TN11 - WELLINGTON TRANSPORT ANALYTICAL TOOLS 2019-21 UPDATE – HEAVY VEHICLE MODEL UPDATE

PREPARED FOR GREATER WELLINGTON REGIONAL COUNCIL

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Greater Wellington Regional Council

TN11 - Wellington Transport Analytical Tools 2019-21 update – Heavy Vehicle Model Update

CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

Executive Summary

This section summarises the source data and development of the 2018 heavy commercial vehicle trip-based model.

Observed Data

Average weekday traffic counts by vehicle type were collated for 2018 by screenline. Turning movement counts at Waterloo Quay / Hinemoa Street and Hutt Road / Aotea Quay from 2016 were used to estimate trips by period peak entering and leaving the Port.

The primary travel pattern data was sample origin-destination matrices. These matrices were from electronic Road User Charge (eRUC) data from the company EROAD for weekdays in March 2019. The data was supplied for four peak periods summing to daily, and as trip matrices in the WPTM 780-zone system.

The peak periods were slightly different to the current model and the model to be developed in Stage 2 of this project. No adjustment for time period could be made, and the difference is noted for reference. The time period difference is not considered a significant issue.

As the eRUC was provided by existing model zone, trips to/from the Port, and the Interislander and Bluebridge Ferry terminals could not be separately identified. This meant that trip distributions for these locations must be estimated using trips to/from the zone they reside within, which will include other activities.

The eRUC sample was expected to be approximately 40% of all movements. Comparing the sample matrices to screenline traffic counts indicated considerable variability across the region with the sample ranging from 10% to 50%.

The expansion from sample to total is based on screenline traffic counts.

The expansion was initially carried out manually, factoring sector-to-sector movements across a hierarchy of screenlines, which is the approach applied for the 2013 model build. No hierarchy of screenlines could be determined that did not result in negative trips for some movements. This method was therefore discarded. Matrix estimation techniques were applied for each of the four peak periods to expand the data. The estimation used screenlines rather than individual counts, effectively eliminating any errors associated with route choice.

Trips that do not cross screenlines also need to be expanded. This was achieved using traffic engineering trip rates. The trip rates were applied to the land use data and the inter-sector trips (produced using matrix estimation) subtracted.

At the end of this process, origin-destination matrices for each of the four peak periods that replicated traffic counts at a screenline level were produced.

Model Development

As the eRUC data was supplied at 780 zone level, the model will be calibrated using this zoning. In Stage 2 of the project, the model will be applied at 820 zones and the validation re-checked.

Separate models were developed for the Port, each of the Ferry terminals (Interislander and Bluebridge), the SH1 and SH2 road externals separately, and for the remaining internal trips.

Trip attraction and distribution are calculated at a daily level.

Trip attractions were mathematically estimated to relate observed activity (expanded eRUC) to 2018 land use (population, households, and employment by type). Regressions were produced at zone level, but due to the variability of the observed data, it was often difficult to find a good relationship. Regressions were therefore also estimated on a sector basis and then applied by zone.

A gravity model was used to distribute internal trips. For the other locations (Port, Ferry Terminals and road externals), one end of the trip was fixed and so distribution is carried out using linear regression equations.

The adopted models are summarised in Section 12.

Sector-based factors are then applied to divide daily demand to the four peak periods. Factors calculated using the expanded eRUC data had significant variability, and also had movements without any observations in some peak periods. Ranges of peak proportions were calculated from traffic counts and applied as constraints to dampen the extremes in the expanded eRUC. As the four peak periods need to sum to 100%, this resulted in some notable changes in the overnight period where any discrepancy was allocated.

For Stage 1 of the Project, factors to convert from the periods in the model to be developed in Stage 2 to the current two hour AM, interpeak, and PM peak periods were calculated from traffic counts.

The 2018 synthetic heavy commercial vehicle matrices were then assigned (in units of vehicles rather than pcus) at 225 zones with 2013 car demand, which was the latest available at the time. The validation of the heavy vehicles was checked against traffic counts. Overall, the HCV flows were the expected order of magnitude. Modelled flows were slightly higher than observed for Upper and Lower Hutt, the latter driven by the model producing higher flows through Ngauranga than observed. The CBD was underestimated, although adjustment of some traffic counts to remove buses was still required. The model results will be revisited in Stage 2 of the project when the new time periods are implemented, and the car demand is the same year as the HCV's (i.e.: both representing 2018).

The heavy commercial vehicle demands are estimated from employment data, which is appropriate for the distribution of trips but is not a robust indicator of total activity. To forecast demand, an equation incorporating GDPPC is therefore used, with a sensitivity factor to adjust the trend of GDPPC growth to align with HCV metrics. This ensures that predicted economic activity drives heavy commercial vehicle forecasts.

1. Introduction

1.1 Project Overview

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

The Analytical Tool referenced in this report is the Demand Model. The Wellington Transport Strategy Model (WTSM) is the Demand Model for the region and currently has 225 zones. Sitting just beneath WTSM is a detailed public transport sub-mode choice and assignment model, the Wellington Public Transport Model (WPTM), which has slightly more detail at 780 zones.

The project is to be delivered in two stages. The first stage involves incremental updates to various modelling tools, while a full rebuild of the Demand Model is anticipated for Stage 2.

1.2 Purpose of this Report

This report summarises the development of a new predictive heavy commercial vehicle (HCV) model, following the same approach as the 2013 model update.

This report covers:

- Source of the sample observed data;
- Sample analysis;
- Expansion of the sample to the total;
- Development of the predictive model;
- High level validation checks; and
- Next steps.

2. Sample Observed Data

The sample observed data was provided by GWRC based on electronic Road User Charge (eRUC) data extracted from the company EROAD's system. We were advised that the sample size could cover up to 40% of heavy commercial vehicles nationwide[1]. The data format was zone-to-zone heavy vehicle movements using the WPTM 780-zoning system.

The data covered:

- Road User Category (RUC) 2+: this excludes vehicles with two axles (except vehicles with 1 single-tyred spaced axle and 1 twin-tyred spaced axle) – this essentially means all light vehicles are excluded;
- 5 minute dwell time trip definition, i.e., if a vehicle stops for more than 5 minutes, this will be recorded as the end of a trip;
- All weekdays in March 2019 (21 days), i.e., the total divided by 21 produces average weekday daily traffic;
- Hourly average of:
  - AM peak (AM): 6am – 9am
  - Interpeak (IP): 9am – 4pm
  - PM peak (PM): 4pm – 6pm
  - Overnight (ON): 6pm – 6am

[1] GWRC OD Matrix & Heatmaps Methodology

Spatially, any HCV trips starting in, ending in, or passing through the Greater Wellington Region, are included in the sample.

Vehicles excluded from the sample because they are RUC class 1 are illustrated below.

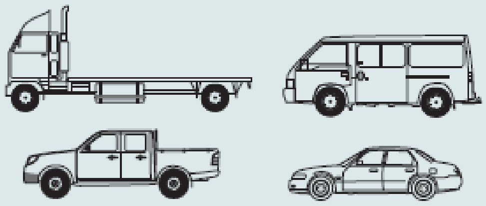
Vehicle sample	RUC vehicle type number	Description	Weight Bands
	1	Powered vehicles with 2 axles (except type 2 or type 299 vehicles)	Not more than 3.5 tonnes
			More than 3.5 tonnes and not more than 6 tonnes
			More than 6 tonnes and not more than 9 tonnes
			Any RUC weight more than 9 tonnes

Figure 2-1: RUC Class 1 Vehicle Types

The average hour samples were factored to periods, representing the time periods for the new model. The new model periods start one hour earlier in the morning and evening peak periods than the current model periods, and an overnight period has also been added. These periods are:

- AM Peak (AM): 6am – 9am (3 hours)
- Interpeak (IP): 9am – 3pm (6 hours)
- PM Peak (PM): 3pm – 6pm (3 hours)
- Overnight (ON): 6pm – 6am (12 hours)
- Daily (DY): 24 hours

The HCV samples by average hour and peak period are shown in the table below.

Table 2-1: HCV Sample by Peak Period

Period	Hourly Average Sample Trips	New Model Period Trips
AM Peak	1,395	4,184
Interpeak	836	5,017
PM Peak	657	1,970
Overnight	142	1,699
Total	**3,029**	**12,871**

3. Port Traffic Count

A tube count was not available for the Port and so alternative data had to be sourced. The Port traffic count was derived by using the turning movement counts[2] at two intersections: Waterloo Quay / Hinemoa Street, and Hutt Road / Aotea Quay on Thursday 10th March 2016. The count data provided:

- AM peak: from 6:30–9:30am, a factor of 1 was used to convert the data for the period of 6:00–9:00am;
- Interpeak: 11:00am–2:00pm, a factor of 2 was applied to derive the interpeak traffic between 9:00am–3:00pm;
- PM peak: 3:30–6:30pm, a factor of 1 was used to convert to 3:00 – 6:00pm period;
- Since the counts did not cover the overnight period (6:00pm – 6:00am), the overnight traffic movement was estimated by applying a factor of 5 (derived from the count data / eRUC sample from

[2] Provided by WAU

AM and PM peak periods) to the eRUC sample. This factor is the average sample of the eRUC data compared with counts over the network.

The adopted freight movements in and out of Wellington port are tabulated below.

Table 3-1: Estimated Wellington Port Freight Traffic Count

Period	In	Out
AM Peak	211	183
Interpeak	380	443
PM Peak	92	119
Overnight	525	595
Sum to Daily	**1,208**	**1,380**

4. Sample Analysis

As the basis of the sample is unknown (aside from sourced from one company supplying eRUC technology), the sample will be expanded using traffic counts grouped into screenlines and sector-to-sector movements. The expansion will be accomplished in two stages, with the inter-sector trips that cross screenlines expanded first. This will be followed by expansion of the intra-sector movements which is more challenging as they do not, by definition, cross the screenlines used to control the expansion.

The 2018 traffic counts input to the expansion are reported in Technical Note 4 of this study. In addition, a count to control heavy commercial vehicles travelling to/from the Port was derived, which is reported here in Section 3.

The inter-sector expansion utilised the sectors shown in Figure 4-1, which are named in Table 4-1. The screenlines that form these sectors are shown Figure 4-2.

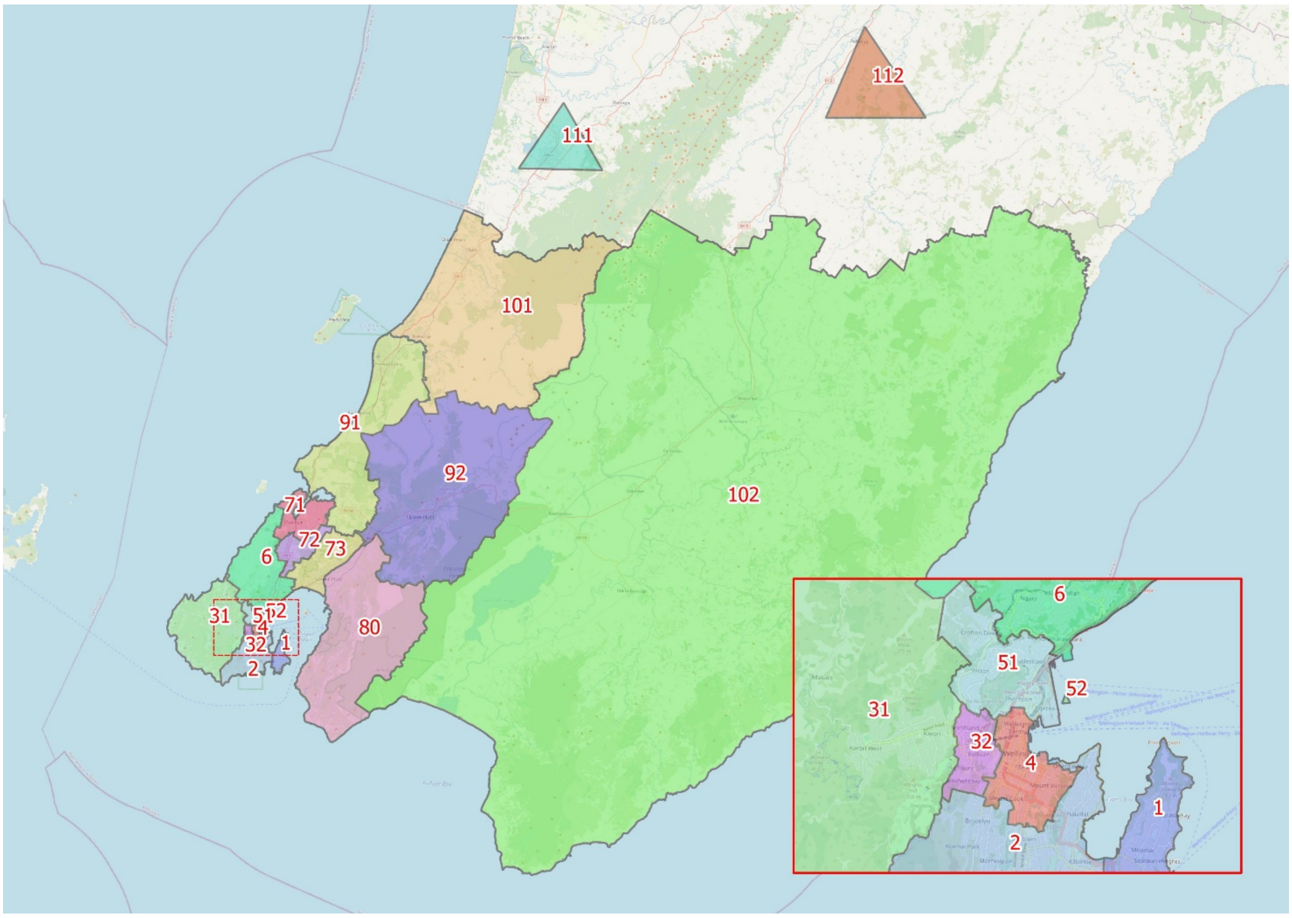


Figure 4-1: Expansion Sectors

Table 4-1: Expansion Sector Names

Sector	Description
1	Miramar
2	Newtown/Island Bay
4	CBD/Mt Vic
6	Khandallah/Johnsonville
31	Karori
32	Kelburn
51	Thorndon
52	Port
71	Porirua
72	Tawa
73	Petone
80	Lower Hutt
91	Paraparaumu/Paekakariki
92	Upper Hutt
101	Waikanae/Otaki
102	Masterton/Featherston

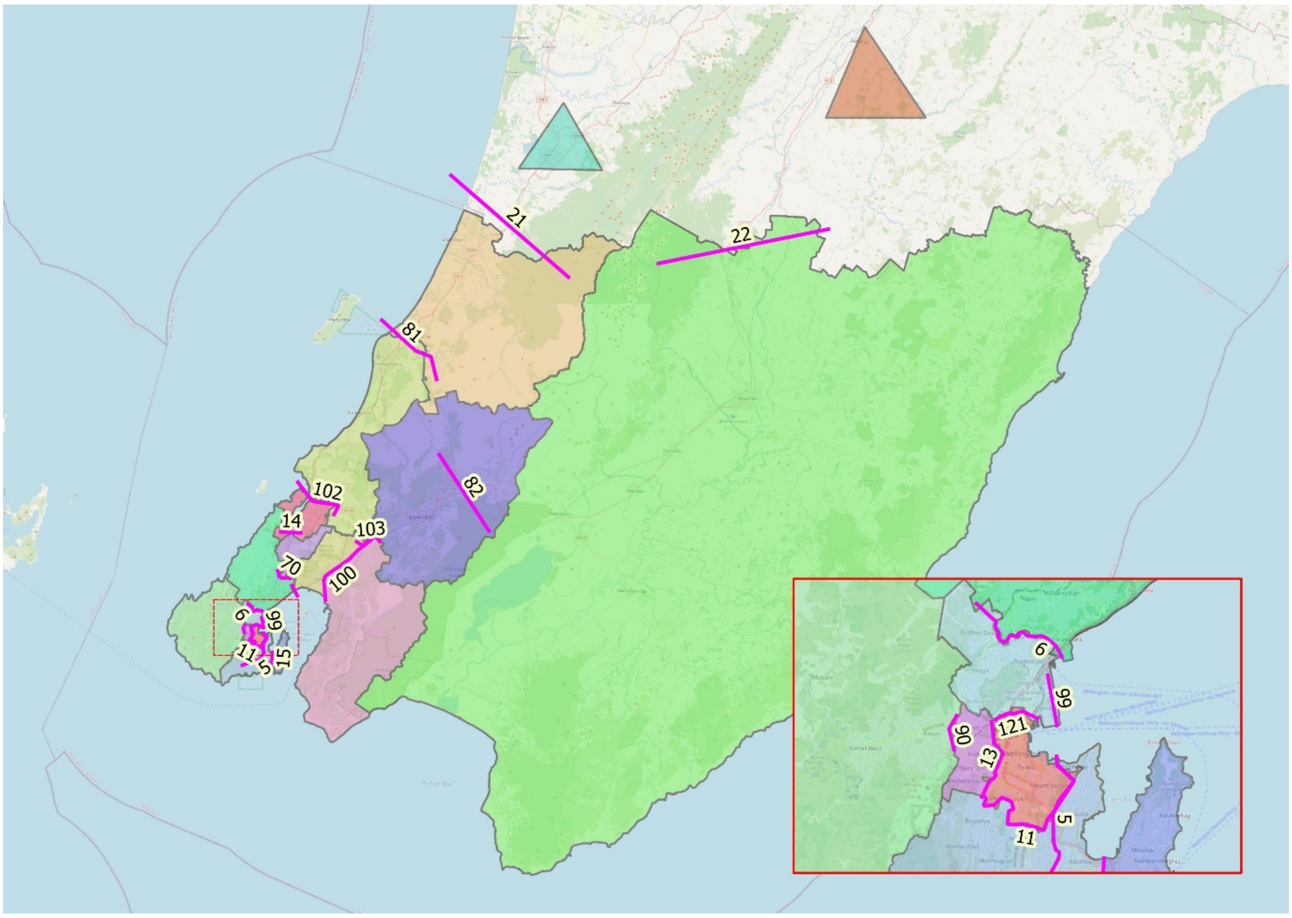


Figure 4-2: Expansion Screenlines

The daily eRUC sample was produced by multiplying the average hourly trips in each period by the number of hours in each period, and then summing to daily. There is a slight disconnect for the interpeak and PM peak where the average hourly sample represents a slightly different period than the model, as shown in the table below. This discrepancy is unlikely to be significant, with sampling and processing errors likely to be greater.

Table 4-2: Hours in Sample and Model

Period	Time Period in Sample	Modelled Period
AM	6-9am	Same
IP	9am-4pm	9am-3pm
PM	4-6pm	3-6pm
ON	6pm-6am	Same

The eRUC sample, traffic count, and sample percentages are tabulated below for each screenline. All volumes are two-way.

Table 4-3: eRUC Sample Percentages

Screenline No.	Screenline Description	Daily eRUC Sample	Daily Traffic Count	Sample Percentage
15	West of Wellington Airport	189	1,050	18%
11	South of Wellington City	573	5,600	10%
13	West of Wellington CBD	173	1,785	10%
90	East of Karori	114	1,174	10%
121	North of Wellington CBD	898	8,522	11%

Screenline No.	Screenline Description	Daily eRUC Sample	Daily Traffic Count	Sample Percentage
99	Wellington Port	790	2,545	31%
6	South of Ngauranga	1,633	7,785	21%
70	North of Ngauranga, SH1 corridor	1,634	3,907	42%
71	North of Ngauranga, SH2	659	1,711	38%
14	South of Porirua	1,252	3,863	32%
102	South of Mana	1,406	4,887	29%
81	North of Paraparaumu	860	2,353	37%
21	Externals via SH1	574	1,264	45%
100	West of Lower Hutt	1,485	6,318	23%
103	North of Lower Hutt	931	2,808	33%
82	North of Upper Hutt on SH2 corridor	640	1,303	49%
22	Externals via SH2	600	1,254	48%
	Total	**14,411**	**58,129**	**25%**

While anecdotally a circa 40% sample was expected, the sample ranges from 10% to 49% with a total sample of 25% considering all screenlines and a screenline average of 29%. While at some locations a sample of 40% or more was achieved (based on comparison with traffic counts), this was not the case at all locations.

Of note, the urban screenlines in the south (15, 11, 13, and 90) have a lower than average sample while regional screenlines, where trip lengths tend to be longer, have a higher sample. Some change in the average trip length is therefore expected since the sample is not balanced across the study area.

5. Sample Expansion

5.1 Pre-Processing

This section covers the expansion of the sample eRUC data to the total.

As the eRUC data was provided at 780 zone definition, the model has been fitted at 780 zone level. In Stage 2 of the project, the model will then be applied at the new 820 zone system and checked against traffic counts.

The Port is obviously a key generator for commercial vehicle movements. However, the eRUC sample did not separately categorise Port activity from trips associated with other activity for the internal zone that the Port is within. The internal zone containing the Port (zone 391 in 780 zone system) is shown in the figure below. So that traffic to and from the Port is produced in the final model, the trips to/from zone 391 were shifted to a new temporary zone for the model development to represent the Port. While this will include some travel to/from other destinations within zone 391, it was deemed preferrable to have observations for the Port.

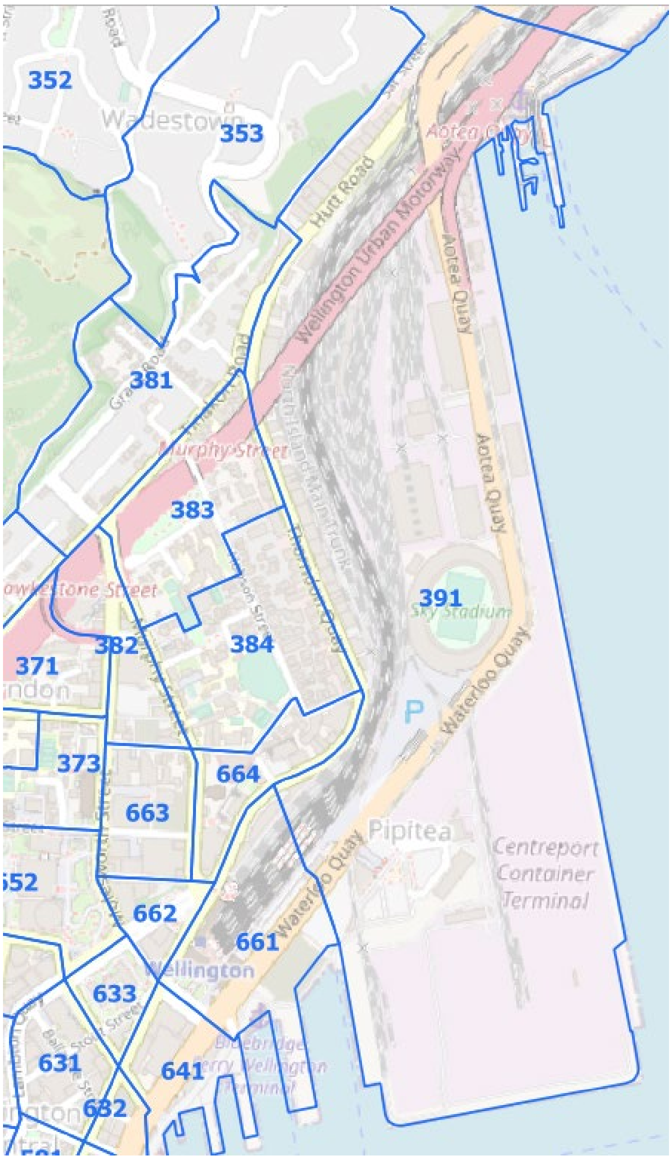


Figure 5-1: Internal Zone 391 Location

Internal zone 391 also contains the Interislander Ferry terminal, although the checking and queuing area are in the adjacent zone 671 (780 zone system). With no control traffic count for the Interislander terminal and no method to separate Port and the remainder of activity, using these trips for the Port distribution is the best way forward.

Similarly, the Bluebridge Ferry Terminal sits within zone 661 (780 zone system) and activity will be intertwined with local trip-making.

The heavy commercial vehicles to/from the two ferry terminals will be slotted in after the main model build.

5.2 Inter-sector Expansion

5.2.1 Method 1 – Sector-based Factoring

Initially, the approach adopted for the 2013 model update was applied to expand the inter-sector sample. This was a manual factoring on a sector-to-sector basis using a pre-determined hierarchy of screenlines. The hierarchy was based on screenlines considered more key, for example, screenline 6 crossing the motorway at Ngauranga and separating commercial/industrial activity in the north from Wellington City and the Port in the south. It is noted that at this stage, the correction for the Port (shifting traffic from zone 391) had not been identified or implemented.

Although different screenline orders were tested, the manual factoring produced negative trips for multiple sector-to-sector movements. While negative trips were not produced when applying this method for the

2013 update, there was only one order that worked. An example is supplied below of the resulting negative expansion factors calculated to convert the interpeak 6-hour sample to interpeak total trips.

Table 5-1: Example – Negative Expansion Factors (Interpeak)

Sector[3]r	1	2	4	6	31	32	51	52	71	72	73	80	91	92	101	102	111	112
1	0.00	10.42	10.42	12.86	46.49	46.49	10.42	-28.26	2.93	2.93	4.48	4.48	2.93	4.48	2.93	4.48	2.93	4.48
2	12.34	0.00	68.67	12.86	46.49	46.49	208.68	-28.26	2.93	2.93	4.48	4.48	2.93	4.48	2.93	4.48	2.93	4.48
4	12.34	26.08	0.00	12.86	46.49	46.49	208.68	-28.26	2.93	2.93	4.48	4.48	2.93	4.48	2.93	4.48	2.93	4.48
6	17.36	17.36	17.36	0.00	17.36	17.36	17.36	17.36	2.93	2.93	4.48	4.48	2.93	4.48	2.93	4.48	2.93	4.48
31	32.57	32.57	32.57	12.86	0.00	129.60	32.57	-28.26	2.93	2.93	4.48	4.48	2.93	4.48	2.93	4.48	2.93	4.48
32	32.57	32.57	32.57	12.86	62.56	0.00	32.57	-28.26	2.93	2.93	4.48	4.48	2.93	4.48	2.93	4.48	2.93	4.48
51	12.34	220.11	220.11	12.86	46.49	46.49	0.00	-28.26	2.93	2.93	4.48	4.48	2.93	4.48	2.93	4.48	2.93	4.48
52	-20.80	-20.80	-20.80	12.86	-20.80	-20.80	-20.80	0.00	2.93	2.93	4.48	4.48	2.93	4.48	2.93	4.48	2.93	4.48
71	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	0.00	13.03	3.33	3.33	2.91	2.91	2.91	2.91	2.91	2.91
72	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	4.66	0.00	3.33	3.33	2.91	4.48	2.91	4.48	2.91	4.48
73	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	2.93	2.93	0.00	8.27	2.93	8.00	2.93	8.00	2.93	8.00
80	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	2.93	2.93	12.75	0.00	2.93	8.00	2.93	8.00	2.93	8.00
91	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	2.93	2.93	3.33	3.33	0.00	2.93	2.62	2.93	2.62	2.93
92	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	2.93	4.66	7.85	7.85	2.91	0.00	2.91	-7.73	2.91	1.42
101	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	2.93	2.93	3.33	3.33	2.80	2.93	0.00	2.93	1.85	2.93
102	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	2.93	4.66	7.85	7.85	2.91	-7.48	2.91	0.00	2.91	1.42
111	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	2.93	2.93	3.33	3.33	2.80	2.93	1.76	2.93	0.00	0.00
112	4.66	4.66	4.66	4.66	4.66	4.66	4.66	4.66	2.93	4.66	7.85	7.85	2.91	0.97	2.91	0.97	0.00	0.00

[3] Sector names irrelevant – it is the negative expansion factors that this table is demonstrating.

The minimum absolute value expansion factor in this example is 0.97, indicating the sample is being reduced below observed. The maximum expansion factor is 220, which is large given a circa 40% sample was expected. Also, for all movements from the urban sectors to/from the Port, a negative expansion (and negative number of trips) is produced. The same issue occurred between Upper Hutt and Masterton/Featherston (sectors 92 and 102 respectively).

This issue reenforces that the eRUC sample does not represent a uniform sample across the region as reported in section 4.

5.2.2 Method 2 – Matrix Estimation

The next approach was to apply automated matrix estimation. This was conducted for each of the four peak periods separately, which were then summed to daily. Prior to matrix estimating, trips to/from the two road externals in the north and the Port were manually factored to match the traffic counts.

The following were applied in the matrix estimation which was carried out in CUBE as it offers screenline-based estimation:

- Assignment was minimum distance-based on an unloaded network;
- An origin-destination (OD) confidence matrix was input for the sample eRUC. A value of zero confidence was set where there were no observations and a value of 10 where there was sample data. This was to reduce the changes to the sample matrix;
- Traffic counts were input on a screenline-basis rather than as individual locations. This minimises errors associated with route choice;
- Screenline traffic count confidence values were specified, which were a factor of ten greater than the sample OD confidences;
- For the interpeak, a trip end control was added as individual OD pairs were changing excessively. The inclusion of a trip end control damps changes to individual OD pairs.

The sample and expanded trips[4] in each period are tabulated below for inter-sector and intra-sector movements. The implicit expansion factors are also reported. Note this is before the final intra-sector expansion has been applied. All trips represent the full new modelled period, for example, the AM is 6-9am.

Table 5-2: Trips and Implicit Expansion Factors, Sample vs Post-Matrix Estimation

	AM	IP	PM	ON	DY
Sample Trips					
Intra-sector	2,216	3,168	1,029	690	7,103
Inter-sector	1,968	1,850	941	1,009	5,768
Total	4,184	5,017	1,970	1,699	12,871
Expanded Trips					
Intra-sector	2,337	4,843	1,094	722	8,996
Inter-sector	5,057	9,399	3,662	4,992	23,110
Total	7,395	14,241	4,756	5,713	32,106
Factors					
Intra-sector	1.05	1.53	1.06	1.05	1.27
Inter-sector	2.57	5.08	3.89	4.95	4.01

There is some change to the intra-sector trips introduced by the matrix estimation. This is related to zones that straddle screenlines. The change to intra-sector trips is small and is discarded later on.

The change in the average trip length was monitored throughout, and the results are shown below.

[4] For internal reference, test 20 was adopted for the AM, PM and overnight periods while Test 31 was adopted for the interpeak.

Table 5-3: Average Trip Length, Sample vs Post-Matrix Estimation

	AM Period	IP Period	PM Period	ON Period	DY
Sample					
Intra-sector	8.96	9.81	9.81	13.12	9.87
Inter-sector	22.87	25.54	25.79	41.36	27.44
Total	15.50	15.61	17.45	29.89	17.74
Expanded Trips					
Intra-sector	8.22	7.62	9.67	12.49	8.42
Inter-sector	17.60	19.78	22.66	22.19	20.28
Total	14.64	15.65	19.68	20.97	16.96

The matrix estimation process has shortened the average trip lengths. This is a typical outcome from matrix estimation. The overnight period in particular has considerably shorter trips although these are smaller in magnitude. For total daily trips, however, the average trip length is only marginally shorter. Trip length distributions are not provided at this stage. This is because the interim expanded demand includes expanded inter-sector trips but sample intra-sector. So comparison between the interim expanded and the sample would not be like-with-like.

5.3 Intra-sector Expansion

Two methods were investigated for the expansion of intra-sector trips, i.e., those which do not cross the screenlines. These are summarised below.

5.3.1 Method 1 – Traffic Count Factors

The first method utilised additional ad-hoc (i.e., not forming screenlines) traffic counts to estimate a growth factor within each sector.

The growth factor was calculated by:

- Assigning the expanded eRUC matrix, which included expanded inter-sector and sample intra-sector trips;
- Subtracting the assigned eRUC flows from the traffic count;
- Dividing the difference calculated above by the intra-sector sample.

Note that changes introduced by matrix estimation to intra-sector demands were removed prior to these factors being applied. Multiple counts were used for this calculation, and factors per sector were produced.

These factors were applied and the resulting demands are shown below.

Table 5-4: Expanded Demands – Method 1 (rejected)

	AM Period	IP Period	PM Period	ON Period	DY
Sample Trips					
Intra-sector	2,216	3,168	1,029	690	7,103
Inter-sector	1,968	1,850	941	1,009	5,768
Total	4,184	5,017	1,970	1,699	12,871
Expanded Trips					
Intra-sector	10,235	23,126	8,857	7,053	49,246
Inter-sector	5,057	9,399	3,662	4,992	23,110
Total	15,292	32,524	12,519	12,045	72,356
Factors					

	AM Period	IP Period	PM Period	ON Period	DY
Intra-sector	4.62	7.30	8.61	10.22	6.93
Inter-sector	2.57	5.08	3.89	4.95	4.01
Total	3.66	6.48	6.35	7.09	5.62

While this method was considered independent as it only relied on traffic counts, it produced demands higher than considered likely, with the intra-sector expansion factors significantly greater than the inter-sector equivalents.

The expanded matrix was assigned to check the factors. However, the lumpiness of the eRUC (with not all OD's observed) meant the comparison was meaningless. Some roads had expanded demands significantly greater than the counts (magnitudes of 10), while other locations were massively underestimated.

This method for intra-sector expansion was therefore rejected.

5.3.2 Method 2 – Trip Rate Factors

The second method to expand the intra-sector trips, which was adopted, is trip-rate based. This is identical to the approach for the development of the 2013 heavy commercial vehicle model.

Trip rates were collated from standard traffic engineering sources[5] and applied to estimate the total number of trips (i.e., sector-to-sector and intra-sector combined) for the AM, interpeak and PM peak periods. These trip rates, tabulated below, calculate an hourly demand which was multiplied by the number of hours in each period to produce the period target. An average of the origins and destinations was used to produce inbound plus outbound travel.

Table 5-5: Trip Rates for Total HCV Movements

Land Use Category	AM Period		IP Period		PM Period	
	Origin	Destination	Origin	Destination	Origin	Destination
Household	0.00294	0.00294	0.00324	0.00324	0.00237	0.00237
Population	0.00107	0.00107	0.00118	0.00118	0.00086	0.00086
Employment Other	0.00837	0.00837	0.00923	0.00923	0.00674	0.00674
Manufacturing Employment	0.03082	0.04941	0.02277	0.03312	0.03856	0.01521
Retail Employment	0.01257	0.01257	0.01386	0.01386	0.01012	0.01012
Transport & Communications Employment	0.02216	0.02484	0.06218	0.06218	0.02430	0.03770
Services Employment	0.00417	0.00417	0.00460	0.00460	0.00336	0.00336

There was no available trip rate to estimate the overnight period. A daily trip rate was available and tested, however, this produced about half the number of expected trips. Instead, an estimate was produced for the overnight assuming that the proportion of inter-sector and intra-sector trips would be the same pre and post expansion. The key figures for this calculation are shown in the table below.

Table 5-6: Derivation of Total Overnight Demand

	Overnight, eRUC Sample		Overnight, eRUC Part Expanded
	Trips	Percentage	Trips
Intra-sector	690	41%	

[5] Sources include: NCHRP Synthesis 298 Truck trip generation data; Bureau of Transportation Statistics (US), Washington State Department of Transportation; Subregional Freight Movements Truck Access Study (Tampa Bat, US); New Zealand survey data (collated project-based data)

	Overnight, eRUC Sample		Overnight, eRUC Part Expanded
	Trips	Percentage	Trips
Inter-sector	1009	59%	4992
Total	1699		

The expanded total and intra-sector trips were calculated on the basis that the 4,992 expanded inter-sector trips would represent 59% both in the sample and in the expanded matrix. A rounded factor of 1.7 (1/0.59) was applied to the expanded overnight inter-sector trips to produce the target total.

From the total demand for each period calculated using trip rates, the expanded intra-sector demand was produced by subtracting the expanded inter-sector trips for each peak period separately.

This approach was tested on a sector-basis, but just as in the 2013 model build, negative trips resulted for some sectors. This calculation was therefore applied on a region-wide basis using a single factor for each peak period. The intra-sector expansion factors and demand totals at each stage of the calculation are tabulated below.

Table 5-7: Estimation of Intra-Sector Demands by Peak Period

	AM Period	IP Period	PM Period	ON Period	Sum to Daily
All trips, trip rate applied	11,271	24,948	9,093	8,486	53,798
Inter-sector trips, expanded	5,057	9,399	3,662	4,992	23,110
Target Intra-Sector Trips	6,213	15,549	5,431	3,494	30,688
Intra-Sector Expansion Factor	2.80	4.91	5.28	5.06	N/A
Final Intra-Sector Trips	6,213	15,549	5,431	3,494	30,688

The sample and resulting total expanded trips in each period are tabulated below for inter-sector and intra-sector movements. The implicit expansion factors are also reported. All trips represent the full new modelled period, for example, the AM is three hours duration from 6-9am.

Table 5-8: Trips and Implicit Expansion Factors, Sample vs Total Estimation

	AM Period	IP Period	PM Period	ON Period	DY
Sample Trips					
Intra-sector	2,216	3,168	1,029	690	7,103
Inter-sector	1,968	1,850	941	1,009	5,768
Total	4,184	5,017	1,970	1,699	12,871
Expanded Trips					
Intra-sector	6,213	15,549	5,431	3,494	30,688
Inter-sector	5,057	9,399	3,662	4,992	23,110
Total	11,271	24,948	9,093	8,486	53,798
Factors					
Intra-sector	2.80	4.91	5.28	5.06	4.32
Inter-sector	2.57	5.08	3.89	4.95	4.01
Total	2.69	4.97	4.61	4.99	4.18

Even though two completely different methods have been used, the implicit expansion factors for the intra-sector and inter-sector movements are similar.

The average trip length for intra-sector and inter-sector trips is shown below for the sample and total expanded matrix, by peak period and daily.

Table 5-9: Average Trip Length, Sample vs Total Expanded Matrix

	AM Period	IP Period	PM Period	ON Period	DY
Sample					
Intra-sector	8.96	9.81	9.81	13.12	9.87
Inter-sector	22.87	25.54	25.79	41.36	27.44
Total	15.50	15.61	17.45	29.89	17.74
Expanded Trips					
Intra-sector	8.96	9.81	9.81	13.12	10.02
Inter-sector	17.60	19.78	22.66	22.19	20.28
Total	12.84	13.57	14.99	18.46	14.43

There is a slight overall shortening of average trip length, primarily from inter-sector trips. This reflects the fact that the sample is not even across the study area, and so changes in trip length are expected.

Trip length distributions for each of the four peak periods and the sum to daily are provided below. The sample eRUC is compared with the final expanded matrix.

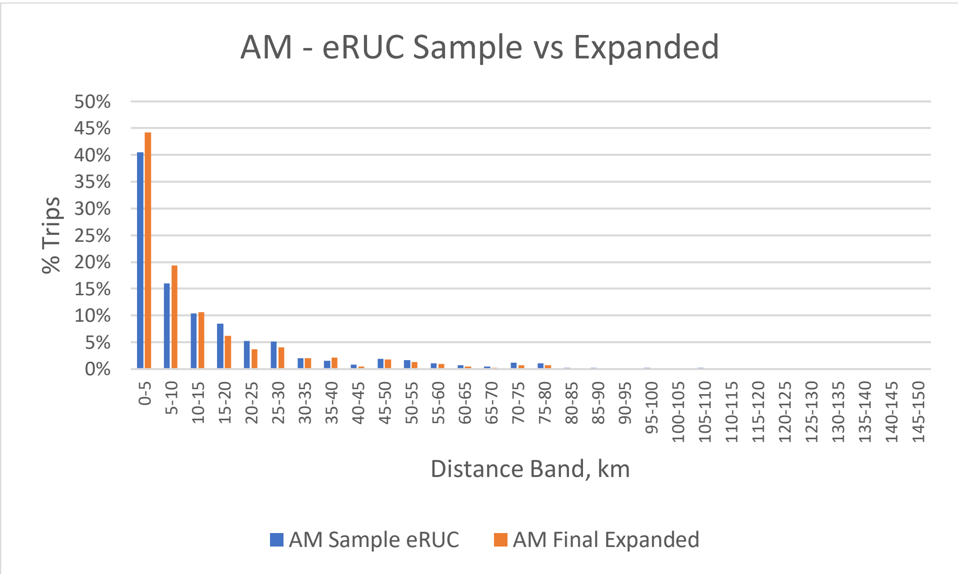


Figure 5-2: Trip Length Distribution for All Trips – Sample eRUC vs Final Expanded – AM Peak Period

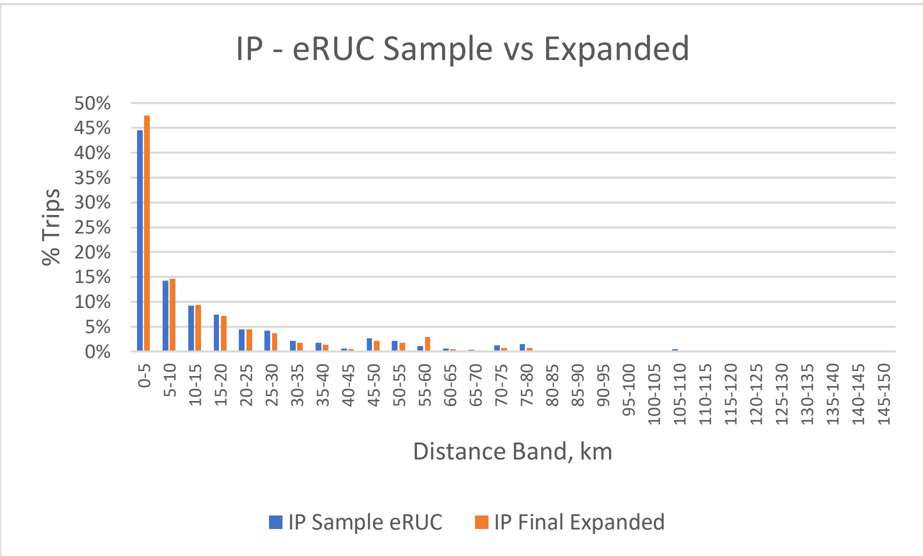


Figure 5-3: Trip Length Distribution for All Trips – Sample eRUC vs Final Expanded – Interpeak Period

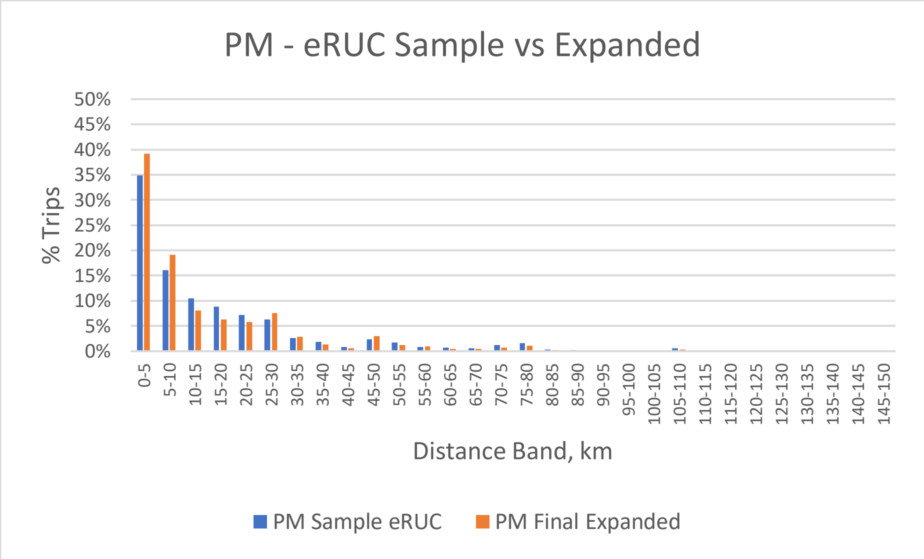


Figure 5-4: Trip Length Distribution for All Trips – Sample eRUC vs Final Expanded – PM Peak Period

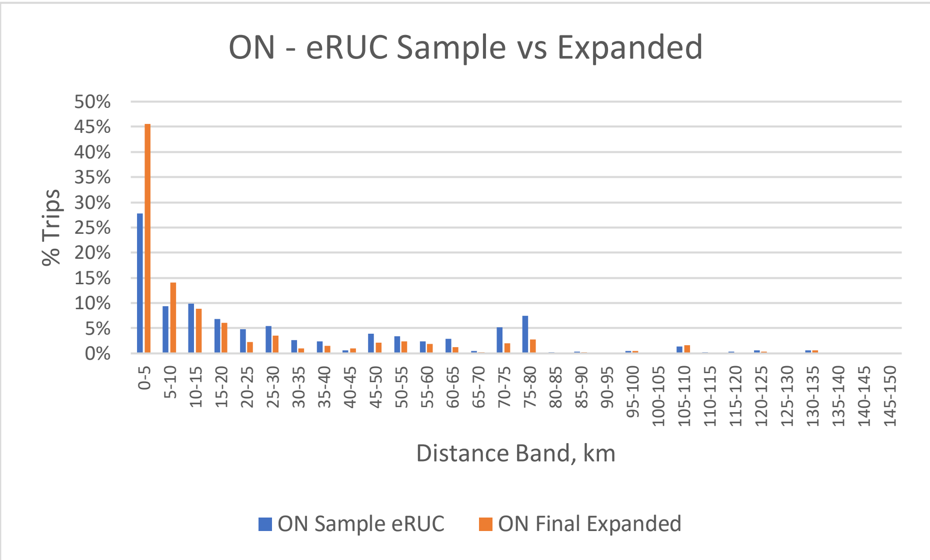


Figure 5-5: Trip Length Distribution for All Trips – Sample eRUC vs Final Expanded – Overnight Period

Aside from the overnight period, each peak period has a slight increase in the number of trips travelling less than 5km. The overnight has a much larger increase, although it is numerically less significant as can be seen from the daily trip length distribution below, when the sum of the peaks only shows a 5% increase in trips travelling less than 5km compared with the sample eRUC.

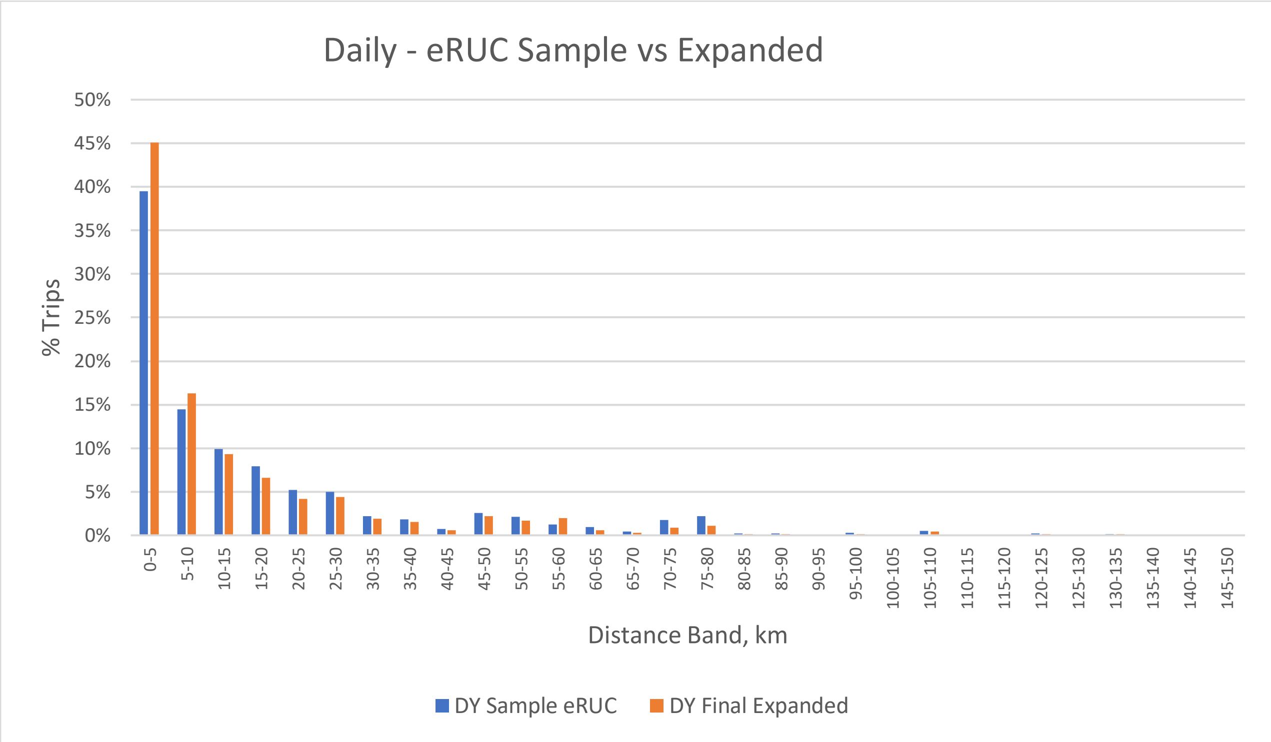


Figure 5-6: Trip Length Distribution for All Trips – Sample eRUC vs Final Expanded – Daily

At a daily level, which will be the primary building block for the model build, the expanded matrix replicates the sample eRUC well in terms of trip length distribution.

5.4 Expanded Matrix

The trips in the final expanded matrix are tabulated below. These are reported for internal, trips to/from State Highway 1 (SH1) or SH2 in the north ("external"), and the Port.

Table 5-10: Expanded eRUC Matrix – Daily Trips

	Internal	Port	External	Total
Internal	48,535	991	1,214	**50,741**
Port	1,103	0	84	**1,187**
External	1,141	74	0	**1,215**
Total	**50,780**	**1,065**	**1,298**	**53,143**

Trips by period are reported in Table 5-8.

6. Model Development – Approach

6.1 Overarching Approach

Similar to the person-based model, the generation and distribution for the heavy commercial vehicle model is calculated at a daily level (average weekday) and then factored to peak periods.

Separate models will be developed for internal trips, trips to/from the Port, trips to/from the Interislander and Bluebridge ferry terminals, and for the road externals of SH1 and SH2 in the north. The Port, ferry terminals, and road externals are treated differently as there are different relationships to explain travel.

The general approach to the trip end and distribution models is summarised in the next two sections respectively.

6.2 Trip End Estimation Approach

Trip ends are predicted by applying multiple linear regression. The dependent variable is the expanded eRUC sample and the independent/explanatory variables are the input land use.

The sample eRUC matrix is very "lumpy", with not all origin-destination (OD) pairs observed. As a result, the OD pairs which have been sampled are expanded to a higher value than in reality to produce representative screenline crossings and total demand. The application of the synthetic model corrects for this lumpiness, but it does produce some challenges in fitting the models.

For each model, the daily origin and destination trips have been averaged and a single model produced. This is because the destination of the first heavy commercial vehicle trip is the origin of the following trip, and so on.

The objective of the regression is to produce a reasonable correlation between land use and trips. This is indicated by the Adjusted R-squared value. An Adjusted R-squared of one indicates an ideal fit, while values less than 0.5 indicate poor correlation. The Adjusted R-Squared is a modified version of the R-squared that accounts for predictors that are not significant in a regression model. The Adjusted R-Squared will only increase if new explanatory variables improve the model. This is not the case with the R-Squared value, which always increases as variables are added.

For each independent variable, a t-statistic of 2.0 or greater is acceptable indicating greater confidence in the variable as a predictor. The p-value measures whether the term has any effect, with p-values closest to zero desirable.

Independent variables need to have a positive coefficient which means that increases in land use will produce an increase in trip-making. In the case of trip end modelling, negative coefficients do not make sense and must be removed. In addition, variables included must be logical from a transport planning perspective. Variables that are illogical must also be removed.

In fitting the models, zones with zero trip ends are removed for the regression modelling. These zones are subsequently included when the model is applied.

This model is estimated at 780 zone level, which is the resolution that the sample eRUC was provided in. The model will subsequently be applied (not re-calibrated/re-estimated) at 820 zones in Stage 2 of this project.

The explanatory land use data by expansion sector is shown in the following table. This represents 2018 Census data. Population is Census Usually Resident Population (CURP), as are the other land use types. It is worth noting that the current 225 zone model will be applied using the Estimated Resident Population definition, which is circa 3% greater. As a result, the models fitted here may need a slight adjustment in the coefficient values. At the time of developing these models, only CURP data was available. The equivalence to Census Australia New Zealand Standard Industry Classification (ANZSIC) categories is provided in Table 6-2.

Table 6-1: Grouped Land Use Data by Expansion Sector

Sector	Description	Households	Population	Employment					
				Other	Manufacturing	Retail	Transport & Communications	Services	Total
1	Miramar	6,951	19,099	20	677	997	2,512	2,143	6,349
2	Newtown/Island Bay	20,202	53,427	51	1,531	2,665	1,006	9,535	14,787
4	CBD/Mt Vic	11,220	28,394	149	3,792	11,369	4,151	58,013	77,474
6	Khandallah/Johnsonville	16,733	47,279	58	2,361	2,191	556	6,010	11,177
31	Karori	5,553	15,759	32	252	424	84	1,872	2,664
32	Kelburn	3,184	9,065	8	176	359	53	2,069	2,665
51	Thorndon	5,160	12,706	8	668	1,501	1,537	13,971	17,685

Sector	Description	Households	Population	Employment					
				Other	Manufacturing	Retail	Transport & Communications	Services	Total
52	Port								
71	Porirua	14,465	47,908	36	2,673	2,812	635	8,682	14,838
72	Tawa	5,575	16,608	12	1,111	897	252	1,830	4,101
73	Petone	9,212	25,100	23	3,532	3,403	486	5,830	13,273
80	Lower Hutt	27,883	79,205	99	5,349	5,276	1,724	16,022	28,470
91	Paraparaumu/Paekakariki	15,620	40,000	143	2,492	2,769	663	7,092	13,160
92	Upper Hutt	16,005	44,397	127	2,735	2,513	612	7,720	13,706
101	Waikanae/Otaki	9,334	22,324	333	1,443	1,306	196	3,116	6,394
102	Masterton/Featherston	17,913	45,330	2,871	3,528	3,528	690	7,863	18,480
Total		**185,010**	**506,601**	**3,970**	**32,320**	**42,008**	**15,157**	**151,768**	**245,223**

Table 6-2: Equivalence of Census Industry Classification to Grouped Land Use Categories

ANZSIC (06) Categories	Grouped Land Use Category
Agriculture, Forestry and Fishing	Employment Other
Mining	Manufacturing
Manufacturing	Manufacturing
Electricity, Gas, Water and Waste Services	Manufacturing
Construction	Manufacturing
Wholesale Trade	Retail
Retail Trade	Retail
Accommodation and Food Services	Retail
Transport, Postal and Warehousing	Transport & Communications
Information Media and Telecommunications	Transport & Communications
Financial and Insurance Services	Services
Rental, Hiring and Real Estate Services	Services
Professional, Scientific and Technical Services	Services
Administrative and Support Services	Services
Public Administration and Safety	Services
Education and Training	Services
Health Care and Social Assistance	Services
Arts and Recreation Services	Services
Other Services	Services

6.3 Distribution Estimation Approach

For the Port and road externals, the distribution model is a multiple linear regression, as described in the previous section. This is because one end of the trip is known for these models.

The distribution of internal heavy commercial vehicle trips will be modelled using a gravity model. This model form states that the interchange volume between a trip producing zone and trip attracting zone is directly proportional to the magnitude of the trip productions and attractions and inversely proportional to the impedance between the zones.

The impedance is based on skimmed distance from the loaded network together with a calibration parameter. The calibration parameter is iteratively adjusted to minimise the error between the observed and calculated origin-destination (OD) demands. The comparison between observed and modelled OD demands is accomplished by using the trip length frequency distribution.

The gravity model formulation which calculates the number of trips between each OD pair is as follows:

$$T_{ij} = a_i P_i b_j A_j F(C_{ij})$$

where:

T_{ij} = trips estimated from zone i to zone j

P_i = productions (or origins in this case) from zone i

A_j = attractions (or destinations) to zone j

a_i, b_j = row/column balancing factors

$F(C_{ij})$ = cost deterrence from zone i to zone j

The cost function can take different forms but the adopted equation is:

$$F(C_{ij}) = e^{(\alpha . C_{ij})}$$

where:

$F(C_{ij})$ = cost deterrence for zone i to zone j

C_{ij} = generalised cost for zone i to zone j

α = alpha coefficient to be calibrated

The cost deterrence matrix was produced by skimming distance from the shortest paths on a 780 zone assignment. Excluding time from the generalised cost means in application, that small changes in travel times will not result in businesses effectively relocating – the three stage model effect.

As there is no intra-zonal distances output these values need to be calculated. Half the distance to the closest zone was used for the intrazonal distances.

The calibration process involves inverting the gravity model so that it is expressed in terms of the cost function as follows:

$$F(C_{ij}) = T_{ij}/(P_i\ A_j)$$

The function value is calculated for each OD pair and allocated to a cost band. The final value of the function in each cost band is the weighted average of the individual cells in that band. The natural log of this average is then calculated and plotted against cost to calculate the alpha value for use in the negative exponential function.

7. Model Development – Internal Trips

7.1 Trip Attractions

The expanded sample eRUC trip ends are shown below aggregated to sector. These are internal-internal trips only, excluding trips to/from the Port and the two road externals in the north.

Table 7-1: Expanded Internal eRUC Observed Origins and Destinations by Sector

Sector No.	Sector Name	Daily Expanded Origins	Daily Expanded Destinations	Daily Expanded Average
1	Miramar	920	935	928
2	Newtown/Island Bay	4,008	3,749	3,878
4	CBD/Mt Vic	2,631	3,662	3,147
6	Khandallah/Johnsonville	2,929	1,770	2,350
31	Karori	806	875	840
32	Kelburn	1,015	872	943
51	Thorndon	1,723	1,635	1,679
71	Porirua	3,787	3,962	3,874
72	Tawa	1,221	1,472	1,346
73	Petone	2,182	3,411	2,797
80	Lower Hutt	9,198	8,358	8,778
91	Paraparaumu/Paekakariki	3,815	3,758	3,787
92	Upper Hutt	2,186	1,997	2,091
101	Waikanae/Otaki	2,069	2,018	2,044
102	Masterton/Featherston	10,046	10,062	10,054
Total		**48,535**	**48,535**	**48,535**

7.1.1 Internal Attractions – Sector-Based Regression

Sector-based regression was investigated to determine the strongest explanatory variables while overcoming the lumpiness of the sample. All variables were added initially, with the results provided below.

Table 7-2: Sector-based Regression – Daily Internal Trip Ends – Model 1

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment -- Other	2.1057	4.24	0.00	0.96	3.25	0.93
Households	-0.0374	-0.11	0.91	-0.79	0.72	
Manufacturing	0.8553	1.21	0.26	-0.78	2.49	
Population	0.0613	0.51	0.62	-0.22	0.34	
Retail	-0.5114	-0.59	0.57	-2.50	1.48	
Services	0.0686	0.51	0.62	-0.24	0.38	
Transport & Communications	0.0716	0.15	0.88	-1.03	1.17	

Households indicated a negative relationship which is not sensible (i.e., more households should not produce fewer trips) and is a similar indicator to population. Households were removed and the regression was rerun.

Table 7-3: Sector-based Regression – Daily Internal Trip Ends – Model 2

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment - Other	2.0784	5.06	0.00	1.15	3.01	0.94

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Manufacturing	0.8712	1.33	0.22	-0.61	2.35	
Population	0.0478	2.21	0.05	0.00	0.10	
Retail	-0.5272	-0.66	0.53	-2.34	1.29	
Services	0.0704	0.56	0.59	-0.21	0.35	
Transport & Communications	0.0666	0.15	0.88	-0.95	1.08	

This time Retail produced a negative relationship. Retail was removed and the regression rerun.

Table 7-4: Sector-based Regression – Daily Internal Trip Ends – Model 3

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment - Other	2.0369	5.17	0.00	1.16	2.92	0.94
Manufacturing	0.5148	1.45	0.18	-0.28	1.31	
Population	0.0509	2.48	0.03	0.01	0.10	
Services	-0.0074	-0.19	0.86	-0.10	0.08	
Transport & Communications	0.0445	0.10	0.92	-0.92	1.01	

Now Services produced a negative relationship. This was removed and the regression rerun.

Table 7-5: Sector-based Regression – Daily Internal Trip Ends – Model 4

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment - Other	2.0437	5.45	0.00	1.22	2.87	0.95
Manufacturing	0.4838	1.61	0.14	-0.18	1.14	
Population	0.0525	2.95	0.01	0.01	0.09	
Transport & Communications	-0.0205	-0.08	0.93	-0.56	0.52	

Now Transport & Communications produced a negative relationship. This was removed and the regression rerun.

Table 7-6: Sector-based Regression – Daily Internal Trip Ends – Model 5

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment - Other	2.0497	5.82	0.00	1.28	2.82	0.95
Manufacturing	0.4728	1.83	0.09	-0.09	1.04	
Population	0.0527	3.11	0.01	0.02	0.09	

Model 5 has an excellent Adjusted R-squared value, with good t-statistics for Population and Employment - Other. The t-statistic for Manufacturing is slightly lower than desirable. Other types of employment are not represented in this model. So increased Retail, Services, Transport & Communications will not generate any additional heavy vehicles trips, which is not ideal.

Following client and stakeholder review, it was requested that households be tested instead of population which is presented as Model 6 below.

Table 7-7: Sector-based Regression – Daily Internal Trip Ends – Model 6

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment - Other	1.9522	5.40	0.00	1.16	2.74	0.95
Manufacturing	0.4989	1.88	0.08	-0.08	1.08	
Households	0.1421	2.92	0.01	0.04	0.25	

Comparing model 6 with model 5, the t-statistics, p-values and Adjusted R-squared values are very similar.

Results by sector are shown below for Model 6. The adjusted predicted ("Adj") results are based on factoring the coefficients so that the observed daily total trips are reproduced.

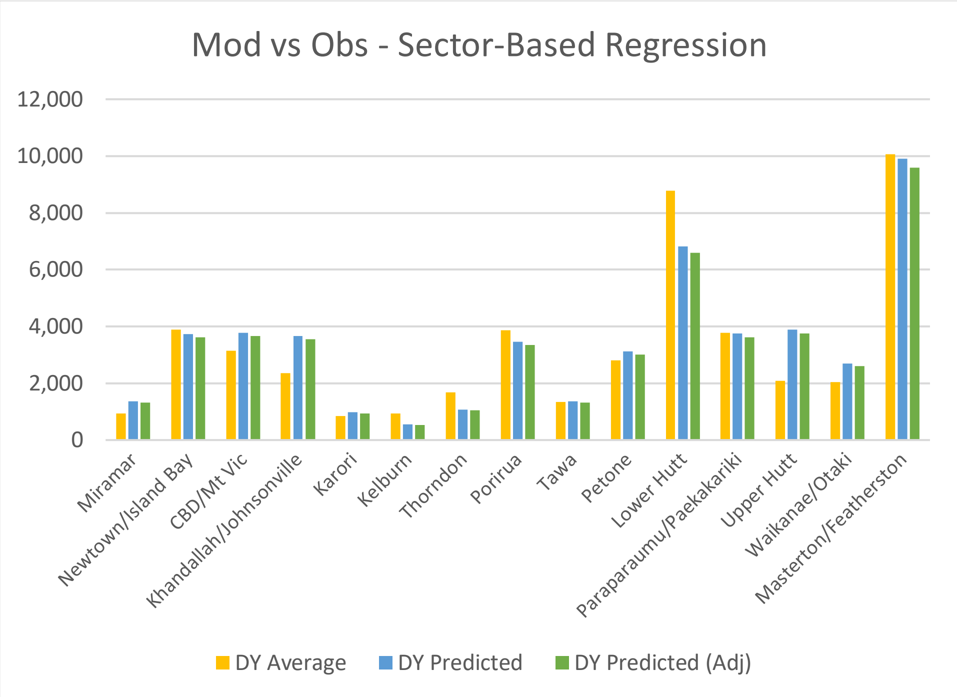


Figure 7-1: Internal Trip Ends – Sector-Based Regression – Results by Sector (Model 6)

There is a relatively good fit overall, with the model slightly underestimating trips in Lower Hutt (sector 80). This model will, however, primarily produce heavy commercial vehicle trips related to manufacturing and other employment, which is limiting.

7.1.2 Internal Attractions – Zone-Based Regression

The process was repeated using zonal observed data.

Table 7-8: Zonal-based Regression – Daily Internal Trip Ends – Model 11

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment - Other	2.0455	12.86	0.00	1.73	2.36	0.55
Household	-0.1347	-1.31	0.19	-0.34	0.07	
Manufacturing	0.9137	15.26	0.00	0.80	1.03	
Population	0.0568	1.49	0.14	-0.02	0.13	
Retail	0.0826	1.63	0.10	-0.02	0.18	
Services	0.0087	0.82	0.42	-0.01	0.03	

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Transport & Communications	0.0455	0.69	0.49	-0.08	0.17	

Households again indicated a negative relationship. Households were removed and the regression was rerun.

Table 7-9: Zonal-based Regression – Daily Internal Trip Ends – Model 12

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment - Other	2.0251	12.79	0.00	1.71	2.34	0.55
Manufacturing	0.9115	15.22	0.00	0.79	1.03	
Population	0.0077	1.39	0.16	0.00	0.02	
Retail	0.0699	1.41	0.16	-0.03	0.17	
Services	0.0089	0.84	0.40	-0.01	0.03	
Transport & Communications	0.0499	0.76	0.45	-0.08	0.18	

There is a strong relationship to Manufacturing and Employment - Other (t-statistic and p-value). The relationship to service and Transport & Communications is weak (with low t-statistics and high p-values), although the coefficient values remain positive. The lower Adjusted R-Squared represents the lumpiness of the sample, which disappears when aggregated to sectors. Significantly, all types of employment are reflected as is a home-based variable (Population).

Following client and stakeholder review, it was requested that households be tested instead of population for the sector-based regressions reported in the previous section. This was also applied to the zonal based regressions and hence population in Model 12 above was replaced with households in Model 13 below.

Table 7-10: Zonal-based Regression – Daily Internal Trip Ends – Model 13

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment - Other	2.0314	12.79	0.00	1.72	2.34	0.55
Manufacturing	0.9146	15.26	0.00	0.80	1.03	
Households	0.0179	1.19	0.23	-0.01	0.05	
Retail	0.0697	1.40	0.16	-0.03	0.17	
Services	0.0091	0.85	0.39	-0.01	0.03	
Transport & Communications	0.0499	0.76	0.45	-0.08	0.18	

The statistical metrics are very similar in Model 13 to Model 12, and hence Model 13 was taken forward.

Model 13 zonal estimates compared with observed are shown in the scatter plot below. At this stage, only zones with a trip in the expanded eRUC matrix are shown.

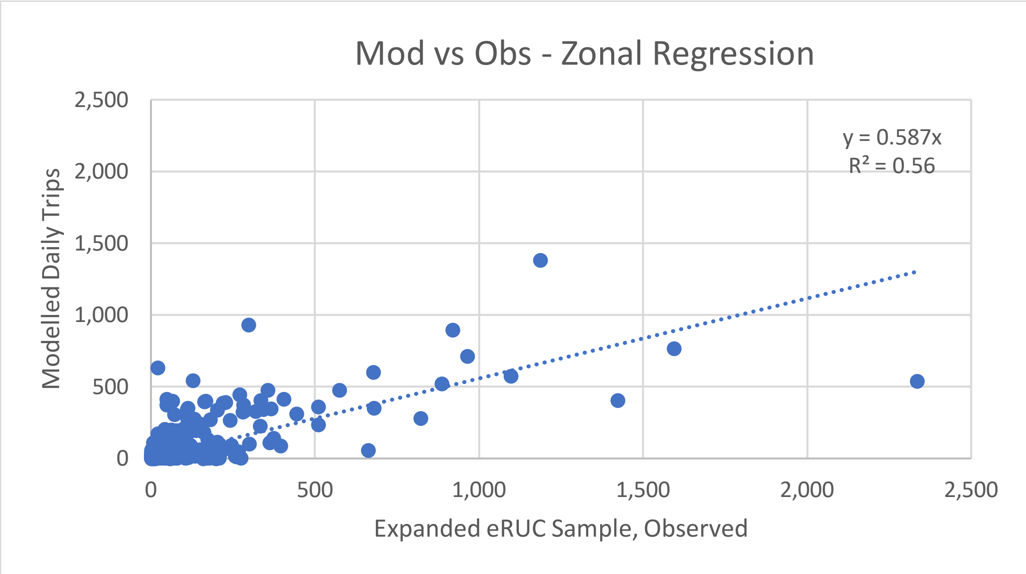


Figure 7-2: Internal Trip Ends – Zone-Based Regression

The large observed values are partly a function of the expansion, which increases the sampled origin-destination pairs to match screenline and trip rate totals. The higher trips for sampled origin-destinations compensates for unobserved trips. This is smoothed/rectified by the application of the synthetic model.

Model 13 was then applied to all zones (irrespective of whether there was an observation in the sample eRUC) and the output daily heavy commercial vehicle trips aggregated to sectors, which is shown below. The adjusted coefficients are calculated so that the total number of daily trips in the expanded eRUC sample is reproduced. All zones including zone 391 (which contains the Port and surrounding activity) were included in this calculation.

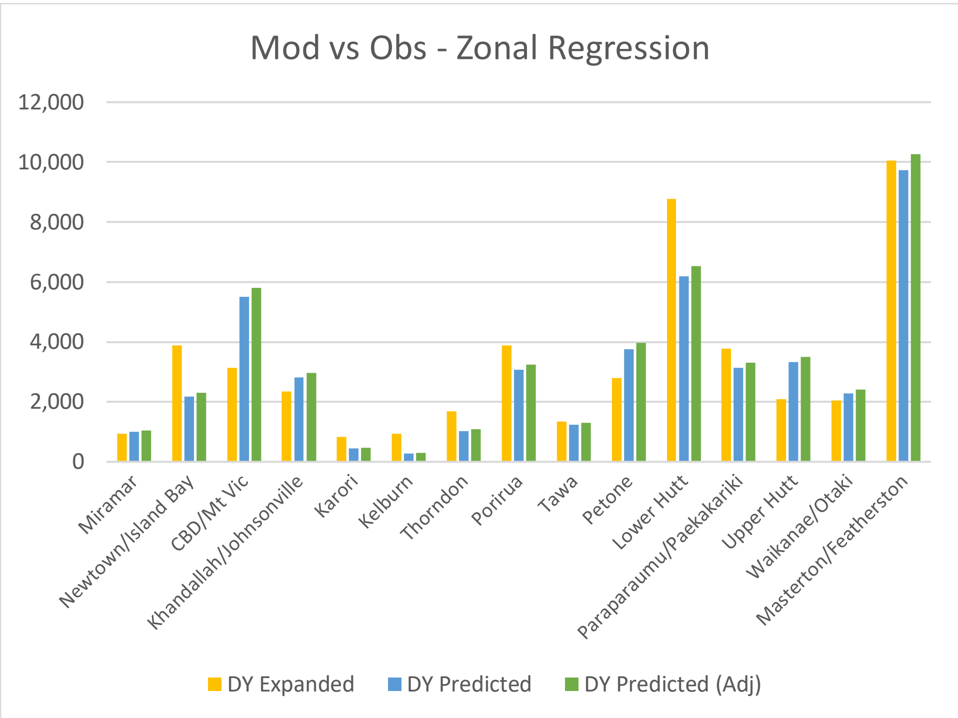


Figure 7-3: Internal Trip Ends – Zone-Based Regression – Results by Sector (Model 13)

There is more variation in this model (compared with the model calculated at a sector basis) with trips in Newtown/Island Bay (sector 2) and Lower Hutt (sector 80) underestimated, and CBD/Mt Vic (sector 4) overestimated. This model, however, includes all the employment types which has stronger explanatory power from a transport planning perspective.

7.1.3 Internal Attractions – Model Selection

The application of Model 6 (sector-based regression) and Model 13 (zone-based regression) is shown below with the daily predicted trips aggregated to sectors in the case of the zonal model. Note that the zonal model has only been applied to zones with observed trips. Adjustment so that the correct total observed trips is reproduced has not been applied in either case.

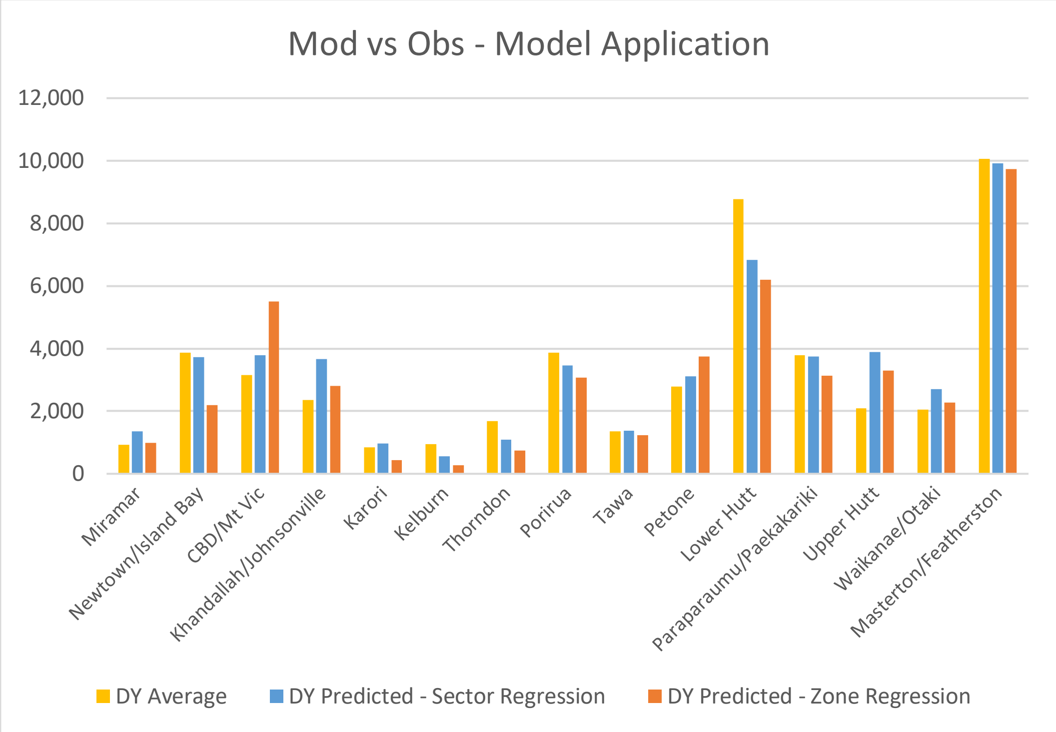


Figure 7-4: Internal Trip Ends – Application of Model 6 (sector) and Model 13 (zonal)

This clearly shows that Model 13, which is preferred as it includes all employment types, will likely overestimate trips to CBD/Mt Vic (sector 4) and underestimate Newtown/Island Bay (sector 2) and Lower Hutt (sector 80). The under and overestimate for Newtown/Island Bay and CBD/Mt Vic (sectors 2 and 4) respectively is exacerbated in Model 13 (zonal) compared with Model 6 (sector). The underestimate for Lower Hutt (sector 80) is similar between the models.

Model 13 (zone-based regression) is still preferred as it includes all the employment types and is more responsive to changes in land use. The application of the model may highlight discrepancies that warrant further adjustment.

The adopted Model 13 for daily internal trip ends is shown below, with the estimated and adjusted coefficient values.

Table 7-11: Daily Internal Trip Ends – Adopted Model 13

Variable	Original Coefficient	Adjusted (Adopted) Coefficients
Employment – Other	2.0314	2.1440
Manufacturing	0.9146	0.9653
Households	0.0179	0.0188
Retail	0.0697	0.0735
Services	0.0091	0.0096
Transport & Communications	0.0499	0.0527

7.2 Trip Distribution

The expanded and sample eRUC trip length distribution (daily internal trips) is shown below to benchmark the calculation and refinement of the alpha parameter in the gravity model.

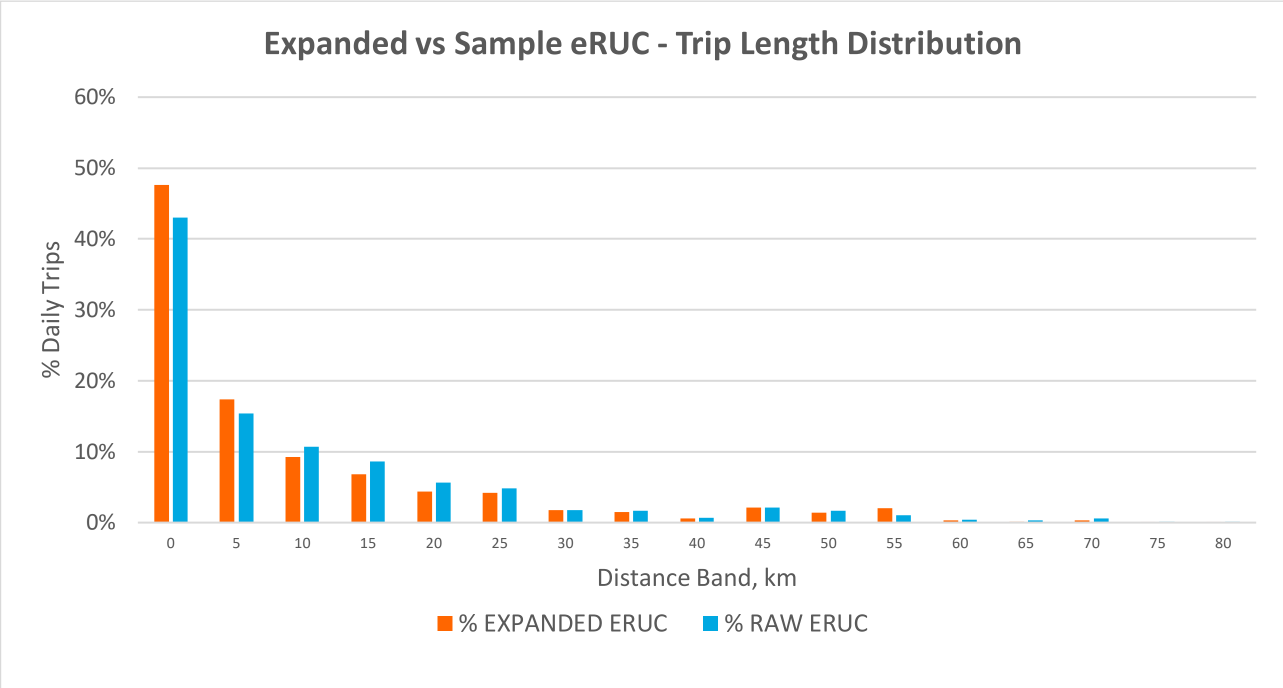


Figure 7-5: Internal Trips – Trip Length Distribution – Sample and Expanded eRUC

The expansion has slightly shortened the trips as discussed in Section 5.3. The average trip length for the sample and expanded eRUC is tabulated below also for benchmarking purposes. Intra-sector and inter-sector are tracked as different expansion processes were applied.

Table 7-12: Sample and Expanded eRUC – Average Trip Length of Internal Trips

	Average Trip Length (km)	
	Sample eRUC	Expanded eRUC
Intra-sector	9.88	10.23
Inter-sector	20.23	13.90
Total Internal	13.93	11.62

For the expanded eRUC internal trips, each OD was divided by the total origins multiplied by the total destinations for that zone ($T_{ij}/(P_i\ A_j)$). The $T_{ij}/(P_i\ A_j)$ values were then grouped into bands and a weighted distance calculated for each band. Trips were summed for each band. This method removes the vertical scatter and by banding the data, enables a trend to be determined. The natural logarithm of the weighted $T_{ij}/(P_i\ A_j)$ for each band was then calculated. The results are plotted below.

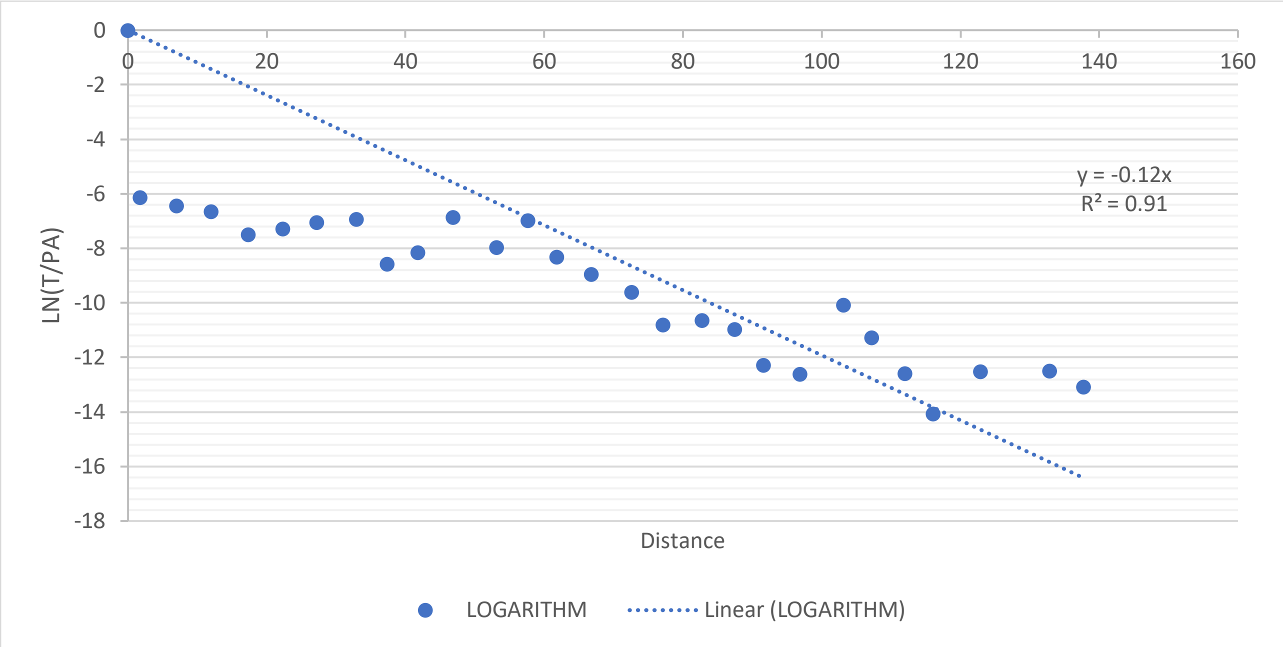


Figure 7-6: Internal Trip Distance – Estimation of Alpha Parameter for Gravity Model

The slope of the trendline provides the alpha value, which is -0.12. The R-Squared value for the trendline is strong.

Next the gravity model with alpha set to -0.12 was applied to the synthetic internal trip ends reported in Section 7.1.3. The resulting trip length frequency is shown below against the expanded eRUC.

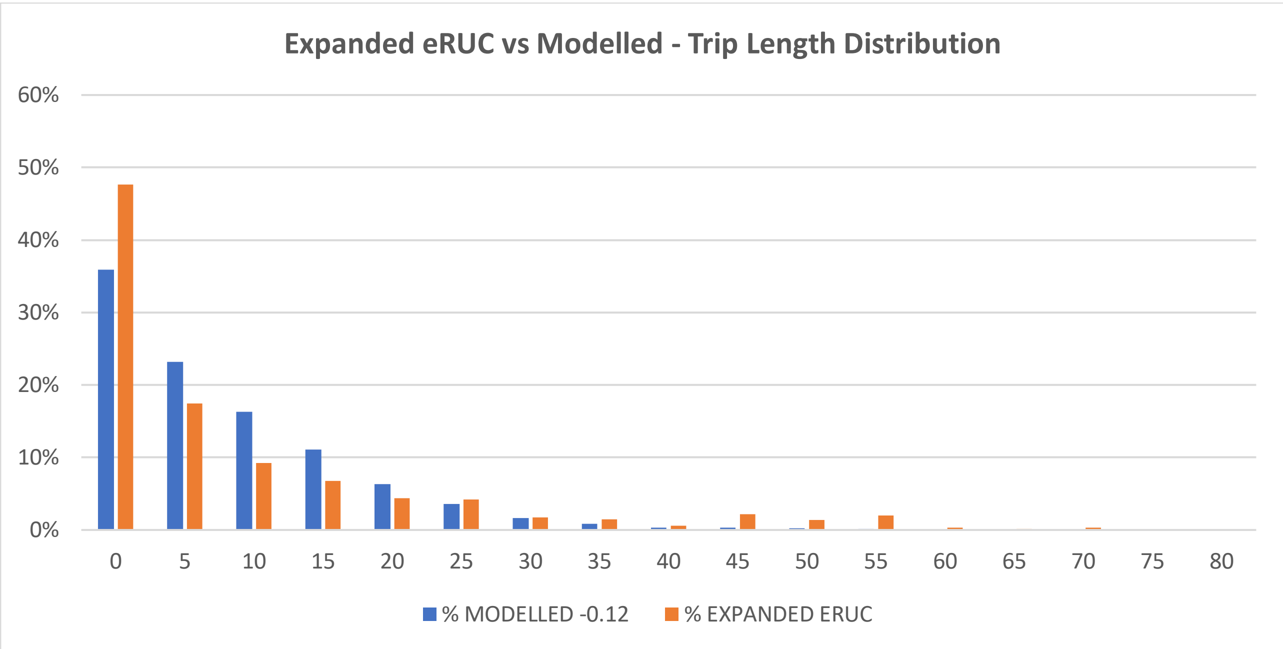


Figure 7-7: Internal Trips – Trip Length Distribution – Observed vs Modelled (α=-0.12)

The model underestimates the very short trips (<5km) but overestimates trips 5-20km. Overall, the modelled average trip length is slightly too short as shown in Table 7-11. Different values of alpha were tested to improve the match of the modelled average trip length to observed, and are tabulated below.

Table 7-13: Sample and Expanded eRUC – Average Trip Length of Internal Trips

Alpha	Average Trip Length (km)		
	Sample eRUC	Expanded eRUC	Modelled
-0.12	13.93	11.62	10.39
-0.11			11.17
-0.10			12.08
-0.08			14.46

The optimum value for alpha appears to be is -0.11 which reproduces the average trip length of the expanded eRUC. Trip length distributions are shown below for applying an alpha value of -0.08 and -0.11 respectively to the synthetic trip ends.

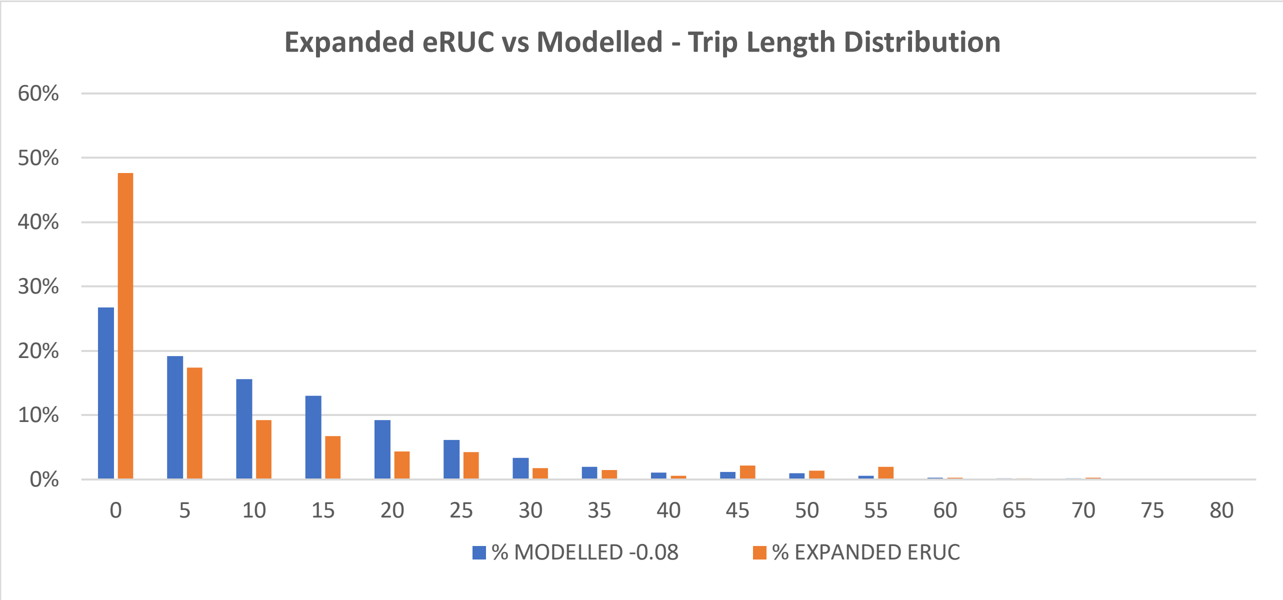


Figure 7-8: Internal Trips – Trip Length Distribution – Observed vs Modelled (α=-0.08)

Figure 7-8 clearly shows that the modelled trip length is too long. An alpha value of -0.08 also significantly underestimates the trips less than 5km.

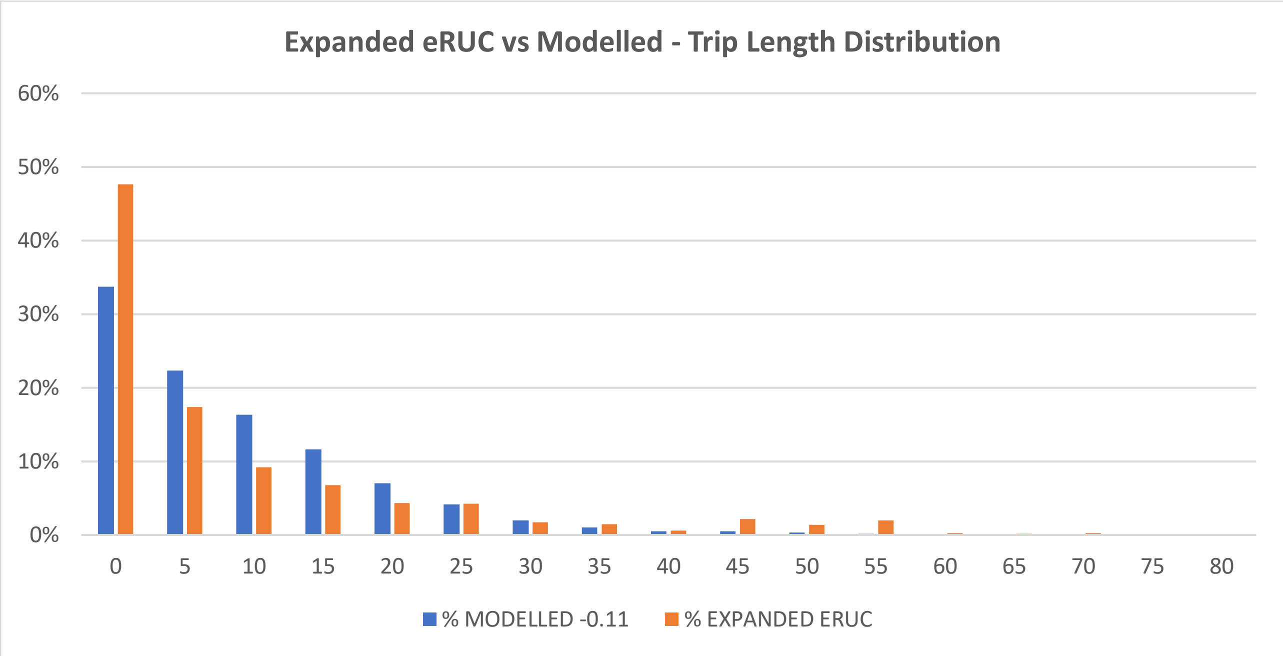


Figure 7-9: Internal Trips – Trip Length Distribution – Observed vs Modelled (α=-0.11)

While an alpha value of -0.11 still underestimates very short trips (<5km), the expanded sample does have a slightly shorter trip length than the original sample eRUC. So estimating fewer short trips is considered acceptable.

8. Port Model

For trips to/from the Port, the traffic volume at one end of the trip is known. This means that only the non-Port end of trips needs to be predicted. Hence the "distribution" of trips for the Port is calculated by applying a linear regression model. Again, the dependent variable is the expanded eRUC sample (non-Port end) and the independent/explanatory variables are the input land use by zone. Daily inbound and outbound trips were averaged so that a single model is applied for the origin (inbound) and destination (outbound) of Port trips. Port to road external trips are excluded at this stage as there is no land use to regress against.

The observed trips are shown below aggregated to sector.

Table 8-1: Expanded Port eRUC Observed Origins and Destinations by Sector

Sector		Daily Expanded Origins	Daily Expanded Destinations	Daily Expanded Average
1	Miramar	5	6	5
2	Newtown/Island Bay	12	19	15
4	CBD/Mt Vic	38	51	44
6	Khandallah/Johnsonville	105	117	111
31	Karori	1	1	1
32	Kelburn	1	1	1
51	Thorndon	32	42	37
71	Porirua	63	47	55
72	Tawa	30	42	36
73	Petone	84	86	85
80	Lower Hutt	213	213	213

Sector		Daily Expanded Origins	Daily Expanded Destinations	Daily Expanded Average
91	Paraparaumu/Paekakariki	68	116	92
92	Upper Hutt	73	74	74
101	Waikanae/Otaki	20	34	27
102	Masterton/Featherston	246	255	251
Total		**991**	**1103**	**1047**

8.1 Port Trips – Sector-Based Regression

Regression was initially undertaken on a sector basis, as that smooths out the lumpiness of the observed sample. All independent variables were initially included, with the results shown in the table below.

Table 8-2: Sector-based Regression – Daily Port Distribution – Model 1

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment - Other	0.0521	4.49	0.00	0.03	0.08	0.93
Household	-0.0036	-0.47	0.65	-0.02	0.01	
Manufacturing	0.0625	3.78	0.01	0.02	0.10	
Population	0.0011	0.38	0.71	-0.01	0.01	
Retail	-0.0428	-2.13	0.07	-0.09	0.00	
Services	0.0049	1.56	0.16	0.00	0.01	
Transport & Communications	0.0017	0.16	0.88	-0.02	0.03	

Households and Retail showed a negative relationship which is unacceptable. As households is reflected by population, households were removed and the regression rerun.

Table 8-3: Sector-based Regression – Daily Port Distribution – Model 2

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment - Other	0.0494	5.09	0.00	0.03	0.07	0.93
Manufacturing	0.0640	4.13	0.00	0.03	0.10	
Population	-0.0002	-0.45	0.67	0.00	0.00	
Retail	-0.0444	-2.34	0.04	-0.09	0.00	
Services	0.0050	1.70	0.12	0.00	0.01	
Transport & Communications	0.0013	0.12	0.91	-0.02	0.03	

Now Population and Retail showed a negative relationship. Population was removed as it had the weakest relationship. The regression was rerun as shown below.

Table 8-4: Sector-based Regression – Daily Port Distribution – Model 3

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment - Other	0.0497	5.35	0.00	0.03	0.07	0.94
Manufacturing	0.0594	5.37	0.00	0.03	0.08	
Retail	-0.0425	-2.39	0.04	-0.08	0.00	

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Services	0.0049	1.74	0.11	0.00	0.01	
Transport & Communications	-0.0001	-0.01	0.99	-0.02	0.02	

Retail and Transport & Communications have a negative relationship, the latter was removed as it has the weakest explanatory power.

Table 8-5: Sector-based Regression – Daily Port Distribution – Model 4

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment - Other	0.0497	5.63	0.00	0.03	0.07	0.95
Manufacturing	0.0594	5.64	0.00	0.04	0.08	
Retail	-0.0425	-2.51	0.03	-0.08	-0.01	
Services	0.0049	1.87	0.09	0.00	0.01	

Retail continued to show a negative relationship and was removed.

Table 8-6: Sector-based Regression – Daily Port Distribution – Model 5

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment - Other	0.0459	4.39	0.00	0.02	0.07	0.92
Manufacturing	0.0344	8.23	0.00	0.03	0.04	
Services	-0.0016	-2.66	0.02	0.00	0.00	

Now Services had a negative coefficient value and had to be removed.

Table 8-7: Sector-based Regression – Daily Port Distribution – Model 6

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment - Other	0.0509	4.08	0.00	0.02	0.08	0.89
Manufacturing	0.0266	7.39	0.00	0.02	0.03	

The final Port regression model has a good Adjusted R-squared value and both explanatory variables show strong relationships. However, not all employment types are included, which is poor from a transport planning perspective. Total employment was then added back in to address this.

Table 8-8: Sector-based Regression – Daily Port Distribution – Model 7

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment – Other	0.0472	4.60	0.00	0.02	0.07	0.93
Manufacturing	0.0368	7.77	0.00	0.03	0.05	
Total Employment	-0.0013	-2.74	0.02	0.00	0.00	

Unfortunately, a strong negative relationship to total employment was found and so the best model estimated on a sector basis remains as Model 6.

8.2 Port Trips – Zone-Based Regression

Regressions on a zonal basis were then undertaken. Zones with zero observed trips were removed from the estimation. All variables were added initially.

Table 8-9: Zone-based Regression – Daily Port Distribution – Model 11

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment - Other	0.0870	4.76	0.00	0.05	0.12	0.37
Household	-0.0230	-1.33	0.18	-0.06	0.01	
Manufacturing	0.0356	5.73	0.00	0.02	0.05	
Population	0.0070	1.04	0.30	-0.01	0.02	
Retail	-0.0038	-0.66	0.51	-0.02	0.01	
Services	-0.0012	-0.95	0.35	0.00	0.00	
Transport & Communications	0.0250	3.01	0.00	0.01	0.04	

Households, and retail and services employment showed negative relationships. Households were removed as population is still included.

Table 8-10: Zone-based Regression – Daily Port Distribution – Model 12

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment - Other	0.0867	4.73	0.00	0.05	0.12	0.37
Manufacturing	0.0361	5.82	0.00	0.02	0.05	
Population	-0.0019	-2.02	0.05	0.00	0.00	
Retail	-0.0050	-0.89	0.38	-0.02	0.01	
Services	-0.0013	-1.04	0.30	0.00	0.00	
Transport & Communications	0.0255	3.06	0.00	0.01	0.04	

Now Population, Retail and Services showed negative relationships. Population was removed as from a transport planning perspective it is less likely to be associated with trips to/from the Port.

Table 8-11: Zone-based Regression – Daily Port Distribution – Model 13

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment - Other	0.0713	4.24	0.00	0.04	0.10	0.36
Manufacturing	0.0331	5.44	0.00	0.02	0.05	
Retail	-0.0079	-1.43	0.16	-0.02	0.00	
Services	-0.0012	-0.99	0.32	0.00	0.00	
Transport & Communications	0.0256	3.04	0.00	0.01	0.04	

After rerunning, Retail and Services were still showing negative relationships. Services was removed as it had the lowest t-statistic.

Table 8-12: Zone-based Regression – Daily Port Distribution – Model 14

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment - Other	0.0713	4.24	0.00	0.04	0.10	0.36
Manufacturing	0.0329	5.40	0.00	0.02	0.04	
Retail	-0.0103	-2.04	0.04	-0.02	0.00	
Transport & Communications	0.0241	2.91	0.00	0.01	0.04	

Retail remained negative and was therefore removed.

Table 8-13: Zone-based Regression – Daily Port Distribution – Model 15

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment - Other	0.0692	4.08	0.00	0.04	0.10	0.34
Manufacturing	0.0255	5.15	0.00	0.02	0.04	
Transport & Communications	0.0205	2.51	0.01	0.00	0.04	

All variables now show a positive correlation to Port activity. The t-statistics are all greater than two, and p-values are less than 0.05. The adjusted R-squared is poor and reflects the lumpiness of the sample as well as the weak overall correlation. Similar to the sector-based regression, not all employment types are reflected which is poor. Total employment was again reintroduced.

Table 8-14: Zone-based Regression – Daily Port Distribution – Model 16

Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Employment - Other	0.0724	4.29	0.00	0.04	0.11	0.36
Manufacturing	0.0321	5.43	0.00	0.02	0.04	
Total Employment	-0.0020	-2.00	0.05	0.00	0.00	
Transport & Communications	0.0270	3.10	0.00	0.01	0.04	

Unfortunately, a strong negative relationship to total employment was found and so the best model estimated on a zone basis remains as Model 15.

8.3 Port Trips – Model Selection

The application of Model 6 (sector-based regression) and Model 15 (zone-based regression) is shown below with the daily predicted trips aggregated to sectors in the case of the zonal model. Note that the zonal model has only been applied to zones with observed trips. Adjustment so that the correct total observed trips is reproduced has not been applied in either case.

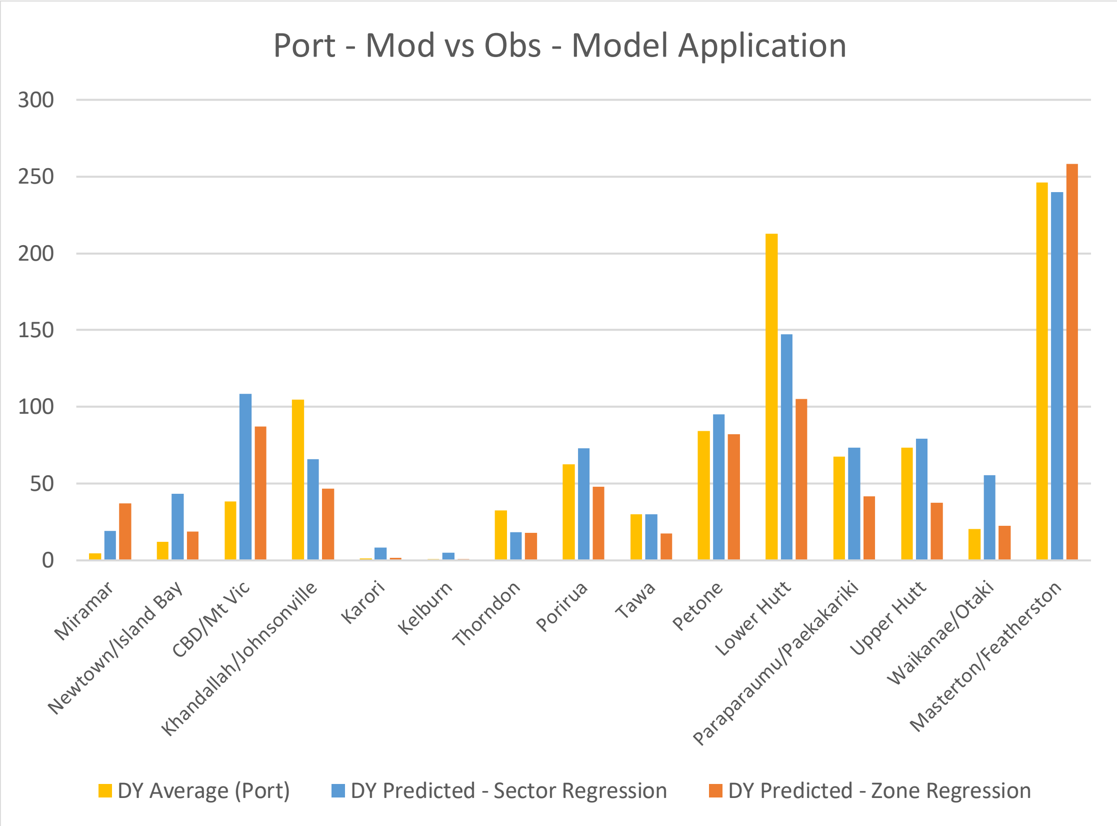


Figure 8-1: Port Trips – Application of Model 6 (sector) and Model 15 (zonal)

Again, the sector-based model tends to replicate observed slightly better aside from over-estimates for Newtown/Island Bay, CBD/Mt Vic and Waikanae/Otaki (sectors 2, 4, and 101 respectively). However, the largest of the overestimates only equates to 60 trips.

Model 15 (zonal) is preferred at this stage as it includes Transport & Communication – one more employment type than the sector-based regression.

The application of Model 15 is shown below to all zones. The adjusted coefficients values were then calculated so that the correct total number of trips (average inbound plus outbound) was reproduced.

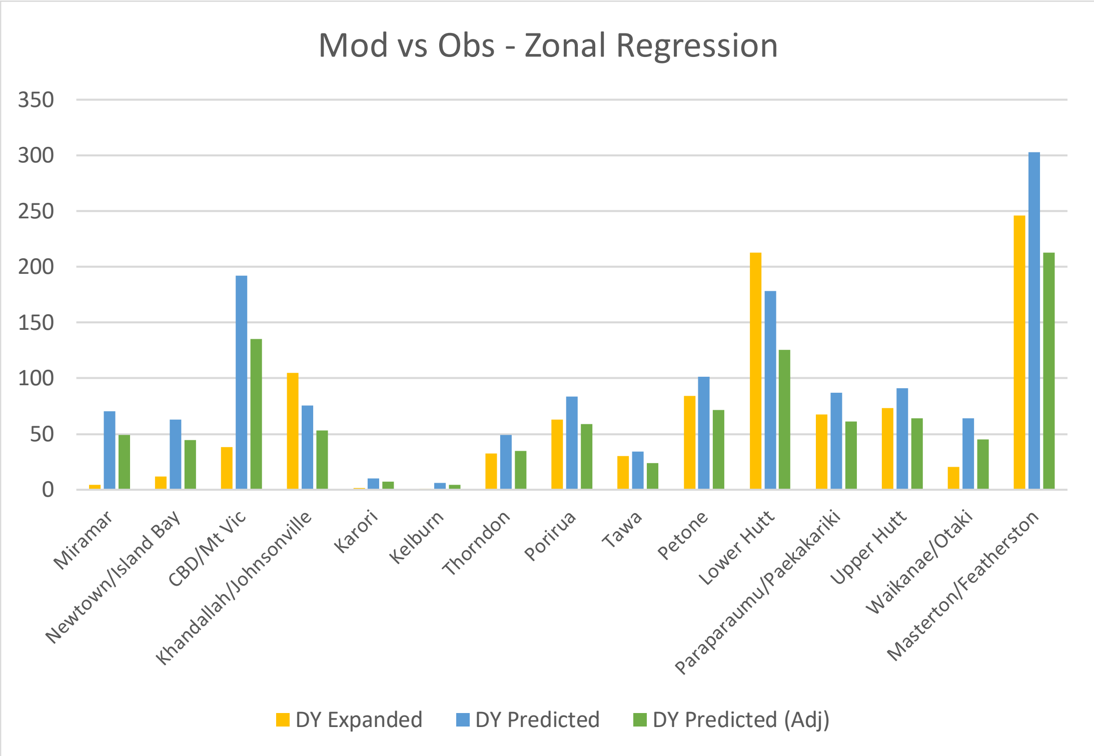


Figure 8-2: Port Trips – Zone-Based Regression – Results by Sector

The traffic count at the Port was then used to recalculate the final coefficient values for traffic inbound to the Port and outbound separately. The Port to external traffic was removed (see Section 11 for Port-external trips), with the remainder forming the target totals as shown in the table below.

Table 8-15: Target Port-Internal Trips

Metric	To Port	From Port
Daily Port Count	1207	1338
Less External	74	84
Target Count	1133	1254

The adopted inbound and outbound coefficients are shown in the following table for the daily heavy commercial vehicle Port trips model.

Table 8-16: Daily Port Trips – Adopted Model

Variable	Adjusted Coefficient, To Port	Adjusted Coefficient, From Port
Employment - Other	0.0556	0.0615
Manufacturing	0.0205	0.0227
Transport & Communications	0.0165	0.0183

These coefficients were applied on a zonal basis. The resulting trips by sector are tabulated below.

Table 8-17: Predicted Daily Trips to/from Port, Excluding Externals

Sector No	Sector Name	Daily Predicted Origins, To Port	Daily Predicted Destinations, From Port
1	Miramar	56	62
2	Newtown/Island Bay	51	56

Sector No	Sector Name	Daily Predicted Origins, To Port	Daily Predicted Destinations, From Port
4	CBD/Mt Vic	155	171
6	Khandallah/Johnsonville	61	67
31	Karori	8	9
32	Kelburn	5	5
51	Thorndon	40	44
71	Porirua	67	74
72	Tawa	28	31
73	Petone	82	90
80	Lower Hutt	144	159
91	Paraparaumu/Paekakariki	70	77
92	Upper Hutt	73	81
101	Waikanae/Otaki	51	57
102	Masterton/Featherston	243	269
Total		**1133**	**1254**

9. Ferry Terminal Models

9.1 Observed Data

The heavy vehicle volume data source was the same used in the Ferry Terminal Model. The source and data limitations are set out in Technical Note 14 (TN 14). Bluebridge trips were factored to March 2018 using the same approach as outlined in TN 14. The data provided by Bluebridge was in lineal metres. It was assumed that every 20m would equate to one heavy vehicle. 3.5hrs was added the departure time from Picton to allow for the Ferry crossing time, and 1 hour subtracted from the Wellington to Picton departure time to allow for when the vehicles arrived at the Ferry. The times were then grouped into four periods: AM (6am-9am), IP (9am-3pm), PM (3pm-6pm), and Overnight (6pm-6am).

A summary of the trip generation data is shown below.

Table 18: Trip Generation Summary

	Bluebridge – Picton to Wellington	Bluebridge – Wellington to Picton	Interislander – Picton to Wellington	Interislander – Wellington to Picton
AM	-	15	34	18
IP	12	16	31	11
PM	17	-	22	18
ON	41	43	57	78
Total	69	74	144	125

9.2 Trip Distribution Model

There was no observed data to calculate the distribution for the Interislander and Bluebridge Ferry terminals. The Interislander Ferry terminal is in the same zone as the Port and the eRUC data to/from this zone was used for the Port distribution. Hence the Port distribution was adopted and applied for the Interislander terminal. It seems likely that the heavy vehicle distribution will be similar for both ferry terminals, so the Port distribution was also used for Bluebridge.

Coefficients (to and from the Port) were adopted from the Port model distribution (refer to Table 8-16 above) and factored so that the total daily trips to and from each of the Ferry terminals was reproduced.

The resulting coefficients from this process are shown in tables below.

Table 9-19: Daily Bluebridge Trips – Adopted Model

Variable	Coefficient, To Bluebridge	Coefficient, From Bluebridge
Employment - Other	0.0036	0.0034
Manufacturing	0.0013	0.0013
Transport & Communications	0.0011	0.0010

Table 9-20: Daily Interislander Trips – Adopted Model

Variable	Coefficient, To Interislander	Coefficient, From Interislander
Employment - Other	0.0061	0.0071
Manufacturing	0.0023	0.0026
Transport & Communications	0.0018	0.0021

No comparisons to observed can be provided as there is no observed data. This is not considered significant as the vehicle numbers are relatively small.

No trips have been specifically modelled between the Port and either of the Ferry terminals since there is no observed data. These trips are included in the Port model but will be to/from the internal zones where the Interislander and Bluebridge terminals are located (i.e. the ferry is not identified separately from other activity/land use in the same zone).

Similarly, trips from the two road externals to the two ferry terminals are not explicitly represented for the same reason. These trips are included in the External model (see Section 10) and are represented as to/from the internal zones where each of the ferry terminals is located.

If there was an order-of-magnitude change in ferry terminal traffic, then an adjustment would be warranted in the model. However, given the magnitude of the daily generation, this simplistic assumption seems appropriate.

10. Road Externals Models

Similar to the Port, for trips to/from the road externals in the north, one end of the trip is clearly known. This means that only the internal end of trips needs to be predicted. So the "distribution" of trips is calculated by applying a linear regression model. Again, the dependent variable is the expanded eRUC sample (internal trip end) and the independent/explanatory variables are the input land use by zone. Daily inbound and outbound trips were averaged so that a single model is applied for the origin (inbound) and destination (outbound) of external trips.

To determine if a single distribution model can be produced the sectors where trips to and from the SH1 and SH2 northern externals is shown below.

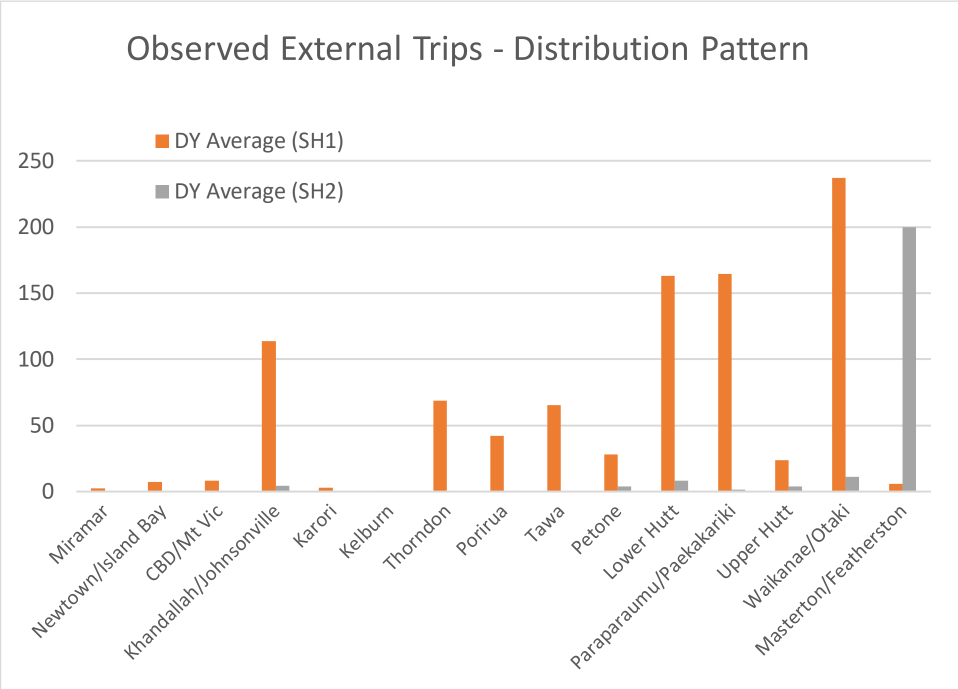


Figure 10-1: Sector for Internal End of External Trips

Clearly, there is a very different pattern, so separate models for SH1 and SH2 will be required.

10.1 SH1 External Trips

The same approach to the regression was carried out, with forwards and backwards stepwise regression using all the variables. It was difficult to find any relationship. Both zonal (excluding zones without any observed trips) and sector-based regressions were tested.

Based on the trip pattern in Figure 10-1, it seems that the distance to/from the external location plays a key role. This is because there is a large number of trips to/from Waikanae/Otaki (sector 101) which is adjacent to the SH1 external and a similarly high number of trips to/from Masterton/Featherston (sector 102) which is adjacent to SH2.

The distance (from an internal zone to the external) was extracted from the skimmed distance matrix and included in the regression with the inverse of distance. The average of to and from the external zone was used.

The correlation between these variables and average daily trips to SH1 is shown below. Dominant employment types divided by distance were also examined.

Table 10-1: Correlation Matrix for Average Daily Trips to SH1

Variable	Pearson's R	p-value
Population	0.267	0.336
Employment Other	-0.127	0.651
Manufacturing	0.221	0.429
Retail	-0.059	0.834
Transport & Communications	-0.188	0.501
Services	-0.128	0.65
Total Employment	-0.105	0.711
Ave. Distance to SH1	-0.764	<0.001
Inverse Ave. Distance to SH1	0.73	0.002
Manufacturing/Ave. Distance to SH1	0.776	<0.001

Variable	Pearson's R	p-value
Transport & Communications /Ave. Distance to SH1	0.036	0.899
Total Employment /Ave. Distance to SH1	0.242	0.386

There is a strong negative correlation to distance, and a strong positive correlation to the inverse of distance. Manufacturing jobs divided by distance shows an equally strong relationship.

The model results for sector and zonal regressions using manufacturing employment divided by distance is shown below.

Table 10-2: SH1 External – Model 1

Analysis Type	Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Sector	Manufacturing/Ave. Distance to SH1	1.8224	6.69	0.00	1.24	2.41	0.74
Zonal		1.7262	10.33	0.00	1.40	2.06	0.38

As seen before, the Adjusted R-Squared is poor at a zonal level at least in part due to the sparseness of the sample (which may in fact be representative). The Adjusted R-Squared improves when the regression is run by sector. In both cases, the t-statistic is strong as is the p-value.

However, this model will show no response if other types of employment increase. To address this, total employment was added even though Table 10-1 shows limited correlation.

Table 10-3: SH1 External – Model 2

Analysis Type	Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Sector	Manufacturing/Ave. Distance to SH1	2.2884	7.09	0.00	1.59	2.99	0.80
	Total Employment	-0.0013	-2.18	0.05	-0.0026	0.0000	
Zonal	Manufacturing/Ave. Distance to SH1	1.6182	8.58	0.00	1.25	1.99	0.38
	Total Employment	0.0012	1.23	0.22	-0.0007	0.0031	

At a sector-level, the coefficient is negative although it has the same value but positive at a zonal level. Including total employment will ensure the model is responsive and this is more desirable from a transport planning perspective.

Of interest, the value of the coefficient for manufacturing employment divided by distance is quite different for the sector and zonal level regressions. The zonal regression will be adopted as the coefficient value is similar in magnitude to the previous model, prior to forcing in total employment. Total employment divided by distance to/from SH1 was tested instead of total employment. This produced a larger overestimate to the CBD as a result of the coefficient values and less reliance on manufacturing.

The zonal model including total employment was applied and the predicted daily trips aggregated to sectors. To ensure a like-with-like comparison, the coefficients were adjusted so that the total number of trips was correct. These adjusted coefficients will require subsequent refinement to consider directionality and remove the Port-external traffic which is handled separately. The comparison of observed with the model application is provided below.

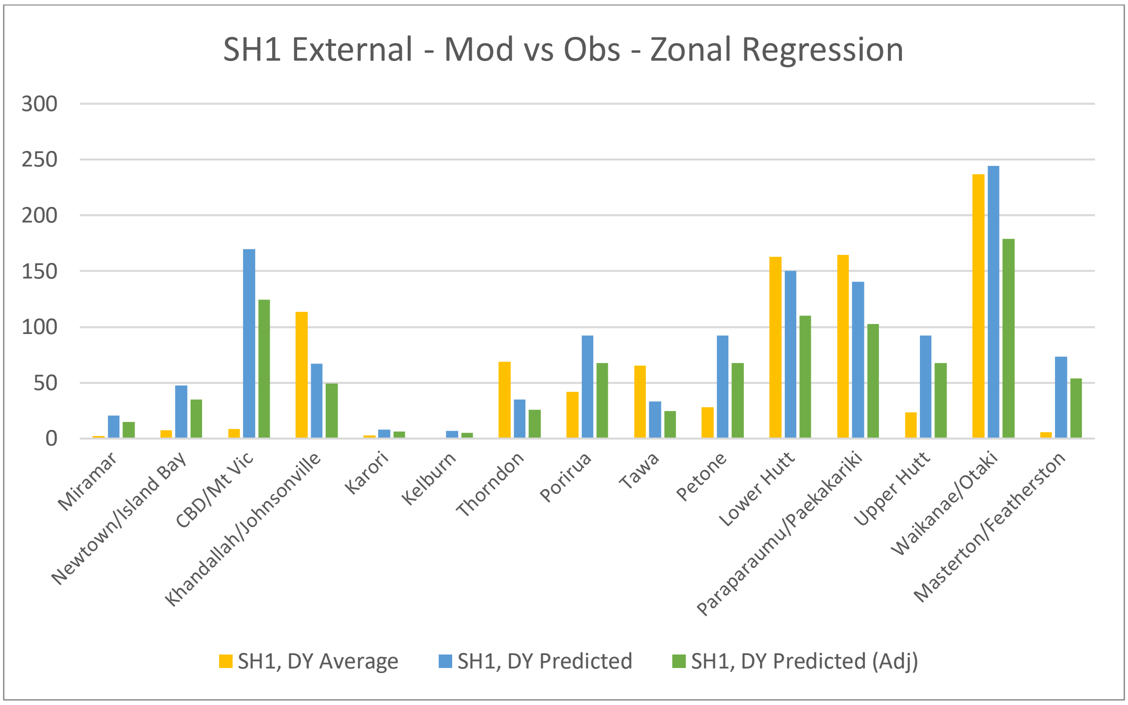


Figure 10-2: SH1 External - Application of Zonal Regression Model, Aggregated to Sectors

The model significantly overestimates trips to/from the CBD (sector 4), although the magnitude is less than 200. This is half associated with forcing in total employment to ensure the model is responsive and half model overestimation. Similarly, Miramar (sector 1) and Newtown/Island Bay (sector 2) are overestimated for the same reason.

The model is, at best, an average fit, although the magnitudes of the numbers is very small.

The alternative would be to adopt the observed expanded eRUC and apply growth factoring for future years. This is not preferred as the observed is exceptionally lumpy. Applying the synthetic model will smooth out the inconsistencies found in the observed due to sampling.

The traffic count at the SH1 external was then used to recalculate the final coefficient values for traffic inbound to the study area and outbound separately. The external to Port traffic was removed, with the remainder forming the target totals as shown in the table below.

Table 10-4: Target SH1 Exterrnal Trips

Metric	Inbound/South	Outbound/North
Daily Count	1011	1042
Less Trips to/from Port	71	80
Target Volume	940	962

Note that there are no trips from the SH1 external to the SH2 external.

The adopted inbound and outbound coefficients are shown in the following table for the daily heavy commercial vehicle SH1 external trips model.

Table 10-5: Daily SH1 Trips – Adopted Model

Variable	Inbound/South	Outbound/North
Manufacturing/Ave. Distance to SH1	1.19401	1.22238
Total Employment	0.00087	0.00089

These coefficients were applied and the resulting trips by sector are tabulated below.

Table 10-6: Predicted Daily Trips to/from SH1 External, Excluding Port

Sector No.	Sector Name	Daily Predicted Origins, Inbound	Daily Predicted Destinations, Outbound
1	Miramar	15	15
2	Newtown/Island Bay	35	36
4	CBD/Mt Vic	125	128
6	Khandallah/Johnsonville	50	51
31	Karori	6	6
32	Kelburn	5	5
51	Thorndon	26	26
71	Porirua	68	70
72	Tawa	25	25
73	Petone	68	70
80	Lower Hutt	111	113
91	Paraparaumu/Paekakariki	104	106
92	Upper Hutt	68	70
101	Waikanae/Otaki	180	185
102	Masterton/Featherston	54	55
Total		**940**	**962**

10.2 SH2 External Trips

The same approach was followed for the SH2 external.

The correlation between these variables and average daily trips to SH2 is shown below. Dominant employment types divided by distance were also examined.

Table 10-7: Correlation Matrix for Average Daily Trips to SH2

Variable	Pearson's R	p-value
Household	0.25	0.369
Population	0.188	0.501
Employment Other	0.996	<0.001
Manufacturing	0.28	0.312
Retail	0.075	0.791
Transport & Communications	-0.093	0.742
Services	-0.053	0.852
Total Employment	0.028	0.922
Ave Distance to SH2	-0.875	<0.001
Inverse Ave Distance to SH2	0.998	<0.001
Manufacturing/Ave. Distance to SH2	0.676	0.006
Transport & Communications /Ave. Distance to SH2	0.096	0.732
Total Employment /Ave. Distance to SH2	0.311	0.26

There is a strong positive correlation to the inverse of distance and other employment. No other employment type shows any strong relationship.

The model results for sector and zonal regressions using other employment divided by distance is shown below.

Table 10-8: SH2 External – Model 1

Analysis Type	Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Sector	Employment Other/Ave. Distance to SH2	4.0646	79.75	0.00	3.95	4.18	1.00
Zonal		3.4948	9.74	0.00	2.78	4.21	0.59

In both models, the t-statistics and p-values are strong. The Adjusted R-Squared is excellent at a sector-level regression but still good at a zonal level given the lumpiness of the data. Again, this model will not respond to most land use changes and is therefore weak from a transport planning perspective. Total employment was added, the results are shown below.

Table 10-9: SH2 External – Model 2

Analysis Type	Variable	Coefficient	t-statistic	p-value	Lower 95%	Upper 95%	Adjusted R-Squared
Sector	Employment Other/Ave. Distance to SH2	4.0343	76.04	0.00	3.91	4.16	1.00
	Total Employment	0.0001	1.38	0.21	-0.0001	0.0002	
Zonal	Employment Other/Ave. Distance to SH2	2.8264	7.19	0.00	2.04	3.61	0.64
	Total Employment	0.0025	3.24	0.00	0.0010	0.0041	

All coefficients values are positive, the t-statistics are acceptable with total employment showing a strong relationship in the zonal regression. The Adjusted R-Squared values are also acceptable.

The values of the coefficient for other employment divided by distance are again very different in the sector and zonal regressions. In this case, the sector regression will be adopted as it is similar in magnitude to the previous model before total employment was added.

The sector-based model was applied on a zonal basis, and the results aggregated to sectors. For comparison purposes, the coefficient values were factored so that the correct number of trips was produced. The results are shown below. Further adjustment of the coefficients will be undertaken to consider directionality and Port-external trips which are handled separately.

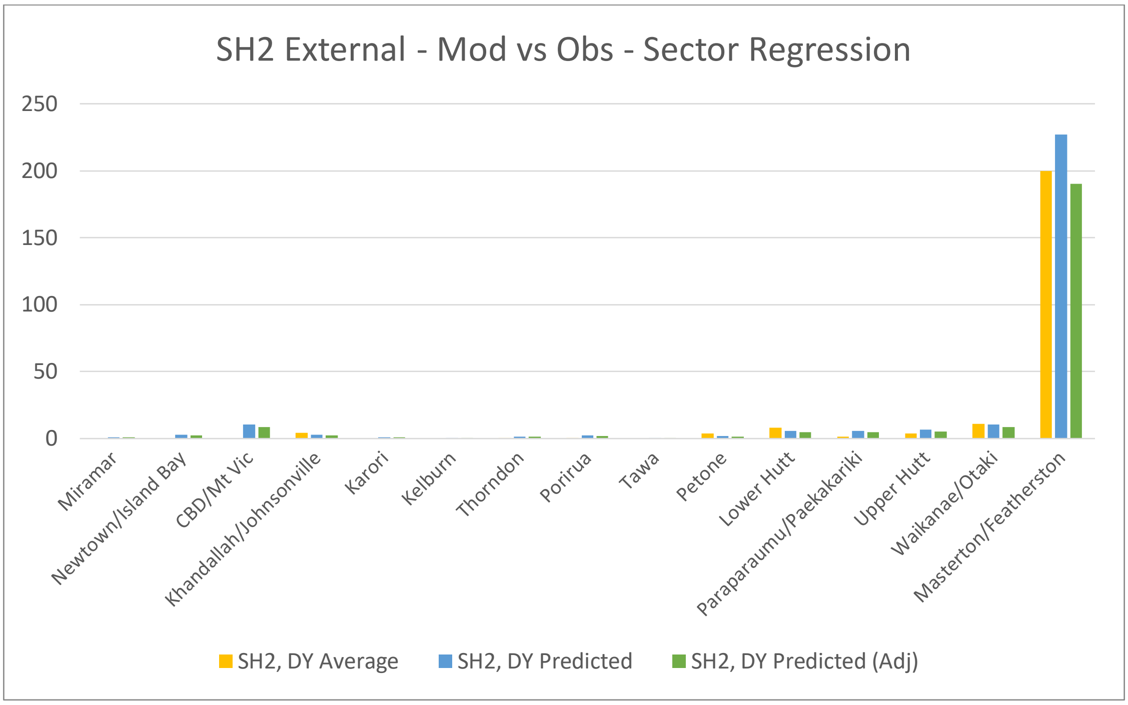


Figure 10-3: SH2 External - Application of Sector Regression Model, Aggregated to Sectors

At this scale, the model appears to perform satisfactorily. Section 102 was removed from the graph to examine trips to/from sectors other sectors.

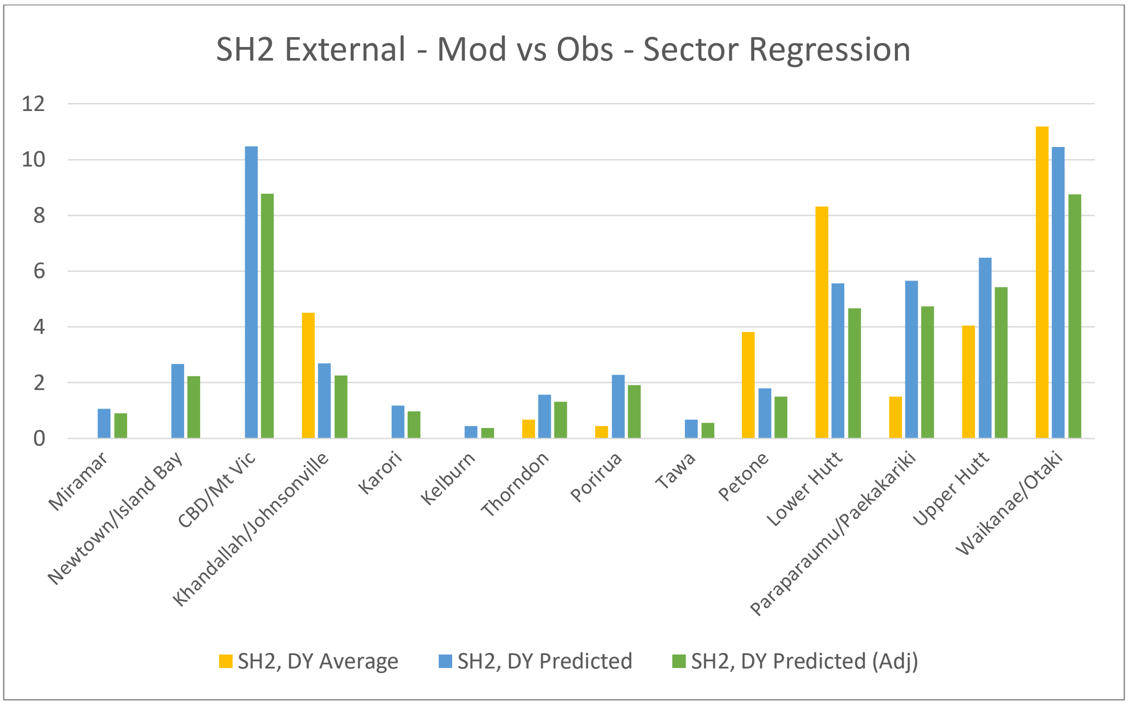


Figure 10-4: SH2 External - Application of Sector Regression Model, Aggregated to Sectors – No Sector 102

While Figure 10-4 shows considerable variation, the scale has a maximum of 12 daily trips. This variation is therefore considered acceptable.

The traffic count at the SH2 external was then used to recalculate the final coefficient values for traffic inbound to the study area and outbound separately. The external to Port traffic was removed, with the remainder forming the target totals as shown in the table below.

Table 10-10: Target SH2 External Trips

Metric	Inbound/South	Outbound/North
Daily Count	212	266
Less Trips to/from Port	3	4
Target Volume	209	262

Note that there are no trips from the SH1 external to the SH2 external.

The adopted inbound and outbound coefficients are shown in the following table for the daily heavy commercial vehicle SH1 external trips model.

Table 10-11: Daily SH2 Trips – Adopted Model

Variable	Inbound/South	Outbound/North
Employment Other/Ave. Distance to SH2	3.018218	3.777114
Total Employment	0.000055	0.000069

These coefficients were applied and the resulting trips by sector are tabulated below.

Table 10-12: Predicted Daily Trips to/from SH2 External, Excluding Port to External Trips

Sector No	Sector Name	Daily Predicted Origins, Inbound	Daily Predicted Destinations, Outbound
1	Miramar	1	1
2	Newtown/Island Bay	2	2
4	CBD/Mt Vic	8	10
6	Khandallah/Johnsonville	2	3
31	Karori	1	1
32	Kelburn	0	0
51	Thorndon	1	1
71	Porirua	2	2
72	Tawa	1	1
73	Petone	1	2
80	Lower Hutt	4	5
91	Paraparaumu/Paekakariki	4	5
92	Upper Hutt	5	6
101	Waikanae/Otaki	8	10
102	Masterton/Featherston	170	212
Total		**209**	**262**

11. Port to/from External Trips

Port to external trips, and vice versa, cannot be estimated using linear regression as the externals have no associated land use. Similarly, while the Port has employment in reality, it is not distinguished separately in the Census but combined with the other development in the meshblock containing the Port.

In the absence of any explanatory data, the Port to/from external trips (defined as the two road externals in the north) will be estimated to retain the current proportions as shown in the following table.

Table 11-1: Port-External Proportions, expanded eRUC

	From the Port	To the Port
Internal	1,103	991
External SH1	80	71
External SH2	4	3
Total	1,187	1,065
Proportion External SH1	6.7%	6.7%
Proportion External SH2	0.3%	0.2%

In forecast mode, internal trips to and from the Port are calculated by applying the model reported in Section 8 of this report. Port to external traffic (and vice-versa for external to Port) is then calculated using the following formula.

$$(Port\text{->}External)_F = (Port\text{->}Internal)_F/(1-X/100) - (Port\text{->}Internal)_F$$

where:

$(Port\text{->}External)_F$ = Future year trips from the Port to external zones

$(Port\text{->}Internal)_F$ = Future year trips from the Port to internal zones, calculated by regression modelling applied to future year land use

X = Total fixed percentage of Port to external trips from 2018 base year

Trips to/from each external can then be obtained by factoring by the relative percentage of each external to the total external percentage.

12. Summary of Adopted Daily Models

For ease of reference, the final adopted models for daily heavy commercial vehicle trips are replicated below.

Table 12-1: Daily Internal Trip Ends – Adopted Model

Variable	Adjusted (Adopted) Coefficients
Employment - Other	2.1440
Manufacturing	0.9653
Households	0.0188
Retail	0.0735
Services	0.0096
Transport & Communications	0.0527

Table 12-2: Daily Internal Trip Distribution – Adopted Model

	Alpha
Calibrated Parameter	`-0.11

Table 12-3: Daily Port Trips – Adopted Model

Variable	Adjusted Coefficient, To Port	Adjusted Coefficient, From Port
Employment - Other	0.0556	0.0615
Manufacturing	0.0205	0.0227
Transport & Communications	0.0165	0.0183

Table 12-4: Daily Bluebridge Trips – Adopted Model

Variable	Coefficient, To Bluebridge	Coefficient, From Bluebridge
Employment - Other	0.0036	0.0042
Manufacturing	0.0013	0.0016
Transport & Communications	0.0011	0.0013

Table 12-5: Daily Interislander Trips – Adopted Model

Variable	Coefficient, To Interislander	Coefficient, From Interislander
Employment - Other	0.0061	0.0088
Manufacturing	0.0023	0.0032
Transport & Communications	0.0018	0.0026

Table 12-6: Daily SH1 External Trips – Adopted Model

Variable	Inbound/South	Outbound/North
Manufacturing/Ave. Distance to SH1	1.19401	1.22238
Total Employment	0.00087	0.00089

Table 12-7: Daily SH2 External Trips – Adopted Model

Variable	Inbound/South	Outbound/North
Employment Other/Ave. Distance to SH2	3.018218	3.777114
Total Employment	0.000055	0.000069

Table 12-8: Daily Port-External Proportions

	From the Port	To the Port
Proportion External SH1	6.7%	6.7%
Proportion External SH2	0.3%	0.2%

The following assumptions/simplifications are summarised:

- There is no land use or other input data to forecast the change in trip making between the Port and the two northern road externals. Observed proportions relative to the externals are therefore applied (see Section 11).
- Input land use for the internal zones where the Port, Interisland ferry terminal, and Bluebridge ferry terminal will include surrounding activity plus activity at these three generators. As a result, unless the input land use is manually adjusted to remove land use related to these three generators, the internal model will produce slightly higher trips. The magnitude is small and not considered significant, but this duplication is recorded for future reference.
- Trips between the Port and each of the ferry terminals are represented in the Port model. Travel for the ferry terminal end of the trip is combined with the surrounding activity for the internal zone where each terminal is located. That is, ferry destinations and destinations to other land use in the same internal zone are combined as there is no data to separate these elements.

- As above, trips between the two road externals in the north and each of the ferry terminals are represented in the Road Externals models. Travel for the ferry terminal end of the trip is combined with the surrounding activity for the internal zone where each terminal is located. That is, ferry destinations and destinations to other land use in the same internal zone are combined as there is no data to separate these elements.

13. Peak Period Factoring

13.1 Daily to Peak Periods

Daily trips are converted to the four modelled periods using sector-to-sector factors.

Sector-based factors were initially calculated using the sample eRUC data and the expansion sectors. This produced the following issues:

- Some sector-to-sector movements had no observations in any peak period, resulting in factors of zero;
- Some sector-to-sector movements were only observed in one peak period, resulting in 100% allocation of the daily demand to that peak;
- Some sector-to-sector movements had no observations in one or two peak periods, which led to no traffic allocated to some peak periods; and
- Excessively high and excessively low proportions were produced. This included 90% or more (less than 100%) allocated to one peak or less than 5%.

The same calculation was applied to the expanded eRUC demands. This produced the same problems as using the sample eRUC.

A more aggregated sector system was developed and adopted, which is illustrated in the following figure.

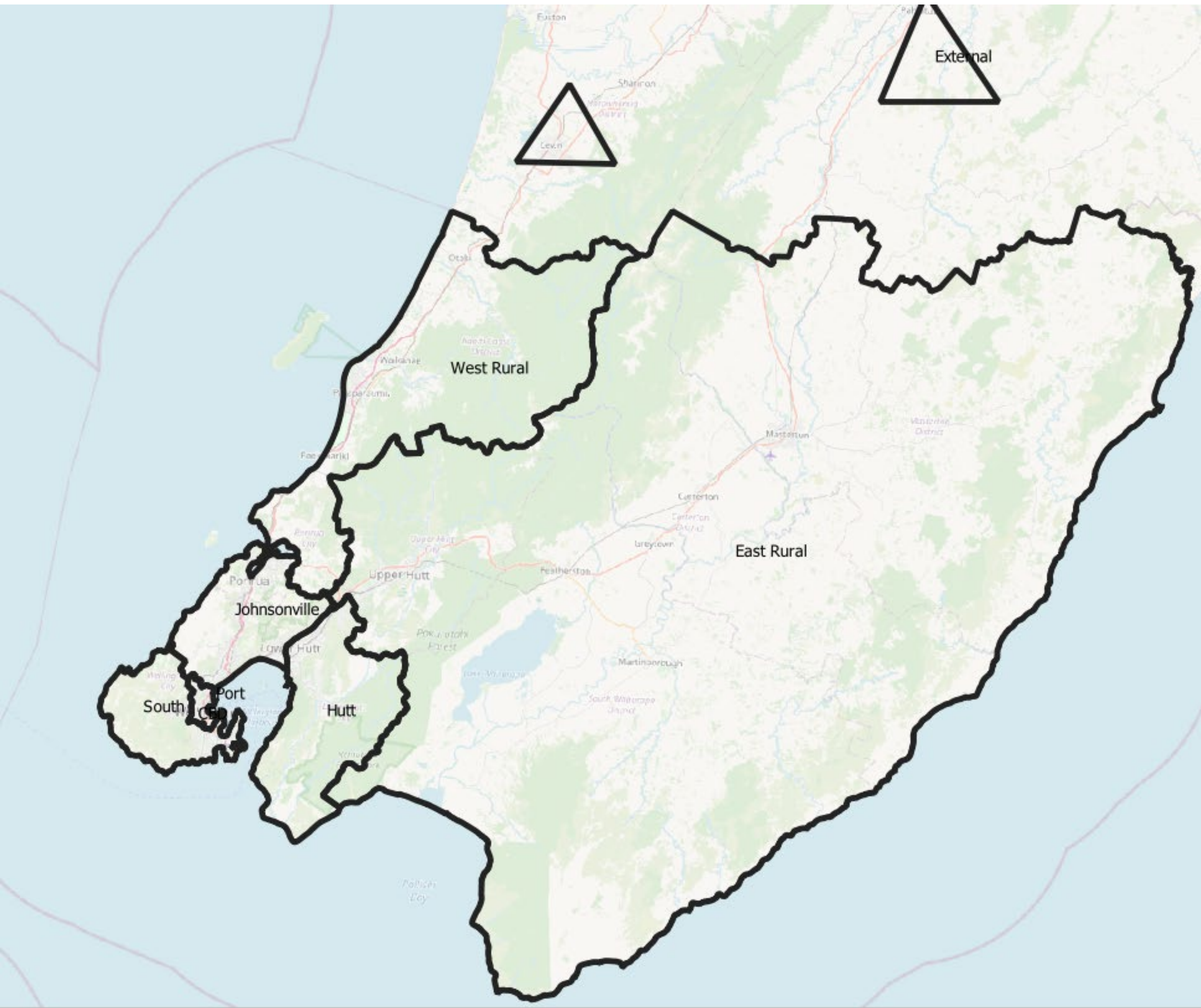


Figure 13-1: Aggregated Sectors for Peak Period Proportion Calculation

The same sectors are shown below centred on Wellington City.

Figure 13-2: Aggregated Sectors for Peak Period Proportion Calculation – Wellington City

In Stage 1 of the project, the ferry terminals do not have separate zones. Hence the Interislander ferry terminal peak period trips will be calculated using the Port factors while Bluebridge ferry terminal will be based on the CBD factors. This can be modified in Stage 2 when the model zoning will change and each ferry terminal will have a separate and unique zone, enabling different factors to be applied.

This sector system was used to recalculate the proportions of the expanded daily eRUC in each peak period. The resulting proportions are shown below.

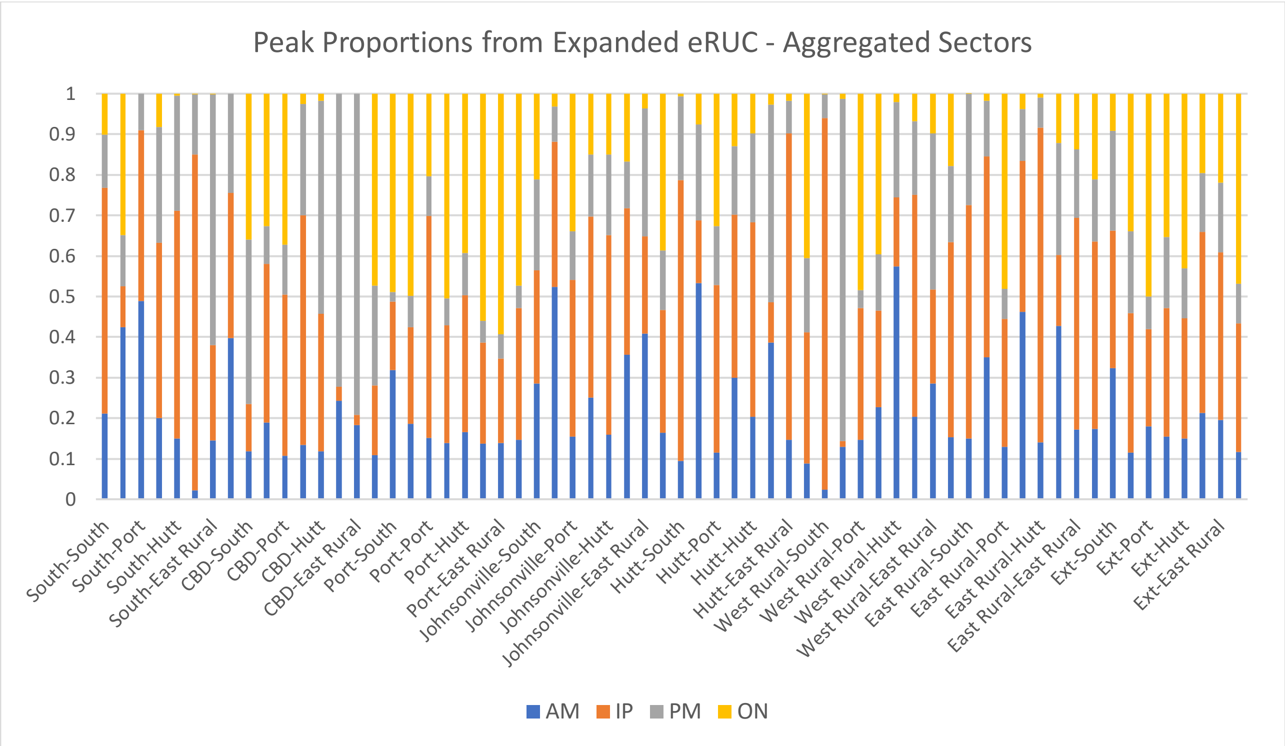


Figure 13-3: Aggregated Sectors, Peak Proportions using Expanded eRUC

While there is a lot of information in Figure 13-3, visually, it is clear that some movements are dominated by one peak period which feels unrealistic. Examples include:

From the Western rural to Hutt sectors almost 60% is predicted to be in the morning peak; and

From the CBD to both West and East rural sectors, over 70% is in the interpeak.

The proportions by peak appear skewed by the sample bias. To benchmark actual proportions, the heavy vehicle traffic counts were reviewed. The minimum and maximum proportions are shown in the following table.

Table 13-1: Minium and Maximum Peak Proportions from Traffic Counts

Metric	Proportion, Period/Day			
	AM	IP	PM	ON
Minimum	0.09	0.10	0.12	0.05
Maximum	0.43	0.55	0.50	0.37

There are no traffic counts where the AM peak proportion reaches 0.6, which was indicated through analysis of the eRUC data. Similarly, the proportion in the interpeak does not reach 0.7 in any of the collated traffic counts. This analysis confirmed that the sector-to-sector proportions calculated using the expanded eRUC data needed to be dampened.

The numbers of traffic counts in each proportion band by peak period is shown below.

Table 13-2: Frequency of Peak Proportions from Traffic Counts

Proportion Band	Number of Counts in Proportion Band			
	AM	IP	PM	ON
0-0.05	0	0	0	0
0.05-0.1	1	0	0	22
0.1-0.15	31	2	23	74
0.15-0.2	81	0	67	57
0.2-0.25	38	0	64	18
0.25-0.35	33	8	29	17
0.35-0.4	3	35	4	1
0.4-0.45	2	84	1	0
0.45-0.55	0	59	1	0
0.55-0.65	0	1	0	0
0.65-0.75	0	0	0	0
0.75-0.85	0	0	0	0
0.85-0.95	0	0	0	0
0.95-1	0	0	0	0
Total Number of Counts	**189**	**189**	**189**	**189**

The information in the above table was expanded to determine lower and upper proportions that regularly occurred in traffic counts by identifying where step-changes occurred and using engineering judgement. These are not the absolute minimum and maximums, as the objective is to dampen the proportions calculated from eRUC rather than replace them completely.

Table 13-3: Lowest and Highest Regular Proportions from Traffic Counts

Proportion Range	Proportion, Period/Day			
	AM	IP	PM	ON
Lowest Regular	0.14	0.37	0.14	0.1
Highest Regular	0.26	0.47	0.26	0.26

The lower and upper values in Table 13-3 were combined with the aggregated sector-to-sector proportions calculated using the expanded eRUC data. If a factor for any period lay outside the range in this table, the values in this table were adopted. For example, an initial AM peak factor of 0.6 was replaced with 0.26. This resulted in the sum of the peaks no longer equally one. The over or underestimation was allocated in proportion to all periods taking into account that the lowest and highest peak proportions in each peak must remain within the range in Table 13-3.

The resulting peak proportions are shown in the following table. Applying a dampening using traffic counts has smoothed out the anomalies.

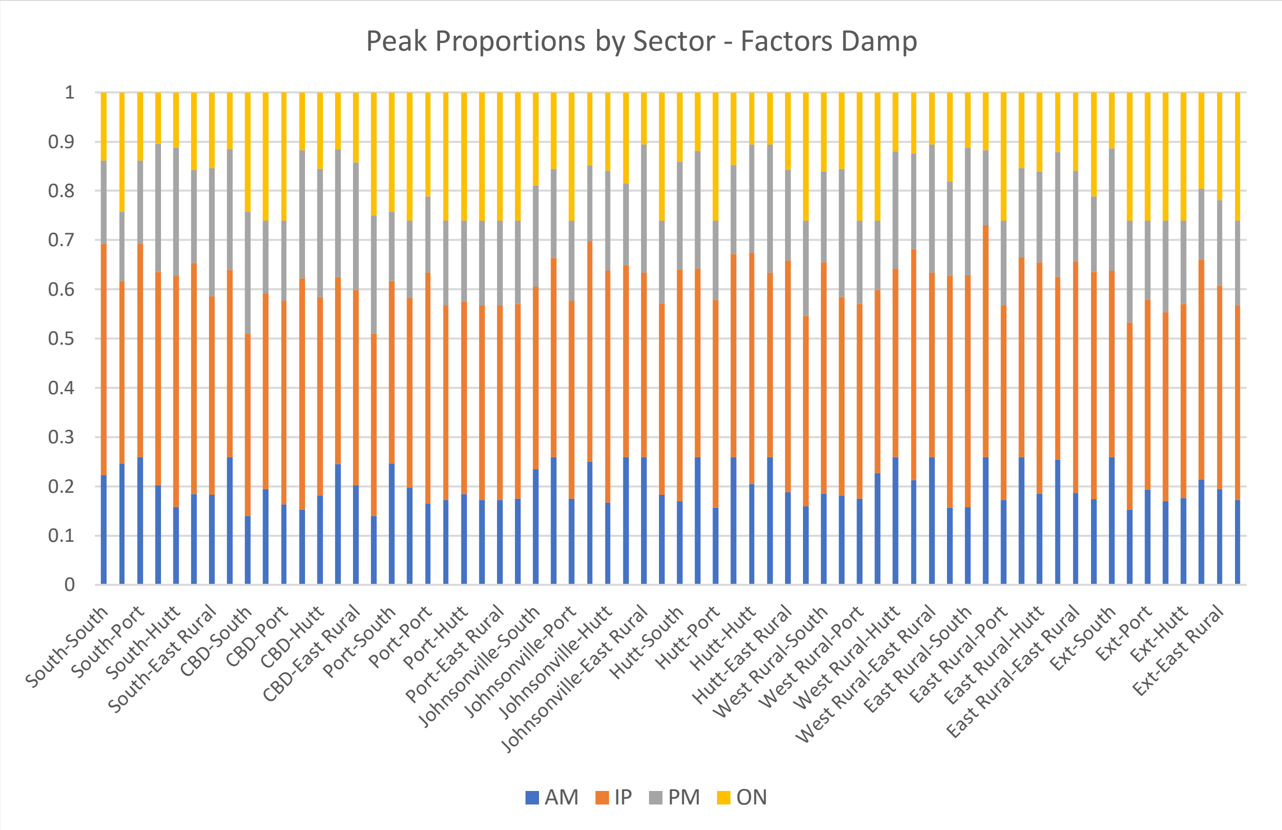


Figure 13-4: Aggregated Sectors, Damped Peak Proportions using Expanded eRUC

These peak period factors were applied to the synthetic daily matrix, which was then compressed to 225 zones, and factored to the two hour AM, interpeak and PM peak periods used by current WTSM. These matrices were assigned and the results compared with observed 2018 traffic counts. As a result, some minor adjustments to the peak period proportions were incorporated ("calibrated" factors) for a small number of movements. In making these adjustments, the lower and upper bounds in Table 13-3 were maintained. Adjustments were then made to the overnight period so that all four peaks still summed to 100%. Again, the lower/upper bounds for the overnight period were maintained.

The damped factor, adjusted calibrated factor (only applied to intra-sector movements), and difference are shown in the table immediately below for the AM and interpeak periods, and in Table 13-5 for the PM and overnight periods.

Table 13-4: Calibration Changes to Peak Period Proportions – AM and Interpeak

Origin Sector	Destination Sector	Proportion, Period/Day					
		AM			IP		
		Damped	Calibrated	Diff	Damped	Calibrated	Diff
South	South	0.22	0.26	0.04	0.47	0.44	-0.03
CBD	CBD	0.19	0.26	0.07	0.40	0.43	0.03
Port	Port	0.16	0.16	0.00	0.47	0.47	0.00
Hutt	Hutt	0.21	0.15	-0.06	0.47	0.44	-0.03
West Rural	West Rural	0.21	0.16	-0.05	0.47	0.47	0.00
East Rural	East Rural	0.19	0.16	-0.03	0.47	0.44	-0.03

Table 13-5: Calibration Changes to Peak Period Proportions – PM and Overnight

Origin Sector	Destination Sector	Proportion, Period/Day					
		PM			ON		
		Damped	Calibrated	Diff	Damped	Calibrated	Diff
South	South	0.17	0.20	0.03	0.14	0.10	-0.04
CBD	CBD	0.15	0.21	0.06	0.26	0.10	-0.16
Port	Port	0.15	0.14	-0.01	0.21	0.23	0.01
Hutt	Hutt	0.22	0.15	-0.07	0.11	0.26	0.15
West Rural	West Rural	0.19	0.19	0.00	0.12	0.18	0.05
East Rural	East Rural	0.18	0.14	-0.04	0.16	0.26	0.10

As the overnight period is adjusted so that the four periods sum to 24 hours, there are quite notable changes introduced by the calibration for the CBD, Hutt and East Rural intra-sector overnight proportions. The impact is currently difficult to check as there are only daytime peak period assignments in WTSM. These factors will be rechecked when the new model is developed and there are four period assignments.

The adopted peak period factors are tabulated in Appendix B.

13.2 Peak Period to 2-hour Peaks in 225 Zone WTSM

The duration of the peak periods in the updated model is different to the current model. In order to integrate the 2018 updated heavy commercial vehicle model, factors to convert from the new time periods to those currently in the 225 zone model are required.

Total traffic counts were used to calculate the factors shown in the following table. This is based on 193 counts with a heavy vehicle flow greater than zero in the database, where each direction is considered a separate "count".

Table 13-6: New to Current Peak Period Factors

Period	No. of Hours	HCV Total Vehicles	Factor
0600-0900	3	22885	0.78
0700-0900	2	17763	
0900-1500	6	49149	0.33
1100-1300	2	16143	
1500-1800	3	23819	0.63
1600-1800	2	15123	

These factors appear logical and compare well to a factor based strictly on the number of hours in each period, which would be 0.66, 0.33, and 0.66 respectively for the AM, interpeak and PM peak periods.

These factors were applied to the 3 hour AM peak matrix, the 6 hour interpeak, and 3 hour PM peak matrices to convert them to the periods in the 225 zone model.

14. Zoning

The model zones (current and new) where special generators are allocated is shown in the following table.

Table 14-1: External Generators – Zone Representation

Activity	Current (225) Model Zone	New (circa 820) Model Zone
SH1 road external	226	2261
SH2 road external	227	2271
Port	228	2281
Interislander ferry terminal	228	2291
Bluebridge ferry terminal	66 (internal zone)	2301

15. Validation Check

The synthetic 2018 heavy commercial vehicles peak period matrices were assigned within the current version of WTSM, which at this stage represented 2013.

The model is ultimately to be applied in units of pcus (passenger car units), however, in the interim the results below are still based on heavy commercial vehicles assigned as vehicles. The use of vehicles will not have had a significant impact on the results below – it is more likely to affect the car assignment. Furthermore, when these checks were carried out, the ferry component had not been developed and hence the results below exclude heavy vehicle trips explicitly to/from the ferry terminals. The numeric number of trips to/from the ferry terminals is minute and will have no impact on the analysis and conclusions in this section.

While it was initially envisaged that the model would be applied at 780 zones, this would require two spatial sets of land use to be input to the model, and significantly more complicated, a 780 zone network and assignment would need to be incorporated to extract the interzonal distance matrix. The latter would require two networks to be created for every scenario tested over the next year while the new model is developed. This adds more complexity than is merited by the interim inclusion of the updated heavy commercial vehicle model at 225 zones rather than the 780 zones level to which it was calibrated.

Validation comparisons (synthetic model versus observed) are provided below to benchmark that the model is producing reasonable outputs. These are not final validation tables – the ferry terminal models need to be added; some counts are currently being checked and will likely change; and the 2018 light vehicle validation is ongoing in parallel with the car trips used to produce the results below representing 2013 two-hour demands.

Two hour period observed volumes are compared with modelled at screenline level below. Separate graphs are provided for the current model AM peak period (0700-0900), interpeak (1100-1300), and PM peak (1600-1800). A trendline forced through zero is plotted, and the slope and R-squared displayed.

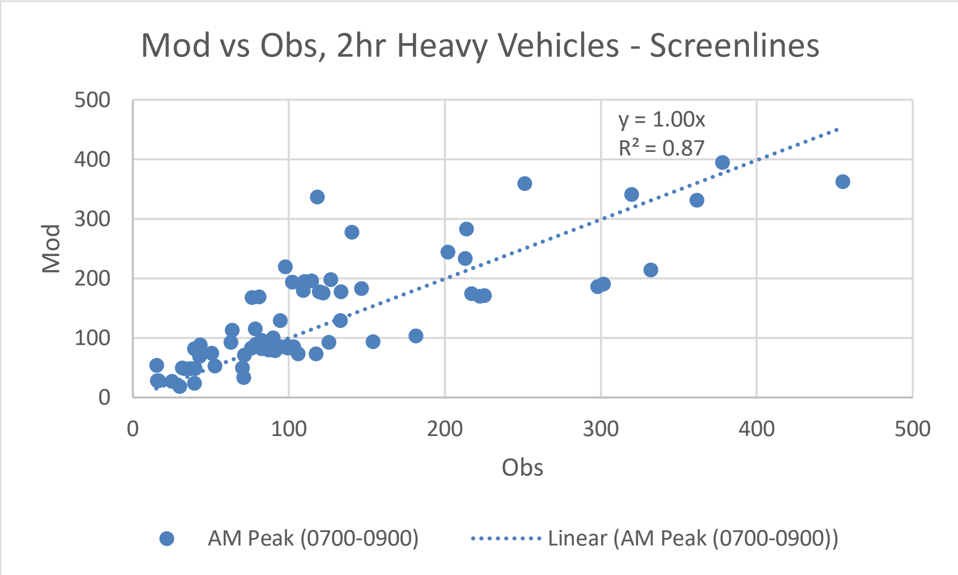


Figure 15-1: Screenline Modelled vs Observed Scatter Plot – HCVs – AM Peak

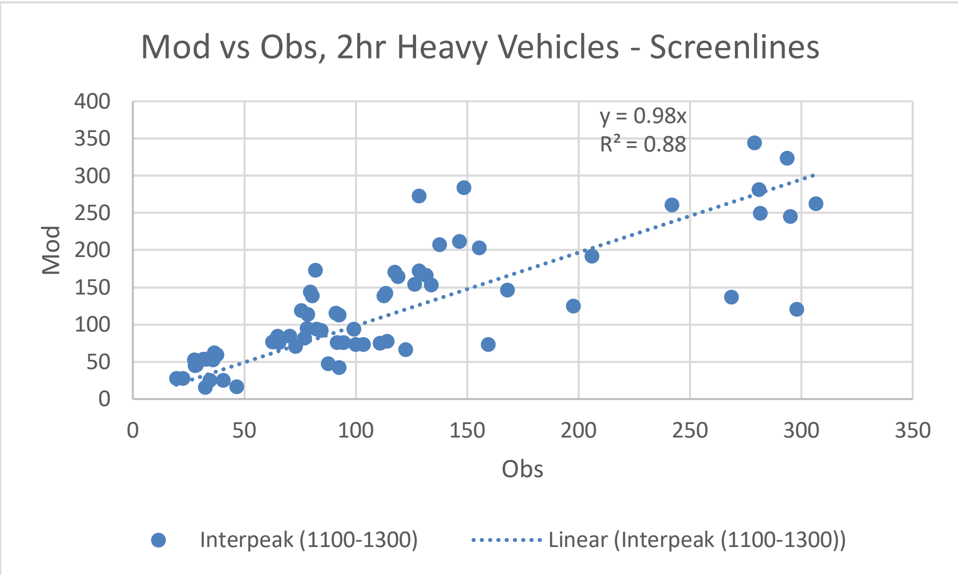


Figure 15-2: Screenline Modelled vs Observed Scatter Plot – HCVs – Interpeak

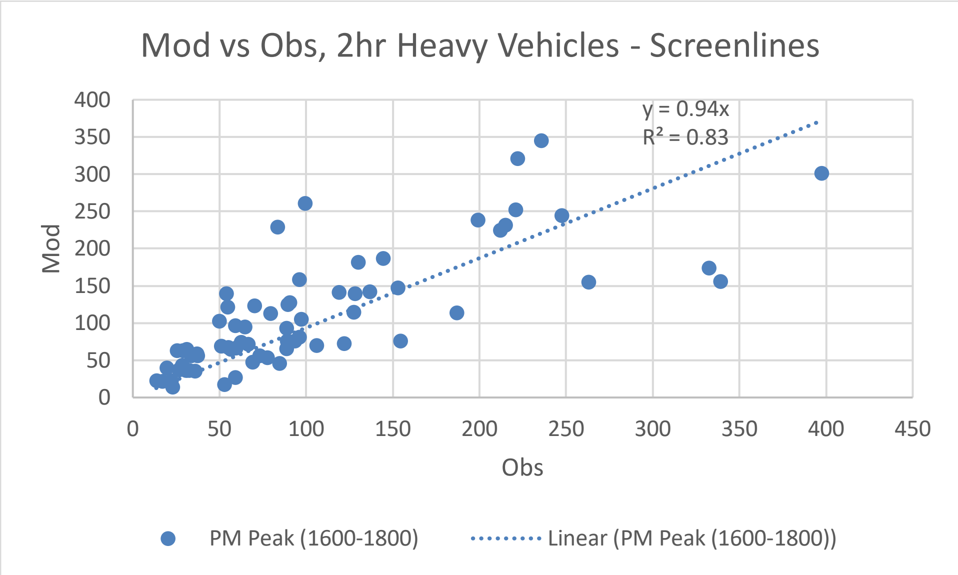


Figure 15-3: Screenline Modelled vs Observed Scatter Plot – HCVs – PM Peak

At a screenline level, the slope of the trendline is robust. Although there is a fair amount of scatter, the values are numerically small and the R-squared values are reasonable.

Note that some counts have been removed from this comparison. This includes counts that have been processed specifically for the new modelled periods and are not readily available in the old/current model periods. Willis Street northbound was also removed – this has a high number of observed heavy vehicles but these will be buses in reality. Refinement of the counts to remove the buses from the heavy vehicles in busy bus corridors is underway. Jervois Quay southbound was also temporarily removed – at a daily level, 30% of the count are heavies which is only 9% northbound. This vehicle type breakdown in this count is suspect and is being checked.

Scatter plots for individual counts compared with modelled are shown below for each of the three current model peak periods.

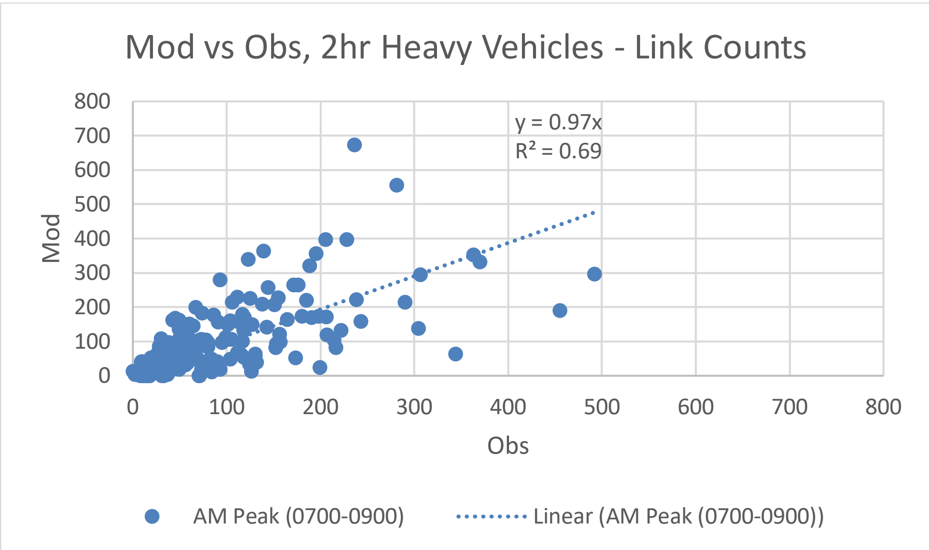


Figure 15-4: Link Counts Modelled vs Observed Scatter Plot – HCVs – AM Peak

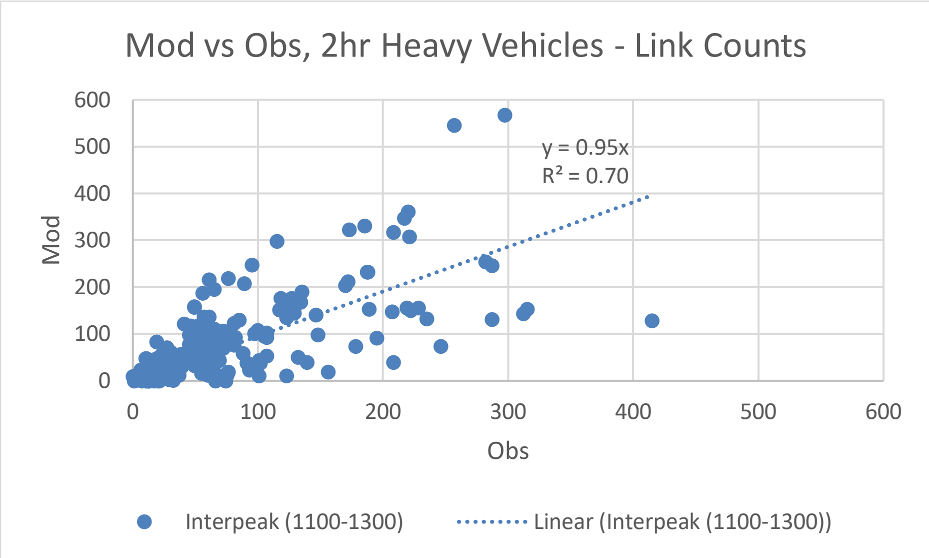


Figure 15-5: Link Counts Modelled vs Observed Scatter Plot – HCVs – Interpeak

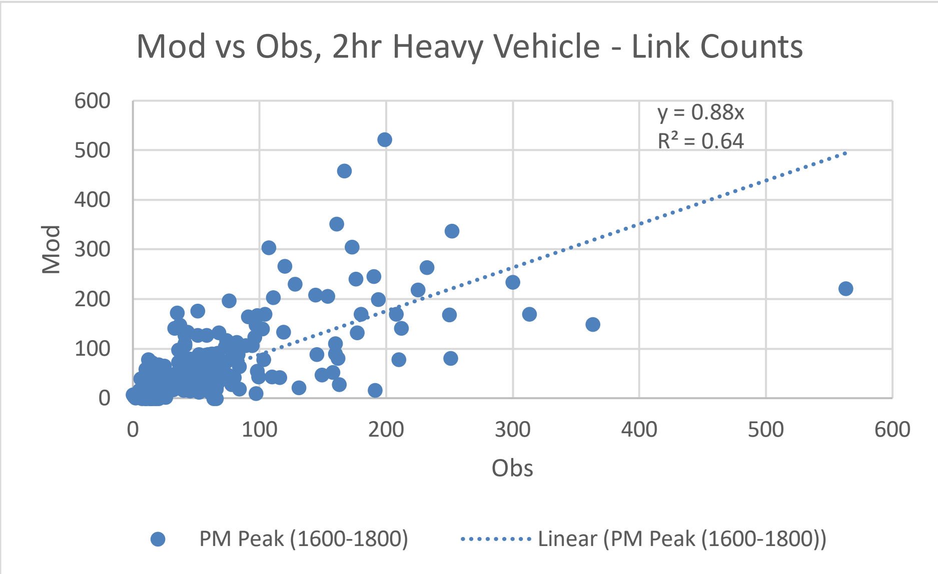


Figure 15-6: Link Counts Modelled vs Observed Scatter Plot – HCVs – PM Peak

As expected, more variation can be seen on an individual location level in all three peak periods. The slow of the trendline is generally acceptable, and the R-squared lower than for screenlines. The AM and interpeak are considered reasonable, although the PM peak may need further attention in the final validation stages.

The GEH criteria in the Waka Kotahi Model Development Guidelines are all easily achieved. GEH comparisons are not tabulated as they are not considered a good indicator for heavy commercial vehicles where the flows are much lower than light vehicles.

Following client and stakeholder review, it was requested that additional analysis be provided to demonstrate the geographic representation. Observed and modelled flows by screenline are therefore shown in the following tables first aggregated to Territorial Authority and then for individual screenlines. The flows are averages of the two hour modelled periods; flows are summed for both directions of travel; and absolute and relative differences are provided. In both tables, results are provided from the south to the north.

Diagrams of the screenline locations can be found in Technical Note 4 and the Addendum to Technical Note 4.

Table 15-1: Observed and Modelled Flows by Screenline Grouped to Territorial Authority

Screenline Group	AM, 1 hour average				IP, 1 hour average				PM, 1 hour average			
	Obs	Mod	Obs - Mod	Obs / Mod	Obs	Mod	Obs - Mod	Obs / Mod	Obs	Mod	Obs - Mod	Obs / Mod
Wellington (incl Port)	5,029	5,189	159	3%	4,559	4,406	(152)	-3%	4,378	4,235	(143)	-3%
Lower Hutt	1,455	1,717	262	18%	1,222	1,533	311	25%	1,065	1,376	311	29%
Upper Hutt	485	761	276	57%	441	674	233	53%	373	589	216	58%
Carterton	142	196	55	39%	133	214	81	61%	126	147	22	17%
Porirua	712	860	148	21%	707	699	(7)	-1%	560	596	37	7%
Kapiti	344	401	57	17%	379	387	8	2%	275	337	62	23%
Road Externals (north)	155	174	19	12%	162	174	13	8%	119	139	20	17%
Total	8,321	9,298		12%	7,601	8,088		6%	6,893	7,419		8%

Table 15-2: Observed and Modelled Flows by Screenline

Screenline	Screenline Name	AM, 1 hour average				IP, 1 hour average				PM, 1 hour average			
		Obs	Mod	Obs - Mod	Obs / Mod	Obs	Mod	Obs - Mod	Obs / Mod	Obs	Mod	Obs - Mod	Obs / Mod
W2	Miramar Peninsula	82	152	70	86%	74	122	48	65%	65	121	57	88%
W6	South Wellington	176	124	-52	-29%	180	90	-90	-50%	154	94	-60	-39%
W1	CBD	1191	1060	-131	-11%	1061	833	-227	-21%	1018	855	-163	-16%
W12	CBD Te Aro East-West	524	359	-165	-31%	437	283	-153	-35%	602	312	-290	-48%
W11	CBD Te Aro North-South	549	389	-160	-29%	496	246	-250	-50%	520	288	-232	-45%
W10	CBD Lambton	430	536	107	25%	364	423	59	16%	392	432	40	10%
P	Port	154	153	0	0%	136	147	12	9%	66	120	53	80%
W3	Karori	96	62	-34	-36%	75	51	-24	-32%	81	50	-31	-38%
W9	Thorndon	429	389	-39	-9%	344	399	56	16%	368	379	11	3%
W4	Kaiwharawhara	629	754	125	20%	573	668	96	17%	458	667	210	46%
W8	North Wellington	300	464	165	55%	302	416	114	38%	226	340	114	51%
W5	Churton Park	224	370	146	65%	237	335	99	42%	198	264	66	33%
W7	Tawa	248	375	127	51%	260	339	79	30%	209	266	58	28%
L1	Lower Hutt South	259	615	357	138%	277	557	280	101%	183	491	308	168%
L3	Lower Hutt Central	575	566	-9	-2%	537	506	-31	-6%	411	463	52	13%
L4	Lower Hutt East	280	187	-92	-33%	182	189	7	4%	244	152	-91	-38%
L2	Lower Hutt North	342	348	6	2%	226	282	56	25%	227	270	43	19%
U2	Upper Hutt South	158	338	180	114%	160	283	123	77%	109	261	153	141%
U4	Upper Hutt Central	228	258	31	14%	184	229	45	25%	186	199	14	7%
U1	Upper Hutt North	68	108	40	60%	56	105	50	89%	48	83	35	73%
U3	Remutaka	32	57	25	78%	42	57	15	35%	31	45	15	48%
C1	Wairarapa South	65	99	34	53%	64	107	43	68%	59	74	15	26%
C2	Wairarapa North	77	97	20	27%	69	107	38	55%	67	73	6	10%
P3	Porirua South	256	364	108	42%	261	308	47	18%	207	228	21	10%
P2	SH58	94	164	70	75%	57	92	35	62%	63	122	59	95%
P1	Porirua North	178	160	-18	-10%	192	150	-42	-22%	151	110	-40	-27%
P4	Pukerua Bay	185	172	-13	-7%	198	150	-48	-24%	140	136	-4	-3%
K2	Kāpiti South	202	172	-30	-15%	225	153	-72	-32%	166	138	-28	-17%
K1	Kāpiti North	142	229	87	61%	154	233	79	52%	109	199	90	83%
E	North Road Externals	155	174	19	12%	162	174	13	8%	119	139	20	17%

The summary by Territorial Authority shows:

- Upper Hutt and Lower Hutt modelled flows are consistently higher than observed in all three peak periods. For Lower Hutt, this is dominated by one state highway location. These results will be reviewed in Stage 2 when the new time periods are implemented. If the model is still too high in these areas, the attraction model coefficients may need to be factored down.
- Overall, the model is slightly higher than observed although the traffic counts include some buses. Again, the model will be reassessed in Stage 2 with the new time periods and updated traffic counts. If necessary, the peak period factors will be adjusted, or the attraction model coefficients will be reduced.

For individual screenlines, the results indicate:

- Significant variation on a percentage basis, although the observed volumes are numerically small.
- Central city screenlines (W1, W11 and W12) are low in all three peak periods, however, the observed counts still include some buses so the model should be less. The traffic counts are being adjusted to remove buses and will be used in Stage 2 with the new time periods.
- The screenline through Ngauranga (L1) is notably high in all three peak periods. Again, this will be reviewed in Stage 2 when the new time periods are implemented.
- The screenline south of Upper Hutt (U2) is high. However, the next screenline south (Lower Hutt North, L2, south of SH58) matches observed well, as does the screenline intercepting trip in/out of Lower Hutt (Lower Hutt Central, L3) and traffic on SH58 (P2). So the Upper Hutt South screenline is high, but the three screenlines south all replicate observed well.

The overall percentage of heavy vehicles is shown in the table below for each of the three modelled peak periods. It is noted that the light vehicle observed counts are for 2018 whereas for modelled, the car demands represented 2013.

Table 15-3: Percentage Heavies, Screeline Totals, Observed and Modelled

	Observed, 1 Hour Average Screenline Total				Modelled, 1 Hour Average Screenline Total			
	Light (2018)	Heavy (2018)	Total	% HCV	Light (2013)	Heavy (2018)	Total	% HCV
AM	135,947	8,503	144,449	5.9%	146,664	9,478	156,142	6.1%
IP	100,992	7,745	108,737	7.1%	104,163	8,259	112,422	7.3%
PM	150,309	7,044	157,353	4.5%	157,009	7,568	164,577	4.6%

This table demonstrates that the number of HCV's is the expected order of magnitude, albeit potentially one percent too high. This can be adjusted in Stage 2 of the project using 2018 input land use for cars and HCV's, a consistent zoning system, and updated HCV traffic counts.

Overall, the comparison with observed shows that the model generally reproduces observed and is the appropriate order of magnitude. There are some outliers, and these will be considered in Stage 2 of the project using the updated traffic counts and new model time periods.

16. Future Year Growth

16.1 Model Equation

HCV trips are predominantly estimated using input employment. While employment is appropriate to forecast the relative number of trips to/from each zone, it is not the best predictor for the overall number of trips. This is because HCV activity will relate more to economic activity/growth rather than employment.

The future year demand equation in the original model had a GDP component, but the growth was primarily driven by the change in employment with an influence from GDP growth. This equation was modified in 2013 such that the GDP growth is the dominant driver for the future year number of trips (see TN4: 2013 Commercial Vehicle Model V5, produced for the 2013 model update). The relationship derived during the 2013 model update to forecast the future year total number of trips will therefore be adopted and is shown below rebased to 2018.

$$HCV_F = HCV_{F\text{-}Syn} \times (HCVTotal_{2018} / HCVSynTotal_F) \times (GDPPC_F / GDPPC_{2018})^S$$

Where:

HCV_F	=	Future year HCV trips, OD value
$HCV_{F\text{-}Syn}$	=	Future year synthetic HCV trips, OD value
$HCVTotal_{2018}$	=	2018 HCV demand, total
$HCVSynTotal_F$	=	Future year synthetic HCV demand, total
$GDPPC_{2018}$	=	GDP per capita (nominal) for 2018
$GDPPC_F$	=	GDP per capita (nominal) in future year
S	=	Sensitivity Factor to adjust GDP per capita growth

This equation is applied to the synthesized HCV future year trips on an origin-destination basis to produce the total.

An added benefit of this equation is that it utilises economic parameters already calculated for WTSM (GDP per capita growth).

To check the relationship between economic growth and HCV activity, and determine an appropriate value for the sensitivity factor in the equation, the following analysis was undertaken.

16.2 Trend Analysis – GDPPC vs HCV Activity

The GDPPC and measures of HCV activity are presented in the table below. GDP is the nominal expenditure-based GDP in millions for New Zealand and is consistent with the data used to derive other economic parameters in the model documented in Technical Note 9 of this study.

As the observed number of HCV trips is not available, various data sources have been used as a proxy.

- Vehicle kilometres travelled (VKT) sourced from the Waka Kotahi website and representing heavy vehicle (MCV, HCV1, HCV2 and buses) on state highways in the Wellington region. While VKT on local roads was published, vehicle types were not reported separated, so local roads are excluded. Buses could not be removed from these figures, but will be a relatively small proportion on state highways.
- The heavy truck fleet for the Wellington region sourced from the Ministry of Transport website.

Data for the years 2010 to 2019 is shown, as prior years was not available in some datasets.

Table 16-1: Time Series Economic and HCV Data

Year	Value National Nominal GDP/Capita	Wellington SH HCV VKT (millions)	Wellington Heavy Trucks in Fleet
2010	43.96	91.10	7455
2011	44.23	96.43	7456
2012	44.78	99.48	7371
2013	46.48	106.22	7367
2014	48.45	109.05	7508
2015	49.10	111.45	7668
2016	51.93	108.62	8043
2017	53.13	115.48	8352
2018	54.75	119.98	8628
2019	57.06	117.45	8881

The following graphs plot GDPPC against HCV VKT on State Highways and then HCV fleet respectively.

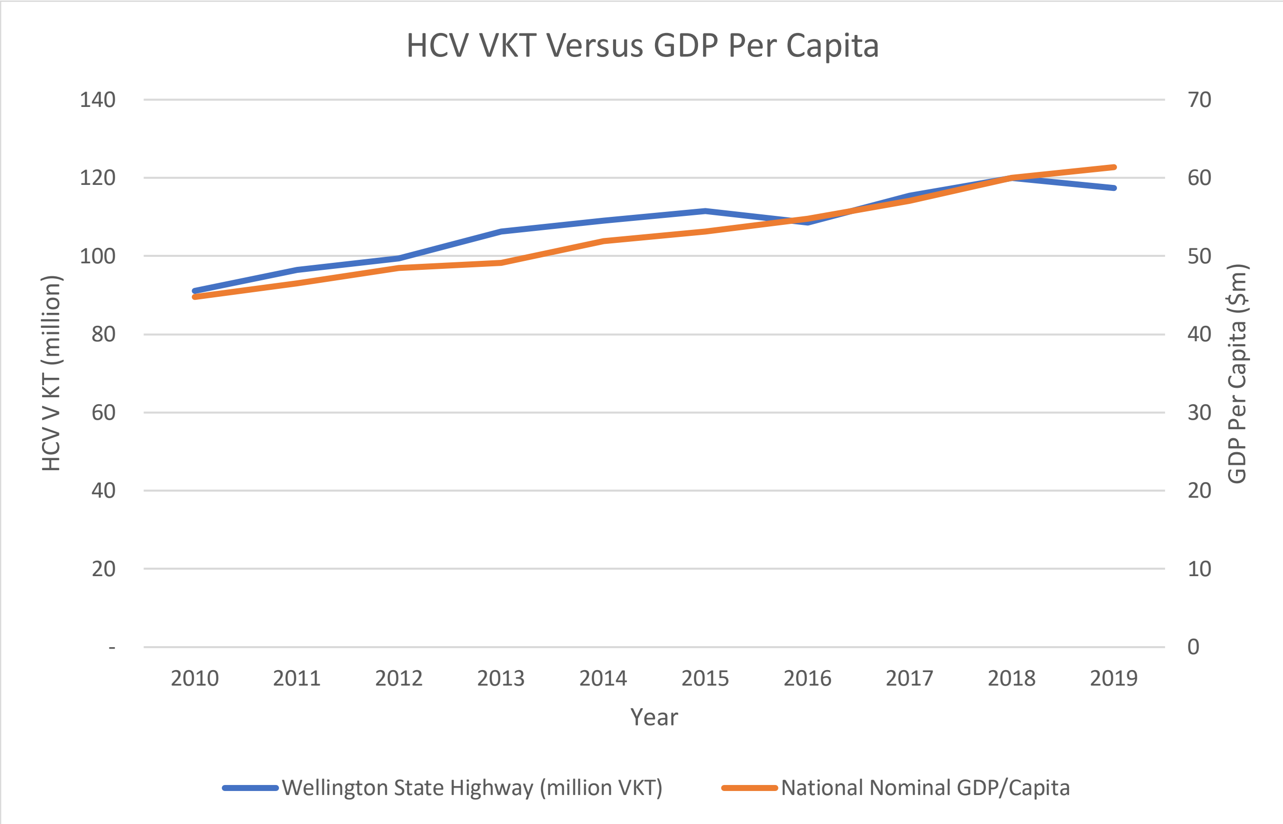


Figure 16-1: HCV VKT vs GDPPC

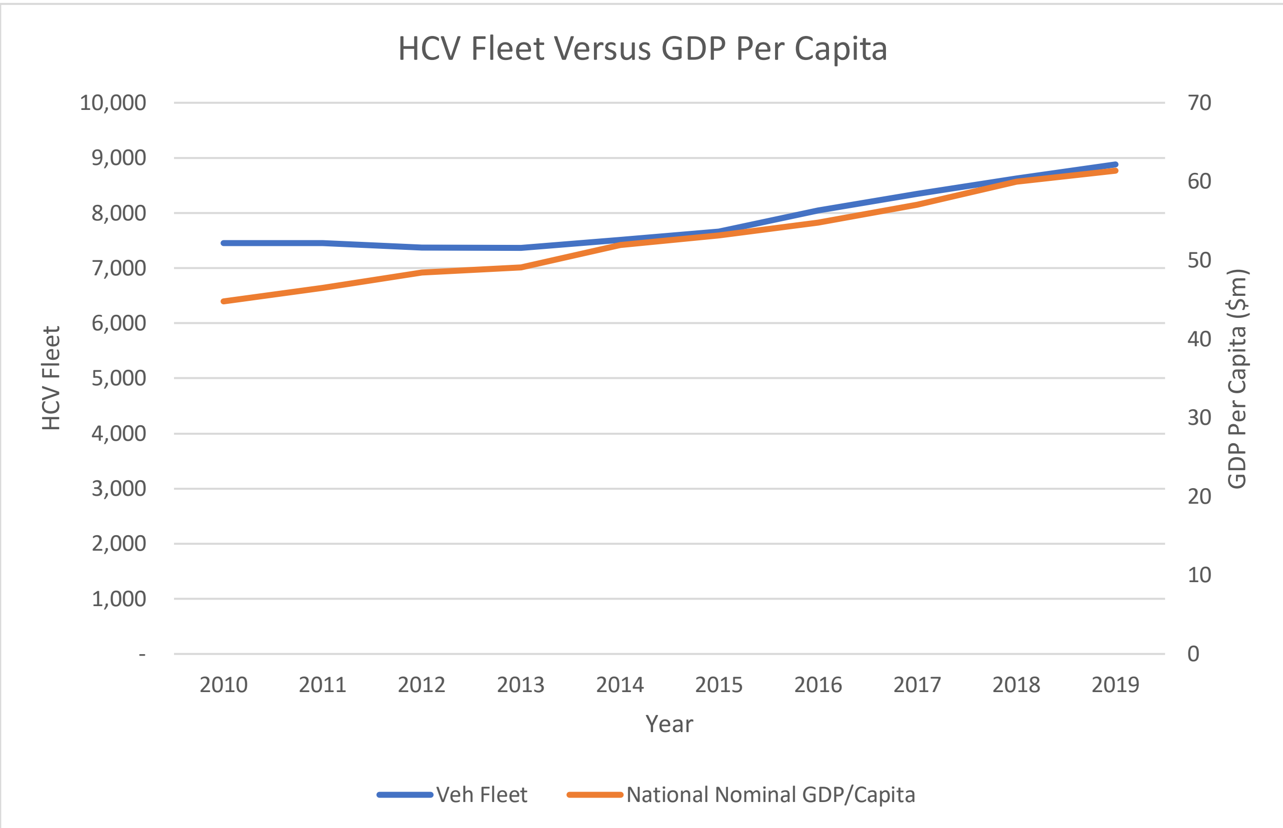


Figure 16-2: HCV Fleet vs GDPPC

There is a good relationship between VKT and GDPPC growth. In terms of fleet, there is a good relationship from 2014 to 2019, with disparity prior to 2014. The same data is shown below as scatter plots against

GDPPC growth, where the 2010 value for each dataset has been normalised to zero (so the trendline can be forced through the origin) and growth calculated from 2010.

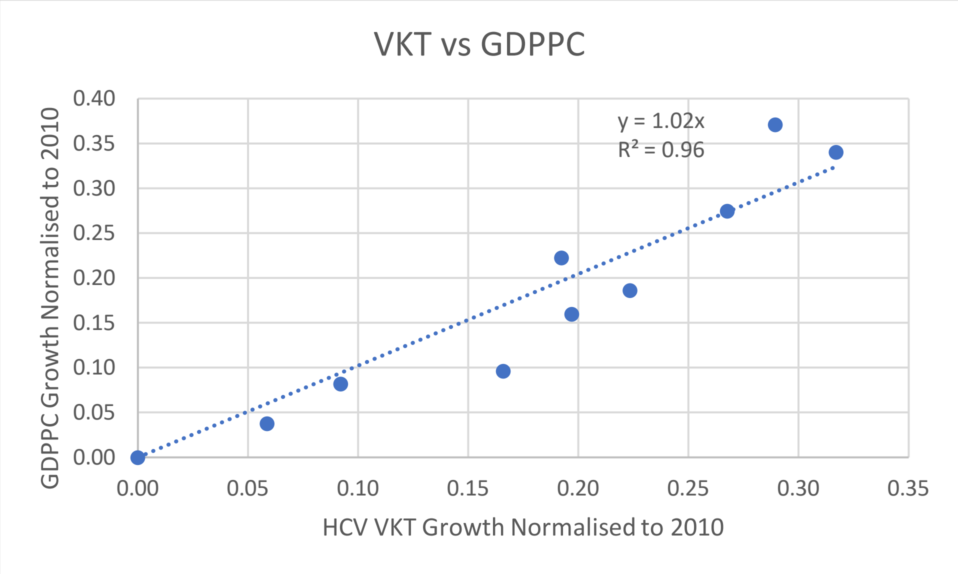


Figure 16-3: HCV VKT vs GDPPC Growth – Zero at 2010

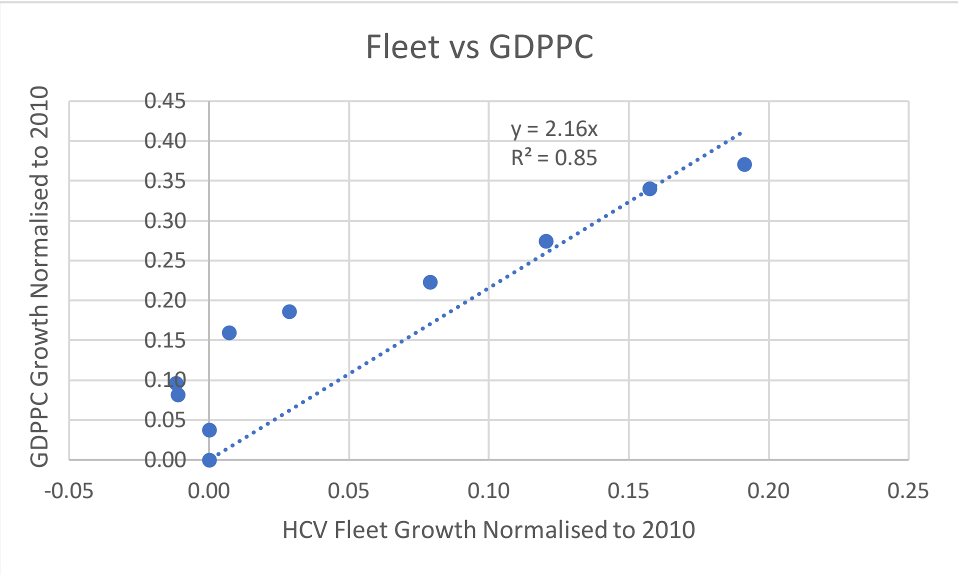


Figure 16-4: HCV Fleet Growth vs GDPPC Growth – Zero at 2010

The scatter plots show a good relationship between VKT and GDPPC growth, with an R-squared of 0.96 and the slope of the trendline (forced through zero) equalling 1.02.

The scatter plot reaffirms the disparity in the relationship of fleet size to GDPPC growth, which is caused by the reduction in fleet between 2012 and 2013. Removing the anomalous data points results in insufficient data to robustly identify the trend.

Based on this analysis, it is concluded there is a good relationship between GDPPC growth and HCV activity, the latter indicated by HCV VKT on state highways in Wellington.

16.3 Value of Sensitivity Parameter

Now that a strong relationship between HCV activity and GDPPC growth has been demonstrated, in this section, the estimation of the recommended value of the Sensitivity Factor in the equation in Section 16.1 is documented.

The approach taken is to use the GDPPC as input, then calculate the Sensitivity Factor which produces the closest estimate of HCV VKT compared with observed.

In the table below, the actual HCV VKT and GPDPC are shown with the forecast (or estimated) HCV VKT based on sensitivity parameter values of 1.00 (to compare the effect of no sensitivity adjustment) and a value of 1.01 which produced the slope of the trendline closet to 1.0 (with the trendline forced through zero).

Table 16-2: Calculate Sensitivity Parameter Using HCV VKT (2010 Base)

Metric	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
GDPPC - actual	44.78	46.48	48.45	49.10	51.93	53.13	54.75	57.06	60.01	61.37
VKT – actual	91.10	96.43	99.48	106.22	109.05	111.45	108.62	115.48	119.98	117.45
Forecast VKT, S=1		94.56	98.57	99.89	105.65	108.09	111.40	116.10	122.11	124.87
Forecast VKT, S=1.01		94.60	98.65	99.98	105.81	108.28	111.63	116.38	122.47	125.27

The actual compared with the estimated HCV VKT is shown in scatter plot format below for a sensitivity parameter value of 1.01 applied exponentially to the ratio of GDPPC growth and calculated from the 2010 base year. VKT is in millions of kilometres and represents Wellington region state highways only.

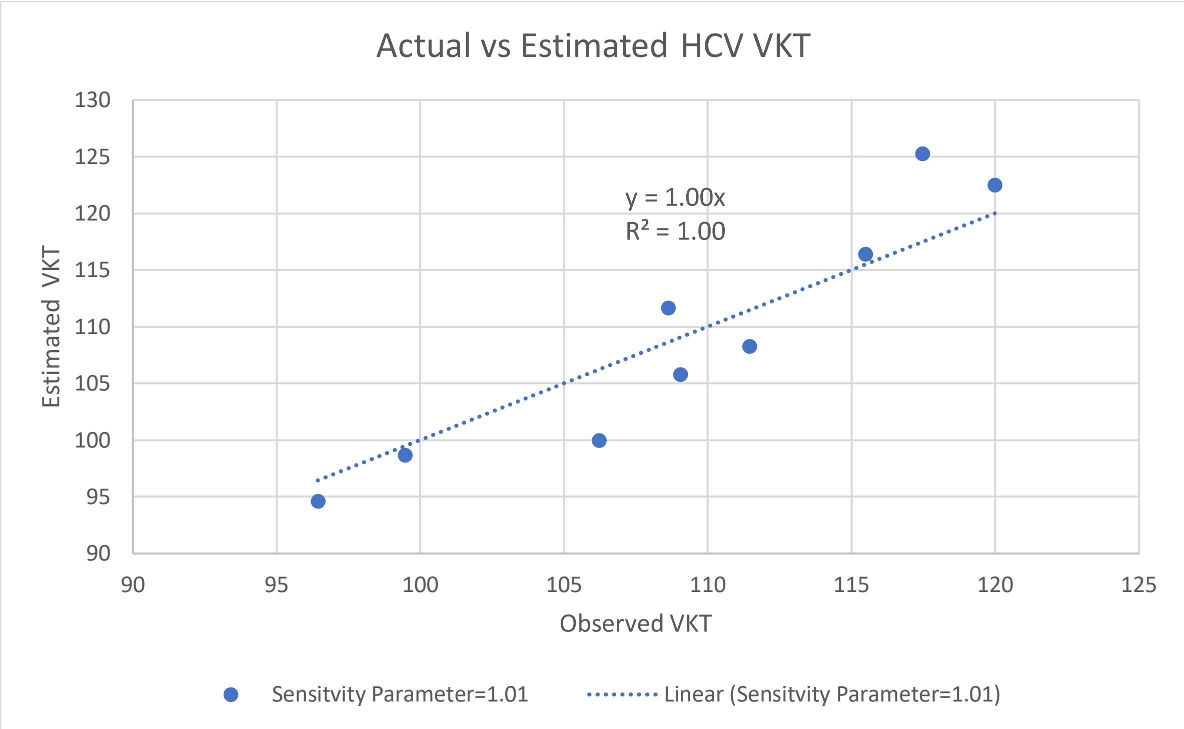


Figure 16-5: Application of Sensitivity=1.01 to reproduce HCV VKT from 2010

The slope of the trendline is ideal as is the R-squared based on a sensitivity factor of 1.01 and HCV VKT estimated from input GDPPC from a base year of 2010.

The same exercise was repeated for a base year of 2010 but only considering data to 2018. This was to check the robustness of the calculated Sensitivity Factor. The resulting Sensitivity Factor was markedly different, and so different year ranges were tested to determine the range of calculated Sensitivity Factors. The results are shown in the following table, including the minimum and maximum error of the estimated VKT compared with observed.

Table 16-3: Sensitivity Factors Calculated for Different Year Ranges

Evaluation Period	No. of Years	Optimum Sensitivity Factor	Min % Error	Max % Error
2010-2019	9	1.01	-5.9%	6.7%

Evaluation Period	No. of Years	Optimum Sensitivity Factor	Min % Error	Max % Error
2010-2018	8	1.1	-5.1%	4.8%
2011-2018	7	0.94	-4.4%	3.6%
2011-2019	8	0.88	-4.7%	4.9%
2012-2018	6	1.01	-5.1%	3.6%
2012-2019	7	0.94	-5.2%	5.8%

The Sensitivity Factors range from 0.88 to 1.1. While this is quite a wide range, it must be borne in mind that the Sensitivity Factor is applied exponentially and the GDPPC growth ratio will dominate the number of HCV trips forecast. Of note, while actual data has been used in this evaluation, in the model, an input estimate of GDPPC growth is used. The assumptions on the GDPPC growth will have a much larger impact on the heavy vehicle trip forecasts than the adopted Sensitivity Factor.

As a result, an initial Sensitivity Factor of 1.01 is recommended for application as this was calculated using the most data. For assessments where heavy vehicle numbers are critical, it is recommended that a series of tests are carried out with varying assumptions on GDPPC growth and the value of the Sensitivity Factor.

17. Next Steps

In the interim, the heavy vehicle model will be applied at 225 zone level within the current WTSM framework. This negates the requirement to input both 225 and 780 zones into WTSM for every scenario evaluated, which would result in considerable additional work.

As part of Stage 2 of this project, the heavy commercial vehicle model will be applied (not calibrated) at the new circa 820 zone system and the validation checked. The peak period trips to/from the Interislander and Bluebridge Ferry Terminals will be checked, and if necessary, specific period factors applied. Separate factors cannot be incorporated at the moment as the Ferry Terminals do not have specific zones but are combined in zones containing other activities.

Appendices

Appendix A Expanded Demands

A.1 AM Period (6-9am)

	1	2	4	6	31	32	51	52	71	72	73	80	91	92	101	102	111	112	Total
1	101	46	9	3	1	2	1	2	20	3	1	4	0	0	0	0	3	0	195
2	22	346	98	30	19	9	161	7	72	16	16	101	4	2	0	0	1	0	906
4	10	49	323	13	5	22	11	6	4	11	7	6	2	1	0	0	1	0	474
6	11	169	41	234	8	411	16	12	45	30	21	22	8	5	2	1	8	0	1,043
31	18	34	43	5	34	58	3	1	3	3	2	1	1	0	1	0	1	0	209
32	1	2	6	2	1	10	1	0	3	1	1	1	0	0	0	0	0	0	30
51	1	9	358	9	5	5	30	1	3	8	6	3	2	0	0	0	3	0	442
52	4	4	13	11	1	1	4	94	4	6	19	35	16	12	5	33	12	0	274
71	11	23	23	40	7	16	9	7	612	130	31	27	53	10	5	1	7	0	1,012
72	3	12	6	12	2	3	4	4	29	132	5	11	13	2	3	0	7	0	249
73	6	18	16	15	3	10	5	20	17	9	238	153	15	17	2	3	10	1	557
80	12	25	15	20	20	16	4	24	30	13	656	1,139	63	45	3	6	17	1	2,110
91	1	6	2	6	1	1	2	8	26	16	12	126	617	5	41	0	35	0	906
92	1	5	3	6	1	7	2	11	7	3	61	49	6	369	1	5	6	1	541
101	0	0	0	2	0	0	0	5	2	1	1	2	28	1	330	0	38	2	412
102	0	0	0	2	0	0	0	31	1	0	2	7	1	4	0	1,600	0	39	1,687
111	1	2	2	12	2	0	6	13	10	8	7	24	32	4	54	0	4	0	180
112	0	0	0	0	0	0	0	0	0	0	2	2	0	0	2	37	0	0	44
Total	202	750	959	424	110	572	257	246	887	388	1,089	1,712	862	479	449	1,688	155	43	11,271

A.2 Interpeak Period (9am-3pm)

	1	2	4	6	31	32	51	52	71	72	73	80	91	92	101	102	111	112	Total
1	175	34	3	6	17	0	0	3	5	17	3	89	39	0	0	0	0	0	392
2	193	711	81	109	249	0	1	4	129	15	19	261	206	5	0	0	4	0	1,987
4	9	52	306	25	0	9	39	20	69	31	38	22	0	0	0	0	1	0	622
6	1	219	292	511	6	3	25	41	25	13	24	42	11	3	14	2	15	1	1,249
31	0	127	0	64	126	7	0	1	0	0	6	45	0	0	0	0	1	0	379
32	0	16	23	95	0	35	448	1	1	0	0	1	0	0	0	0	0	0	620
51	0	4	651	12	1	13	60	8	5	5	2	6	0	0	0	0	7	0	773
52	3	2	13	30	0	0	9	342	15	9	30	72	30	23	7	46	26	1	659
71	0	19	19	23	7	0	17	24	1,216	103	11	148	49	3	1	0	16	0	1,658
72	2	5	16	10	1	1	3	10	101	275	5	12	12	1	0	0	16	0	469
73	0	6	7	12	0	0	0	34	11	6	502	456	14	14	1	2	11	2	1,078
80	2	413	7	27	0	0	3	88	133	13	793	2,696	16	260	1	5	61	4	4,521
91	0	280	0	5	0	0	0	20	40	10	14	12	1,387	5	88	0	98	2	1,963
92	29	0	16	6	0	0	0	34	21	5	29	305	3	680	0	22	9	4	1,162
101	0	0	0	1	0	0	0	8	1	0	0	25	82	0	1,177	0	128	6	1,428
102	0	0	0	2	0	0	0	67	1	0	1	4	0	4	0	5,341	2	105	5,527
111	2	2	3	39	1	0	23	17	14	15	10	47	63	6	117	4	7	0	371
112	0	0	0	2	0	0	0	1	1	0	1	3	0	1	4	75	0	3	91
Total	416	1,892	1,437	979	410	68	630	722	1,789	517	1,488	4,247	1,911	1,004	1,411	5,495	404	127	24,948

A.3 PM Period (3-6pm)

	1	2	4	6	31	32	51	52	71	72	73	80	91	92	101	102	111	112	Total
1	77	6	2	6	0	0	1	0	33	5	2	39	29	1	0	0	1	0	201
2	25	229	7	60	19	12	10	1	119	8	7	154	14	7	0	3	3	0	680
4	5	20	126	24	140	9	20	5	84	3	3	23	10	5	0	0	2	0	479
6	7	101	11	173	9	54	8	12	20	8	3	21	3	5	1	1	9	1	444
31	0	3	78	6	26	1	3	0	3	0	2	8	0	1	0	0	0	0	130
32	0	107	132	10	4	11	67	0	2	2	1	17	2	2	0	0	0	0	357
51	0	10	3	4	0	1	14	4	3	1	1	4	0	0	0	0	10	0	54
52	0	1	3	8	0	0	3	60	6	2	4	22	8	3	1	17	4	0	142
71	33	37	9	9	10	0	2	9	489	26	7	99	17	7	1	1	5	0	760
72	3	2	1	4	0	0	0	2	17	80	2	7	6	1	1	0	6	0	134
73	3	9	6	3	0	0	0	11	7	2	127	138	4	12	0	5	9	0	337
80	22	100	12	14	1	0	4	31	70	4	316	1,224	82	25	2	3	35	1	1,947
91	0	17	0	4	1	35	1	3	17	5	10	51	590	6	13	0	41	0	795
92	1	7	4	3	0	0	0	4	7	0	9	26	4	339	0	6	3	0	412
101	0	0	0	1	0	0	0	1	3	1	1	2	28	1	274	0	45	5	362
102	0	6	0	1	0	0	0	20	1	0	1	4	1	9	0	1,589	0	37	1,670
111	0	3	1	19	0	0	14	6	6	16	3	21	24	5	33	0	2	0	153
112	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	30	0	2	36
Total	176	657	397	350	212	124	148	169	885	162	497	1,858	822	430	328	1,656	176	45	9,093

A.4 Overnight Period (6pm-6am)

	1	2	4	6	31	32	51	52	71	72	73	80	91	92	101	102	111	112	Total
1	58	81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	140
2	45	49	287	1	0	0	0	0	69	0	0	3	0	0	1	0	0	0	456
4	0	254	119	0	0	101	613	7	5	1	0	0	0	0	0	0	0	0	1,100
6	1	5	7	95	0	0	5	40	83	70	4	17	3	1	1	0	33	3	368
31	0	62	0	0	0	0	29	0	0	0	0	0	0	0	0	0	0	0	91
32	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	9
51	0	0	473	3	0	0	6	20	1	2	0	1	0	0	0	0	23	0	529
52	0	13	21	68	0	0	25	127	21	25	33	84	63	36	21	159	37	2	736
71	1	6	7	12	0	0	1	23	266	103	1	3	25	1	0	0	11	0	459
72	40	2	5	7	146	0	3	13	14	176	2	4	15	0	1	0	24	0	453
73	2	0	6	5	0	0	1	20	1	2	110	177	3	1	0	1	7	0	334
80	3	1	2	13	0	0	3	70	7	2	290	552	3	3	2	3	79	4	1,036
91	0	1	0	2	0	0	0	36	10	57	2	3	278	1	5	1	44	0	439
92	0	0	0	0	0	0	1	25	1	0	3	2	2	130	0	2	12	1	179
101	0	0	0	1	0	0	1	7	1	46	0	2	8	0	46	0	42	1	153
102	0	0	0	1	0	0	0	128	0	0	1	1	0	1	0	1,458	0	43	1,634
111	0	1	1	43	0	0	25	35	12	26	9	71	45	9	33	1	12	0	324
112	0	0	0	0	0	0	0	2	0	0	1	2	1	1	1	35	0	3	47
Total	150	476	929	252	146	110	712	552	490	511	457	923	445	184	110	1,660	323	56	8,486

A.5 Daily

	1	2	4	6	31	32	51	52	71	72	73	80	91	92	101	102	111	112	Total
1	411	167	14	16	18	2	2	5	58	24	6	132	68	2	0	0	4	0	928
2	286	1,336	473	200	288	21	172	12	390	39	42	519	224	14	1	3	8	0	4,028
4	24	375	874	63	146	141	683	38	162	45	48	51	13	6	0	0	5	0	2,674
6	20	495	351	1,013	24	468	54	105	173	120	52	102	25	13	17	3	66	5	3,104
31	18	225	122	75	187	66	35	1	6	4	10	54	1	1	1	0	2	0	809
32	1	126	161	107	5	65	516	1	6	3	2	19	2	2	0	0	0	0	1,016
51	1	24	1,486	27	6	19	109	32	11	15	8	13	2	1	0	0	43	0	1,798
52	6	19	51	117	1	1	42	624	47	42	86	213	116	74	34	255	80	4	1,811
71	45	85	58	84	25	16	28	63	2,583	361	50	277	144	21	7	2	39	0	3,888
72	49	21	28	33	150	3	10	30	161	663	14	34	46	3	5	0	53	0	1,304
73	10	34	35	35	3	11	5	84	35	19	977	924	36	44	3	11	38	2	2,307
80	39	539	36	74	21	16	14	213	240	32	2,054	5,612	164	334	8	16	192	10	9,614
91	1	303	2	17	1	37	3	68	93	89	39	192	2,871	17	148	2	219	2	4,103
92	31	11	22	15	1	7	2	73	36	8	102	382	15	1,518	1	35	30	5	2,294
101	0	0	0	6	0	0	1	20	7	48	2	30	145	2	1,827	0	253	13	2,356
102	0	7	0	6	0	0	1	246	2	1	4	16	2	19	0	9,988	2	223	10,518
111	2	7	8	114	3	0	69	71	42	65	28	163	164	24	237	6	24	0	1,028
112	0	0	0	4	0	0	1	3	1	0	5	6	1	3	10	177	0	7	218
Total	944	3,775	3,721	2,005	879	873	1,747	1,689	4,051	1,579	3,530	8,741	4,040	2,097	2,298	10,499	1,057	272	53,798

Appendix B Peak Period Factors

B.1 AM Peak (6-9am) Factors

Sector	South	CBD	Port	Johnsonville	Hutt	West Rural	East Rural	Externals
South	0.26	0.25	0.26	0.20	0.16	0.18	0.18	0.26
CBD	0.14	0.26	0.16	0.15	0.18	0.24	0.20	0.14
Port	0.25	0.20	0.16	0.17	0.18	0.17	0.17	0.17
Johnsonville	0.24	0.26	0.17	0.25	0.17	0.26	0.26	0.18
Hutt	0.17	0.26	0.16	0.26	0.15	0.26	0.19	0.16
West Rural	0.19	0.18	0.17	0.23	0.26	0.16	0.26	0.16
East Rural	0.16	0.26	0.17	0.26	0.19	0.25	0.16	0.17
Externals	0.26	0.15	0.19	0.17	0.18	0.21	0.20	0.17

B.2 Interpeak (9am-3pm) Factors

Sector	South	CBD	Port	Johnsonville	Hutt	West Rural	East Rural	Externals
South	0.44	0.37	0.43	0.43	0.47	0.47	0.40	0.38
CBD	0.37	0.43	0.41	0.47	0.40	0.38	0.40	0.37
Port	0.37	0.39	0.47	0.40	0.39	0.40	0.40	0.40
Johnsonville	0.37	0.40	0.40	0.45	0.47	0.39	0.37	0.39
Hutt	0.47	0.38	0.42	0.41	0.44	0.37	0.47	0.39
West Rural	0.47	0.40	0.40	0.37	0.38	0.47	0.37	0.47
East Rural	0.47	0.47	0.40	0.41	0.47	0.37	0.44	0.46
Externals	0.38	0.38	0.39	0.38	0.39	0.45	0.41	0.40

B.3 PM Peak (3pm-6pm) Factors

Sector	South	CBD	Port	Johnsonville	Hutt	West Rural	East Rural	Externals
South	0.20	0.14	0.17	0.26	0.26	0.19	0.26	0.25
CBD	0.25	0.21	0.16	0.26	0.26	0.26	0.26	0.24
Port	0.14	0.16	0.14	0.17	0.16	0.17	0.17	0.17
Johnsonville	0.21	0.18	0.16	0.15	0.20	0.16	0.26	0.17
Hutt	0.22	0.24	0.16	0.18	0.15	0.26	0.18	0.19
West Rural	0.19	0.26	0.17	0.14	0.24	0.19	0.26	0.19
East Rural	0.26	0.15	0.17	0.18	0.18	0.25	0.14	0.15
Externals	0.25	0.21	0.16	0.19	0.17	0.14	0.17	0.17

B.4 Overnight (6pm-6am) Factors

Sector	South	CBD	Port	Johnsonville	Hutt	West Rural	East Rural	Externals
South	0.10	0.24	0.14	0.11	0.11	0.16	0.15	0.11
CBD	0.24	0.10	0.26	0.12	0.15	0.12	0.14	0.25
Port	0.24	0.26	0.23	0.26	0.26	0.26	0.26	0.26
Johnsonville	0.19	0.15	0.26	0.15	0.16	0.19	0.11	0.26
Hutt	0.14	0.12	0.26	0.15	0.26	0.11	0.16	0.26
West Rural	0.16	0.15	0.26	0.26	0.12	0.18	0.11	0.18
East Rural	0.11	0.12	0.26	0.15	0.16	0.12	0.26	0.21
Externals	0.11	0.26	0.26	0.26	0.26	0.20	0.22	0.26

Appendix C Comments and Responses

Section.	Comment By	Comment	Response
General	Andy Ford, GWRC	The note is pretty impenetrable – overload of coefficients, factors etc – and must admit I found it really hard to follow and pull out the salient points Accept that this is the nature of such technical reports, however a simple exec summary would be quite useful – approach, challenges, outputs, interim validation, limitations and next steps.	We accept that this report contains a lot of analysis which makes it challenging to read. We have included more detail than the equivalent for the 2013 model update as we realised some key steps/factors were not previously reported (by us) and should have been for completeness. Hence this report is more detailed. We included Section 12 (Summary of Adopted Model Coefficients) to improve the readability of this report, but we will add an Executive Summary.
General	Andy Ford, GWRC	Can you refer to the sectors by name as opposed to number – helps make the tables a bit more digestible and understandable.	Report updated (text and graphs) with sector names instead of numbers.
General	Andy Ford, GWRC	I can see that the technical approach is thorough and robust – I suppose what I am looking for (and what doesn't really come through in the report) is some confirmation that this produces a realistic representation of the number and distribution of HCV trips, both at a high level and within significant areas of interest, to provide me with greater confidence in the HCV demand than is currently the case in WTSM. And equally if there are some areas where the representation is less than good, highlight these so that we can understand the limitations and work to address them.	There is more observed travel pattern data, which inherently reduces uncertainty. The 2019 daily sample had 14,000 trips whereas for the 2013 model development, the sample was only 8,000 daily trips, 4,200 of which was from eRUC. The sample travel pattern data could have some bias as it is sourced from only one company. Understanding any bias is constrained by the commercial confidentiality of the supplier. However, ensuring there is no bias would require a significant financial investment, the merit of which is questionable. To identify potential areas of weakness, we could compare the synthetic demands to the expanded eRUC. However, given the sample eRUC has significant geographic variation, ranging from 10-50% depending on the screenline, this is not a particularly robust comparison. We can identify screenlines and hence areas that are high or low, and as you noted, this is best achieved in the final model validation during Stage 2. This will also follow final adjustment

Section.	Comment By	Comment	Response
			of the peak period proportions which cannot be undertaken until Stage 2.
General	Andy Ford, GWRC	I do accept that to some extent this further confirmation will take place during the final validation process, therefore don't want you to do abortive work at this stage, however I wonder if there is perhaps a more compelling way to draw out some of the key validation points (both +ve and –ve) that will be of interest to model users?	Results by screenline have been included in Section 15, which shows positives and negatives as well as geographic coverage.
General	Tony Brennand, Waka Kotahi	Overall a very good report which I enjoyed reading. There is some good work here which I hope one day is presented at a conference. Some of it looks cutting edge.	Thank you.
General	Tony Brennand, Waka Kotahi	The other comment I would make is it is likely to have some feel for the variability of trip matrices by time period. This would be helpful as the WTSM model will need to be applied in sensitivity testing or scenario modelling. It would be helpful to be able to vary future HCV matrices so that they can easily support the examination of different scenarios in a robust and consistent way.	A simple process to enable adjusted HCV matrices to be tested can be incorporated in Stage 2. This could also be accomplished by adjusting the peak period proportions.
General	Ian Clark, Flow	I am generally not repeating comments already provided by Andy and Tony.	Appreciated.
2	Ian Clark, Flow	Section 2, page 1. Should we be worried at the 5 minute dwell time as a cut off? Presumably if a vehicle was caught in congestion then this could trigger the cut off?	The 5 minute dwell indicating a trip end was integral to the data available to us, so this was outside of our control. Even if we were able to specify the dwell time for a trip cut-off, only the data supplier is able to interrogate the impact. The data is provided to us in aggregate format for confidentiality reason. Having said this, we have sourced and processed tracking data previously. We found that as well as dwell time cut-offs we needed to buffer intersections and railway crossings so that slow moving traffic was not flagged as a trip end. Given that eRUC data processing has been ongoing for many years (since before 2013), it's expected that the data suppliers have honed their processes. But it is an unknown,

Section.	Comment By	Comment	Response
			which is offset by the considerable expense of collecting an alternative dataset.
2	Ian Clark, Flow	Also, we often only use "neutral weekdays", whereas section 2 refers to the use of data from all weekdays (21 days in March 2019).	The eRUC data was purchased prior to this study and so the month and year was already locked in. There were no holidays in Wellington in March 2019, so the weekday data is considered representative.
3	Ian Clark, Flow	Section 3, page 2. Would it have made any difference if you had derived overnight trip estimates from weekday inter peak rather than peak info (with different factors – but would the distribution have been different?)	Preferably, we would not have had to estimate the observed Port count at all. The interpeak was not used as we needed to partially derive the interpeak count as well, factoring from 3 observed hours to 6 modelled hours.
4	Ian Clark, Flow	Section 4, page 6. I am unclear why the 29% sample was reached, when a 40% sample was expected (as stated in Section 2).	The expected 40% sample was anecdotal, the 29% was based on comparison with 2018 traffic counts. In some locations, the sample was 40% or more while in others, it was considerably less. We will add a sentence to the report to clarify.
5	Ian Clark, Flow	Section 5. page 12. I am unclear why the daily trip rate method produced only half of the expected trips.	We cannot explain this either, so we discarded the daily trip rate.
5	Ian Clark, Flow	Section 5.2.2, page 10. Am I right in saying that the interpeak factors in Table 5-2 include the trip end control (referred to in the text above the table)? So the interpeak factor was even higher, without this control.	Yes, the figures in Table 5-2 are a result of incorporating trip end controls for the interpeak only. The overall total number of interpeak trips was not necessarily higher, but certain OD movements were excessively large. This was addressed by adding trip end controls.
5	Ian Clark, Flow	Section 5, page 14. I guess it is to be expected that the expansion would lead to a reduced trip length. Presumably this is completely separate from my first point about the 5 minute cut off, which would also reduce the trip length (by dividing one trip into two).	Yes, although we did spend significant time reviewing the expansion and the impact on trip length. Yes, the 5 minute dwell is a separate issue. The analysis in this section is seeking to replicate the eRUC as supplied, which may (or may not) include some truncated trips as a result of congestion. Truncated trips may not occur if the polling is very accurate (i.e. able to identify that a vehicle has moved slightly in congestion). As we noted above, we do not have access to the raw data to comment further but it is a limitation we should understand.

Section.	Comment By	Comment	Response
7-10	Tony Brennand, Waka Kotahi	When estimating the coefficients of population and households I wonder about dropping households and going with population as a result of a negative coefficient. Households are generally regarded as a more reliable predictor and I would drop population. When I think of freight movement households seems like it is a more logical variable.	Agree that households are a more reliable predictor and more logically associated with freight movements. Including either population or households was evaluated in the model estimation. In almost all cases, both population and households had a negative relationship.
7	Tony Brennand, Waka Kotahi	Tab 7.6 Having a model not being a function of retail, services and communications is a concern. How will this be rectified? The problem is the negative coefficient they generate. The R^2 is fine. This suggests the coefficients of some of the other variables are over estimated. Again I suggest taking out population and replacing it with households.	We concur that a model that excludes key employment types is less than ideal and problematic. The sector-based model which did not include all employment types was therefore not adopted. This is summarised in section 7.1.3. Additional model (model 6, sector-based) added with households instead of population. We have also added model 13 (zone based) using households instead of population replacing model 12.
7	Ian Clark, Flow	Section 7, pages 20-21 and later sections. The regression process described seems logical, and the removal of the negative results that don't make sense is also logical – although I note Tony's comments about the removal of some variables from the equations that it could seem desirable to leave in.	Noted. We have responded above to Tony's specific suggestions. We have adopted a model including all variables. This has a poorer statistical fit, but is more representative from a transport planning perspective.
7	Tony Brennand, Waka Kotahi	I wonder about the need for Fig 7.6 to force the fit line through the origin which seems to lead to some deviation of modelled v observed again for short trips but allow it to have an intercept on the vertical axis. In fact, an intercept of zero on the vertical axis of the log-term seems infeasible. This may lead to a slightly different formulation of the cost function on page 19. However, I accept that post estimation optimisation of this coefficient does not make this a key issue.	This purpose of this trendline is to estimate the parameter α in the gravity model $F(C_{ij}) = e^{(\alpha.C_{ij})}$. Including a constant would distort the distribution function.
8	Tony Brennand, Waka Kotahi	In Tab 8.13, model 15 has a poor R^2 agree the problems encountered in estimating short trips in the last part of section 7 should not be a worry as it is problematic getting reliable data here.	Noted.

Section.	Comment By	Comment	Response
8	Tony Brennand, Waka Kotahi	The Port model 15 has a poor R^2 of 0.34 implying the model has poor explanatory power. This suggest there are other variables responsible or there are significant levels of uncorrelated or random trip generation. There may be a need to rethink the model formulation. In the case of freight I wonder whether there is a general GDP related component that may also help with the models that do not respond to retail, services and communications are arguably covered.	Model 15 is a zone-based regression, all of which have relatively poor R squared values which is partly a function of the sample. We have tested adding GDPPC to the Port Model as a constant (GDPPC multiplied by a coefficient). This had a poor t-statistic and resulted in allocating Port-related HCV trips to every zone, including residential areas. GDP is therefore included in the equation that controls the total number of trips.
8 & 10	Tony Brennand, Waka Kotahi	Again GDP should be looked at as a variable for external trip generation and Port to/from external trips. Sect. 16.2 shows the importance of GDP as a contributing factor.	See above response. Tested and discarded.
8	Ian Clark, Flow	Section 8.2. Tony has already commented on the R squared values in this section, which would appear to be of concern.	The poor R squared reflects the mismatch between the explanatory land use data and the expanded eRUC. The problem is exacerbated by the data we had to use as "Port" which included adjacent non-Port activity. This is because the eRUC data was supplied by model zone, and the Port is currently not in an individual zone. The alternative to the synthetic model would be to adopt the eRUC matrices (i.e no "model") and factor them for future years. We believe this is a weaker approach as the synthetic model smooths out the lumps created by expanding the sample eRUC data.
15	Andy Ford, GWRC	Validation checks are where I have focussed most of my attention: • accept that what is presented in TN 11 is subject to change during the final validation in Stage 2, therefore should be interpreted in this context • R squared and y=x is very good, however what I am looking for is whether there is any bias in particular areas? • Specifically, I'm keen to understand how many short distance HCV trips are generated within Wellington	Agreed. Results by screenline have been included in Section 15, which shows geographic coverage and over and underestimates by area. We suggest that a more robust representation of "reality" would be required to draw any meaningful conclusions on trip

Section.	Comment By	Comment	Response
		CBD (and other suburbs for that matter) and how this compares with the reality. • Presumably the link count validation could be used at a geographic area (i.e. within particular sectors - provided sufficient data is available) to give an indication of whether at a high level we have reasonable volumes of trucks? If we don't have the count data, does it pass the "sniff test" – for example, percentage HCVs as a % of total traffic volumes? I also wonder if some of the stats could be presented more visually – I'd find a map with count locations / screen lines colour coded according to validation a lot more useful than scatterplots	length by area. This is because the eRUC sample varied considerably across the region (see Table 4.3) and hence the expansion has impacted on trip length (expanded vs sample). The synthetic model lengthens trips as shown in Fig 7-9, so the synthetic model does not have more short trips than the expanded observed. Results by screenline have been included in Section 15, which shows geographic coverage and over and underestimates by area. A table of percentage HCVs has also been included, noting modelled cars represent 2013 while HCV's are 2018.
15	Ian Clark, Flow	Section 15. Andy has already commented on the validation results received. I concur with the comment on page 53, that while the GEH results apparently reach the Model Development Guideline standards, these results relate to small numbers, meaning that the MDG standards are not strictly applicable. I wonder if there would be value in highlighting some of the locations where the validation is not that good (this is a similar comment to Andy's), as this may assist in the consideration of the aspects of the model where the R squared values were low (eg Section 8.2). On the other hand, there appears to still be a data processing component required (eg page 52 notes the need to remove buses from the counts of "heavy vehicles")	Results by screenline and commentary have been included in Section 15, which shows geographic coverage and over and underestimates by area.
16	Andy Ford, GWRC	Forecast approach with growth in HCV linked to GDP is robust.	Noted.
16	Ian Clark, Flow	Section 16.2 is an interesting diversion, in that it seeks to establish a relationship between GDP (per capita) and VKT – which presumably will be of use at the forecasting stage. The	Noted

Section.	Comment By	Comment	Response
		saying around past performance does not guarantee future trends comes to mind here, but the logic of the analysis seems sound. The following section (16.3) refers to the sensitivity of the assumption (around the correlation of GDP and VKT), with the important recommendation around the range of tests required where the forecasts of HCVs are critical.	While we concur that "the past does not necessarily guarantee the future", forecasting the total number of future HCV movements based entirely on employment predictions, which are themselves inherently difficult to estimate, is considered weaker than adding the link to GDP.

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