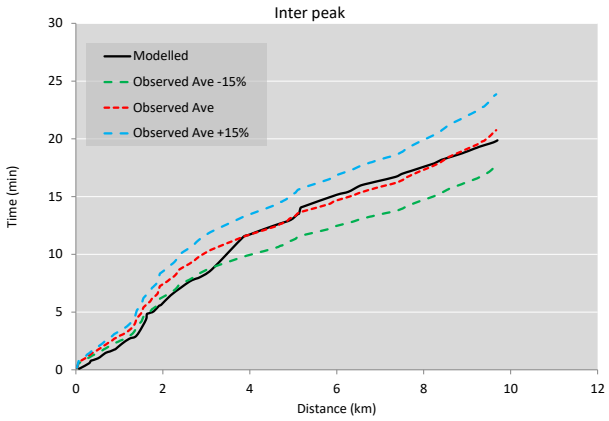


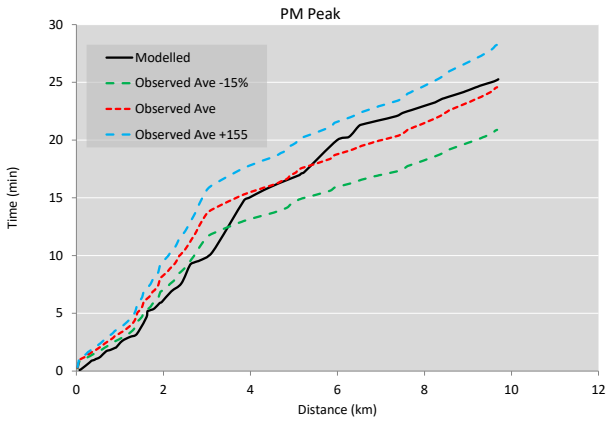




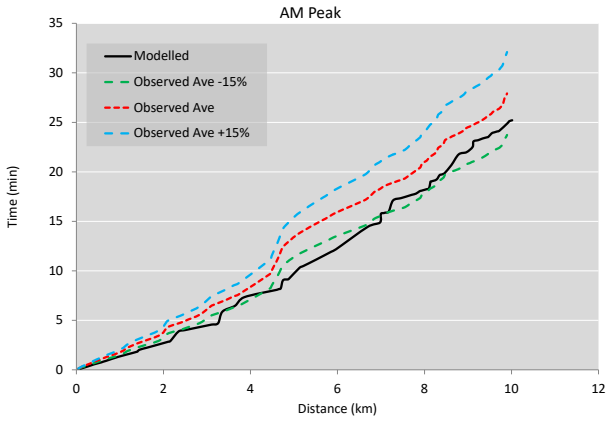
Route 6 – Southbound

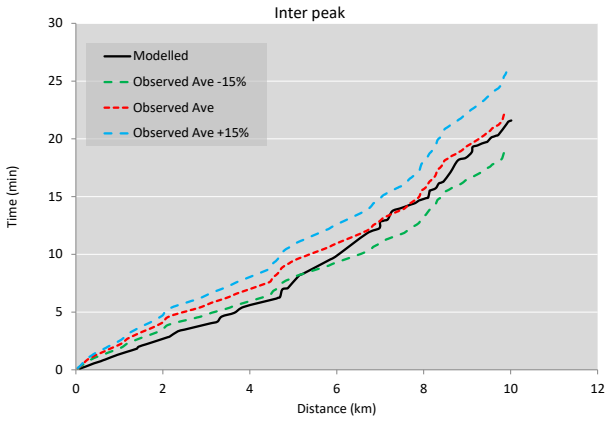


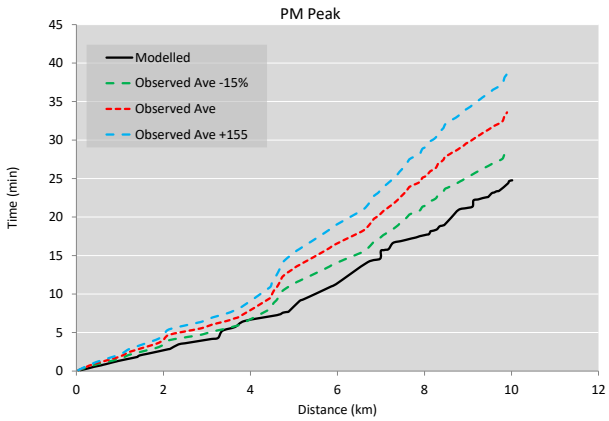




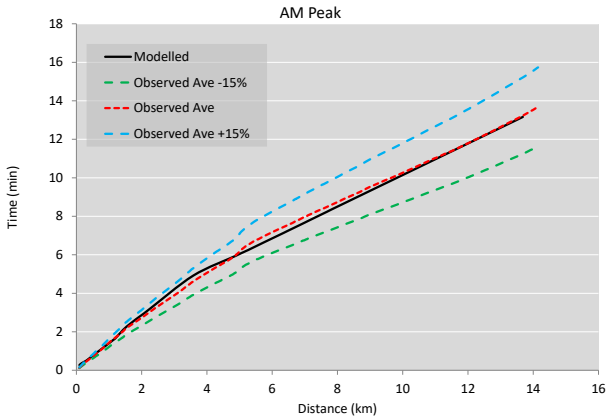
Route 7 – Northbound

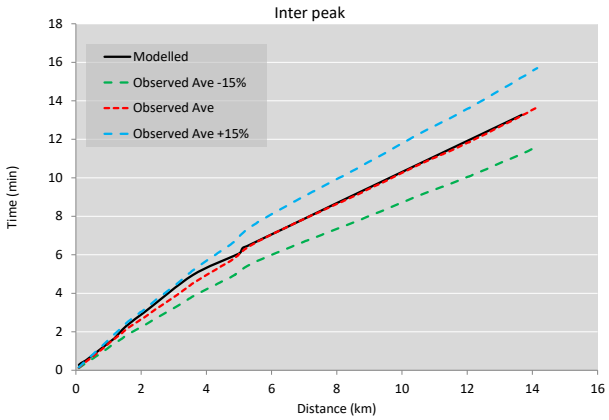


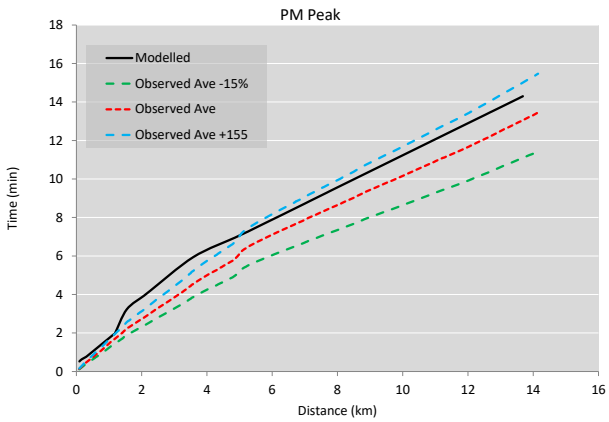




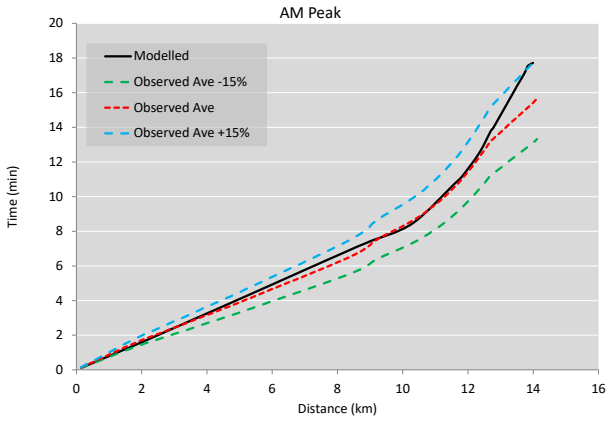
Route 7 – Southbound

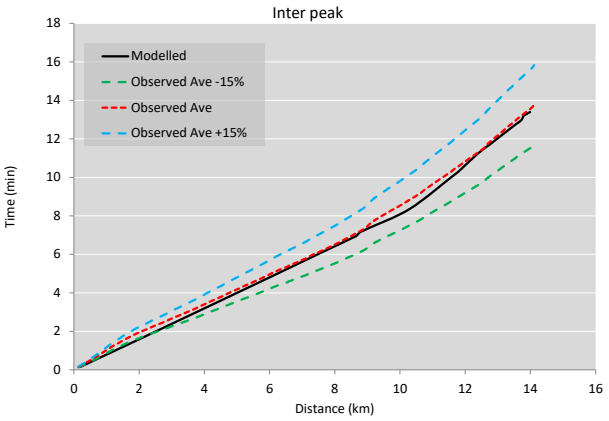


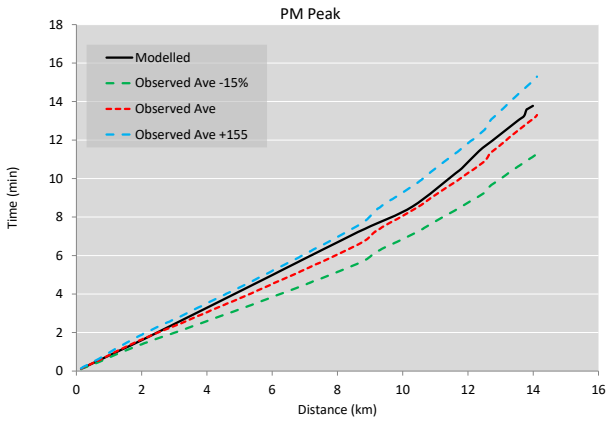




Route 8 – Northbound







Route 8 – Southbound

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