TN27 - WELLINGTON TRANSPORT ANALYTICAL TOOLS 2019-23 UPDATE – EXTERNAL LIGHT VEHICLE MODEL

PREPARED FOR GREATER WELLINGTON REGIONAL COUNCIL

November 2022

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REVISION SCHEDULE

Rev No.	Date	Description	Signature or Typed Name (documentation on file)			
			Prepared by	Checked by	Reviewed by	Approved by
1	7 Sep 2022	Internal draft	LA/JEB	JEB	GC	
2	13 Oct 2022	Second draft, for comment	LA/JEB	JEB	GC	JEB
3	30 Nov 2022	Final version, updated and including client comments	JEB/LA	JEB	GC	JEB
4	2 June 2023	Final – reporting corrected to match analysis and model	JEB/LA	JEB	GC	JEB

Greater Wellington Regional Council

TN27 - Wellington Transport Analytical Tools 2019-23 update – External Light Vehicle Model

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APPENDICES

1. Introduction

This technical note is part of a series documenting the 2019-2023 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 is the client for this project. This project is being delivered by Stantec and Jacobs, supported by GWRC transport planners.

This technical note documents the development of the model to predict light vehicle demands travelling from outside the modelled area into the modelled area and vice versa via State Highway 1 (SH1) or State Highway 2 (SH2) in the north of the region.

The external light vehicle model is separated into two models, one for SH1 (external zone 2261) and one for SH2 (external zone 2271). Linear regression models have been fitted to distribute the daily external light vehicle demand to internal zones. These regression models have the form of coefficients multiplied by explanatory data that is appropriate to transport such as employment, population, and potentially distance. The daily demand is the sum of both inbound and outbound trips. The demand is then converted to peak periods using fixed sector-based factors.

In version 1 of this technical note, a distance skim on a minimum generalised cost skim was used. Version 2 of this note addressed client comments. Version 3 (this note) has the distance skim changed to be on a minimum distance path. This means the external light vehicle model does not need to be iteratively recalculated and can be applied once at the start, reducing run times. The only notable difference is that households are no longer an explanatory variable for the SH2 model.

2. Data

2.1 Observed Demand Data

The observed data used is sourced from the Wellington Transport Assignment Model (WTAM). The WTAM has demands from 2018 mobile phone data which have been factored to the northern external road screenline counts and then matrix estimated to the internal screenlines. The daily trips are the sum of the four modelled periods, AM, interpeak (IP), PM and overnight (ON) for each zone to/from each of the external zones. The reason for summing the inbound and outbound trips is to provide enough information for each zone to enable estimation of a robust model.

Attractors (zone number in brackets) that are to be removed from the observed data before applying regression techniques are:

- Port (2281)
- Ferry Terminals (2291 and 2301)
- Airport (2311)
- the opposite external zone (SH1 model removed zone 2271, SH2 model removed 2261)
- any zones that had zero daily trips

The rationale for these adjustments in turn is:

- Only heavy vehicles are modelled to the Port special generator zone, so external light vehicles will not be represented
- Light vehicle trips to/from the Ferry Terminals have a separate model, so are not modelled in this module
- This light vehicle external model will also not produce any trips to/from the Airport flight-related zone (zone 2311) as there is a separate Airport Model
- Any trips between SH1 and SH2 without an intermediate stop are likely spurious, so have been removed
- Zones with zero trips but non-zero land use will result in a poor model being estimated, particularly as the lack of trips might be due to missing observations

Trip purposes are not considered for external light vehicles, due to the small volumes and limited observed data.

The observed and modelled external flows have been aggregated to 11 sectors in this technical note for reporting. The 11 sectors are illustrated below.

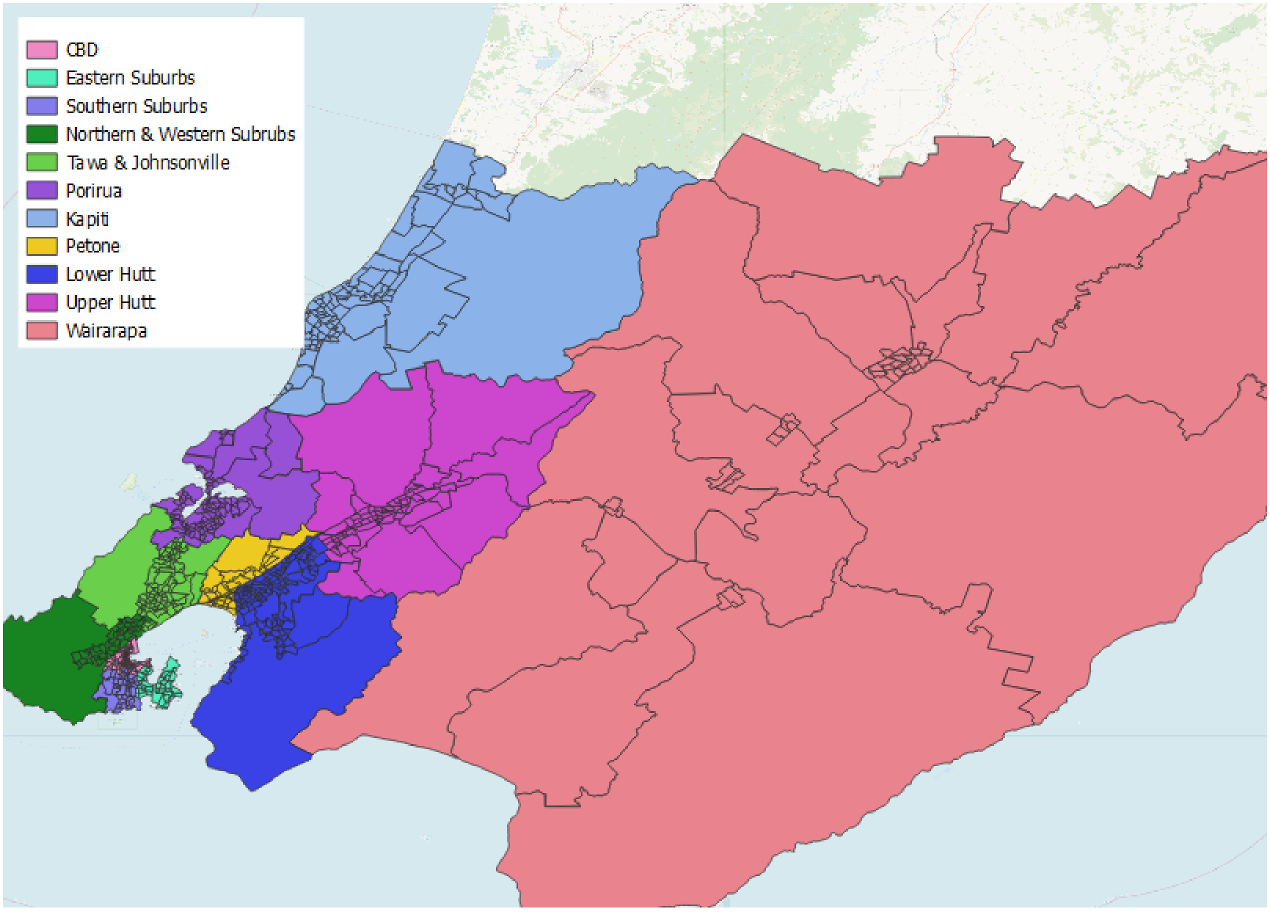

Figure 2-1: 11 Sectors

It should be noted that the WTAM demand matrices used as the source of observed trips are not the final version, as both models (WTAM and externals) were progressed in parallel. The observed daily two-way trips used for the external model estimation are shown below.

Table 2-1: Observed Daily External Light Vehicle Trips (Two-Way)

Sector Name	SH1		SH2
	Observed	Observed, Adjusted	Observed
CBD	1,104	1,104	156
Eastern suburbs	3,015	510	196
Kapiti	5,976	5,976	153
Lower Hutt	817	817	154
North and Western suburbs	416	416	54
Petone	381	381	57
Porirua	1,076	1,076	84
Southern suburbs	362	362	62
Tawa and Johnsonville	709	709	85
Upper Hutt	631	631	169
Wairarapa	986	986	1,730
Grand Total	15,472	12,966	2,900

There is a large number of trips between the Eastern suburbs and the SH1 external. This is associated with zone 71, which contains the Airport. As Airport-related trips are treated separately, and since this data point appears to be an outlier, observed trips for zone 71 have been removed for the SH1 model estimation. The "Observed, Adjusted" trips in the table above excludes zone 71.

The external light vehicle traffic flows are shown below from traffic counts. These form the control totals for the model that will be implemented. There are some very minor differences to the observed figures shown in Table 2-1, which is associated with WTAM processing.

Table 2-2: Traffic Count - Daily External Light Vehicle Trips

External	NB	SB	Two Way
SH1	7,808	7,611	15,419
SH2	1,529	1,332	2,861

2.2 Explanatory Data

The main explanatory data is Census data from 2018 which has been processed to the 820 zone system as well as factored from usual resident population to estimated resident population definition. The initial group of land use types to be input to the linear regression is:

- Agriculture, Forestry, and Fishing
- Mining
- Manufacturing
- Electricity, Gas, Water and Waste Services
- Construction
- Wholesale Trade
- Retail Trade
- Accommodation and Food Services
- Transport, Postal and Warehousing
- Information, Media and Telecommunications
- Financial and Insurance Services
- Rental, Hiring and Real Estate Services
- Professional, Scientific and Technical Services
- Administrative and Support Services
- Public Administration and Safety
- Education and Training
- Health Care and Social Assistance
- Arts and Recreation Services
- Other Services
- Total Employed
- Total Households (HH)
- Total Population

In addition to the above land use variables, the distance from each zone to each external was subsequently included. This was because greater interaction was observed nearer to the northern externals. Because the regression coefficients are to be positive, the distance was inverted so that zones closer to the externals had higher distance values that those further away. The distance skim is extracted on a minimum distance path.

3. Regression Process and Results

3.1 Model Estimation

Linear regression techniques were applied to calculate coefficient values using the explanatory data described in section 2.2 and observed data from section 2.1. For SH1, the "observed, modified" data has been used which excludes the outlier of trips to/from the zone containing the Airport (zone 71).

The regression coefficients need to be positive (i.e. if the land use increases, so does the demand). Very few of the land use types produced a positive coefficient value for either of the external zones. The best relationship for the daily demand at each external zone included the inverse of distance and initially had R-Squared values around 0.3-0.4. By squaring the inverted distance, this gave more weight to zones closer to the external boundary and increased the R-Squared value to 0.7 for SH1 and 0.5 for SH2.

The model estimation/regression process was checked using other regression software (MiniTab) which included the functionality to perform stepwise regression (where the regression software keeps only the variables with a statistically sound relationship). The same results were found, in that, no better relationship could be produced using more comprehensive regression software. The estimated models for SH1 and SH2 are reported below in Table 3-1 and Table 3-2.

Table 3-1: Regression Outputs for SH1

SH1 – External 2261									
Coefficients **Term**				**Coef**	**SE Coef**	**T-Value**	**P-Value**	**VIF**
Total Employment				0.011	0.0013	8.077	0	1.1
Households				0.015	0.00295	5.1	0	1.2
Inv Dist^2				24826	625	39.704	0	1.1
Model Summary								
S	**R-sq**	**R-sq(adj)**	**R-sq(pred)**					
22.266	71.73%	71.63%	68.30%					

Table 3-2: Regression Outputs for SH2

SH2 – External 2271								
Coefficients **Term**				**Coef**	**SE Coef**	**T-Value**	**P-Value**	**VIF**
Total Employment				0.000752	0.000475	1.583	0.114	1.1
Inv Dist^2				32,501	1,028	31.936	0	1.1
Model Summary								
S	**R-sq**	**R-sq(adj)**	**R-sq(pred)**					
8.290	59.1%	58.9%	0.00%					

R-Squared (adjusted R-Squared, R-sq(adj), should be used), T values, and P-values measure the fit of the regression between the observed trip ends and the explanatory data. The higher the R-squared values, the better and ideally greater than 90% with respect to the overall fit of the data. For individual coefficients, however, the T value is important – any number greater than two generally meaning a strong correlation and a lower chance that the variable has a random relationship with the results. The P-value is a measure of the strength of the evidence that the variable is truly representative of the data. Typically, the smaller the P-value (for example, less than 0.01), the stronger the evidence the variable represents the data.

The inverted distance squared, total employment, and households were the variables that best predicted the daily demand for the SH1 externals. Each variable has a strong T-value and zero P-value indicating the variables are statistically significant. For SH2, households had a negative relationship and had to be excluded (population had the same issue). Total employment has a correlation but not a strong one, evident from the T value being just less than two. Total employment was retained in the SH2 externals model, however, so that a land use response is included.

The models have an R-squared (adjusted) of 71.6% for SH1 and 59.1% for SH2. The overall fit is not ideal, however, with low R-squared values particularly for SH2. But due to the data available and the numerically small number of externals, this is the best model that could be estimated and is considered sufficient.

Note that for flexibility and at the request of the client, an additional variable has been added to enable alternative distributions to be assessed. This is described with the final model coefficients in Section 6.

3.2 Model Application

The model was then applied. Results for SH1, then for SH2 are provided below.

3.2.1 SH1

The coefficients estimated through regression were multiplied by the explanatory data for every zone, irrespective of whether there are observed trips or not. The modelled trips include zone 71 (where the Airport is located), which was removed from the "Observed Adjusted" data. The adjusted observed, modelled, and the difference are provided below by 11 sectors for external light vehicle trips to/from the SH1 external. The same information is shown in bar chart format in Section 6.

Table 3-3: Modelled vs Observed (Adjusted) Summary Table for SH1

Sector Name	Observed, Adjusted	Modelled	Modelled - Observed Adjusted
CBD	1,104	1,695	591
Eastern suburbs	510	459	-51
Kapiti	5,976	5,176	-800
Lower Hutt	817	1,346	530
North and Western suburbs	416	500	84
Petone	381	481	100
Porirua	1,076	1,143	67
Southern suburbs	362	512	150
Tawa and Johnsonville	709	824	116
Upper Hutt	631	890	258
Wairarapa	986	591	-395
Grand Total	12,966	13,618	652

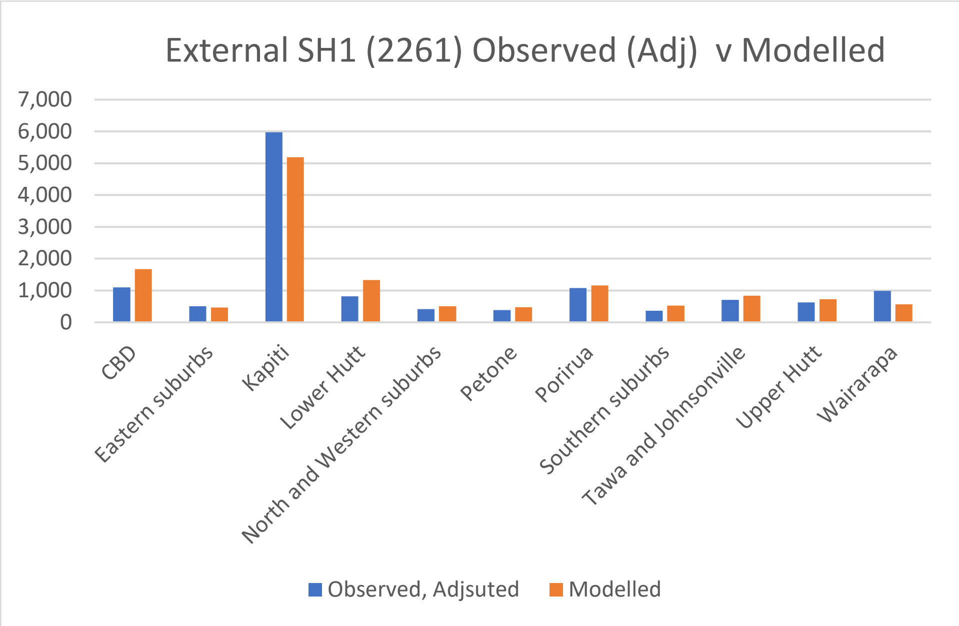

Figure 3-1: Modelled vs observed (adjusted) daily trips by sector for SH1

The model replicates observed well, with no anomalies geographically.

A zonal scatter plot of the same information is provided below. This includes zone 71 for modelled but excludes the spurious observed data.

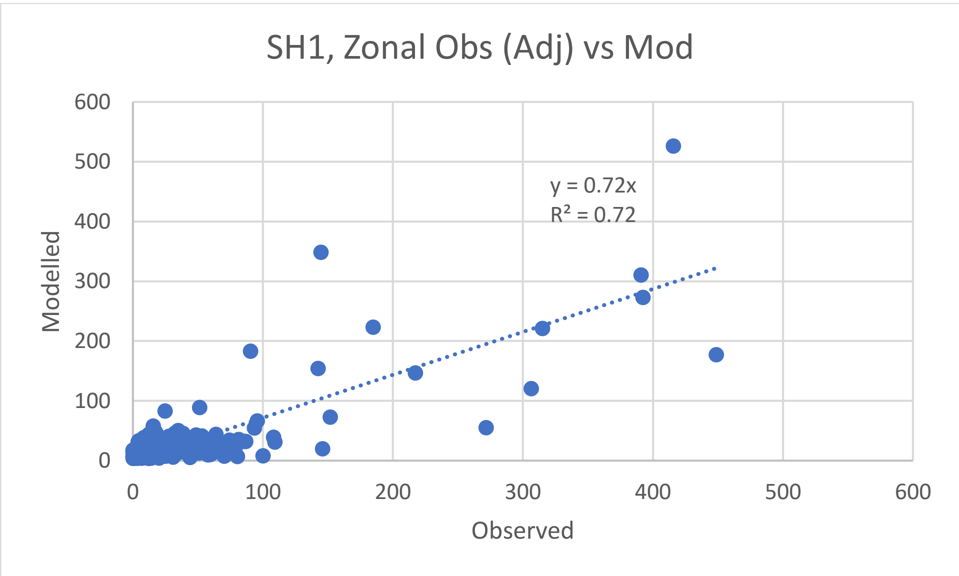

Figure 3-2: Zonal modelled vs observed (adjusted) daily trips for SH1

From Figure 3-2, the slope of the trendline indicates the model will tend to underestimate observed on a zonal basis, although the R-squared value is just within acceptable bounds. There are a small number of zones with a relatively high number of trips that may be obscuring the relationship. The same information is plotted below for zones where the observed is less than or equal to 200 trips per day.

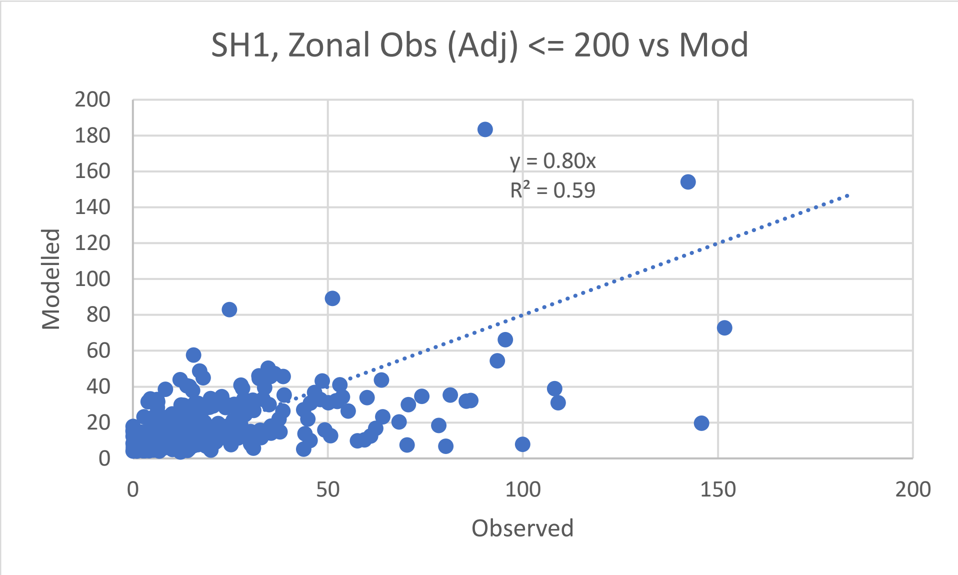

Figure 3-3: Zonal modelled vs observed (adjusted) less than or equal to 200 daily trips for SH1

For observed trips less than or equal to 200, more variation can be seen, which is expected. The slope of the trendline has improved slightly but still confirms the model will tend to underestimate trips on a zonal basis. The R-squared value has also reduced and has a similar magnitude to the SH2 analysis provided in the next section.

While the slope of the trendline and the R-squared value are not ideal, the number of trips is relatively small, and as such, this variation is considered acceptable.

The application of the estimated coefficients to explanatory data does not replicate the traffic count at SH1. This is primarily due to the removal of a large number of observed spurious trips to/from zone 71. The model coefficients have therefore been scaled consistently so that the correct total number of trips are produced. The regressed and scaled coefficients are shown in Table 3-4.

Table 3-4: SH1, Regressed and Scaled Coefficients

External	Explanatory Data	Regressed Coefficient	Scaled & Adopted Coefficient
SH1	Total Employment	0.011	0.0125
	Households	0.015	0.0170
	Inv Dist^2	24826	28206

The modelled trips for SH1 using the scaled coefficients are shown below in Table 3-5. This is primarily for reference, as comparisons to observed are not compatible due to the issue with zone 71 and the resulting differences in totals.

Table 3-5: Modelled External Light Vehicle Trips by Sector for SH1

Sector Name	Scaled Modelled
CBD	1,925
Eastern suburbs	521
Kapiti	5,880
Lower Hutt	1,529
North and Western suburbs	568
Petone	546
Porirua	1,298
Southern suburbs	581
Tawa and Johnsonville	936
Upper Hutt	1,010
Wairarapa	671
Grand Total	15,465

3.2.2 SH2

The coefficients estimated by regression were applied to zonal data to produce modelled trips. These have then been aggregated to 11 sectors and are shown in Table 3-6 as "Modelled". The same information is shown in bar chart format in Figure 3-4.

As expected, the total number of trips did not replicate the traffic count, and so the coefficients were consistently scaled. This is labelled as "Scaled Modelled" in Table 3-6.

The derivation of the trips labelled "factored model" is explained in the text following Table 3-6, which is associated with correcting trip to/from Wairarapa.

Table 3-6: Modelled VS Observed Summary Table for SH2

Sector Name	Observed	Modelled	Scaled Modelled	Factored Model	Mod vs Obs
CBD	156	290	234	168	12
Eastern suburbs	196	85	69	49	-147
Kapiti	153	177	144	103	-50
Lower Hutt	154	408	331	236	82
North and Western suburbs	54	110	89	64	9
Petone	57	135	109	78	21
Porirua	84	237	193	137	53
Southern suburbs	62	98	80	57	-5
Tawa and Johnsonville	85	186	151	107	22
Upper Hutt	169	297	241	172	3
Wairarapa	1,730	1,546	1,256	1,730	0
Grand Total	2,900	3,570	2,897	2,900	

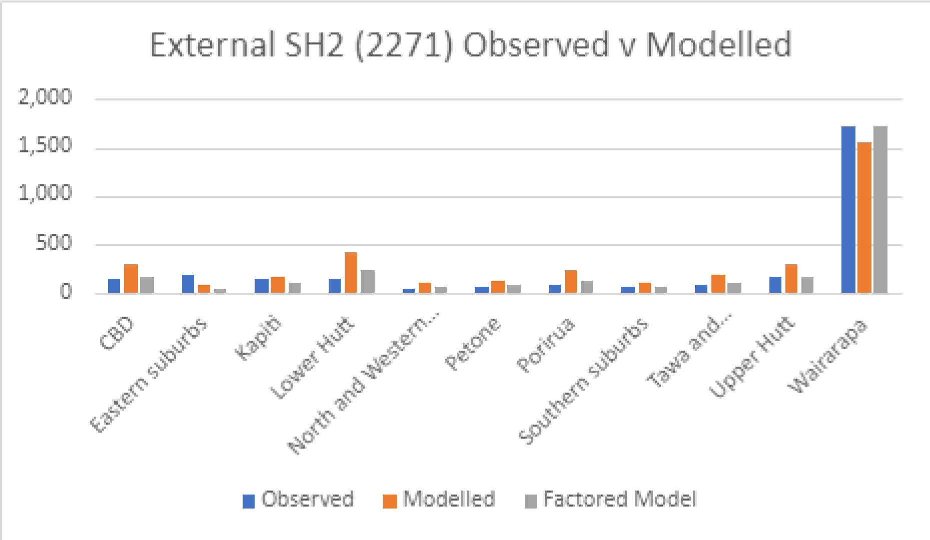

Figure 3-4: Modelled vs observed daily trips by sector for SH2

A significant underestimate for Wairarapa can be seen in Table 3-6 (1730 observed vs 1256 in the scaled model).

This discrepancy is either due to issues in the "observed" data which is from mobile phone tracking data, or that the explanatory variables available do not explain travel behaviour for these trips. The regression was revisited but no better relationship could be found.

The next step was to apply a factor to all trips to/from sector 11 to correct the Wairarapa underestimate. A single factor to adjust the other sectors was then calculated and applied.

The final modelled trips are labelled "factored model" in Table 3-6. These are based on:

- Coefficients estimated by regression, scaled such that the correct total is produced
- A correction factor for sector 11, and a single factor for the rest of the modelled area

Figure 3-5 shows that the factored modelled trips match observed well on a geographic basis. A zonal comparison is provided below.

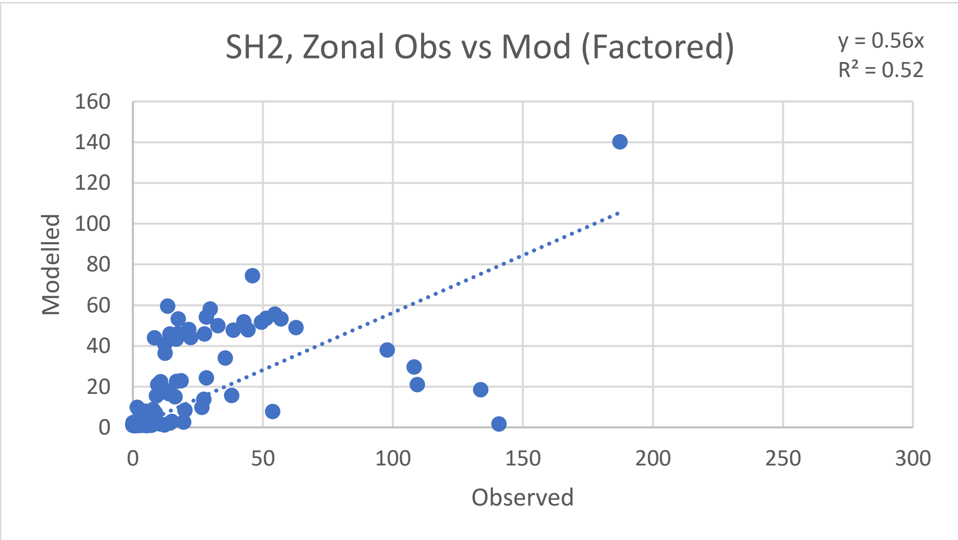

Figure 3-5: Zonal modelled (factored for sector 11) vs observed daily trips for SH2

The R-squared is poor but this is expected based on the regression results. The slope of the trendline is also weak, indicating a tendency for the model to underestimate SH2 external trips. While these results are not ideal, no better relationship could be determined, and the trips are numerically small.

The coefficients estimated from regression, and the final model coefficients are shown below.

Table 3-7: SH2, Regressed and Scaled Coefficients

External	Explanatory Data	Regressed Coefficient	Scaled & Adopted Coefficient
SH2	Total Employment	0.000752	0.0006
	Inv Dist^2	32501	26399
	Wairarapa Adjustment (sector 11)		1.3775
	Rest of Model Adjustment		0.7129

4. Peak Periods

Converting the daily trips to peak periods will be accomplished by applying fixed factors. The time period definitions are shown in the table below.

Table 4-1: Time Period Definitions

Period	Hours
AM peak (AM)	6-9am
Interpeak (IP)	9am-3pm
PM peak (PM)	3-6pm
Overnight (ON)	6pm-6am

The proportions in each peak period were calculated from the light vehicle traffic counts at SH1 and SH2 combined and are shown below for inbound to the CBD and outbound.

Table 4-2: Proportions from Traffic Counts

Period	Inbound (to CBD)	Outbound (from CBD)
AM	0.17	0.15
IP	0.39	0.41
PM	0.25	0.25
ON	0.19	0.20

A flat factor will not reflect the length of the trip, and so peak period proportions by area were calculated from the Qrious demand matrices (including matrix estimation applied for the WTAM). To simplify the model implementation, the same geographic sectors as the Heavy Commercial Vehicle model have been adopted, which are shown below in Figure 4-1.

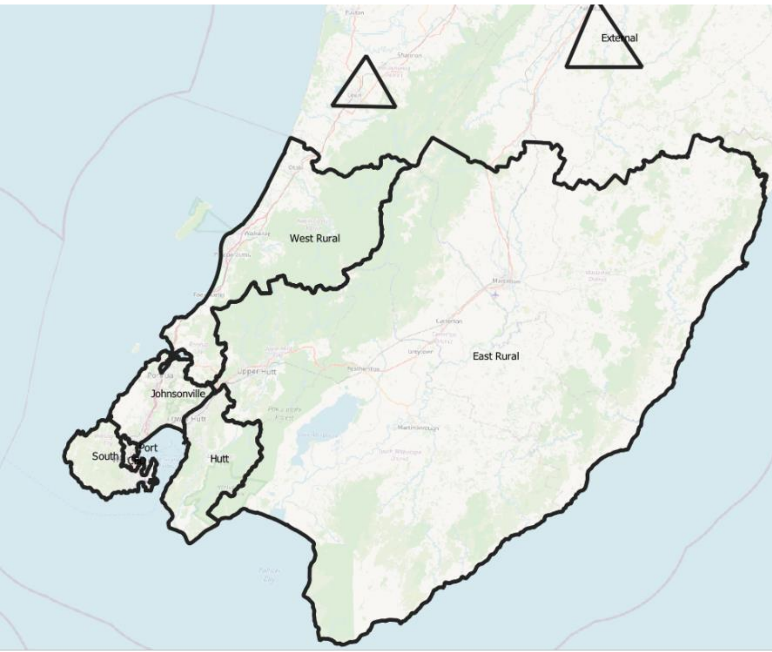

Figure 4-1: Sectors for Peak Period Factors

The peak period proportions for external trips in the Qrious demand matrices are reported below for these sectors. In addition, the average (not weighted) is shown and the proportions from traffic counts.

Table 4-3: WTAM Daily to Peak Period Factors

Sector	Inbound (to CBD)				Outbound (from CBD)			
	AM	IP	PM	ON	AM	IP	PM	ON
South	0.19	0.40	0.21	0.20	0.15	0.44	0.16	0.25
CBD	0.24	0.37	0.26	0.13	0.10	0.35	0.35	0.20
Johnsonville	0.14	0.45	0.26	0.14	0.12	0.37	0.27	0.24
Hutt	0.24	0.37	0.28	0.11	0.16	0.38	0.20	0.26
West Rural	0.20	0.37	0.29	0.14	0.18	0.36	0.32	0.13
East Rural	0.14	0.36	0.39	0.12	0.19	0.40	0.26	0.16
Average	0.19	0.39	0.28	0.14	0.15	0.38	0.26	0.21
Traffic Count	0.17	0.39	0.25	0.19	0.15	0.41	0.25	0.20

The overall period average is very similar to the traffic counts, which is expected as the Qrious matrices were factored to traffic counts by period. The variation by area is not excessive and is therefore considered appropriate.

The AM and PM peak periods need to be further disaggregated into the peak hour and remaining period which is referred to as the "shoulder". The AM peak hour is 8-9am while the PM peak hour is 5-6pm. Peak period to hour/shoulder proportions from the WTAM adjusted matrices by area are shown below.

Table 4-4: Peak Period to Shoulder/ Hour Factors from WTAM

Sector	AM				PM			
	Inbound (to CBD)		Outbound (from CBD		Inbound (to CBD)		Outbound (from CBD)	
	Shoulder	Peak	Shoulder	Peak	Shoulder	Peak	Shoulder	Peak
South	0.97	0.03	0.68	0.32	0.85	0.15	0.74	0.26
CBD	0.64	0.36	0.42	0.58	0.62	0.38	0.65	0.35
Johnsonville	0.55	0.45	0.43	0.57	0.67	0.33	0.68	0.32
Hutt	0.35	0.65	0.54	0.46	0.64	0.36	0.63	0.37
West Rural	0.47	0.53	0.52	0.48	0.66	0.34	0.66	0.34
East Rural	0.42	0.58	0.50	0.50	0.60	0.40	0.69	0.31

The same hour proportions from the light vehicle traffic counts are shown below.

Table 4-5: Peak Period to Peak Hour Factoring from Traffic Counts

Location	Direction	Proportion	
		AM Peak Hour	PM Peak Hour
SH1	NB	0.44	0.32
	SB	0.40	0.33
	Two-way	0.42	0.32
SH2	NB	0.52	0.28
	SB	0.49	0.33
	Two-way	0.51	0.31

The PM peak hour is very consistent, irrespective of direction or location. It is therefore recommended that the SH1 PM peak hour proportion from traffic counts is adopted and applied.

The AM peak shows more variability in terms of location, although the two directions are similar. It is therefore recommended that the SH1 and SH2 peak hour proportions from traffic counts are adopted and applied.

The recommended peak hour proportions are shown below.

Table 4-6: Peak Period to Peak Hour Factors - Recommended

Location	Proportion	
	AM Peak Hour	PM Peak Hour
SH1	0.42	0.32
SH2	0.51	0.32

5. Future Year Growth

Future year traffic flows at the northern road externals will be calculated by applying a percentage per annum growth (linear) derived from trend analysis of existing light vehicle traffic counts.

Counts have been sourced from the Waka Kotahi Traffic Monitoring System (TMS). The sites used are:

- SH1: ID 01N00998 – North of Waitohu River Bridge
- SH2: ID 00200864 – South of Readers Cutting

These sites are shown graphically below.

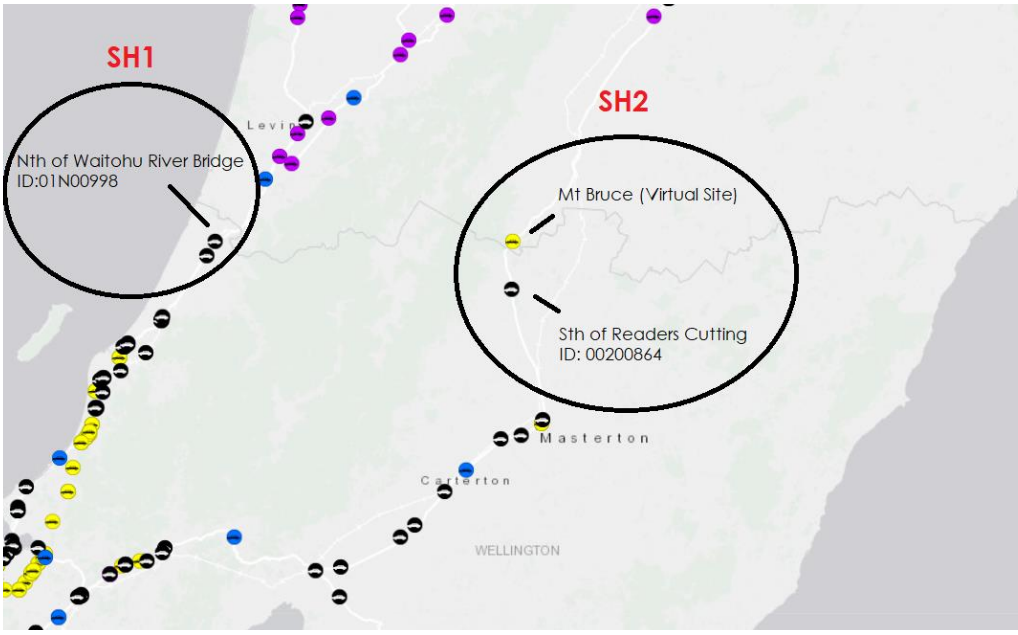

Figure 5-1 TMS Sites

On SH2, the northern model external is nearer the Mt Bruce count site, however, this is a virtual site and historic data could not be sourced. But the Mt Bruce and South of Readers Cutting sites are close to the Regional Boundary as seen in the figure above, so using data from the latter site is considered a sound replacement.

Light vehicle traffic counts for 2013 to 2019 on weekdays at the two sites were extracted. This will include some public holidays, but this is not expected to affect this analysis which evaluates year-on-year trends.

5.1 SH1

For SH1, there appears to be data collection issues/road disruptions from the last quarter of 2018 to 2019 for one of the directions, so this direction has been excluded from the trend analysis. It is noted that years 2013 to 2018 show that total numbers for each direction, before the disruption, are very similar. So the SH1 flows are for one direction only.

The historic annual weekday light vehicle traffic counts for one direction on SH1 are shown in Figure 5-2 below, including the trendline and R^2. This shows a good correlation.

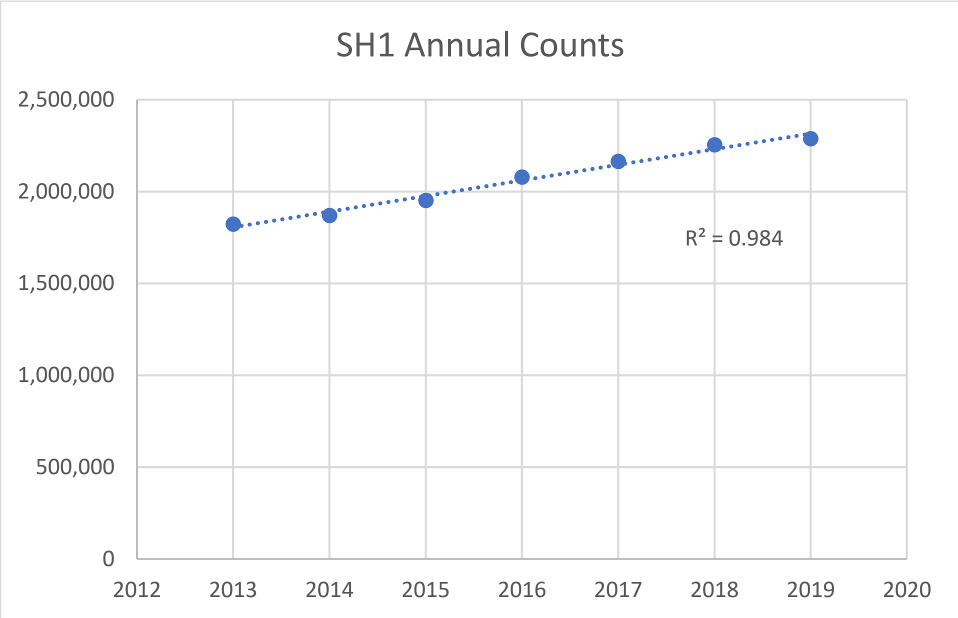

Figure 5-2: SH1 Weekday Light Vehicles – Historic Traffic Counts

Future year forecasts were then calculated by applying MS Excel's "forecast.linear" function. From this forecast growth, an overall percentage per annum has been selected to be used in the model.

The historic and forecast flows are shown in the table below. The first forecast column is calculated using the Excel function which does not produce a constant percentage per annum change. For SH1, a growth of 3.2% per annum was identified to best fit the data. The application of this fixed percentage per annum is shown in the final forecast column, using linear (not compound) growth.

Table 5-1: SH1 Weekday Light Vehicles - Historic and Forecast

Year	SH1 Observed	SH1 Forecast	Growth from Previous Year	SH1 Forecast, specified % p.a.
2013	1,821,994			
2014	1,869,557		2.5%	
2015	1,950,477		4.1%	
2016	2,077,695		6.1%	
2017	2,164,055		4.0%	
2018	2,253,729		4.0%	
2019	2,287,808		1.5%	
2020		2,400,668	4.7%	2,361,018
2021		2,485,646	3.4%	2,436,570
2022		2,570,623	3.3%	2,514,541
2023		2,655,600	3.2%	2,595,006
2024		2,740,578	3.1%	2,678,046
2025		2,825,555	3.0%	2,763,744
2026		2,910,532	2.9%	2,852,183

The observed and forecast traffic flows from the table above are shown graphically below. The green bars show the forecasts from Excel, while the red line shows the application of the fixed percentage per annum.

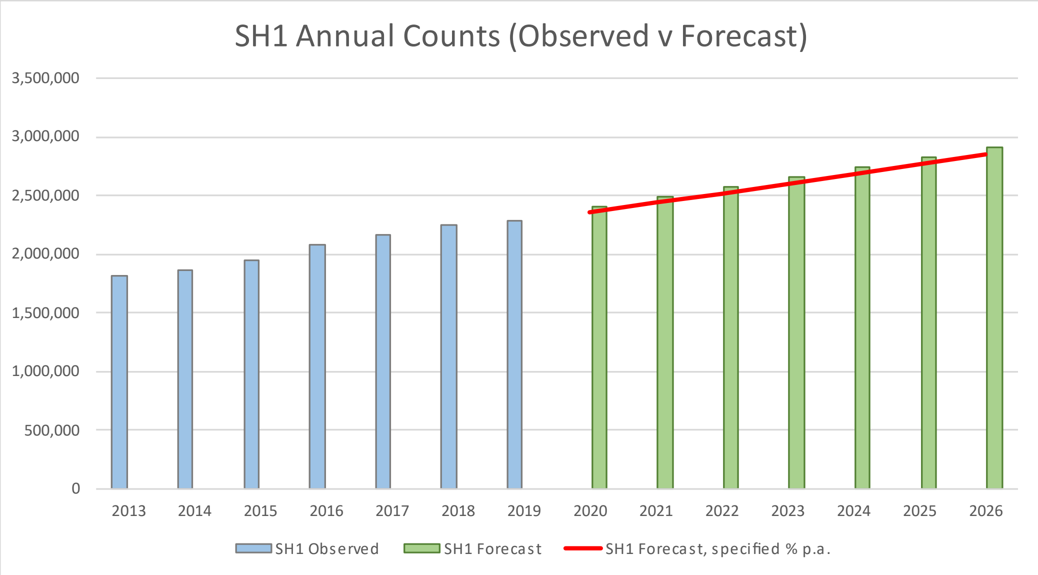

Figure 5-3: SH1 Weekday Light Vehicles – Historic and Forecast

This shows that the adopted percentage per annum growth produces an appropriate forecast.

5.2 SH2

The same analysis is provided below for SH2.

Historic weekday light vehicle flows on SH2 for both directions of travel are shown below.

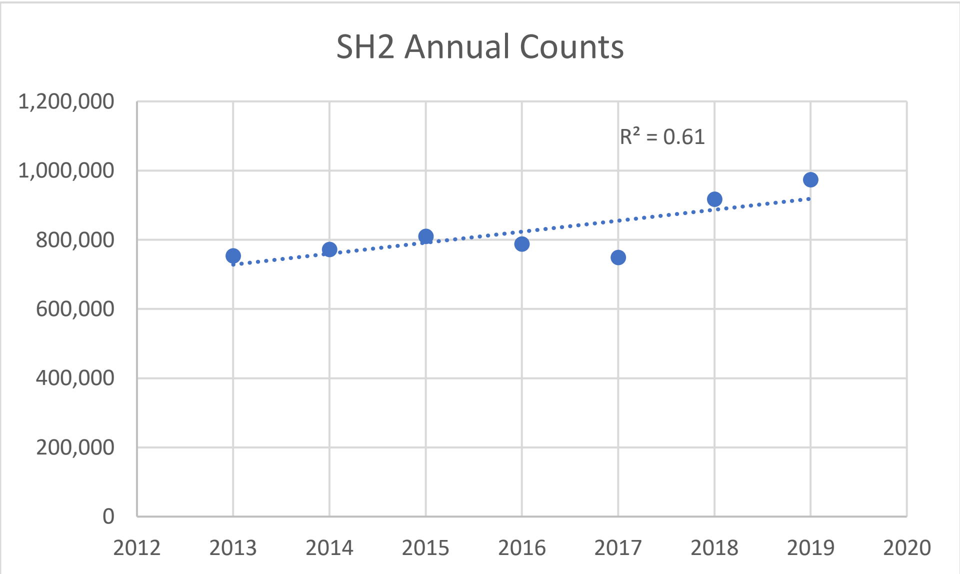

Figure 5-4: SH2 Weekday Light Vehicles – Historic Traffic Counts

For 2016 and 2017, there is a significant and unexplained drop, producing a poor relationship over time. These two years were removed from the historic dataset, and the resulting trend is shown below.

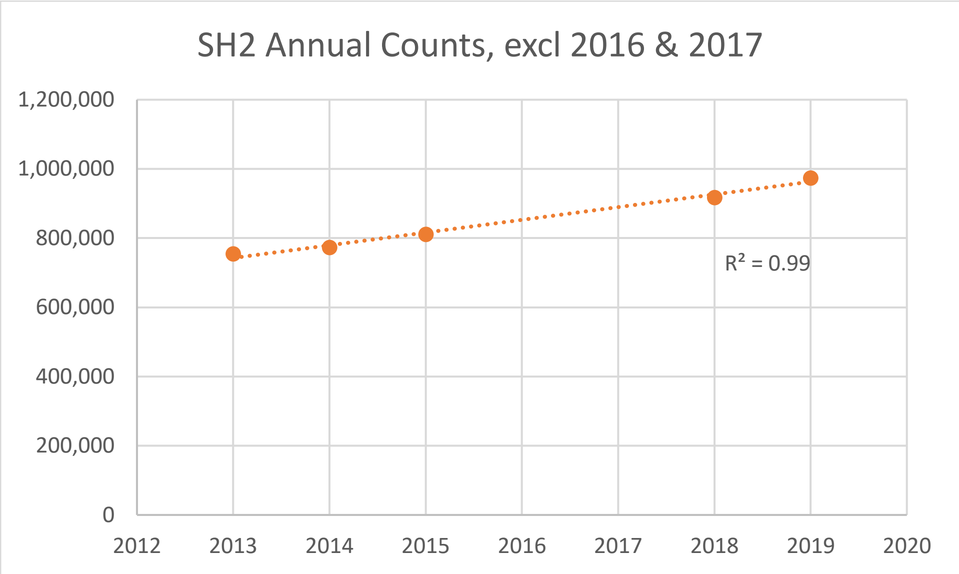

Figure 5-5: SH2 Weekday Light Vehicles – Historic Traffic Counts excluding 2016 and 2017

The years 2016 and 2017 have therefore not been considered in the trend analysis for SH2.

The table below provides historic and forecast traffic flows. The first forecast column is calculated using the Excel function, excluding 2016 and 2017, which does not produce a constant percentage per annum change. For SH2, a growth of 3.2% per annum was also identified to best fit the data. The application of this fixed percentage per annum is shown in the final forecast column, based on linear (not compound) growth.

Table 5-2: SH2 Weekday Light Vehicles - Historic and Forecast

Year	SH2 Observed	SH2 Forecast, excl 2016 & 2017	Growth from Previous Year	SH2 Forecast, specified % p.a.
2013	753,754			
2014	772,555		2.4%	
2015	810,069		4.6%	
2016	787,659		-2.8%	
2017	748,735		-5.2%	
2018	917,201		18.4%	
2019	973,733		5.8%	
2020		999,769	2.6%	1,004,892
2021		1,036,509	3.5%	1,037,049
2022		1,073,248	3.4%	1,070,235
2023		1,109,988	3.3%	1,104,482
2024		1,146,727	3.2%	1,139,826
2025		1,183,467	3.1%	1,176,300
2026		1,220,207	3.0%	1,213,942

The observed and forecast traffic flows from the table above are shown graphically below. The green bars show the forecasts from Excel, while the red line shows the application of the fixed percentage per annum.

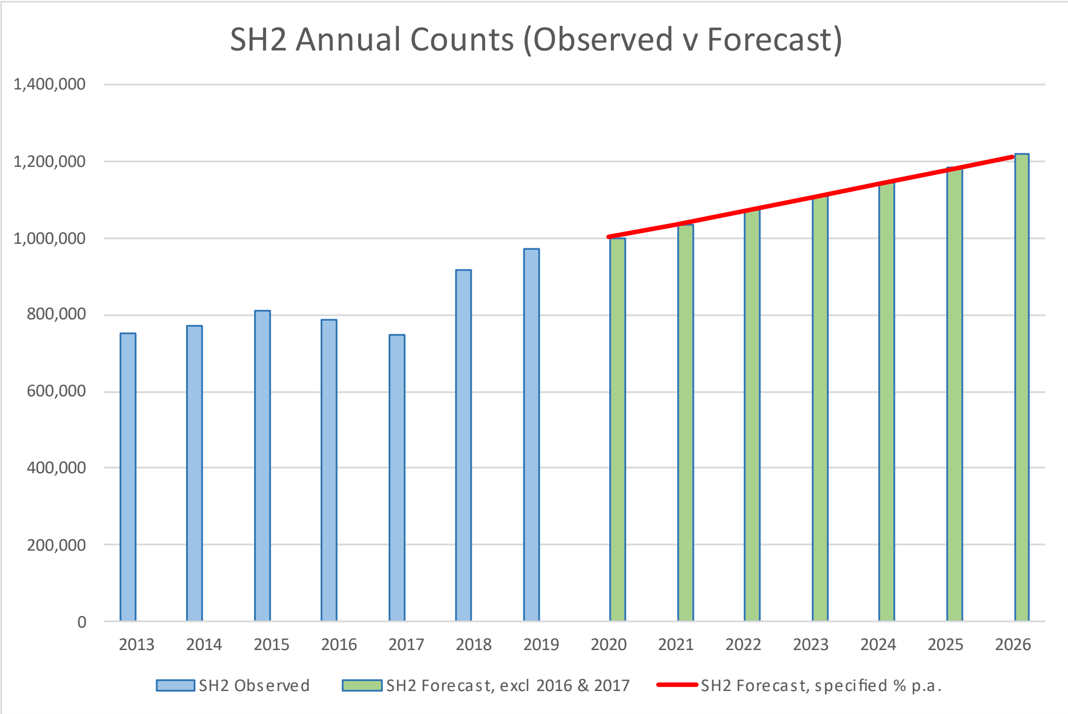

Figure 5-6: SH2 Weekday Light Vehicles – Historic and Forecast

This shows that the adopted percentage per annum growth produces an appropriate forecast.

5.3 Adopted Growth

Based on historic trends, the recommended growth for each of the northern road externals is shown in the table below.

Table 5-3: Recommended Percentage Per Annum Growth (Linear)

Year	Adopted Growth
SH1	3.2%
SH2	3.2%

This is considered a relatively healthy growth. For long term forecasting (i.e. 40 years) and interventions in the northern extremes of the region, it is recommended that a lower external growth should be assessed as a sensitivity test.

For the model itself, future year flows will be read from an input file, which will specify the daily inbound and outbound trips (separately) at each of SH1 and SH2, calculated external to the model. This ensures the total number of daily trips at either SH1 or SH2 can be adjusted for scenario testing.

6. Final Model Coefficients

The model coefficients are replicated here for future ease of reference.

For the distribution, the client has requested the flexibility to test alternate distributions. As such, the ability to specify a trip distribution "adjustment" has been included in the External LV model. This adjustment consists of an optional input trip matrix specifying positive/negative cell adjustments at daily level. Care must be taken such that negative values do not result as no check is made. Likewise, care must be taken to ensure the required external control total is specified. Whilst this methodology involves some user preparation work outside of the model it does provide a very flexible adjustment process, and guarantees that the input adjustment is fully realised.

Table 6-1: Adopted Distribution Coefficients

External	Explanatory Data	Adopted Coefficient
SH1	Total Employment	0.0125
	Households	0.0170
	Inv Dist^2	28206
SH2	Total Employment	0.0006
	Inv Dist^2	26399
	Wairarapa Adjustment (sector 11)	1.3775
	Rest of Model Adjustment	0.7129

Table 6-2: Adopted Daily to Peak Period Factors

Sector	Inbound (to CBD)				Outbound (from CBD)			
	AM	IP	PM	ON	AM	IP	PM	ON
South	0.19	0.40	0.21	0.20	0.15	0.44	0.16	0.25
CBD	0.24	0.37	0.26	0.13	0.10	0.35	0.35	0.20
Johnsonville	0.14	0.45	0.26	0.14	0.12	0.37	0.27	0.24
Hutt	0.24	0.37	0.28	0.11	0.16	0.38	0.20	0.26
West Rural	0.20	0.37	0.29	0.14	0.18	0.36	0.32	0.13
East Rural	0.14	0.36	0.39	0.12	0.19	0.40	0.26	0.16

Table 6-3: Adopted Peak Hour Proportions of Peak Period

Location	Proportion	
	AM Peak Hour	PM Peak Hour
SH1	0.42	0.32
SH2	0.51	0.32

Table 6-4: Adopted Future Year Growth (Linear)

Year	Growth, %p.a.
SH1	3.2%
SH2	3.2%

7. Summary

The external light vehicle model is comprised of the following components:

- Distribution of two-way daily trips to internal zones, achieved by applying linear regression models for SH1 and SH2 separately.
- Factoring from daily to peak period, achieved by applying sector-based factors.
- Factoring from the AM and PM peak periods to peak hours, achieved by applying a network-wide factor.
- Future growth, achieved by applying a percentage per annum growth calculated from trend analysis of traffic counts.
- Allowance for optional daily trip adjustment on a cell-by-cell basis.

For the internal distribution, after regressing both road externals separately, the same variables were found to best predict daily demand. The models include coefficients for total employment, households, and the inverse of distance squared. The resulting model for SH1 is considered appropriate with an R^2 of 0.72 and minimal errors by sector when applied. The model for SH2 is much poorer, with an R^2 of 0.50, and a notable underestimate of trips to/from Wairarapa. The SH2 model can be improved by only relating travel to the inverse of distance squared, that is, removing any relationship to households or jobs, but this is not considered a sound transport planning approach.

Both internal distribution models are therefore considered sufficient because of the numerically small traffic flows and the limited observed data available.

Daily flows are converted to peak periods using sector-based factors calculated from the Qrious mobile phone matrices. The AM and PM peak periods are then converted to peak hour and shoulder using network-wide factors calculated from traffic counts.

Future year flows are calculated by applying a percentage per annum growth to the 2018 base year observed light vehicle traffic flows at each road external. At both SH1 and SH2, a growth of 3.2% per annum has been calculated by trend analysis of historic traffic counts. These is a relatively healthy grow, and sensitivities tests are advised for any infrastructure assessments focused on the northern boundary of the modelled area.

The calculated daily distribution can be altered by specifying an optional adjustment matrix to increase or decrease the number of trips on a cell-by-cell basis. Care is required to ensure negative cells do not arise when adjusting the distribution.

Appendices

Appendix A Comments and Responses

No.	Comment By	Comment	Response
1	Andy Ford	No substantive comments, the proof will be to some extent in the validation.	Agreed
2		SH2 – the Wairarapa discrepancy is noted but as you state, the overall number of trips are low.	Yes, and we have applied a correction factor to Wairarapa to address this.
3		For future growth, a better option could be to take some of the Horowhenua population projections (developed by Sense Partners who have developed the Wellington projections) and use this to develop a more robust basis for future growth than just taking recent trends?	This could be a viable approach but would need to be confirmed by plotting previous Horowhenua population against traffic counts at the SH1 external and determining if there is a relationship. This is likely to be constrained by access to annual (or regular) Horowhenua population data. It is also possible that there is no relationship – as population grows, so do local amenities, and the need to travel south changes with that balance.
4		In this context, and given there will be an increasing focus of growth in Horowhenua, it would be useful if the external car model has the functionality / flexibility to adjust both the quantum and distribution of future growth from the SH1 external – in other words, we need the flexibility to test alternative future growth scenarios that may also include additional growth on PT from Levin and farther north (implying lower growth in car trips to Wellington CBD) but perhaps more growth between say Levin and Kapiti.	The quantum of growth will be easy to adjust. The model will have an accessible file specifying the control totals for each modelled year (for SH1 and SH2 separately, inbound and outbound separately). This can be modified as required. Adjusting the distribution is slightly more complicated. To enable this, we have included a zonal vector that will contain the desired trip adjustment per zone (to be manually input by the user). The adjustment can be positive or negative. Care will be required to ensure negative trips to do arise.
5	Ian Clark	I have no additional substantive points on TN27, other than those noted by Andy. I think my main concern was around the use of historical growth rates to estimate future growth rates at the externals – which was the point raised by Andy.	See responses above.

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