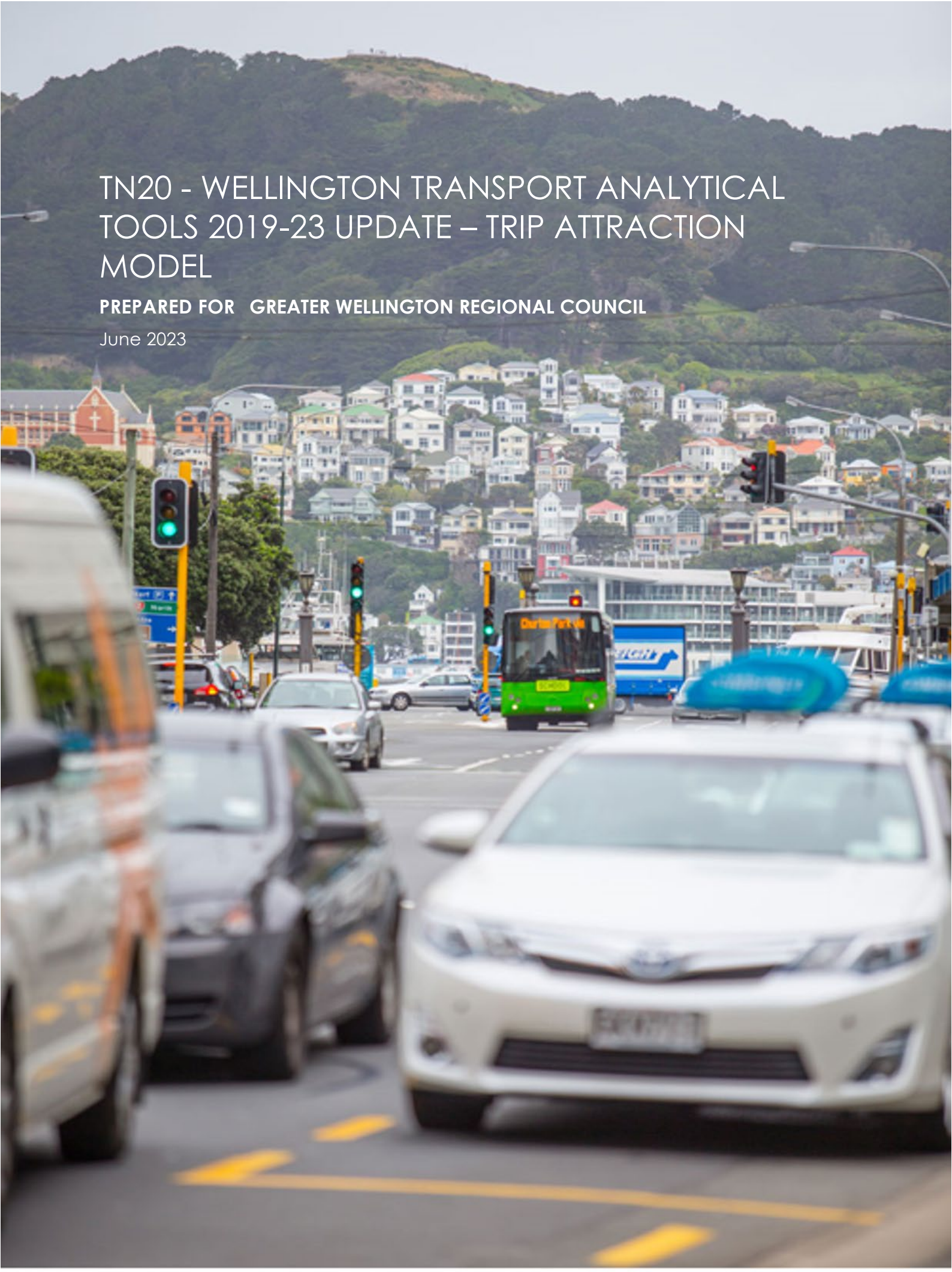

TN20 - WELLINGTON TRANSPORT ANALYTICAL TOOLS 2019-23 UPDATE – TRIP ATTRACTION MODEL

PREPARED FOR GREATER WELLINGTON REGIONAL COUNCIL

June 2023

Stantec | JACOBS

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REVISION SCHEDULE

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1	23 May 2022	Draft (very rough for comment)	VW	DH	JEB	
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4	26 June 2023	Final draft, revised to include equations modified during validation	JEB	GC	JEB	JEB

Greater Wellington Regional Council

TN20 - Wellington Transport Analytical Tools 2019-23 update – Trip Attraction Model

CONTENTS

LIST OF TABLES

LIST OF FIGURES

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 are the client for this project. This project is being primarily delivered by Stantec and Jacobs, supported by GWRC transport planners.

The purpose of this note is to document the procedure and resulting coefficients for the trip attraction model.

The first version of this technical note was circulated as a draft to reach agreement on including CBD sector-based adjustments. Comments were made on version 1, and responses are provided in Appendix A. This final and fourth version of the technical note includes changes to the attraction model incorporated during model validation. For some trip purposes, it was determined that household vehicle availability needed to be reflected, which is documented in this updated technical note.

Abbreviations used in this report include:

- One plus (1+) refers to one or more
- Car used occasionally for vehicle to shorten heading lengths

2. Observed and Explanatory Data

The observed attraction trip ends for which regression equations were fitted was sourced from the Household Travel Survey (HTS). Models were developed for the following trip purposes:

- **HBW** - Home Based Work
- **HBE** - Home Based Education
- **HBS** - Home Based Shop
- **HBO** - Home Based Other
- **BSN (ori)** - Business (Origin)
- **BSN (des)** - Business (Destination)
- **NHBO (ori)** - Non-Home Based Other (Origin)
- **NHBO (des)** - Non-Home Based Other (Destination)

In addition, home-based trip purposes also had models estimated by household vehicle availability. Two vehicle availability groups were formed, households with no vehicles available and those with one or more vehicles.

Expanded daily (weekday) internal trips were used from the HTS.

Business trips includes both home-based and non home-based trips which were too small to estimate separately. Business trips are therefore treated as "non home based".

For Business and non home-based other trips, both origin and destination attraction models are estimated. The total number of trips is then controlled by a trip production model for each purpose.

The expanded trips from the HTS by household vehicle availability are provided in the table below.

Table 2-1: Expanded Trips by Purpose and Vehicle Availability

Trip Purpose	Zero Vehicles Available	One Plus Vehicles Available	Total Trips
HBW	20,580	277,247	297,827
HBE	8,555	197,398	205,954
HBS	21,654	258,244	279,898

Trip Purpose	Zero Vehicles Available	One Plus Vehicles Available	Total Trips
HBO	26,265	458,316	484,581
BSN	N/A	N/A	116,612
NHB	N/A	N/A	710,913

The explanatory data is predominantly demographics (population, households, jobs by type) from Census and school roll from the Ministry of Education. Census data uses the Estimated Resident Population definition, representing July 2018 and including Census undercount corrections.

The total number of jobs is shown below by Australian and New Zealand Standard Industry Classification (ANZSIC) for the 2006 definition.

Table 2-2: Number of Jobs by Industry (ANZSIC 2006)

Industry	Number of Jobs
Agriculture, Forestry and Fishing	4,121
Mining	258
Manufacturing	12,836
Electricity, Gas, Water and Waste Services	2,238
Construction	18,218
Wholesale Trade	7,832
Retail Trade	19,884
Accommodation and Food Services	15,891
Transport, Postal and Warehousing	8,604
Information Media and Telecommunications	7,129
Financial and Insurance Services	11,057
Rental, Hiring and Real Estate Services	4,092
Professional, Scientific and Technical Services	36,045
Administrative and Support Services	9,986
Public Administration and Safety	34,715
Education and Training	21,854
Health Care and Social Assistance	24,102

Industry	Number of Jobs
Arts and Recreation Services	5,712
Other Services	9,993
Total Jobs	**254,567**

Other explanatory data is specified below.

Table 2-3: Other Explanatory Data

Metric	Value
Population	525,899
Households	192,339
Primary and Secondary Roll ("Pri & Sec")	88,128
Tertiary Roll ("Ter")	49,330
Accessibility	N/A, described below

During model validation, households without a car were found to have different travel behaviour particularly for mode and destination choice. The attraction models were revisited to separately calculate attractions for households without a vehicle available. To improve the fit, it was found that accessibility needed to be incorporated. Three different accessibility values were used, which are:

- Households (home end) divided by distance (in kilometres) (HHwAccess_1)
- Households (home end) divided by distance (in kilometres) to the power of 1.5 (HH/(dist^1.5)) (HHwAccess_1.5)
- Households (home end) divided by distance (in kilometres) to the power of 2 (HH/(dist^2)) (HHwAccess_2)

The accessibility values are in matrix form by 820 zones, and were converted to 225 zonal values (described in next section) by:

1. For each destination zone, calculate the average across all origins. This produces an initial accessibility value for each destination zone (vector form)
2. Calculate the overall average from step 1
3. Normalise by dividing each zonal destination average (step 1) by the overall average (step 2)
4. Aggregate the 820 zones to the 225 sectors. Take the average of the normalised accessibility (step 3) for the 820 destination zones that are within each 225 zone sector

The resulting accessibility values are shown in the following graphs and mapped in Figure 2-3.

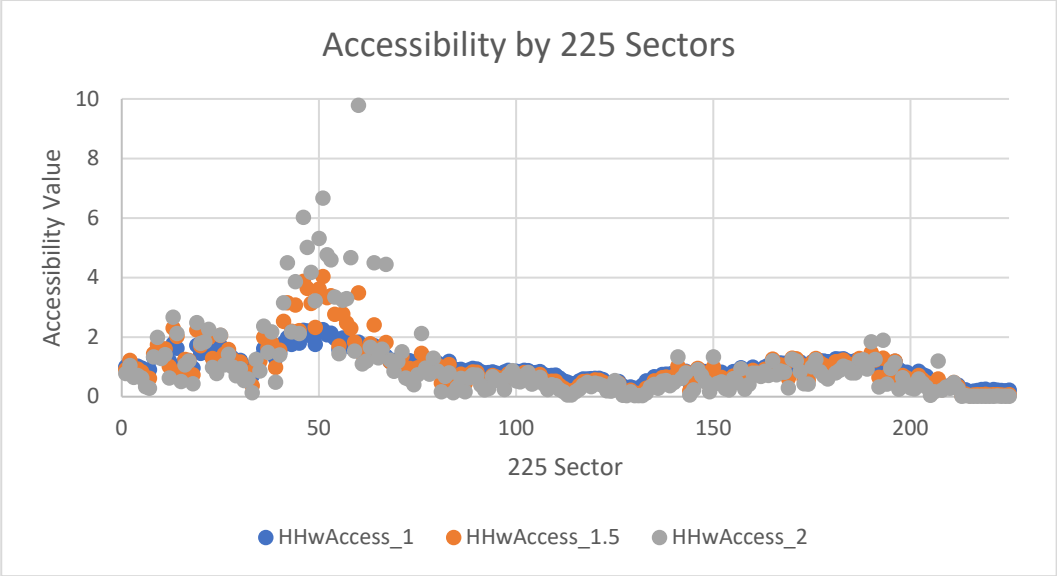

Figure 2-1: Accessibility Values by 225 Sector/Zone

As the accessibility values overlap and are difficult to read, they are plotted side-by-side in the figure below with the same maximum value on the y-axis.

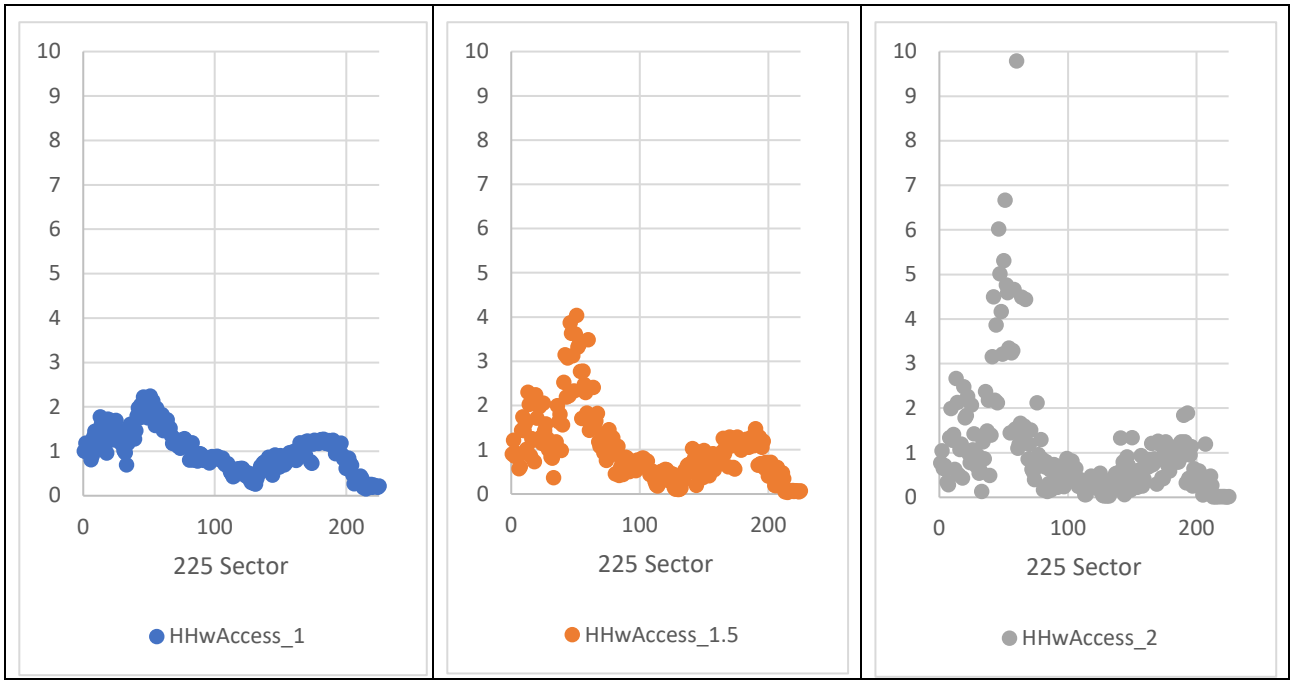

Figure 2-2: Accessibility Values Side-by-side by 225 Sector/Zone

HHwAccess_2 (HH/(dist^2)) is mapped below, with green showing low accessibility and high values in red. This shows high accessibility in Wellington particularly around the CBD (approximately zones 40 to 60) but much lower in more rural areas like Wairarapa.

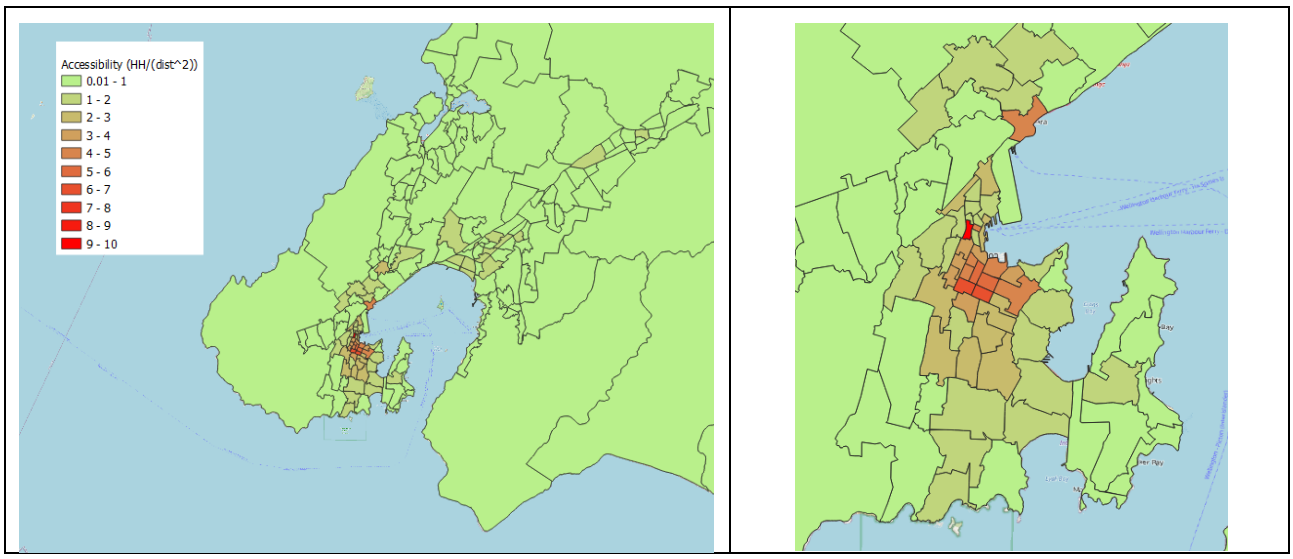

Figure 2-3: Mapped Accessibility (HHwAccess_2)

3. Regression Methodology

The regression analysis was completed using specialist statistical software[1]. Trip ends for each purpose were regressed against the explanatory variables (excluding accessibility) initially.

The regression was a forward stepwise regression with a constant of zero forced in each instance. Variables were only permitted to have non-negative coefficients in the analysis.

The first pass of the regression model included all variables (excluding accessibility) to see which were significant. Some variables were excluded if they were not logical to be included, for example, manufacturing jobs in home-based education.

Following the first round of regression carried out at 820 zones, it was noted that a number of trips near the boundary of zones had been incorrectly allocated in the adjacent zone. This was evident because there were education trips to zones without schools. This issue is because the coordinate the trip was geocoded to in the HTS was in the middle of the road on the boundary of two zones. The decision was made to aggregate the zones to a sector system (circa WTSM 225 zones) to resolve this problem. The steps taken to fit the attraction models are:

1. Extract HTS trip end data by trip purpose.
2. Collate explanatory data by zone.
3. Models initially regressed at 820 zones but the lumpiness of the HTS caused issues. Trips and explanatory data aggregated to sectors (circa 225 zones) and models by purpose regressed at 225 zones instead. Zones/sectors with no observed data were removed from the regression.
4. The coefficients estimated from the regression software were then applied to the explanatory data for all zone (225 zones). This is referred to in the tables below as the "fitted attraction" results.
5. Applying the estimated coefficients did not reproduce the correct total number of trips. The coefficients were factored so that the total trips matched the total observed HTS data. This is referred to in the tables below as the "scaled fitting attraction" results.
6. For most trip purposes, the CBD had a higher number of modelled trips compared with observed. This was consistent for all purposes except home-based work. Therefore, a CBD correction factor was calculated and applied to scale the CBD trips to match observed. This required a compensating factor to be applied to all non-CBD zones. This is referred to in the tables below as the "scaled fitted attraction (CBD scaled)".

Model were initially regressed by purpose irrespective of vehicle availability. During model validation, the home-based attraction models were updated to consider two vehicle availability groups, zero or one plus vehicles available. Observed trips were extracted from the HTS by purpose and vehicle availability, and the regressions rerun to recalculate the coefficients and check the statistical indicators. Not all

[1] Minitab was primarily used, with refinements using the Excel add-on RegressIt

explanatory data was included in the rerun regressions, only the data found to be significant for the regressions carried out irrespective of vehicle availability. Some explanatory values then produced negative coefficient values, and these were removed. For zero vehicle availability households, accessibility was also incorporated.

4. Regression Results

The results of the regression analysis are summarised below. R-Squared (adjusted R-Squared should be used), t statistics, and P-values measure the fit of the regression between the HTS attraction 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 figures below show the coefficients, T-values, P-values and R-Squared from the specialised regression software for each trip purpose. In most cases, the T-values and P-values are strong. In all cases, the explanatory variables are considered appropriate and all coefficient values are positive.

4.1 Home-Based Work

The results of the regression for all households which initially included all explanatory variables (aside from accessibility) are shown below.

Table 4-1: HBW Coefficients – All Households (Not Used)

Variable	Coefficient	T-Statistic	P-value	R-Squared	Adjusted R-Squared
Administrative and Support Services	4.05	2.53	0.012	91.0%	90.47%
Construction	1.82	1.78	0.077		
Education and Training	0.904	1.86	0.065		
Health Care and Social Assistance	1.682	5.4	0.000		
Information Media and Telecommunications	2.284	3.85	0.000		
Manufacturing	2.076	2.5	0.013		
Mining	34.8	3.17	0.002		
Professional, Scientific and Technical Services	1.191	3.59	0.000		
Public Administration and Safety	1.533	10.63	0.000		
Retail Trade	1.515	2.78	0.006		

While this model was ultimately not used, it identifies the explanatory variables that are included in subsequent regressions split by vehicle availability. While construction and education/training have less explanatory power, all other variables show a strong relationship (t-statistics and P-values). The adjusted R-Squared is excellent.

As stated above, the observed trips were then split into households with one or more vehicles available and those with no vehicles available. The regressions were rerun using the explanatory data above. Commentary is provided following the next two tables.

Table 4-2: HBW Coefficients – Households with One Plus Vehicles Available

Variable	Coefficient	t-Statistic	P-value	R-Squared	Adjusted R-Squared
Administrative and Support Services	3.795	2.483	0.014	90.4%	89.83%
Construction	2.431	2.486	0.014		

Variable	Coefficient	t-Statistic	P-value	R-Squared	Adjusted R-Squared
Education and Training	0.872	1.874	0.063		
Health Care and Social Assistance	1.392	4.675	0.000		
Information Media and Telecommunications	1.996	3.518	0.001		
Manufacturing	1.884	2.377	0.019		
Mining	35.441	3.371	0.001		
Professional, Scientific and Technical Services	0.865	2.726	0.007		
Public Administration and Safety	1.467	10.651	0.000		
Retail Trade	1.454	2.796	0.006		

Table 4-3: HBW Coefficients – Households with Zero Vehicles Available

Variable	Coefficient	t-Statistic	P-value	R-Squared	Adjusted R-Squared
Administrative and Support Services	0.025	0.033	0.974		
Construction	0.859	0.800	0.428		
Health Care and Social Assistance	0.379	2.805	0.007		
Information Media and Telecommunications	0.350	1.114	0.271		
Manufacturing	0.072	0.101	0.920	71.2%	65.96%
Professional, Scientific and Technical Services	0.334	2.135	0.038		
Public Administration and Safety	0.042	0.713	0.479		
Retail Trade	0.022	0.053	0.958		

For one plus vehicles, the same explanatory variables are included, are statistically significant, have similar strong t-statistics and P-values, and a good adjusted R-Squared.

For zero vehicles available, Mining and Education/Training produced negative coefficients and were therefore removed. While the other explanatory variables are retained, almost all have weak explanatory power (low t-statistic and high P-value), and the adjusted R-Squared relationship demonstrates considerable variation. The number of trips are numerically small (see Table 2-1), however, a better relationship could not be fitted.

Even though the model for HBW zero vehicles available is poor in terms of explanatory power, the separation of attractions by vehicle availability was retained. This was because during validation, trips using public transport did not validate well, and this was partly associated with the attraction model. People without a vehicle available were found to make different attraction choices compared to those with a vehicle.

4.2 Home-Based Education

The results of the regression for all households which initially included all explanatory variables (aside from accessibility) are shown below.

Table 4-4: HBE Coefficients – All Households

Variable	Coefficient	t-Statistic	P-value	R-Squared	Adjusted R-Squared
Primary and Secondary roll	1.890	12.08	0.000	52.48%	51.80%
Tertiary roll	0.180	2.550	0.012		

For home-based education, the R-Squared value is poor. This is exacerbated by the mismatch between observed trip ends in the HTS and education locations with 13,000 daily education trips (out of 205,000) destined for zones without any schools. It is noted that education jobs were tested and the model was significantly poorer (R-Squared circa 35%). With the small HTS sample and the anomalies in the geocoding, it is not possible to produce a model with a better fit.

For households with one plus vehicles available, the above model was adopted directly due to the issues with fitting the model and that the majority of trips are from households with a vehicle available.

For households with no vehicles available, the regression was rerun with the same explanatory variables. The results were again poor, so accessibility was incorporated. The school rolls for primary plus secondary students and tertiary students were multiplied by the accessibility variable (households/distance^1.5) and used as the explanatory variables. As shown in Table 4-5, the input variables were statistically significant (t statistics greater than two) although the model shows significant variation overall (very low adjusted R-Squared).

Table 4-5: HBE Coefficients – Households with Zero Vehicles Available

Variable	Coefficient	t-Statistic	P-value	R-Squared	Adjusted R-Squared
Primary and Secondary roll, weighted by access 1.5	0.093	2.408	0.024	35.78%	30.65%
Tertiary roll, weighted by access 1.5	0.034	2.845	0.009		

Again, even though the model for HBE zero vehicles available is weak overall, the separation of attractions by vehicle availability was retained to improve the validation, particularly for household's captive to public transport.

4.3 Home-Based Shop

The results of the regression for all households which initially included all explanatory variables (aside from accessibility) are shown below.

Table 4-6: HBS Coefficients – All Households (Not Used)

Variable	Coefficient	t-Statistic	P-value	R-Squared	Adjusted R-Squared
Retail Trade	13.496	28.82	0.000	81.94%	81.84%

While this model was ultimately not used, it identifies the main explanatory variable that is included in subsequent regressions split by vehicle availability.

The table below shows the regression results for households with one or more vehicles available. Again, retail employment has strong explanatory power and while the adjusted R-Squared is lower than ideal, there is still a reasonable relationship.

Table 4-7: HBS Coefficients – Households with One Plus Vehicles Available

Variable	Coefficient	t-Statistic	P-value	R-Squared	Adjusted R-Squared
Retail Trade	12.494	28.159	0.000	81.33%	81.23%

For households with zero vehicles available, the regression was also rerun and found to be poor. Accessibility was therefore included as a multiplier to retail employment. In this case, the accessibility variable was households divided by distance (HHwAccess_1). This produced a strong correlation in terms

of explanatory power of the variable. While the adjusted R-Squared is low, this reflects the small sample, the numerically small number of observed trips, and the variability of the observed dataset.

Table 4-8: HBS Coefficients – Households with Zero Vehicles Available

Variable	Coefficient	t-Statistic	P-value	R-Squared	Adjusted R-Squared
Retail Trade, weighted by access 1.0	1.030	8.919	0.000	54.66%	53.97%

4.4 Home-Based Other

The results of the regression for all households which initially included all explanatory variables (aside from accessibility) are shown below.

Table 4-9: HBO Coefficients – All Households (Not Used)

Variable	Coefficient	T-Statistic	P-value	R-Squared	Adjusted R-Squared
Accommodation and Food Services	2.64	2.13	0.034	77.99%	76.95%
Health Care and Social Assistance	1.472	2.78	0.006		
Households	1.268	11.64	0.000		
Retail Trade	7.172	7.29	0.000		

While this model was ultimately not used, it identifies the explanatory variables that are included in subsequent regressions split by vehicle availability.

For households with one or more vehicles, the same variables were found to be significant albeit less so for Accommodation and Food Services employment. The adjusted R-Squared is considered acceptable, albeit lower than ideal reflecting the small sample of the HTS.

Table 4-10: HBO Coefficients – Households with One Plus Vehicles Available

Variable	Coefficient	T-Statistic	P-value	R-Squared	Adjusted R-Squared
Accommodation and Food Services	1.997	1.653	0.100	76.64%	76.19%
Health Care and Social Assistance	1.035	2.004	0.046		
Households	1.259	11.854	0.000		
Retail Trade	6.986	7.280	0.000		

For households with zero vehicles available, the regression was also rerun and found to be poor. Accessibility was therefore included as a multiplier to all variables. In this case, the accessibility variable was households divided by distance squared (HHwAccess_2). Health Care and Social Assistance employment produced a negative coefficient and was removed. The remaining three variables have strong explanatory power. While the adjusted R-Squared is lower, this reflects the lumpiness of the HTS and the numerically small number of trips.

Table 4-11: HBO Coefficients – Households with Zero Vehicles Available

Variable	Coefficient	T-Statistic	P-value	R-Squared	Adjusted R-Squared
Health Care and Social Assistance, weighted by access 2.0	0.179	3.410	0.001	57.68%	56.36%
Households, weighted by access 2.0	0.115	4.804	0.000		
Retail Trade, weighted by access 2.0	0.284	2.944	0.004		

4.5 Business

The statistical outputs from the regression modelling for business origins are provided below. No segmentation by household vehicle availability is included for business trips.

Table 4-12: BSN Origin Coefficients

Variable	Coefficient	T-Statistic	P-value	R-Squared	Adjusted R-Squared
Arts and Recreation Services	2.235	3.13	0.002	60.20%	59.20%
Construction	2.539	5.94	0.000		
Health Care and Social Assistance	0.767	3.59	0.000		
Other Services	2.32	1.7	0.090		
Total Employment	0.0263	0.51	0.609		

Three of the five variables have good explanatory power. Although total employment has a relatively poor relationship, it is included so that some business trips are generated where there is employment. Business origins have a poor R-Squared value, which is a reflection of the smaller number of trips.

The statistical outputs from the regression modelling for business destinations are provided below.

Table 4-13: BSN Destination Coefficients

Variable	Coefficient	T-Statistic	P-value	R-Squared	Adjusted R-Squared
Construction	1.228	2.05	0.041	60.08%	58.82%
Health Care and Social Assistance	0.578	2.58	0.011		
Households	0.1401	2.66	0.008		
Retail Trade	0.659	1.8	0.074		
Total Employment	0.0733	2	0.047		
Wholesale Trade	2.076	2.43	0.016		

Similarly, business destinations have a poor R-Squared value, although most variables have strong explanatory power.

4.6 Non Home-based Other

The statistical outputs from the regression modelling for non home-based other origins are provided below. No segmentation by household vehicle availability is included for business trips.

Table 4-14: NHBO Origin Coefficients

Variable	Coefficient	T-Statistic	P-value	R-Squared	Adjusted R-Squared
Accommodation and Food Services	9.37	7.56	0.000	92.71%	92.50%
Education and Training	4.606	6.12	0.000		
Health Care and Social Assistance	1.906	3.85	0.000		
Other Services	9.68	3.49	0.001		
Public Administration and Safety	0.949	4.69	0.000		
Retail Trade	11.78	11.47	0.000		

Table 4-15: NHBO Destination Coefficients

Variable	Coefficient	T-Statistic	P-value	R-Squared	Adjusted R-Squared
Accommodation and Food Services	9.3	6.37	0.000	92.99%	92.76%
Arts and Recreation Services	3.24	1.67	0.096		
Education and Training	3.431	4.62	0.000		
Health Care and Social Assistance	2.109	4.28	0.000		
Other Services	7.44	2.7	0.007		
Public Administration and Safety	0.557	2.78	0.006		
Retail Trade	13.58	13.39	0.000		

The models for origins and destinations both fit well (high adjusted R-Squared), with all variables have good explanatory power.

5. Comparing Modelled vs Observed Trip Ends

The estimated models are compared to observed (HTS) in this section.

There are still zones at 225 zone level without any trips observed. While this will be correct for some purposes, there will be instances of missing trips associated with the small HTS sample. For example, there are 45 zones (at 225 zone level) containing schools with no school trips in the HTS. In comparing modelled to observed, only zones with observed trips can be included. However, when the model is applied, all zones must be considered. So different zone groups are considered at different stages of the calculations reported below, which is noted below.

The following tables and graphs are provided for each trip purpose.

- Table of observed and modelled trip ends aggregated to 11 sectors.
- Same information shown graphically on a bar chart.
- Scatter diagram of observed vs final modelled trip ends by zone (225 zones). The R-Squared calculated by Excel and the slope of the trendline forced through zero are shown. It is noted that these values from Excel will differ to the values from specialist regression software.

The columns in the tables and graph are:

- HTS Attraction – observed trip ends from the HTS. Origins and destinations are reported for business and non home-based other trips. Only zones with observed trips are included.
- Fitted Attraction – application of the coefficients estimated through linear regression to the explanatory data at 225 zones. The same zones as above are used, as this is a comparison of

modelled to observed, which requires observed data. These coefficients do not reproduce the total number of observed trips which is typical.

- Scaled Fitted Attraction –model coefficients scaled/factored consistently so that the total number of trips matches observed. All zones are included in this calculation to align with how the model will be applied. The scaled attractions can be compared to observed in the bar graphs as the totals are the same, and the issue with missing zonal data will not be a problem at sector level.
- Scaled Fitted Attraction (CBD scaled) – for many purposes, the modelled CBD trip ends were overestimated. A geographic factor therefore had to be calculated and applied to the CBD to correct the trip ends. A second factor is then applied to all other locations so that the total number of trips matches observed. All zones are included in this calculation.

It is noted that different scales are used in the bar graphs by trip purpose so that the differences are clear.

The 11 sectors are shown graphically in the figures below.

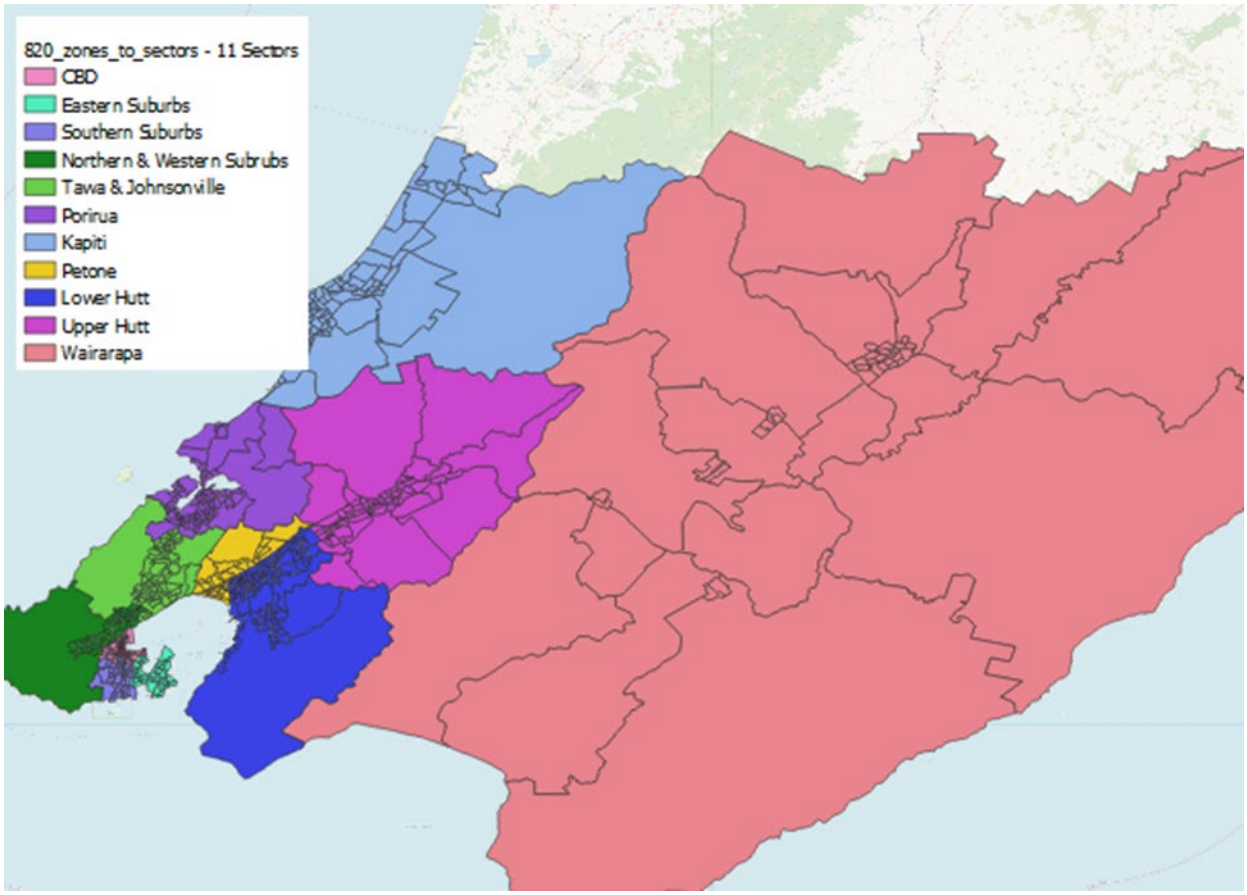

Figure 5-1: 11 Sectors, Region-wide

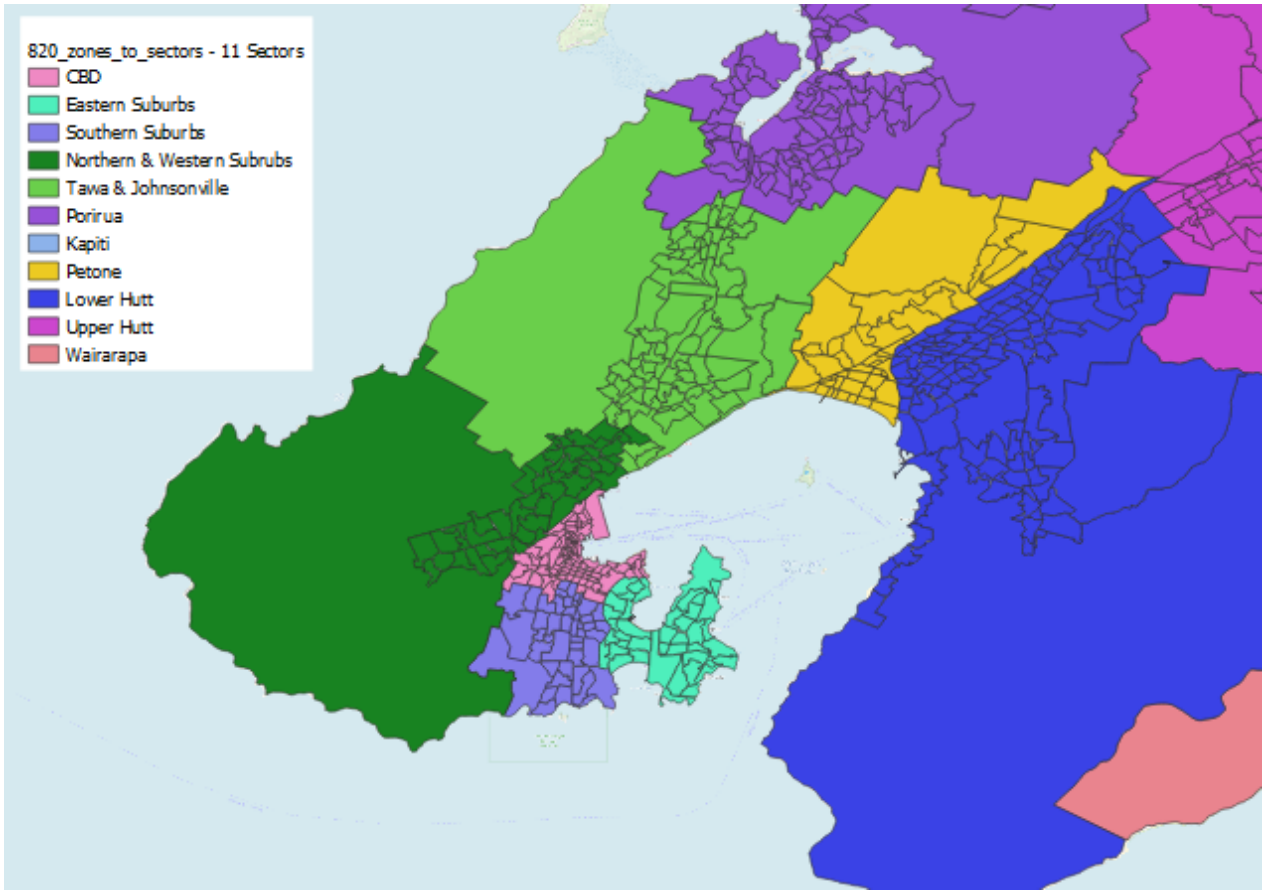

Figure 5-2: 11 Sectors, Wellington City

The scaled attractions at 225 sectors are shown geographically in Appendix B for the models not split by vehicle availability. While these are not the final models, the results will be generally representative.

5.1 Home-Based Work – 1+ Car Available Households

Table 5-1: HBW 1+ Car Available Modelled VS Observed Summary Table

Sector Name	HTS Attraction (observed)	Fitted Attraction	Scaled Fitted Attraction	Scaled Fitted Attraction (CBD scaled)	Scaled Attraction VS HTS Difference
CBD	109,670	105,420	99,603	109,663	-7
Eastern suburbs	13,698	13,243	12,514	11,800	-1,898
Southern suburbs	13,323	14,058	13,285	12,528	-795
North and Western suburbs	6,768	8,846	8,359	7,882	1,115
Tawa and Johnsonville	17,512	16,813	15,888	14,982	-2,530
Porirua	23,669	23,178	21,903	20,654	-3,015
Kapiti	17,771	21,646	20,455	19,289	1,518
Petone	14,437	17,189	16,243	15,317	880
Lower Hutt	34,549	35,042	33,114	31,226	-3,323
Upper Hutt	11,547	17,496	16,533	15,590	4,044
Wairarapa	14,305	20,453	19,328	18,227	3,922
	277,247	**293,384**	**277,224**	**277,159**	**-88**

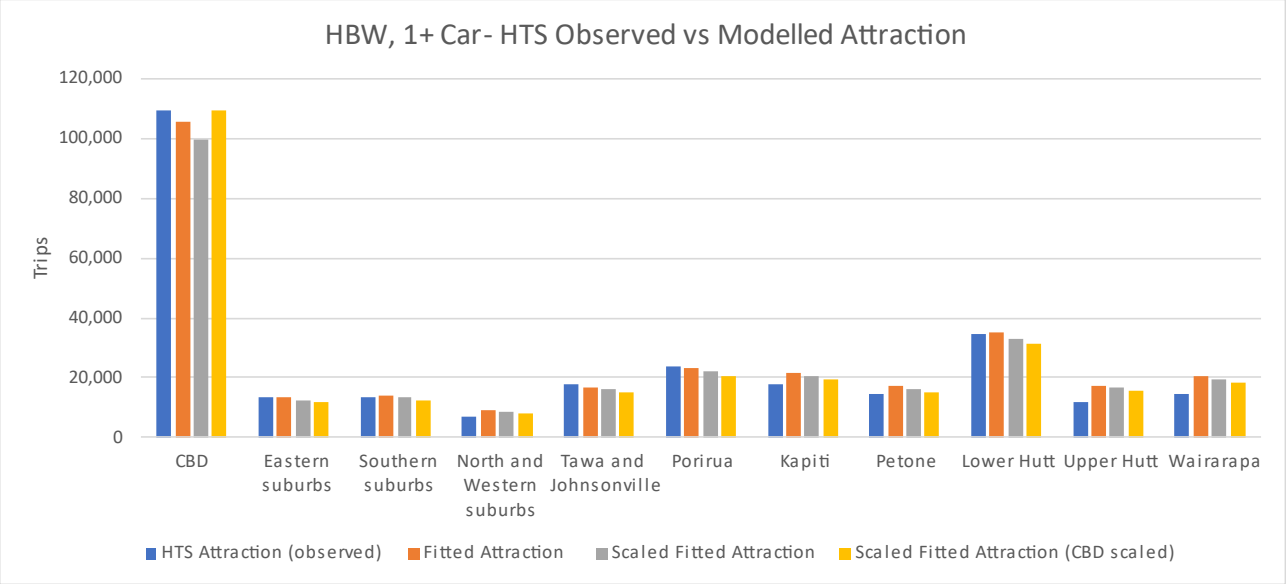

Figure 5-3: HBW 1+ car available – modelled vs observed daily trips by sector

The scatter plot only includes zones with observed data, as we cannot distinguish between no trips in reality compared with missing data in the HTS. As a result, the slope of the trendline will always be less than one, as there are other zones containing modelled trips which are not plotted (because there is no observed).

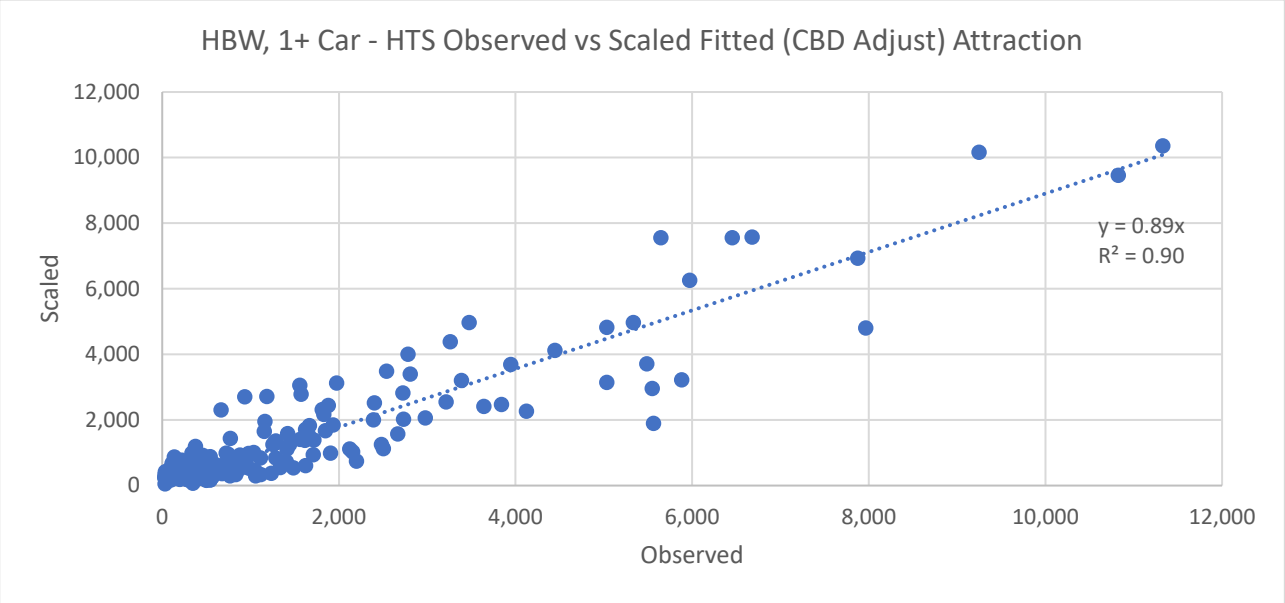

Figure 5-4: HBW 1+ car available – modelled vs observed zonal scatter plot

These results show:

- The coefficients estimated by the regression only needed minimal scaling.
- Geographically, the model replicates observed well.
- On a zonal basis, the scatter about the trendline is minimal and the model is overall a good fit.

5.2 Home-Based Work – 0 Car Available Households

Table 5-2: HBW 0 Car Available Modelled VS Observed Summary Table

Sector Name	HTS Attraction (observed)	Fitted Attraction	Scaled Fitted Attraction	Scaled Fitted Attraction (CBD scaled)	Scaled Attraction VS HTS Difference
CBD	13,315	12,562	6,088	13,314	-1
Eastern suburbs	921	2,111	1,025	515	-406
Southern suburbs	1,181	2,650	1,287	646	-535
North and Western suburbs	283	1,561	758	380	97
Tawa and Johnsonville	0	2,595	1,260	632	632
Porirua	280	3,666	1,779	893	613
Kapiti	0	3,642	1,768	888	888
Petone	862	2,666	1,294	650	-213
Lower Hutt	2,523	5,359	2,601	1,306	-1,217
Upper Hutt	924	2,570	1,247	626	-298
Wairarapa	290	3,004	1,458	732	442
	20,580	**42,386**	**20,565**	**20,582**	**2**

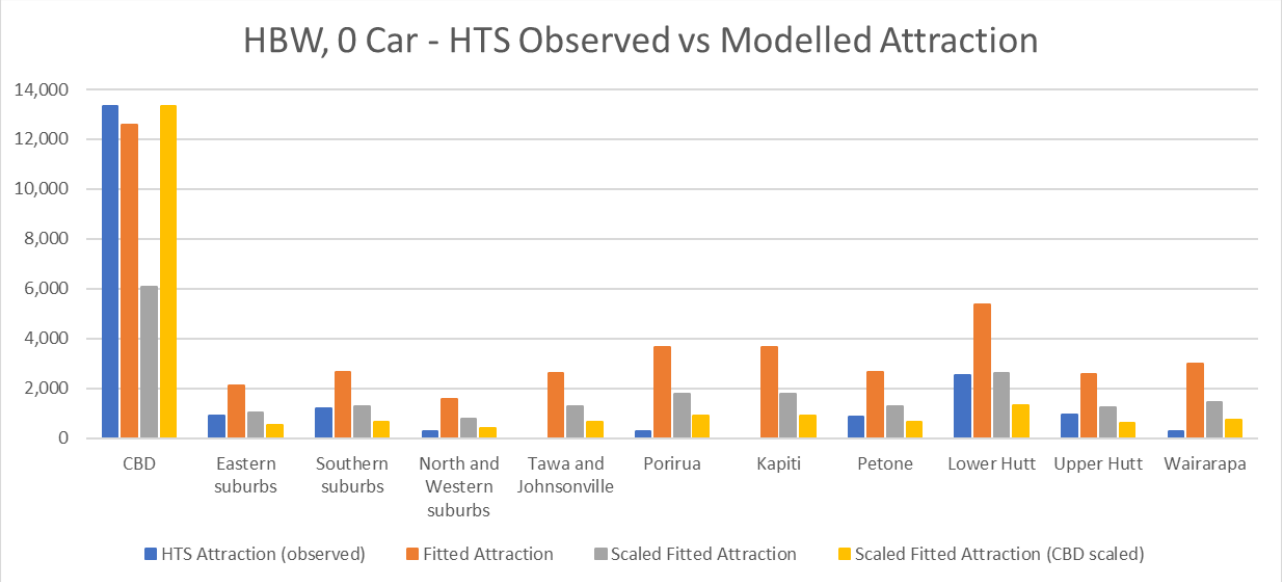

Figure 5-5: HBW 0 car available – modelled vs observed daily trips by sector

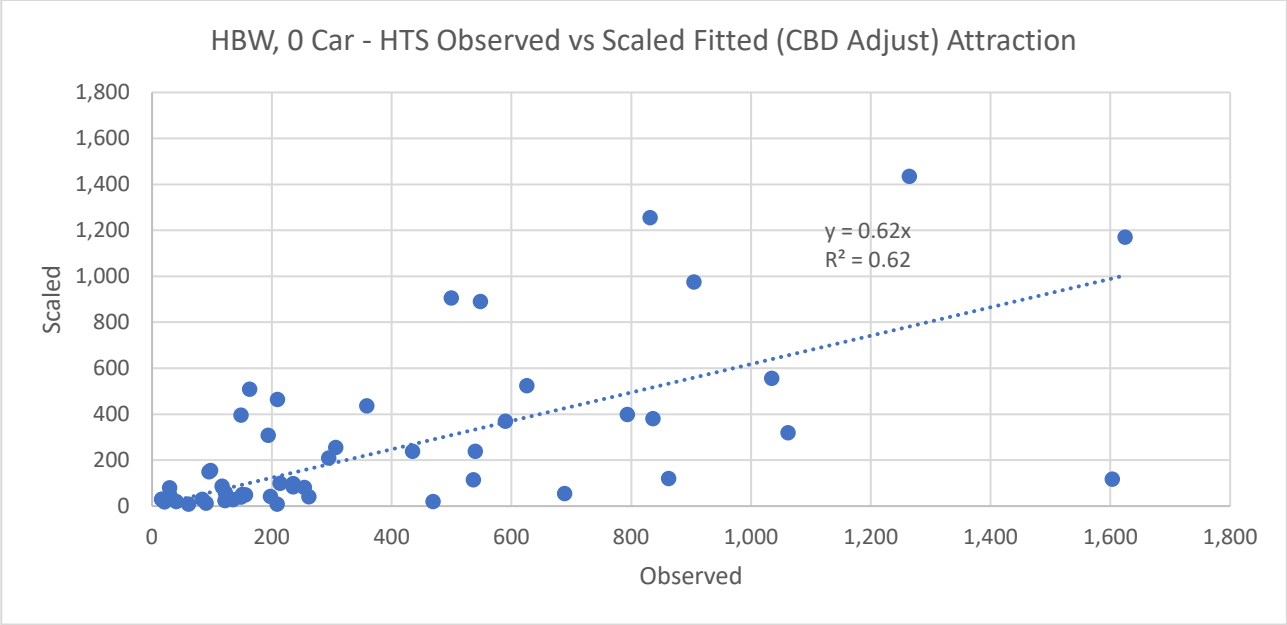

Figure 5-6: HBW 0 car available – modelled vs observed zonal scatter plot

These results show:

- The initial fitted model replicated the CBD, but significantly overestimated all other regions. Applying the scaling (to correct the total number of trips) then significantly underestimated CBD attractions. As a result, the scaling of the estimated coefficients is significant.
- Geographically, there is a notable scatter.
- The variability of modelled compared with observed, and the challenge with fitting the CBD attractions and the rest of the region using a single equation is a reflection of the very small number of trips. The model was retained as it did improve the overall validation, particularly for public transport trips.

5.3 Home-based Education - 1+ Car Available Households

The home-based education model was initially regressed against education employment so that school roll did not have to be forecast, however, two issues were discovered:

- education employment in the CBD did not relate to schools
- the number of education employees were not directly related to the number of students and therefore school activity.

Based on the above information, school roll data was used to see if it would produce a better regression fit. This was separated into Primary / Secondary and Tertiary to allow Tertiary to have its own attraction coefficient.

Table 5-3: HBE 1+ Car Available - Modelled VS Observed Summary Table

Sector Name	HTS Attraction (observed)	Fitted Attraction	Scaled Fitted Attraction	Scaled Attraction VS HTS Difference
CBD	20,242	19,129	22,940	2,698
Eastern suburbs	22,112	11,023	13,219	-8,893
Southern suburbs	6,727	8,941	10,722	3,995
North and Western suburbs	7,930	8,380	10,050	2,120
Tawa and Johnsonville	26,150	19,147	22,961	-3,189
Porirua	22,249	18,305	21,951	-298
Kapiti	13,672	16,456	19,734	6,062
Petone	11,233	6,342	7,605	-3,628

Sector Name	HTS Attraction (observed)	Fitted Attraction	Scaled Fitted Attraction	Scaled Attraction VS HTS Difference
Lower Hutt	32,054	27,686	33,201	1,147
Upper Hutt	19,006	14,604	17,513	-1,492
Wairarapa	16,023	14,595	17,503	1,479
	197,398	**164,606**	**197,398**	**0**

It is noted that this is the application of the overall model applied to households with one or more vehicles, but with the scaling of the coefficients adjusted to produce the correct number of attractions for one plus vehicle available households. This was considered appropriate given the small number of educations trips associated with zero vehicle households.

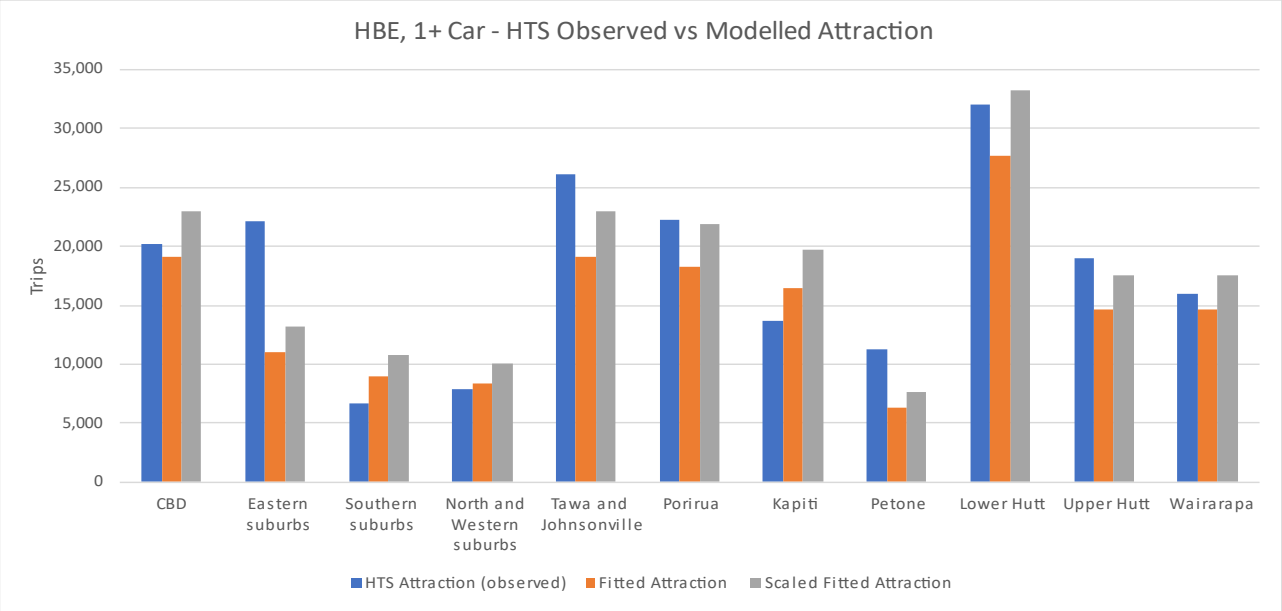

Figure 5-7: HBE 1+ car available – modelled vs observed daily trips by sector

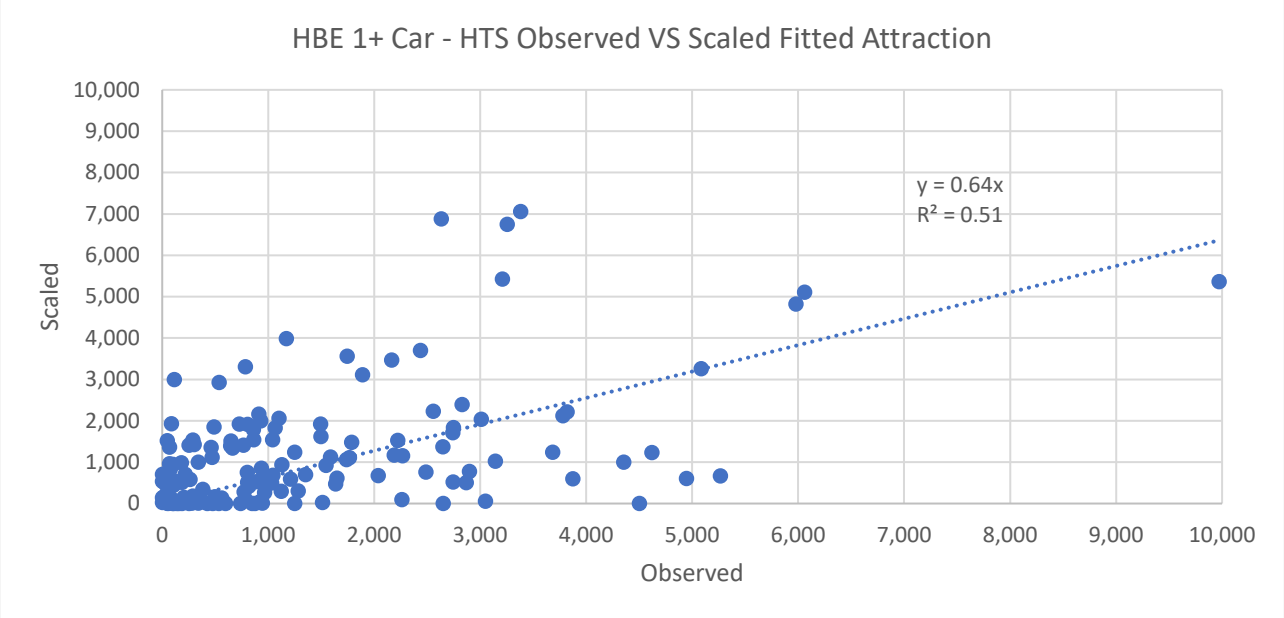

Figure 5-8: HBE 1+ car available – modelled vs observed zonal scatter plot

These results show:

- The total number of trips is underestimated when the coefficients estimated through regression are applied to zones where there are trips in the HTS. This reflects the lumpiness of the HTS and the incorrect geocoding of destinations.
- Trips to the CBD are slightly overestimated.
- Geographically, the model is poor with Eastern Suburbs underestimated, while Kapiti is overestimated. Further adjustment to this model may be required on application[2]. For the Eastern Suburbs, the HTS was expanded based on Eastern and Southern combined. Considering these two areas combined, the model still underestimates school trips to Eastern/Southern, but the underestimate is not as significant.
- On a zonal basis, the R-Squared is poor indicating a good deal of divergence between observed and modelled. It is noted that the observed HTS data is very lumpy, and in some instances, allocated to the wrong zone.

5.4 Home-based Education - 0 Car Available Households

Table 5-4: HBE 0 Car Available, Modelled VS Observed Summary Table

Sector Name	HTS Attraction (observed)	Fitted Attraction	Scaled Fitted Attraction	Scaled Attraction VS HTS Difference
CBD	3,203	3,778	3,108	-95
Eastern suburbs	1,473	706	581	-892
Southern suburbs	773	1,458	1,199	426
North and Western suburbs	515	408	336	-179
Tawa and Johnsonville	132	1,053	866	734
Porirua	1,308	488	401	-907
Kapiti	0	283	233	233
Petone	0	409	337	337
Lower Hutt	814	1,107	911	96
Upper Hutt	298	482	396	98
Wairarapa	38	228	187	149
	3,203	**3,778**	**3,108**	**-95**

[2] Further adjustment was not required.

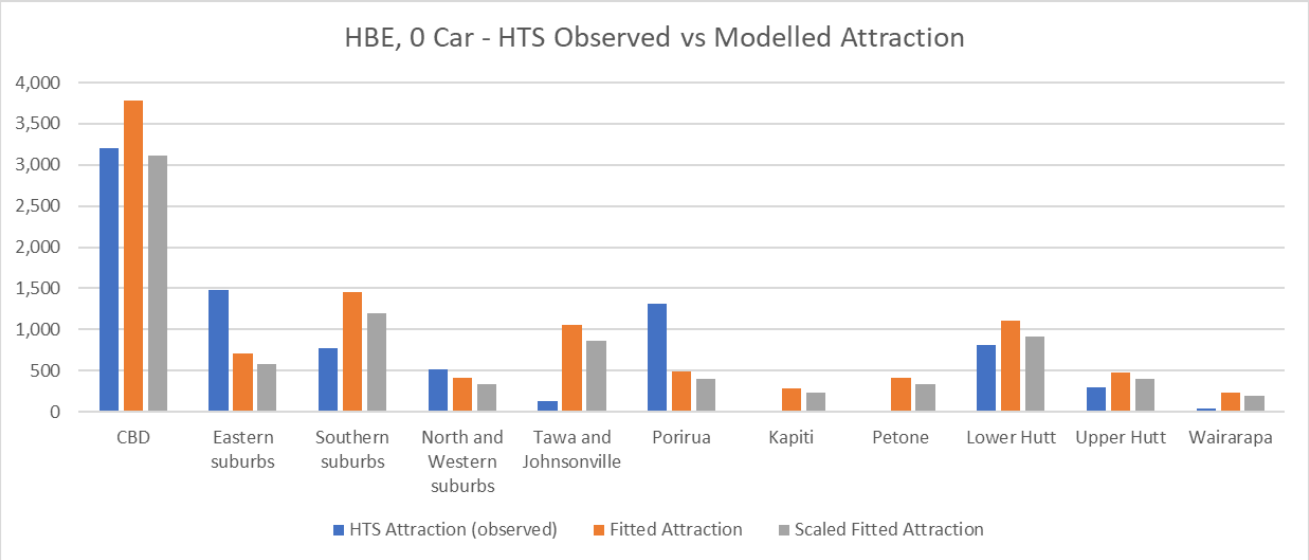

Figure 5-9: HBE 0 car available – modelled vs observed daily trips by sector

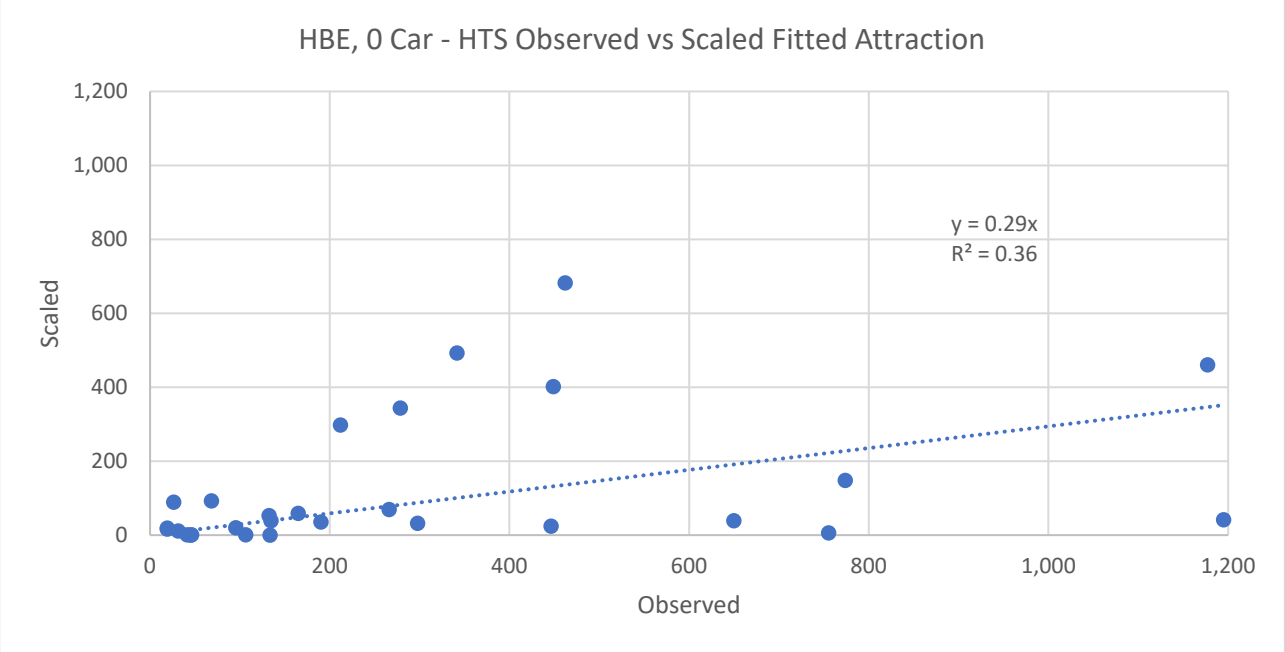

Figure 5-10: HBE 0 car available – modelled vs observed zonal scatter plot

These results show:

- The coefficients estimated through regression overestimated the CBD slightly, which came back into line when then coefficients were scaled to produce the correct total number of trips. No adjustment for the CBD was therefore included.
- The Eastern suburbs are underestimated while the Southern are overestimated, although these two areas were expanded together in the HTS and hence the observed may have some variation. The trips are numerically small so this is not concerning.
- There is considerable scatter and a poor R-Squared, reflecting that there are only 28 observations – insufficient to develop a robust relationship. The trips are numerically small, however, and including this model improved the validation of public transport trips.

5.5 Home-based Shop - 1+ Car Available Households

Table 5-5: HBS 1+ Car Available Modelled VS Observed Summary Table

Sector Name	HTS Attraction (observed)	Fitted Attraction	Scaled Fitted Attraction	Scaled Fitted Attraction (CBD scaled)	Scaled Attraction VS HTS Difference
CBD	30,767	58,376	60,684	30,767	0
Eastern suburbs	20,882	14,319	14,885	17,139	-3,744
Southern suburbs	10,300	9,992	10,387	11,960	1,660
North and Western suburbs	13,988	10,054	10,452	12,034	-1,953
Tawa and Johnsonville	23,475	13,558	14,094	16,228	-7,247
Porirua	31,314	22,404	23,290	26,816	-4,498
Kapiti	34,450	26,332	27,373	31,519	-2,931
Petone	15,601	18,904	19,651	22,627	7,025
Lower Hutt	38,880	34,773	36,147	41,621	2,741
Upper Hutt	18,539	16,064	16,699	19,228	689
Wairarapa	20,049	23,649	24,583	28,306	8,258
	258,244	**248,424**	**258,244**	**258,244**	**0**

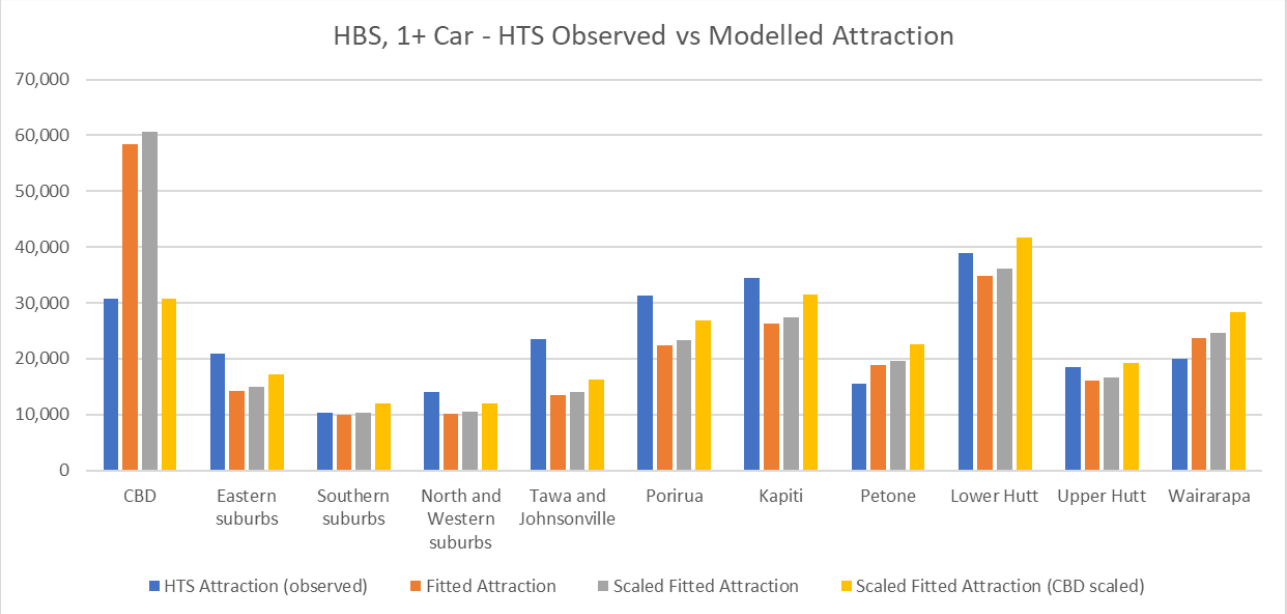

Figure 5-11: HBS 1+ car available – modelled vs observed daily trips by sector

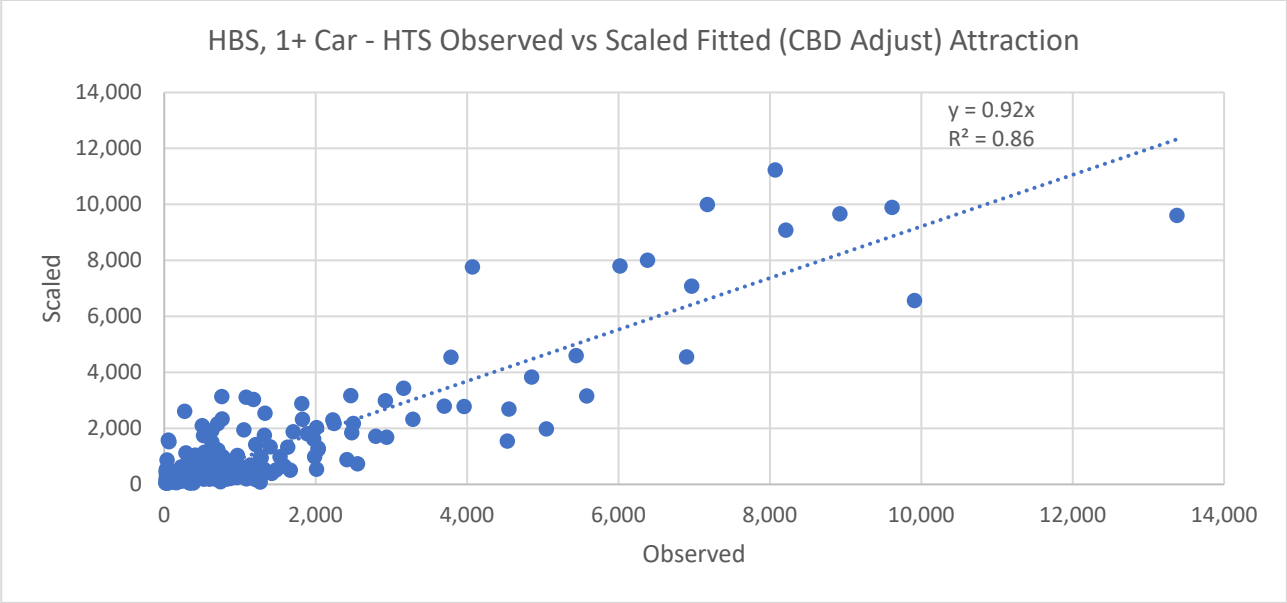

Figure 5-12: HBS 1+ car available – modelled vs observed zonal scatter plot

These results show:

- While the application of the coefficients estimated by regression produces about the correct magnitude of total trips, the CBD is significantly overestimated (approximately double). This suggests the relationship between home-based shopping trips and retail jobs is quite different in the CBD compared to the rest of the region. As discussed in the comments (Appendix A), this may be due to more CBD shopping trips being non-home-based. There is insufficient data to estimate a separate CBD shopping model, and so the region wide model must be scaled for the CBD.
- Geographically, shopping trips to Tawa & Johnsonville and Kapiti are underestimated, while Wairarapa is overestimated.
- On a zonal basis, for zones with large numbers of shopping trips, the model tends to underestimate. When the model is applied, it may be necessary to introduce a correction for large malls. It is noted that the potential zonal error in the observed trips (i.e. trips allocated to the wrong zone) has not been investigated for shopping as it is less clear-cut than education trips. Given that the model is still producing a sizeable numbers of trips, the geocoding error is less likely to be the primary cause of the model discrepancies.

5.6 Home-based Shop - 0 Car Available Households

Table 5-6: HBS 0 Car Available, Modelled VS Observed Summary Table

Sector Name	HTS Attraction (observed)	Fitted Attraction	Scaled Fitted Attraction	Scaled Attraction VS HTS Difference
CBD	7,529	8,854	8,214	685
Eastern suburbs	2,759	1,516	1,406	-1,353
Southern suburbs	1,201	1,307	1,213	11
North and Western suburbs	1,000	1,029	954	-46
Tawa and Johnsonville	1,693	1,213	1,125	-567
Porirua	2,594	1,475	1,368	-1,226
Kapiti	1,044	1,159	1,075	31
Petone	593	1,809	1,678	1,084
Lower Hutt	1,386	3,221	2,988	1,602
Upper Hutt	1,456	1,043	967	-489
Wairarapa	398	717	665	267
	21,654	**23,342**	**21,654**	**0**

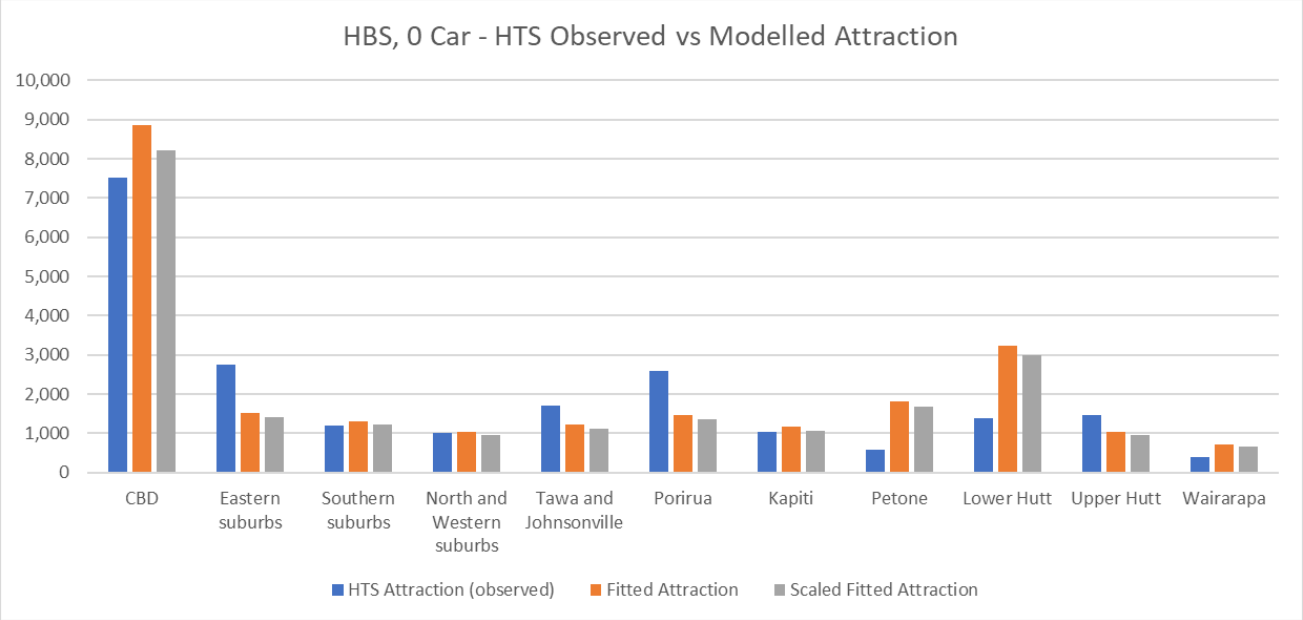

Figure 5-13: HBS 0 car available – modelled vs observed daily trips by sector

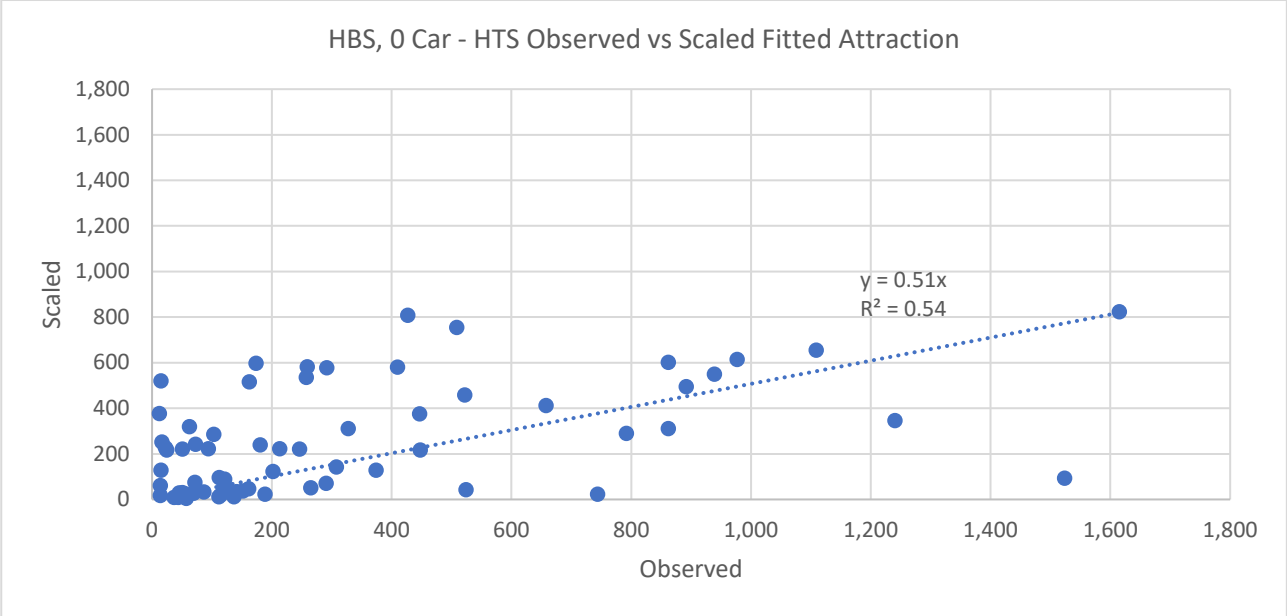

Figure 5-14: HBS 0 car available – modelled vs observed zonal scatter plot

These results show:

- The coefficients estimated by the regression only needed minimal scaling.
- The CBD did not require any further adjustment.
- Porirua is underestimated, while Lower Hutt is overestimated. Although the number of trips are numerically small.
- There is considerable scatter and a weak R-Squared, again reflecting the relatively small sample.

5.7 Home-based Other – 1+ Car Available Households

Table 5-7: HBO 1+ Car Available Modelled VS Observed Summary Table

Sector Name	HTS Attraction (observed)	Fitted Attraction	Scaled Fitted Attraction	Scaled Fitted Attraction (CBD scaled)	Scaled Attraction VS HTS Difference
CBD	56,995	69,588	72,861	56,995	0
Eastern suburbs	33,834	27,685	28,988	30,181	-3,653
Southern suburbs	22,572	30,217	31,639	32,941	10,369
North and Western suburbs	23,283	26,490	27,736	28,878	5,595
Tawa and Johnsonville	40,694	33,672	35,256	36,707	-3,987
Porirua	56,934	40,324	42,222	43,959	-12,974
Kapiti	57,184	47,601	49,840	51,892	-5,292
Petone	22,541	25,408	26,604	27,699	5,158
Lower Hutt	78,515	62,902	65,861	68,572	-9,943
Upper Hutt	30,443	32,604	34,138	35,543	5,100
Wairarapa	35,322	41,232	43,172	44,949	9,627
	458,316	**437,723**	**458,316**	**458,316**	**0**

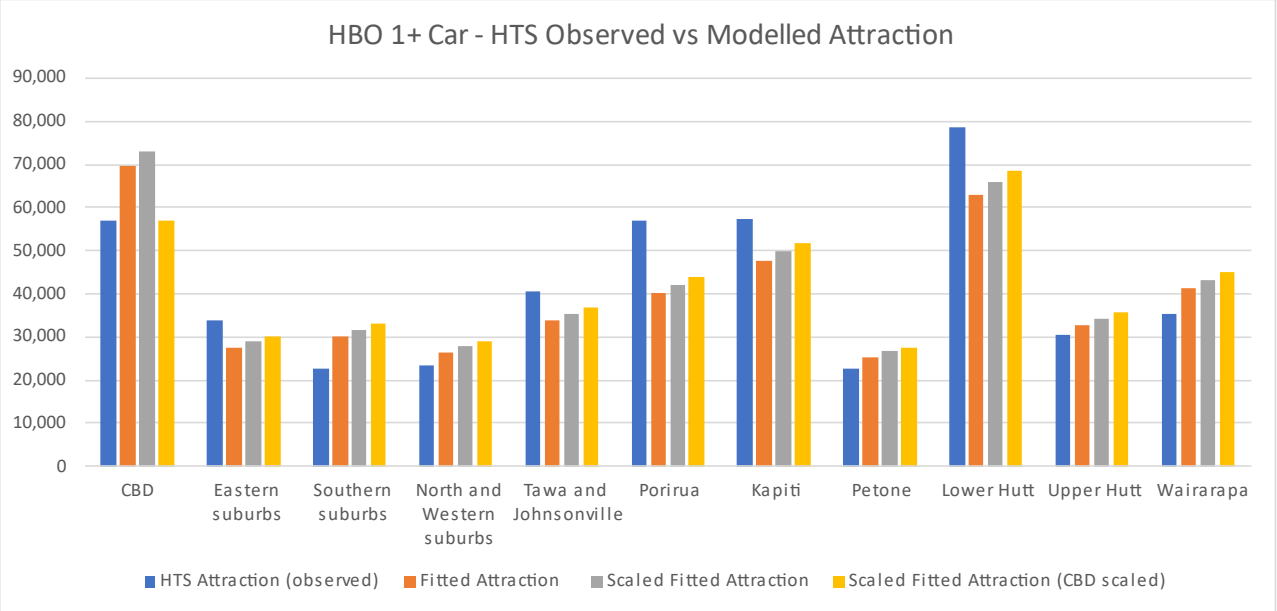

Figure 5-15: HBO 1+ car available – modelled vs observed daily trips by sector

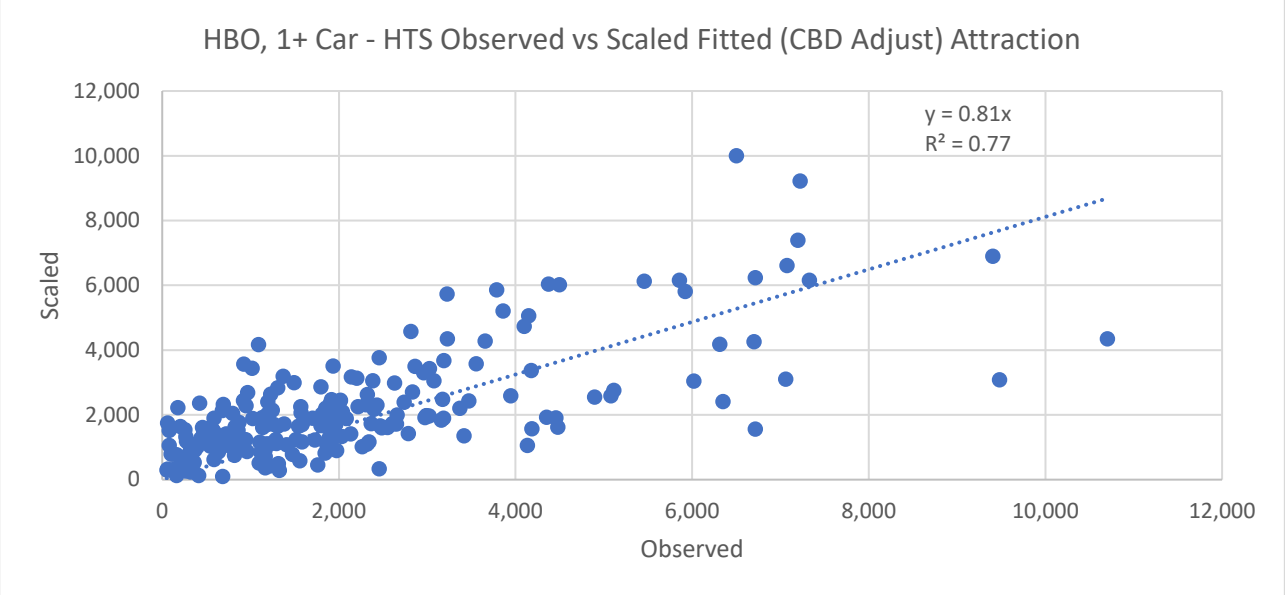

Figure 5-16: HBO 1+ car available – modelled vs observed zonal scatter plot

These results show:

- The model overestimated trips to the CBD, which was exacerbated when the coefficients were scaled so that the correct total was replicated.
- Geographically, Porirua and Lower Hutt is significantly underestimated, offset by smaller overestimates elsewhere.
- On a zonal basis, there is a lot of scatter. There is a mix of over and underestimation of the larger attractors. The lower R-Squared value highlights the scatter.

5.8 Home-based Other - 0 Car Available Households

Table 5-8: HBO 0 Car Available, Modelled VS Observed Summary Table

Sector Name	HTS Attraction (observed)	Fitted Attraction	Scaled Fitted Attraction	Scaled Attraction VS HTS Difference
CBD	8,499	9,662	7,408	-1,091
Eastern suburbs	3,690	2,539	1,946	-1,744
Southern suburbs	3,749	4,909	3,764	15
North and Western suburbs	397	2,398	1,839	1,442
Tawa and Johnsonville	267	2,540	1,947	1,680
Porirua	1,374	1,872	1,435	62
Kapiti	1,321	1,485	1,138	-182
Petone	857	1,774	1,360	503
Lower Hutt	4,542	4,526	3,470	-1,072
Upper Hutt	727	1,640	1,257	531
Wairarapa	842	912	699	-143
	26,265	**34,258**	**26,265**	**0**

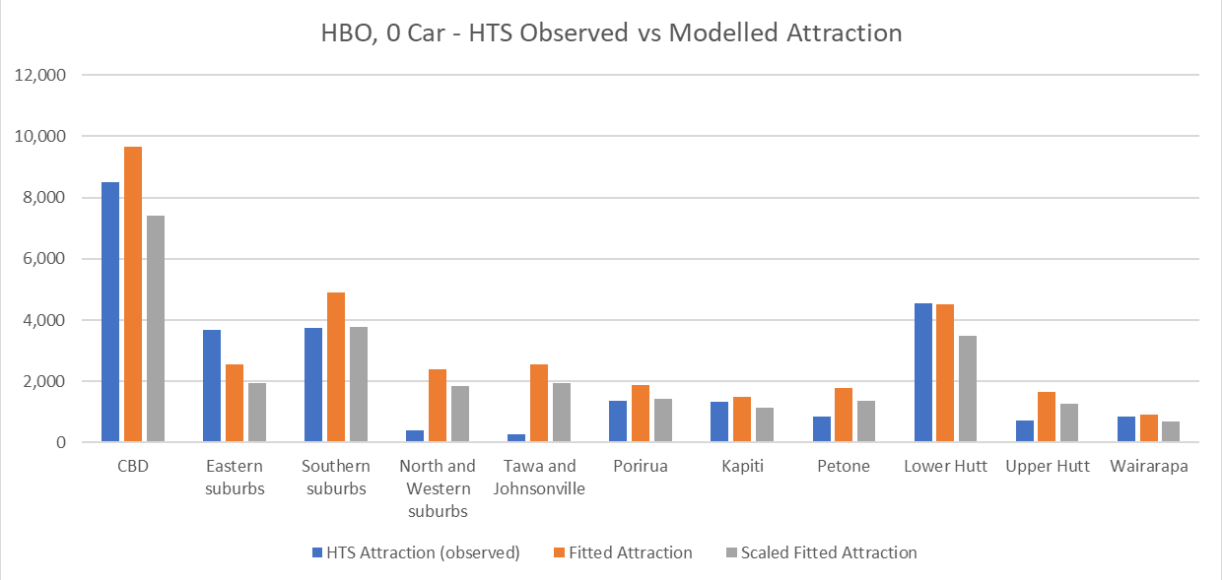

Figure 5-17: HBO 0 car available – modelled vs observed daily trips by sector

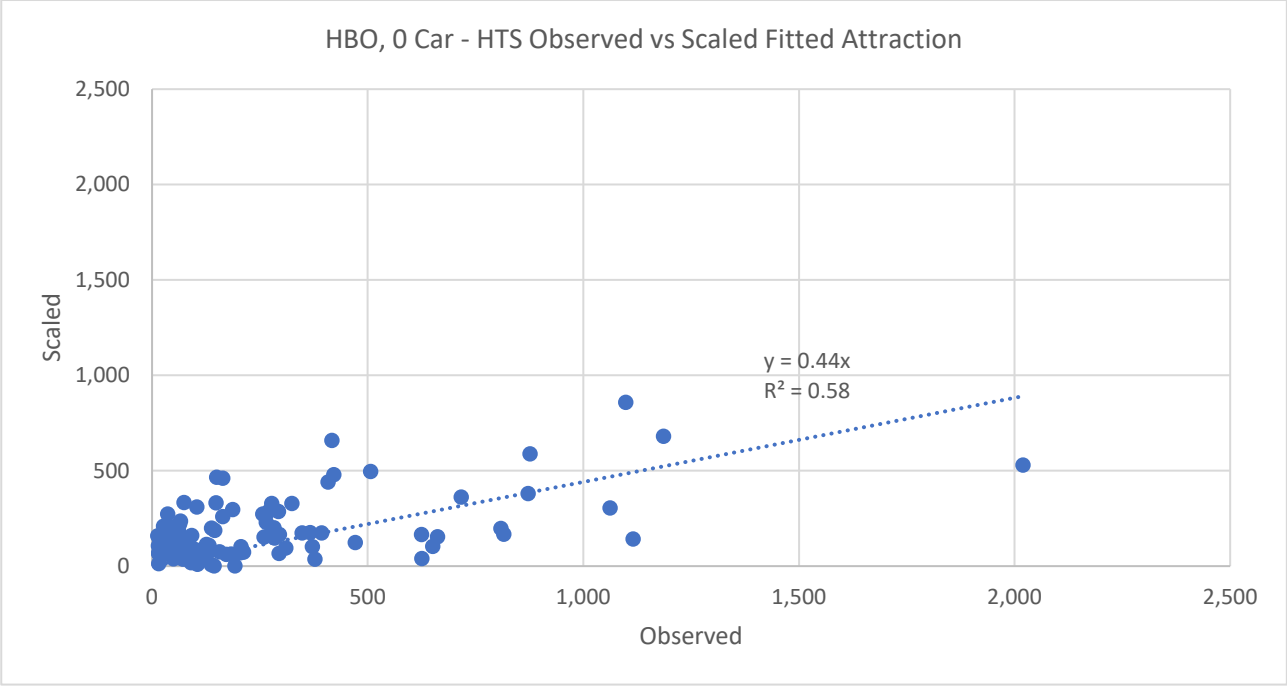

Figure 5-18: HBO 0 car available – modelled vs observed zonal scatter plot

These results show:

- The coefficients estimated through regression overestimated the number of trips.
- Trips to Tawa and North & Western suburbs are overestimated, although the observed trips are very small. Trips to the CBD, Eastern suburbs, and Lower Hutt are slightly underestimated. The numeric value of the differences is small.
- There is considerable scatter, again reflecting the very small number of observations in the HTS.

5.9 Business Origins

Table 5-9: BSN Origins Modelled VS Observed Summary Table

Sector Name	HTS Attraction (observed)	Fitted Attraction	Scaled Fitted Attraction	Scaled Calculated Attraction (CBD scaled)	Scaled Attraction VS HTS Difference
CBD	20,325	23,234	25,232	19,833	-492
Eastern suburbs	6,491	4,650	5,050	5,358	-1,132
Southern suburbs	6,007	7,304	8,051	8,542	2,536
North and Western suburbs	2,954	4,181	4,591	4,871	1,918
Tawa and Johnsonville	4,387	6,965	8,301	8,808	4,421
Porirua	15,059	10,125	11,328	12,019	-3,040
Kapiti	8,716	10,158	11,657	12,369	3,652
Petone	11,360	8,816	9,574	10,158	-1,202
Lower Hutt	18,315	13,629	15,026	15,943	-2,372
Upper Hutt	8,069	6,844	8,150	8,647	578
Wairarapa	14,930	8,897	9,662	10,251	-4,679
	116,612	**104,803**	**116,624**	**116,799**	**187**

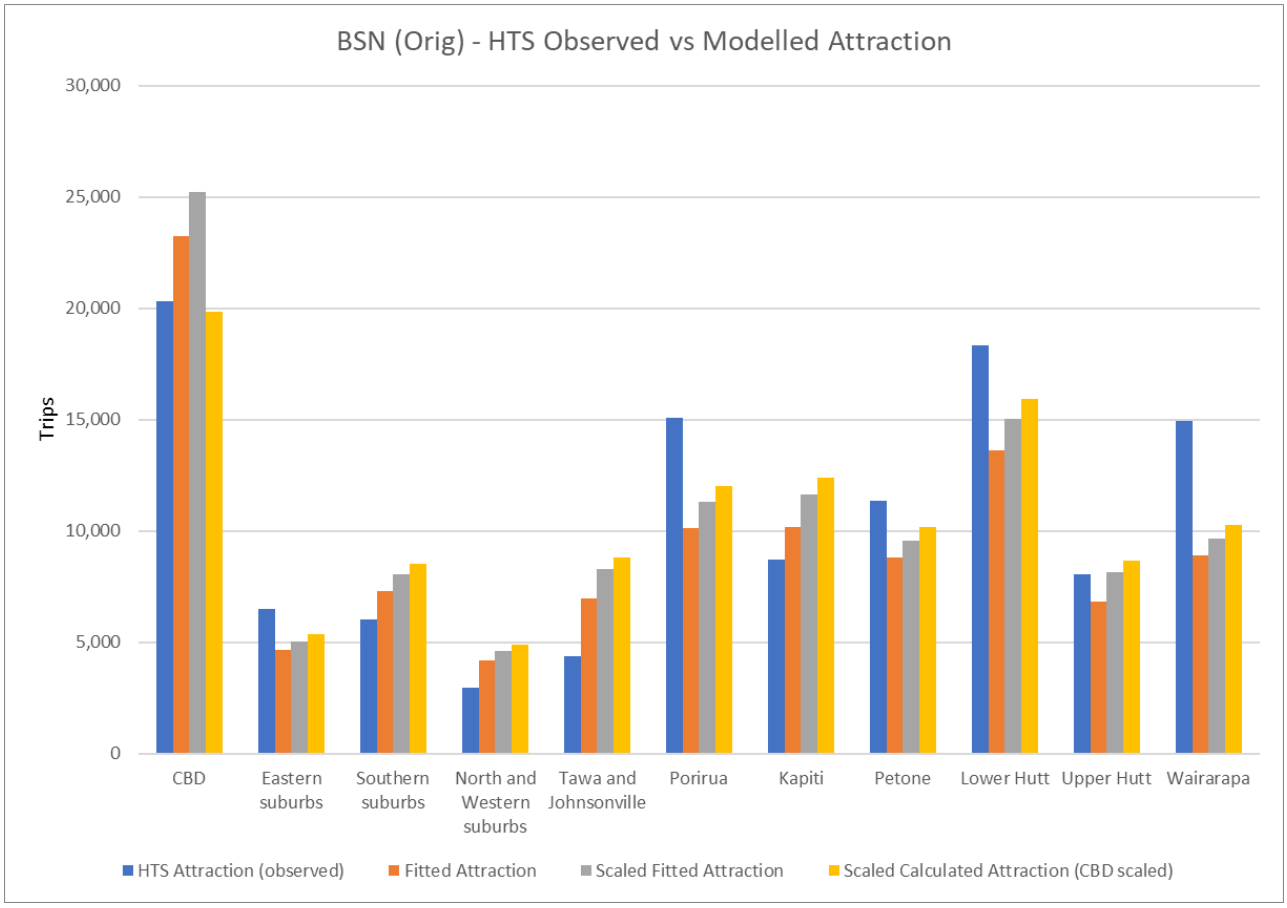

Figure 5-19: BSN Origins – modelled vs observed daily trips by sector

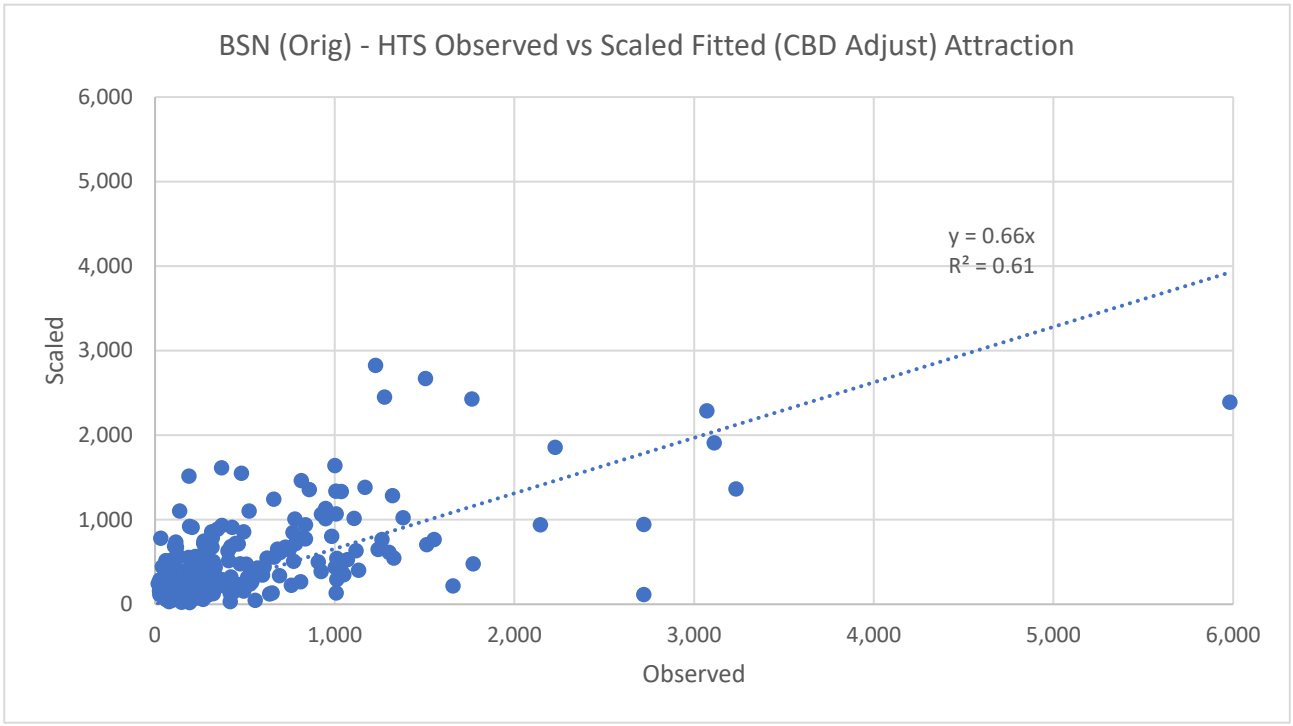

Figure 5-20: BSN Origins – modelled vs observed zonal scatter plot

These results show:

- The CBD was overestimated, while Lower Hutt and Wairarapa were underestimated. The correction for the CBD reduced this discrepancy although it is still notable in the final factored model.
- On a zonal basis, there is a lot of scatter with the larger attractors both over and underestimated.

5.10 Business Destinations

Table 5-10: BSN Destinations Modelled VS Observed Summary Table

Sector Name	HTS Attraction (observed)	Fitted Attraction	Scaled Fitted Attraction	Scaled Fitted Attraction (CBD scaled)	Scaled Attraction VS HTS Difference
CBD	20,352	21,044	22,054	20,356	4
Eastern suburbs	6,570	5,329	5,585	5,685	-884
Southern suburbs	6,084	7,066	7,793	7,933	1,849
North and Western suburbs	3,011	5,141	5,439	5,537	2,526
Tawa and Johnsonville	4,505	7,663	8,882	9,041	4,536
Porirua	14,417	10,133	11,074	11,274	-3,143
Kapiti	9,111	10,018	11,341	11,545	2,433
Petone	10,438	8,639	9,154	9,319	-1,119
Lower Hutt	17,834	15,722	16,931	17,236	-598
Upper Hutt	9,715	6,076	8,198	8,346	-1,369
Wairarapa	14,576	9,697	10,163	10,346	-4,230
	116,612	**106,528**	**116,614**	**116,618**	**6**

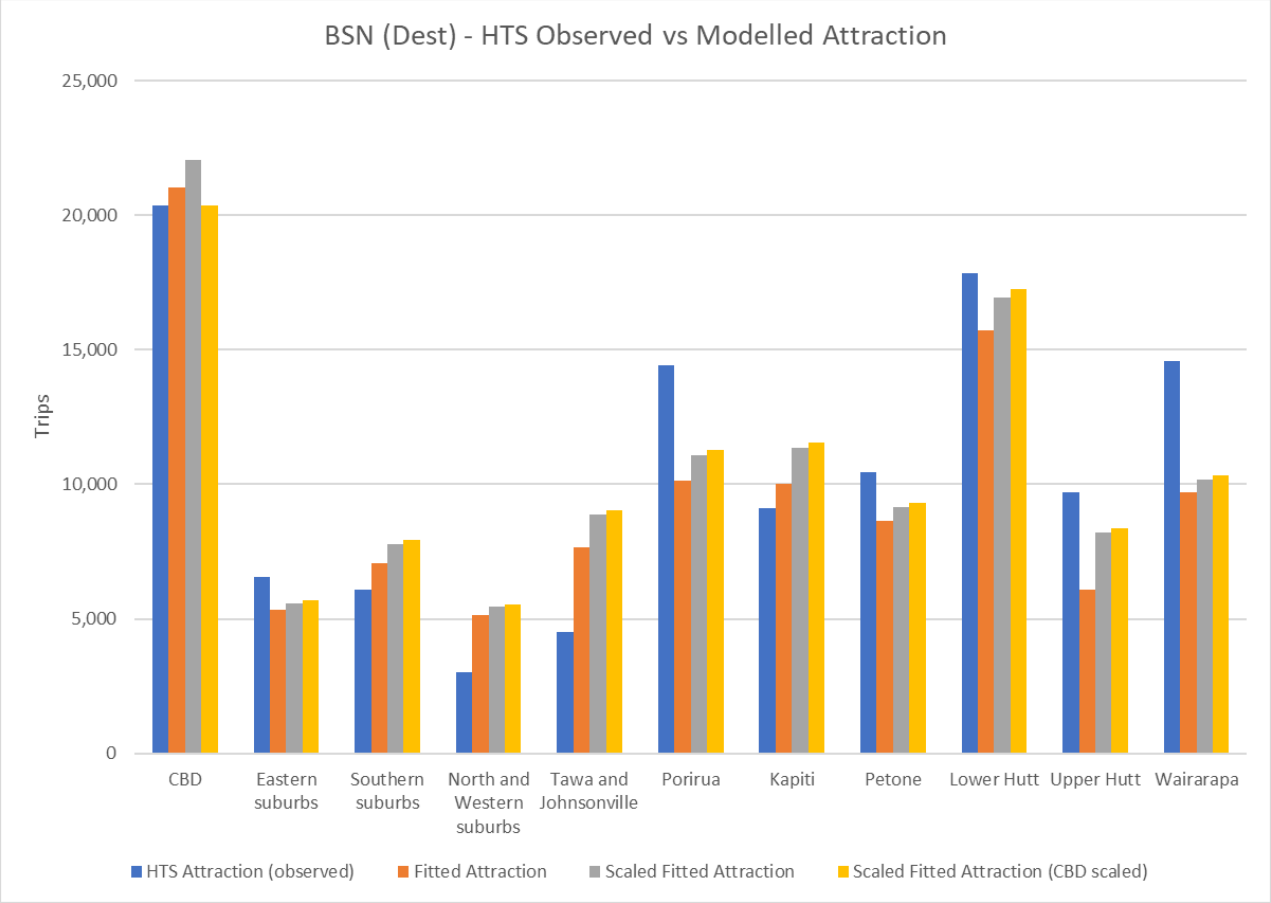

Figure 5-21: BSN Destinations – modelled vs observed daily trips by sector

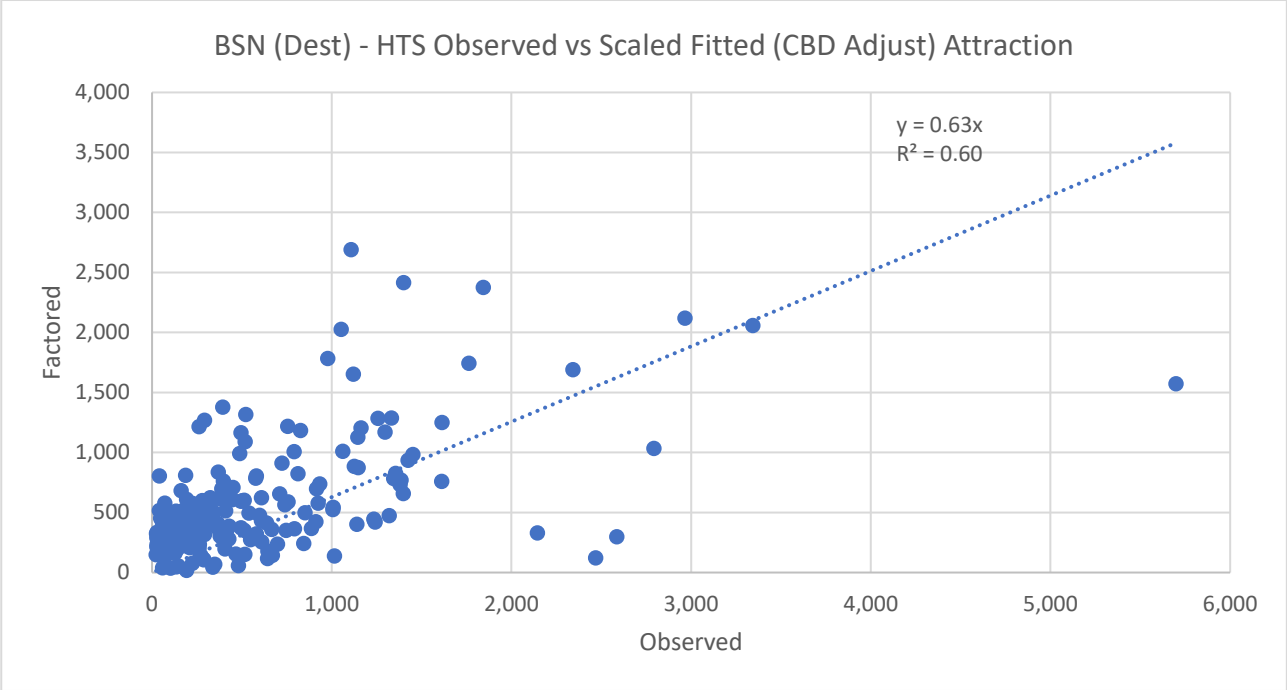

Figure 5-22: BSN Destination – modelled vs observed zonal scatter plot

These results show:

- A similar pattern for business destinations compared with origins, noting the origins will include home and non-home locations.
- The CBD is only slightly overestimated by the application of the coefficients estimated from regression, although Wairarapa is still notably underestimated. Porirua also stands out as underestimated.
- On a zonal basis, there is significant scatter with the high attractors generally underestimated.

5.11 Non Home-based Other Origins

Table 5-11: NHBO Origins Modelled VS Observed Summary Table

Sector Name	HTS Attraction (observed)	Fitted Attraction	Scaled Fitted Attraction	Scaled Fitted Attraction (CBD scaled)	Scaled Attraction VS HTS Difference
CBD	201,835	202,544	218,342	201,966	132
Eastern suburbs	42,228	34,524	37,217	38,408	-3,820
Southern suburbs	35,175	36,142	38,961	40,208	5,034
North and Western suburbs	24,421	25,125	27,085	27,952	3,531
Tawa and Johnsonville	41,336	34,830	37,547	38,749	-2,588
Porirua	68,396	54,682	58,947	60,833	-7,563
Kapiti	57,441	55,570	61,834	63,813	6,371
Petone	32,682	39,638	42,730	44,097	11,415
Lower Hutt	106,270	81,330	87,674	90,479	-15,790
Upper Hutt	45,250	39,577	42,664	44,029	-1,221
Wairarapa	55,879	52,701	57,841	59,691	3,813
	710,913	**656,664**	**710,842**	**710,226**	**-687**

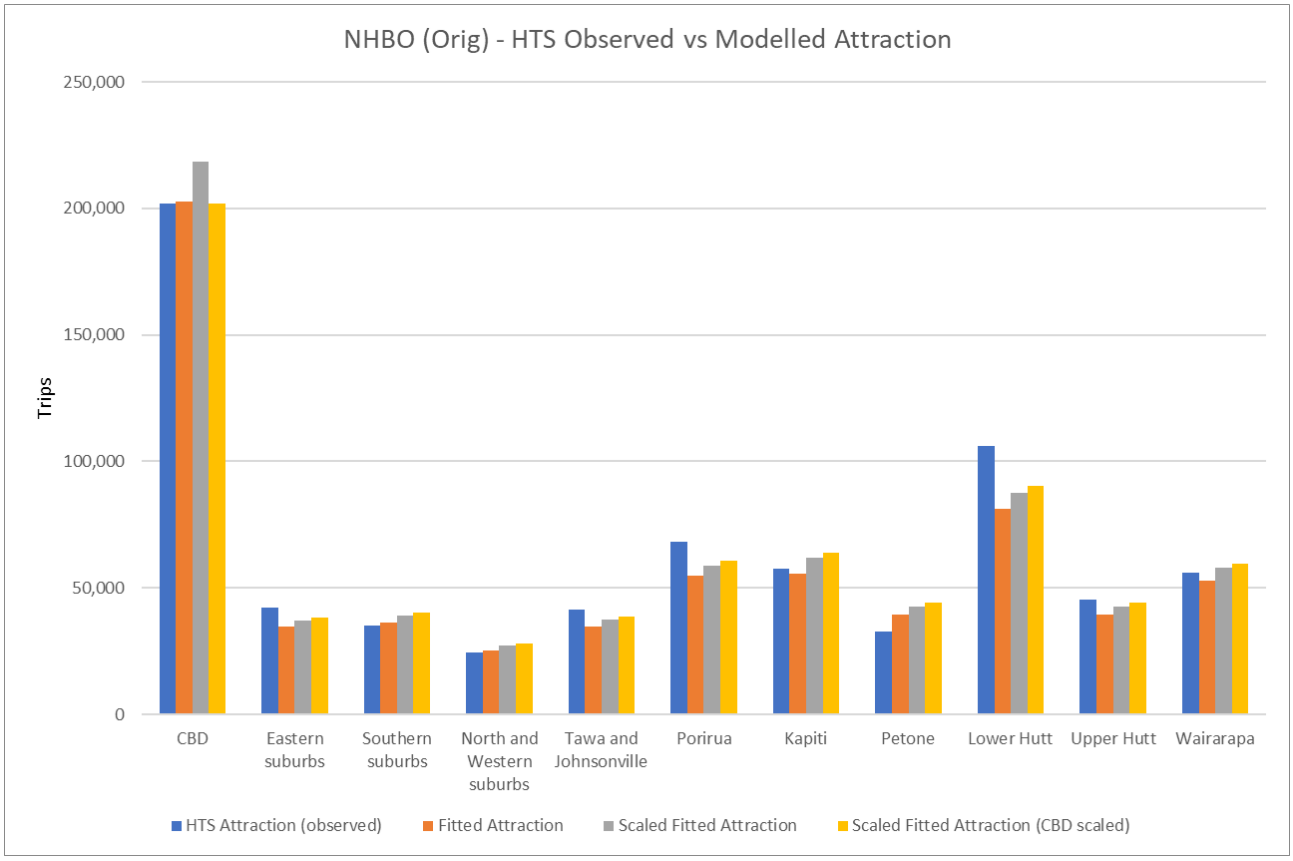

Figure 5-23: NHBO Origins – modelled vs observed daily trips by sector

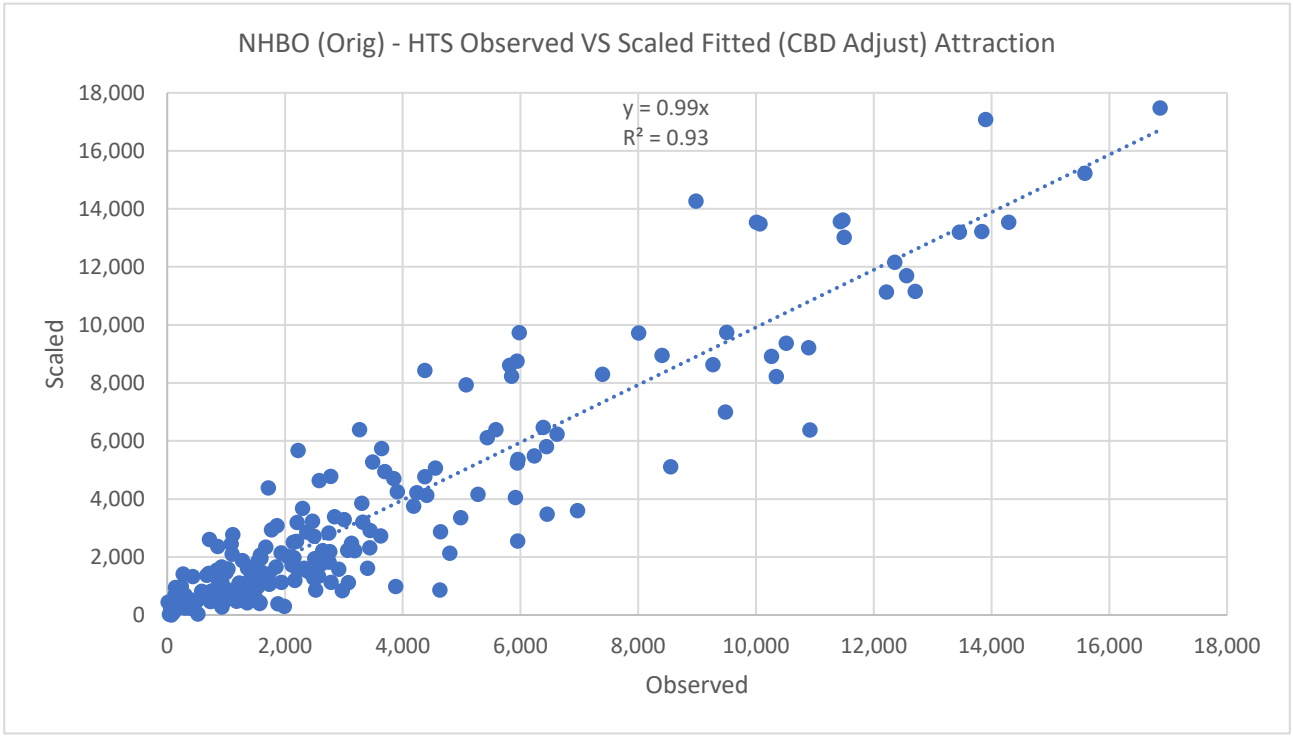

Figure 5-24: NHBO Origins – modelled vs observed zonal scatter plot

These results show:

- The non home-based other origins are numerically large and a better fit in total, by area, and by zone.
- The coefficients estimated by regression replicated the CBD well without adjustment, due to the CBD accounting for just under 30% of all NHBO trips. However, once all zones were included and the error

in the total was corrected by factoring the coefficients, the CBD was overestimated and needed to be corrected.

- Geographically, the model replicates observed relatively well and this is primarily because of the large number of trips.
- By zone, there is less scatter evident and large observed attractors are better much replicated by the model. Aggregating other trip purposes may address some of the variability produced by the model, but this would be offset by a poorer forecasting ability.

5.12 Non Home-based Other Destinations

Table 5-12: NHBO Destinations Modelled VS Observed Summary Table

Sector Name	HTS Attraction (observed)	Fitted Attraction	Scaled Fitted Attraction	Scaled Fitted Attraction (CBD scaled)	Scaled Attraction VS HTS Difference
CBD	187,443	196,161	212,639	187,122	-321
Eastern suburbs	45,107	35,281	38,245	40,234	-4,873
Southern suburbs	33,810	36,351	39,405	41,454	7,644
North and Western suburbs	27,295	25,245	27,366	28,789	1,493
Tawa and Johnsonville	42,125	34,571	37,475	39,424	-2,701
Porirua	69,354	54,068	58,609	61,657	-7,698
Kapiti	58,108	56,902	63,155	66,439	8,330
Petone	36,664	41,347	44,821	47,151	10,487
Lower Hutt	107,017	81,037	87,844	92,412	-14,605
Upper Hutt	47,637	39,178	42,468	44,677	-2,960
Wairarapa	56,352	53,757	58,877	61,939	5,587
	710,913	**653,899**	**710,903**	**711,297**	**384**

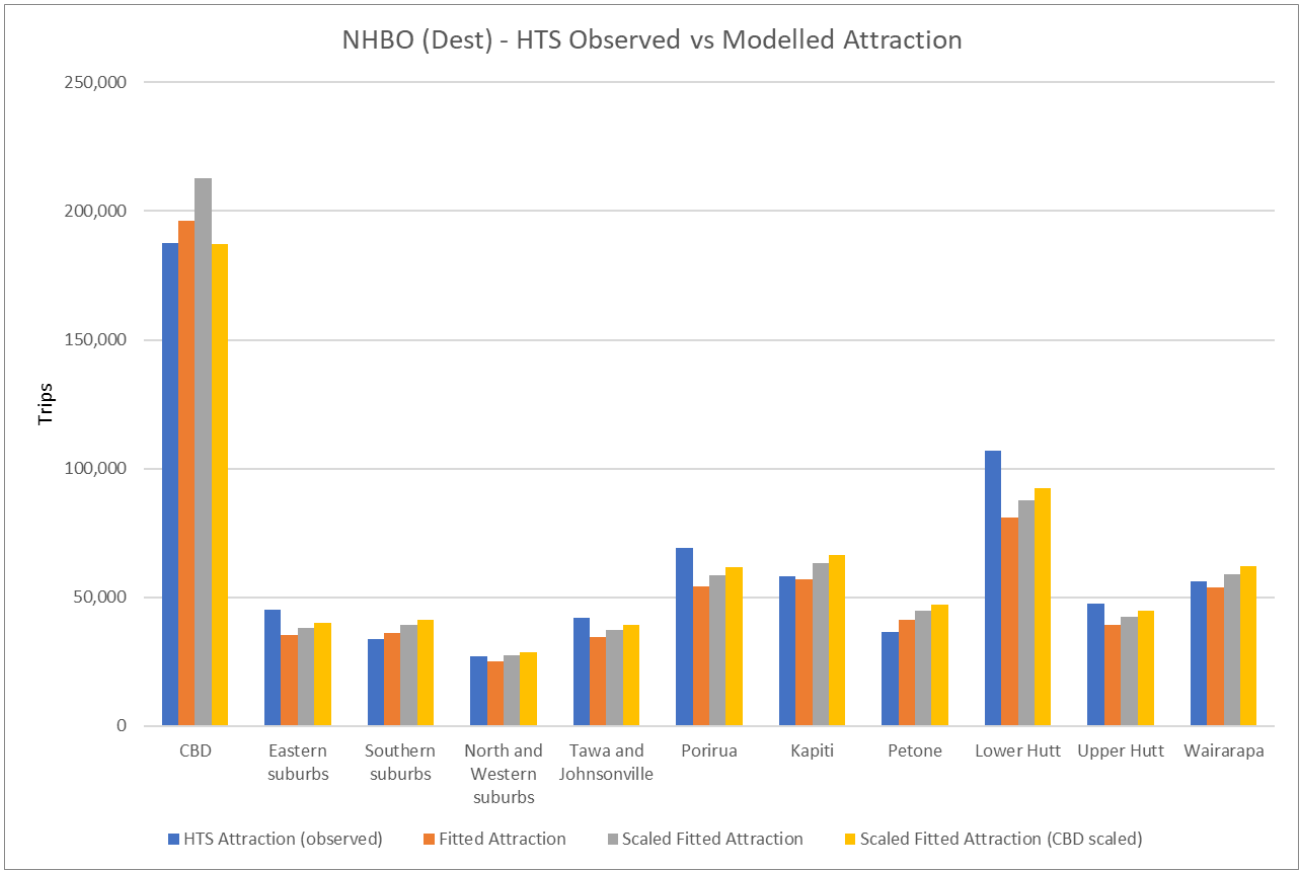

Figure 5-25: NHBO Destinations – modelled vs observed daily trips by sector

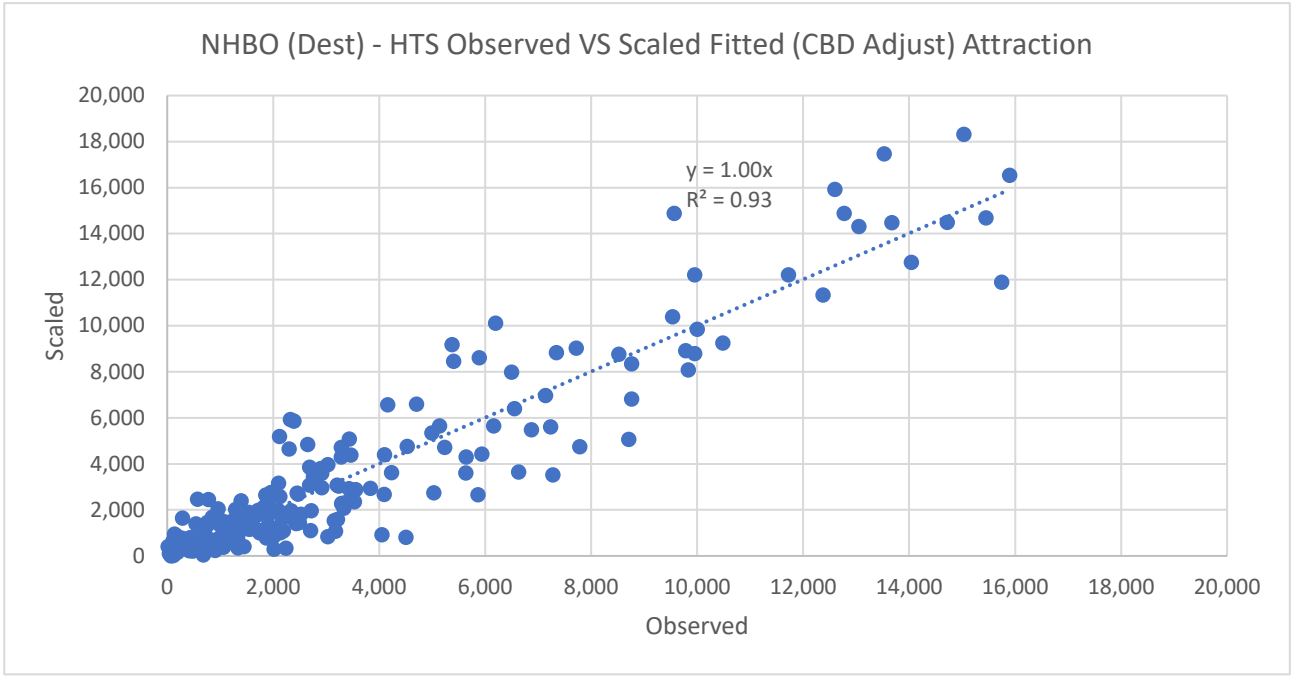

Figure 5-26: NHBO Destinations – modelled vs observed zonal scatter plot

These results show:

- The commentary for non home-based origins applies to destinations as well.
- By zone, there is minimal scatter and no obvious large discrepancies for the larger attractors.
- Geographically, Lower Hutt is again slightly underestimated.

6. Observations

The main observations noted during the development of the attraction models are provided below.

- The zones were aggregated to the larger 225 zone system in order to create reasonable correlations. This is because of the lumpiness of the HTS (small sample, large expansion factors, some trips geocoded to coordinates on zone boundaries then automatically allocated to the adjacent incorrect zone). Even then, all purposes have some zones with no observed trips. While this may be correct in some cases, it cannot be confirmed, identified or corrected.
- The CBD sector had to be treated differently and scaled for most trip purposes. This may be because there are a lot of ministries and head offices in the CBD, relating to Government.
- For home-based trip purposes, the models were re-estimated during validation to separate attraction trips associated with households without a vehicle available and those with one or more vehicles. This was to improve the validation for public transport, which is the primary mode for trips to/from households without a vehicle. Many of the estimated attraction models for no vehicle households show weak statistical relationships. This is because the number of trips are small and finding robust relationships is difficult. Introducing vehicle availability segmentation did significantly improve the overall model validation, and so was retained.

The factors applied to the coefficients produced by statistical software (section 4) to produce the same number of trips as the HTS are provided below for completeness. These factors have been already applied to the model parameters in the next section.

Table 6-1: Attraction Model – Scaling Factors Applied to Regressed Coefficients

Purpose	Scaling Factor
HBW - 1+ car	0.945
HBW – 0 car	0.486
HBE - 1+ car	1.199
HBE - 0 car	0.823
HBS - 1+ car	1.040
HBS - 0 car	0.928
HBO - 1+ car	1.047
HBO - 0 car	0.767
BSN - Orig	1.086
BSN - Dest	1.048
NHBO - Orig	1.078
NHBO - Dest	1.084

7. Final Attraction Model Coefficients

The final attraction model coefficient values, scaled to produce the correct totals, are tabulated below by purpose. The CBD and non-CBD adjustment factors are tabulated in Table 7-13. The CBD and non-CBD adjustments are applied multiplicatively in addition to the scaled coefficients.

Table 7-1: Attraction Model Coefficients – HBW 1+ Car Available

Explanatory Variable	HBW
Employment: Mining	33.491
Employment: Manufacturing	1.78
Employment: Construction	2.297
Employment: Retail Trade	1.374
Employment: Information Media and Telecommunications	1.886
Employment: Professional, Scientific and Technical Services	0.817
Employment: Administrative and Support Services	3.587
Employment: Public Administration and Safety	1.386
Employment: Education and Training	0.824
Employment: Health Care and Social Assistance	1.316

Table 7-2: Attraction Model Coefficients – HBW 0 Car Available

Explanatory Variable	HBW
Employment: Mining	0.035
Employment: Manufacturing	0.417
Employment: Construction	0.011
Employment: Retail Trade	0.17
Employment: Information Media and Telecommunications	0.162
Employment: Professional, Scientific and Technical Services	0.012
Employment: Administrative and Support Services	0.02
Employment: Public Administration and Safety	0.184
Employment: Education and Training	0.035
Employment: Health Care and Social Assistance	0.417

Table 7-3: Attraction Model Coefficients –HBE 1+ Car Available

Explanatory Variable	HBE
School Roll: Primary + Secondary	2.267
School Roll: Tertiary	0.216

Table 7-4: Attraction Model Coefficients –HBE 0 Car Available

Explanatory Variable	HBE
School Roll: Primary + Secondary	0.077
School Roll: Tertiary	0.028

Table 7-5: Attraction Model Coefficients –HBS 1+ Car Available

Explanatory Variable	HBSH
Employment: Retail Trade	12.987

Table 7-6: Attraction Model Coefficients –HBS 0 Car Available

Explanatory Variable	HBSH
Employment: Retail Trade	0.956

Table 7-7: Attraction Model Coefficients –HBO 1+ Car Available

Explanatory Variable	HBO
Households	1.318
Employment: Retail Trade	7.315
Employment: Accommodation and Food Services	2.091
Employment: Health Care and Social Assistance	1.084

Table 7-8: Attraction Model Coefficients –HBO 0 Car Available

Explanatory Variable	HBO
Households	0.088
Employment: Retail Trade	0.218
Employment: Health Care and Social Assistance	0.137

Table 7-9: Attraction Model Coefficients –BSN Orig

Explanatory Variable	BSN Orig
Employment: Construction	2.757
Employment: Health Care and Social Assistance	0.833
Employment: Arts and Recreation Services	2.427
Employment: Other Services	2.52
Employment: Total	0.029

Table 7-10: Attraction Model Coefficients –BSN Dest

Explanatory Variable	BSN Dest
Households	0.147
Employment: Construction	1.287
Employment: Wholesale Trade	2.176
Employment: Retail Trade	0.691
Employment: Health Care and Social Assistance	0.606
Employment: Total	0.077

Table 7-11: Attraction Model Coefficients –NHBO Orig

Explanatory Variable	NHBO Orig
Employment: Retail Trade	12.699
Employment: Accommodation and Food Services	10.101
Employment: Public Administration and Safety	1.023
Employment: Education and Training	4.965
Employment: Health Care and Social Assistance	2.055
Employment: Other Services	10.435

Table 7-12: Attraction Model Coefficients –NHBO Dest

Explanatory Variable	NHBO Dest
Employment: Retail Trade	14.721
Employment: Accommodation and Food Services	10.081
Employment: Public Administration and Safety	0.604
Employment: Education and Training	3.719
Employment: Health Care and Social Assistance	2.286
Employment: Arts and Recreation Services	3.512
Employment: Other Services	8.065

Table 7-13: CBD and Non-CBD Adjustment Factors

Purpose	CBD Adjustment Factor	Non-CBD Adjustment Factor
HBW 1+ Car Available	1.101	0.943
HBW 0 Car Available	2.187[3]	0.502
HBE 1+ Car Available	1 (No adjustment)	1 (No adjustment)
HBE 0 Car Available	1 (No adjustment)	1 (No adjustment)
HBS 1+ Car Available	0.507	1.151
HBS 0 Car Available	1 (No adjustment)	1 (No adjustment)
HBO 1+ Car Available	0.782	1.041
HBO 0 Car Available	1 (No adjustment)	1 (No adjustment)
BSN - Orig	0.786	1.061
BSN - Dest	0.923	1.018
NHBO - Orig	0.925	1.032
NHBO - Dest	0.880	1.052

To simplify implementation In the model, there are input parameters specified for business destinations for one plus vehicle available households and separately for zero vehicle available households. The parameter values are identical. The same applies to business origins, and non home-based other origins and destinations.

[3] While the correct CBD adjustment factor for HBW zero car available households is 2.187, the value 2.183 was input to the model and the model was validated. This error made no substantive difference the value of 2.183 was retained.

Appendices

Appendix A Client Comment on Version 1 and Consultant Response

No.	Comment By	Comment	Response
1	**Andrew Ford**	I'm interested to know what your internal reviewer thought, particularly whether any of the challenges you have encountered – head office syndrome, tertiary education in the CBD – are common to those experienced by colleagues in Oz and farther afield?	We have not seen this issue elsewhere in NZ, and it may be exacerbated by the small sample sizes in the HTS.
2		Generally the explanatory variables seem intuitive to me.	Agreed.
3		Interesting that 'head office syndrome' does not affect HBW – is this because for example a manufacturing company in the Wairarapa would manufacture things (with resulting trip attractions / productions) whereas manufacturing companies the CBD would like be head office registered jobs with quite different characteristics??	It is difficult to know why HBW slightly under-estimates trips to the CBD whereas other purposes over-estimate. This could also be attributable to the small sample sizes in the HTS, or a genuinely different relationship. Unfortunately, we can only work with the data we have.
4		It would be useful to have trip attractions (and productions) by purpose mapped onto WTSM zones to provide an additional sense check of what the model is showing (do any zones stand out as looking odd given what we know about the land use) though I accept that this might be something that is better at a later point in time during the cal / val process; you did use a combination of population / employment as an indication of "activity" for zone disaggregation I seem to remember, so something like this could be useful?	Maps added to show trip attractions for each trip purpose by zone.
5		Interesting to see that NHBO attractions in the CBD don't need too much scaling, with greatest scaling required for HBS. Do we think this is because a lot of shopping trips in the CBD will be non-HBO (popping out to work to shop) whereas elsewhere in the region there will be more specific shopping trips?	Yes, potentially. We are using retail jobs to explain home-based shopping trips across the region, but there could well be fewer home-based shopping jobs per retail job in the CBD with greater NHBO trips. This highlights the weakness of a trip-based (i.e not tour-based) approach.
6		I can understand the logic for having different regression coefficients for primary / secondary vs tertiary – they have quite different travel pattern, one is more predictable than the other, and I imagine we have far greater confidence in primary / education than tertiary; without wanting to complicate things, is there a "simple" way to split	The home-based school attractions can be split into primary/secondary and tertiary as it's based on input land use. This split will not be possible in other stages of the model (i.e.: trip production, mode split, distribution). To differentiate, primary/secondary and tertiary would need to be separate trip

No.	Comment By	Comment	Response
		out the HBEdu matrices into 'primary / secondary' and 'tertiary' as a means of checking demand and distribution, once we get to this stage?	purposes – and more HTS data would likely be needed to estimate the model.
7	**Ian Clark**	Bullet 3, at the bottom of page 2: are we storing up any problems for later, by aggregating to the current number of zones (225), but later using the 820 zones?	We believe it is the converse. Estimating the models at 820 zones produced very poor results because of the geocoding of the trips in the HTS. As an example, we found school trips that were geocoded to the centre of the road (instead of where the school was) and as a result, were allocated to the adjacent (wrong) zone. A robust attraction model could not be fitted as we had school trips to zones where there was no school. Fitting the models at an aggregated number of zones was to overcome this limitation in the HTS. We note it is typical to need zonal aggregation to estimate attraction models due to sample sizes.
8		Section 3 refers to 23 variables, while there are only 19 job types referred to. Are some types split into sub categories? But wait: Table 7.1 gives 23 – there's my answer.	Addressed.
9		Section 4: the explanatory variables seem generally logical However, it may be worthwhile explaining to the reader which of the coefficients truly contributes to the relationship. The text at the top of section gives a good explanation, but I am struggling to see (for example) how mining appears to be important for HBW (ie the T value is above 2, and the P value is very small), when Table 1 indicates there are so few mining jobs.	You are correct that some land use types will have a greater contribution to the trip ends than others. While mining is a minimal contributor overall, it does contribute more for some zones. So it is not straight-forward to show relative contribution by land use type as this will vary by zone over the region. The high T value and low P value indicate whether an explanatory variable is statistically strong rather than necessarily being a large numerical contributor.
10		Section 4: how concerned should we be that the R squared values for some trip types are lower than ideal (HBE, even when split by education type), and BSN (origins and destinations) – more on this below.	Home-based education has a poor fit because we have observed education trips to locations without schools (16 sectors accounting for circa 13,000 daily trips). These trips are impossible to explain using logical explanatory variables. The issue is the HTS – either geocoding errors or just errors. The application of the model will partially address this by ensuring education trips are only attracted to zones where there are schools. When all the model components are linked together, we are expecting that some modules will need to be revisited.
11		Section 5: Does the scale of the CBD factors have any justification, or do these factors just allow the numbers to match (ie often called k factors, I call them fudge factors when I use them).	The CBD scale is to adjust/correct the modelled trips to reflect observed. Yes, it is a "fudge factor". Ideally, a separate CBD model would be developed but the

<table>
<tr><th>No.</th><th>Comment By</th><th>Comment</th><th>Response</th></tr>
<tr><td></td><td></td><td></td><td>HTS sample is too small when split by trip purpose.</td></tr>
<tr><td>12</td><td></td><td>The R squared values in this section look good, but I wonder if R squared figures should also be provided which exclude the CBD zone, as that zone dwarfs the rest and is probably over influencing the r squared values – which may well still look OK.</td><td>R-squared results below for all sectors, excluding the CBD, and CBD only for the modelled vs observed scatter graphs by trip purpose. Excluding the CBD has not significantly changed the relationships.

<table><tr><th rowspan="2">Purpose</th><th colspan="3">R-Squared</th></tr><tr><th>All</th><th>Excl CBD</th><th>CBD only</th></tr><tr><td>HBW</td><td>0.91</td><td>0.8449</td><td>0.9471</td></tr><tr><td>HBE</td><td>0.5321</td><td>0.5229</td><td>0.6757</td></tr><tr><td>HBS</td><td>0.8484</td><td>0.8504</td><td>0.827</td></tr><tr><td>HBO</td><td>0.7857</td><td>0.784</td><td>0.8004</td></tr><tr><td>BSN ORIG</td><td>0.6066</td><td>0.5873</td><td>0.7247</td></tr><tr><td>BSN DEST</td><td>0.5988</td><td>0.5593</td><td>0.8258</td></tr><tr><td>NHB ORIG</td><td>0.9267</td><td>0.9158</td><td>0.9496</td></tr><tr><td>NHB DEST</td><td>0.9289</td><td>0.9123</td><td>0.9722</td></tr></table></td></tr>
<tr><td>13</td><td></td><td>Table 20 for HBE (and the subsequent graphs) indicate that the results for this trip type are “least good”. Presumably this reflects the point, three bullets up, that the correlation for this type was not that good.</td><td>Yes, this reflects that the sample of home-based education trips in the HTS, factored to total persons does not correlate as well with land use that is logical from a transport planning perspective.</td></tr>
<tr><td>14</td><td></td><td>Section 6. Building on Andy’s points on the CBD factors. I can understand that employment and education in the CBD is different, but wonder if we need to think a bit further about how we represent the different trip making. Clearly separating education into primary/secondary and tertiary is part of the story. Could it also be that some of the education related trips are less teaching, and more akin to educational support/office jobs in the CBD, so maybe forming part of a different job type? In fact could the same be for some health related jobs, if some people are office workers rather than front line health workers? And how can we reflect the head office/government ministry issue – could we add an extra sub type, to reduce the need for the scaling/k factors? Or is this just as imprecise?</td><td>A work trip to the CBD for an educational office job should be coded in the HTS as “work” and not “education” because the trip purpose is the reason for the trip and not the type of destination.
Fundamentally, the issue is the small HTS sample whose variability is difficult to explain. So further disaggregation in land use and trip type is unlikely to significantly improve the models – it will just add more variation in the observed data.</td></tr>
</table>

Appendix B Mapped Attractions by Trip Purpose

These figures show modelled daily trip attractions by trip purpose. The same scale is used in all plots for comparison. These are the attractions calculated excluding vehicle availability by household, although significant differences are not expected.

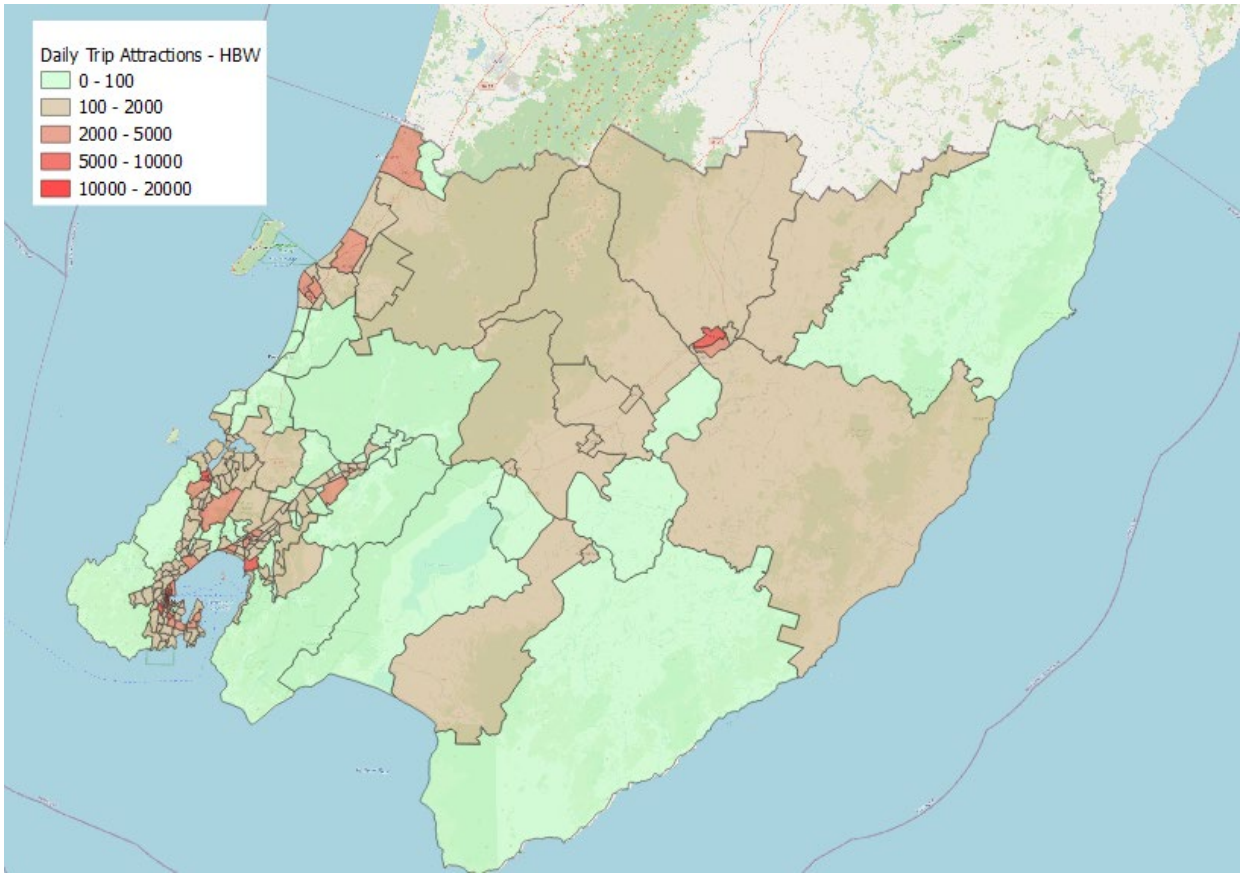

Figure B1: HBW Daily Modelled Trip Attractions

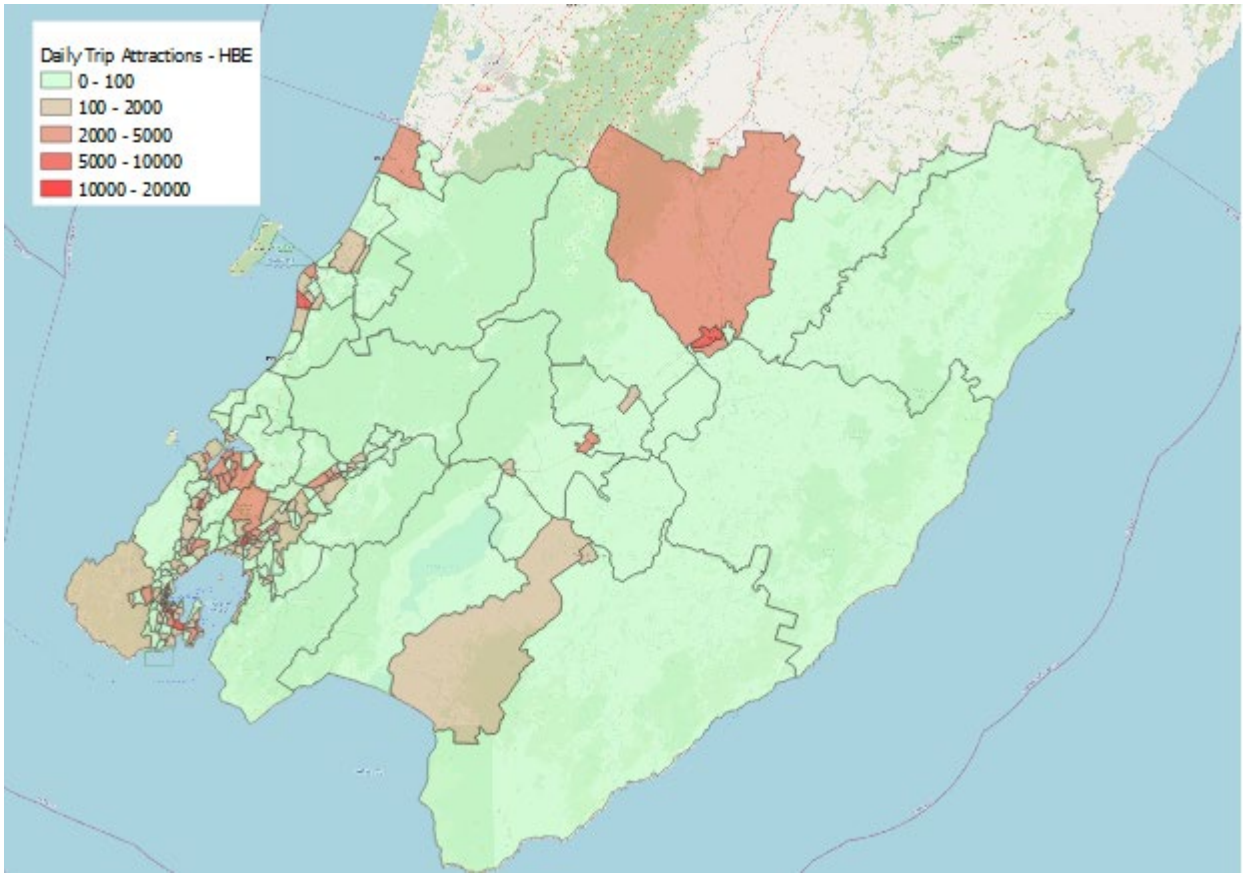

Figure B2: HBE Daily Modelled Trip Attractions

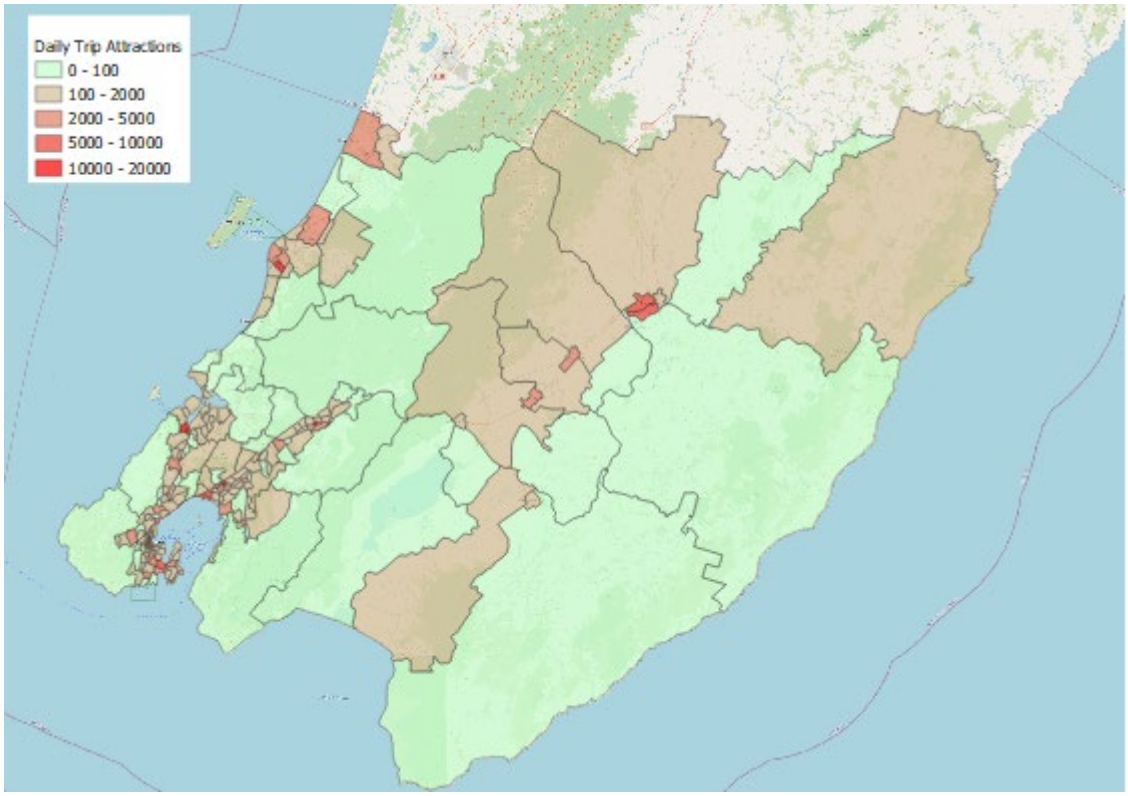

Figure B3: HBE Daily Modelled Trip Attractions

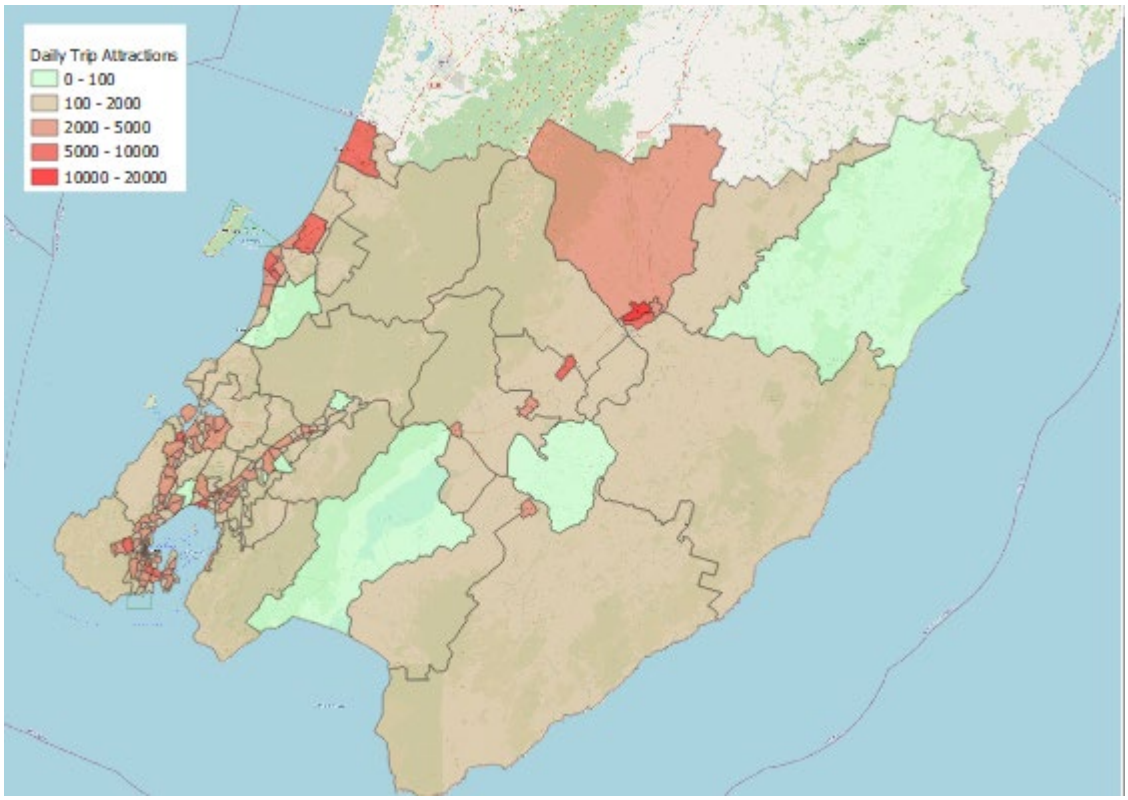

Figure B4: HBO Daily Modelled Trip Attractions

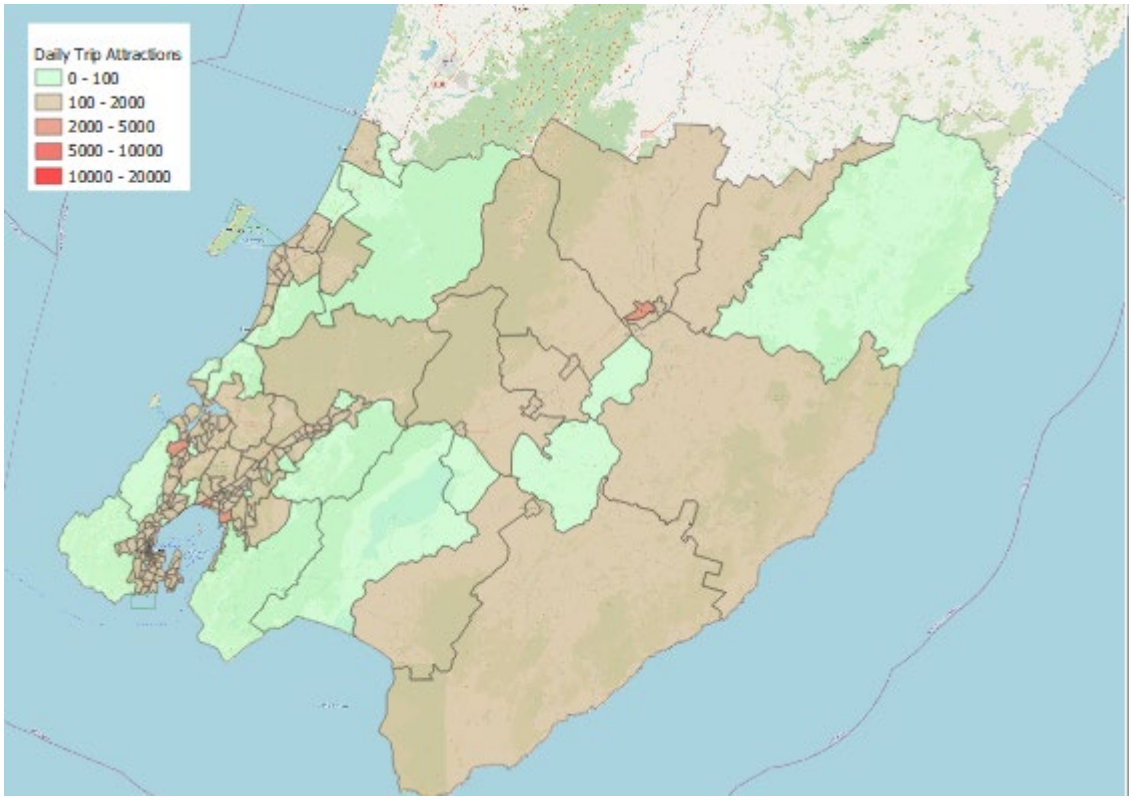

Figure B5: BSN Orig Daily Modelled Trip Attractions

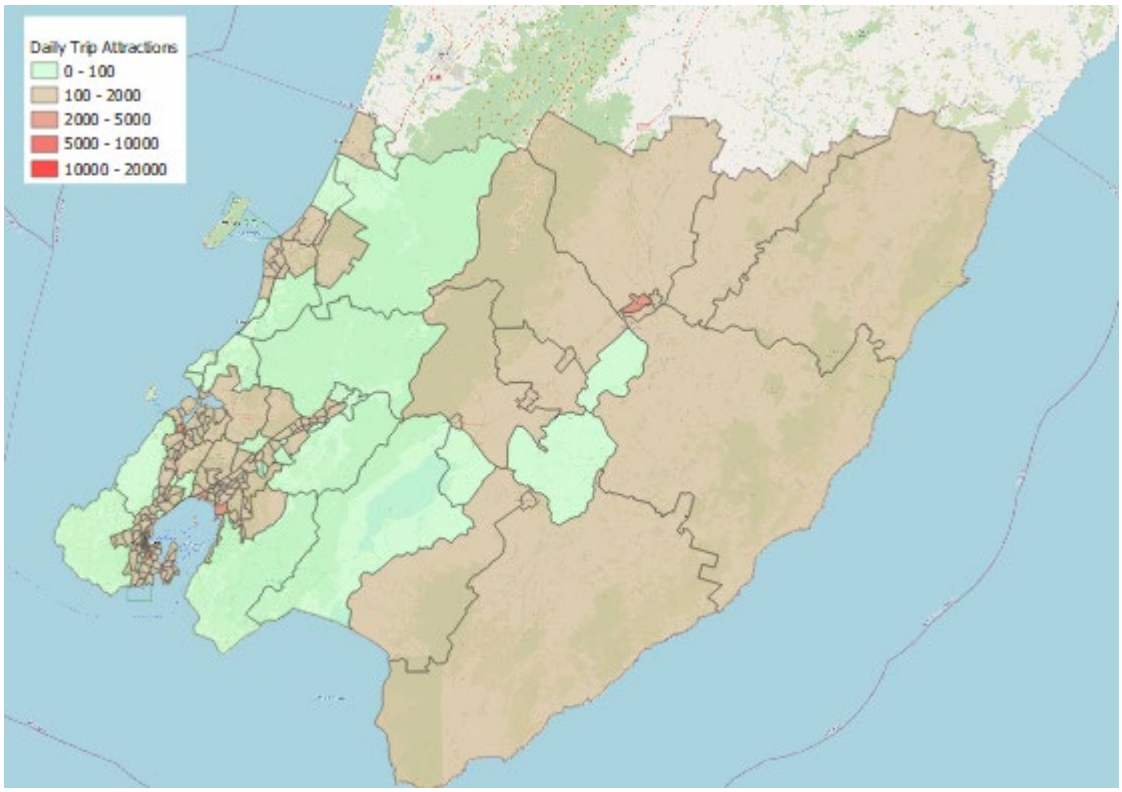

Figure B6: BSN Dest Daily Modelled Trip Attractions

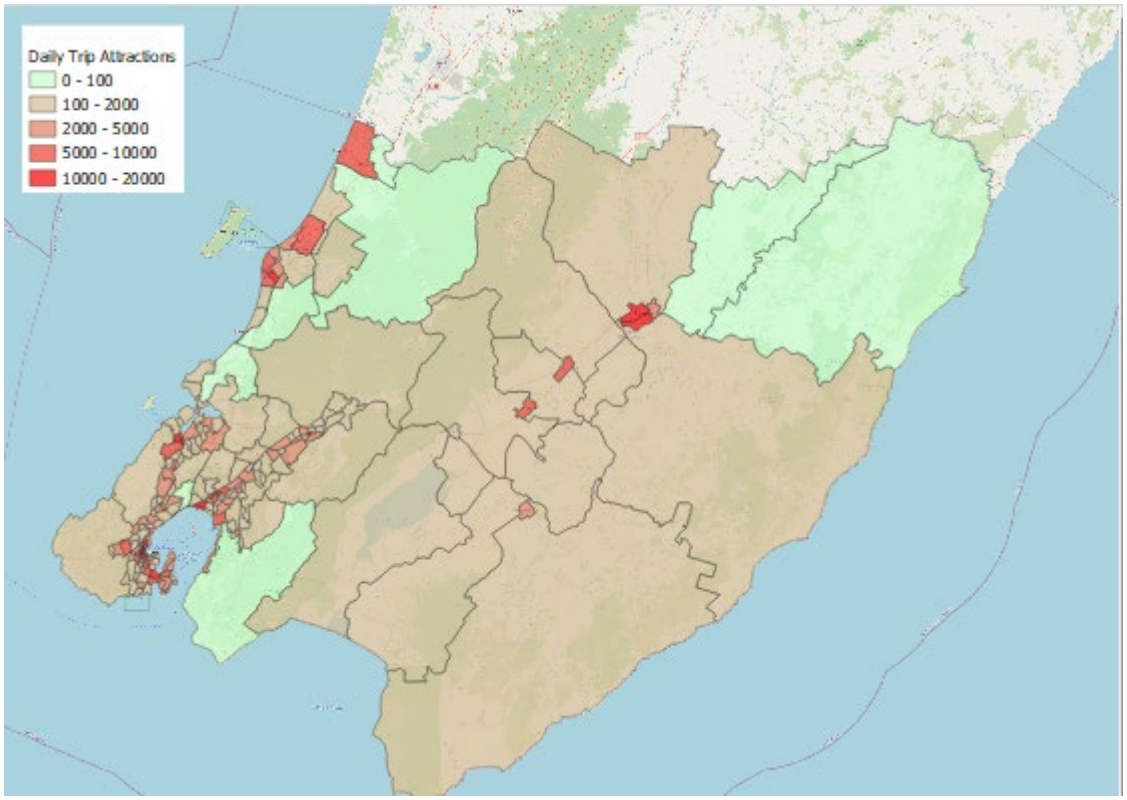

Figure B7: Figure A 7: NHBO Orig Daily Modelled Trip Attractions

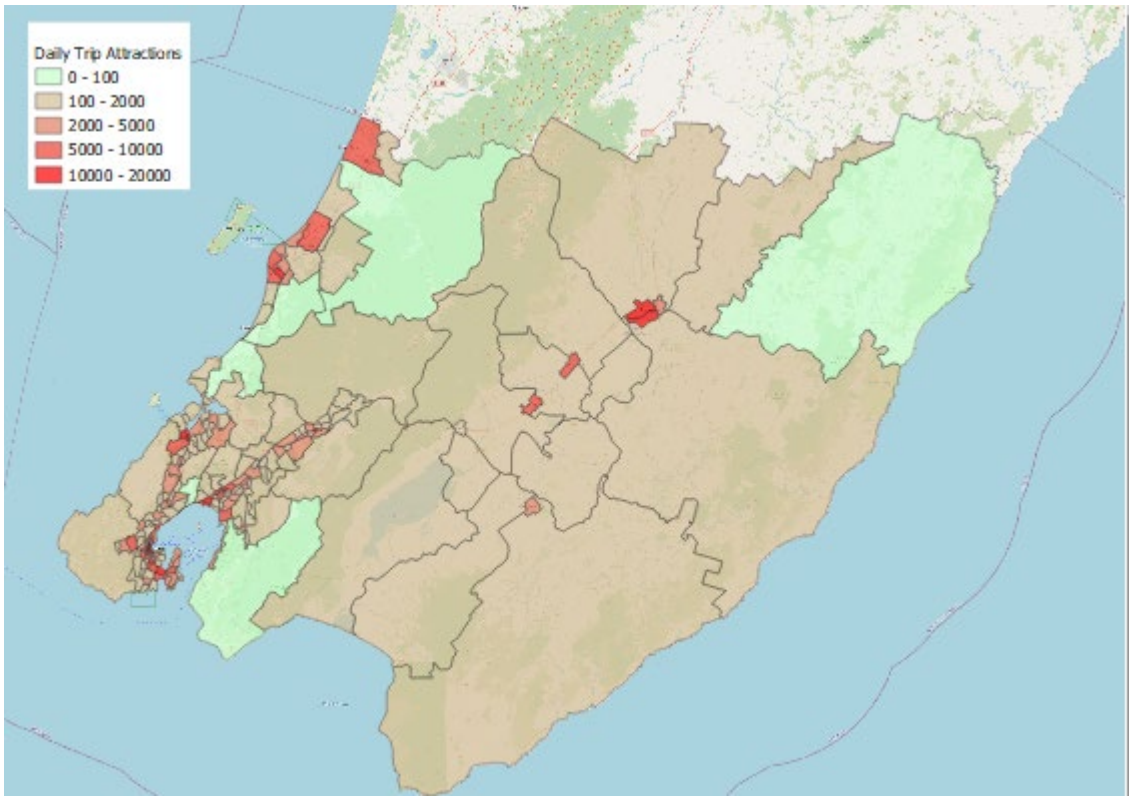

Figure B8: NHBO Dest Daily Modelled Trip Attractions

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