Auckland Cycle Model

Model Development Report

September 2018

flow
TRANSPORTATION SPECIALISTS

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CONTENTS

APPENDICES

1 INTRODUCTION

This report has been prepared by Flow Transportation Specialists (Flow) to document the development of the Auckland Cycle Model. The Auckland Cycle Model was initially developed in 2014 to support the Indicative Business Case for the NZ Transport Agency's SeaPath shared use path project, and has been substantially extended and revised since. It has subsequently been used to evaluate cyclist demands for cycle infrastructure projects across Auckland, on behalf of both Auckland Transport and the NZ Transport Agency, including:

- SeaPath shared use path
- Wynyard Quarter cycle infrastructure
- New Lynn to Avondale shared path
- Quay Street cycleway
- Auckland Urban Cycleways Programme
- Glen Innes and New Lynn Cycle Links to Public Transport
- Mangere Inlet shared path
- Auckland Cycling Programme Business Case
- Te Whau Pathway
- Burnley Terrace cycle link
- The Pt Chevalier, Westmere and Grey Lynn package of cycle routes
- Ti Rakau Drive cycleway component of AMETI project
- The Hingaia South cycle network
- The cycling infrastructure component of the Northern Corridor Improvements project
- Glen Innes to Tamaki Drive shared path
- Inner East and West cycle routes

This report documents the model as it stands in August 2018, including:

- The model's extent, periods represented and level of detail
- The 2013 base model, including its calibration and validation processes
- The forecast demand methodology and the calibration of this process
- The model's limitations.

2 INPUT DATA USED

The development of cyclist demands has relied on inputs from multiple sources, including:

The 2013 New Zealand Census:

- Journey to work cycling trips within the model area (some 5,680 daily cycling trips, representing 96% of the Auckland regional journey to work cycle trip total);
- The trip length profile for cycling journeys to work in the Auckland region.

The Auckland Regional Transport (ART) model:

- Morning and evening peak period person trips for non-active modes, by trip type, for the 2026 and 2046 forecast years.

Auckland Council Land Use Forecasts:

- Projected population and employment forecasts for the Auckland region, by ART model zone.

The UK Department for Transport's (DoT) National Travel Survey Statistics:

- The proportion of daily journey to work trips that took place between 7 and 9 am (60%), and the proportion of work trips to home between 4 and 6 pm (49%).

Strava cycle data:

- Heat maps of routes used by Auckland cyclists using smartphone apps and fitness equipment linked to Strava.

Auckland Transport cycle count data:

- Manual count data collected on a single weekday, generally on a fine day in March 2013 but from a variety of sources and dates, and
- Automatic count data from the 54 cycle counters that Auckland Transport monitors across the region; this automatic data has provided average cyclist numbers over a period of months, or longer.

Where appropriate, count data has been seasonally adjusted, and has been corrected for weather using the procedures in the NZ Transport Agency's Research Report 340 "Estimating Demand for New Cycling Facilities in New Zealand" (McDonald, et at., 2007).

The automatic cycle counters provide continuous data throughout the day, and the analysis of this data has found that weekday cyclist numbers across these count sites have typically fluctuated ±65% from the annual average in 2016. Similarly, weekly counts have fluctuated typically ±25% from the average. This illustrates the considerable fluctuation in cycle volumes, not only seasonally but also weekly and daily.

This fluctuation has also been evident in the manual count data obtained; multiple manual counts were often available for single locations, or for adjacent locations, with these counts fluctuating significantly.

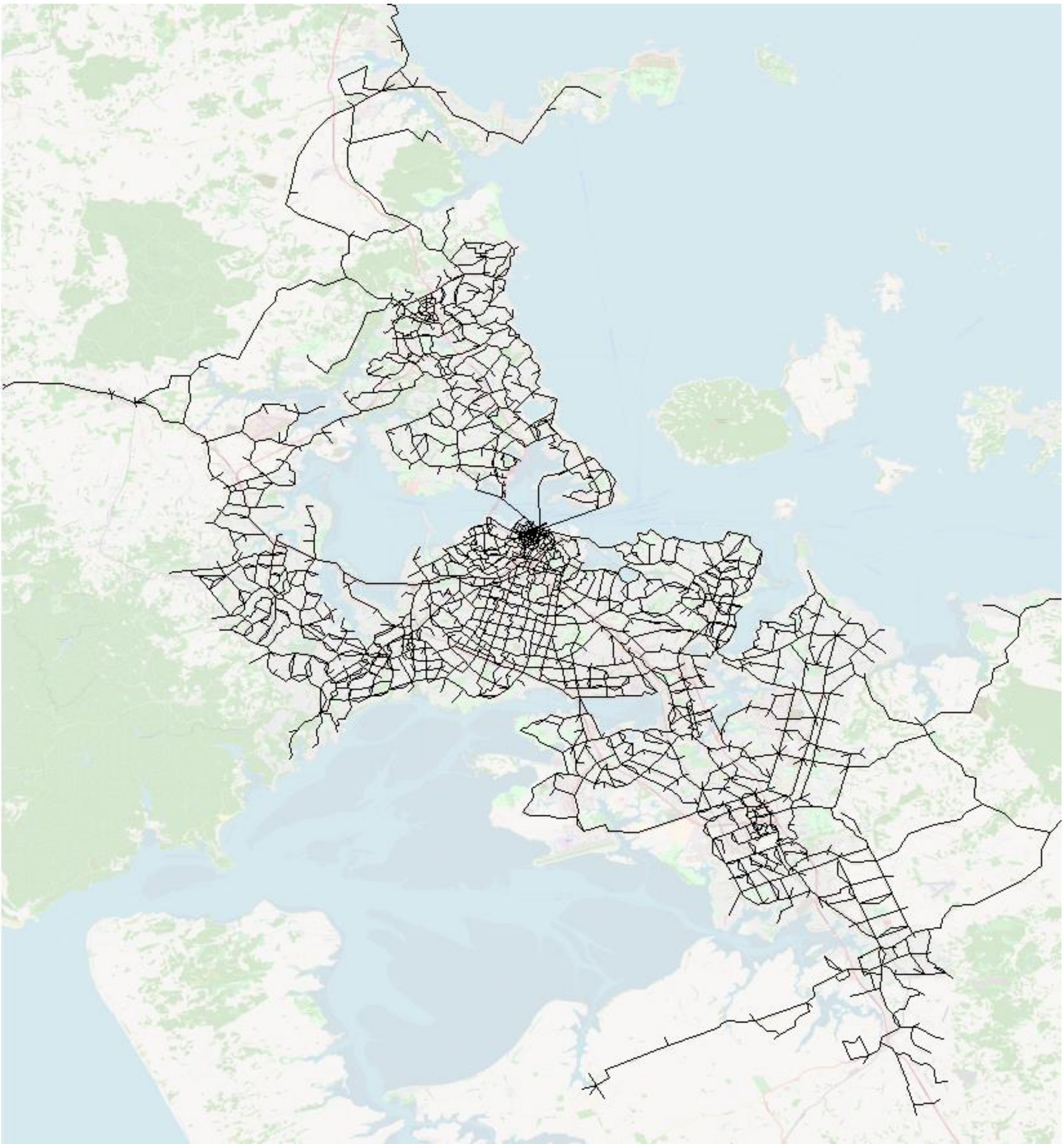
This inherent variability in cyclist numbers has made the development of the Auckland Cycle Model particularly challenging, and the evaluation of the model that follows must therefore be considered in light of this variability.

3 MODELLED NETWORK

The Auckland Cycle Model was originally developed to include only central Auckland and the lower North Shore, but has subsequently been extended to represent all major cycling routes within urban Auckland, with a greater level of detail within the city centre, Auckland's Metropolitan centres, and within the inner suburbs that have the target of increased cycle investment in recent years. The model generally includes all arterial and collector type routes, cycleways and shared paths, some ferry routes as well as footpaths through parks and reserves that are significant to cycle trips.

Figure 1 below illustrates the extent of the model.

Figure 1: Extent of the Auckland Cycle Model



The model represents two-hour morning (7 to 9 am) and evening (4 to 6 pm) peak periods. Insufficient cycle count data was available for the additional development of an interpeak model.

Estimates of daily cyclists have been derived by summing and factoring the morning and evening peak period models. The daily factors used in this process have been obtained from automated cycle count sites across Auckland, and range from 1.4 (am + pm) for routes that are used predominantly by commuter users during the peak periods, to 2.4 or more for routes which experience a high use by recreational users outside the peak periods. The Auckland average is 1.9 (am + pm).

Zones within the modelled area relate to the ART model zone structure, but have been disaggregated into a finer zone structure within the Auckland city centre, Metropolitan Centres, and within Central Auckland and the lower North Shore. There are presently 695 zones within the modelled network.

The model interface uses traditional SATURN[1] traffic modelling software, however the majority of the model mechanism is through a series of spreadsheet based matrices and algorithms. The network has been coded using what SATURN refers to as 'buffer' network. This form of coding excludes capacity considerations and omits all detail at intersections; it allows a large network to be quickly and simply developed and is suitable for cycling networks where capacity constraints are not commonly an issue.

Links within the network have been categorised according to the link categories defined in Table 1. Each link category has then been assigned a 'Relative Attractiveness' (RA) index value, based on the relative level of comfort, safety and inclusiveness that each type of link provides to people on bicycles.

Table 1: Link Categories

Infrastructure Type		**Relative Attractiveness Index**
Cycleways and off road cycle paths	Iconic (for example LightPath and SkyPath)	19
	High standard – cyclist only, or shared path uninterrupted by vehicle crossings or side streets	15
	Average standard – shared use path interrupted by vehicle crossings or side streets	14
	Low standard – a pedestrian footpath	13
	Very low standard – a poor quality pedestrian footpath	12
On road cycle infrastructure	Protected cycle lanes	15
	Painted cycle lanes on a minor/two-lane arterial	14
	Painted cycle lanes on a major/multi-lane arterial	13
Transit lanes	Transit mall	14
	Arterial road with bus lanes	13
No specific cycle infrastructure	Quiet route with local area traffic management – Greenways	14
	Quiet route	13
	Minor/two-lane arterial	12
	Major/multi-lane arterial	11
Rural roads	Rural road	11

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[1] A traffic modelling program for the Simulation and Assignment of Traffic to Urban Road Networks developed by Atkins-ITS Transport Software. http://www.saturnsoftware.co.uk

As a general rule, a Relative Attractiveness rating of 15 has been applied to routes that meet current best practice. The iconic rating has been developed to represent the LightPath cycleway, which due to its combination of colourful design, interactive lighting, harbour and city views, width and media attention, has received an exceptionally high number of cyclists since opening (see forecast model calibration, Section 5.4).

Modelled routes have also been assigned a Relative Attractiveness rating one classification higher where they are considered to be scenic routes that attract significant numbers of recreational cyclists, such as Tamaki Drive. Conversely, routes have been shifted down on classification where they are considered to be of a lower standard or less safe than other facilities of the same type, or where they climb a significant uphill gradient.

Broadly, the Relative Attractiveness scale of 10 to 19 aligns with the Relative Attractiveness scale applied in Simplified Procedures 11 (SP11) of the NZ Transport Agency's Economic Evaluation Manual (EEM), of 1.0 for a route with no dedicated cycle infrastructure to 2.0 for an off-road route.

Relative Attractiveness has been represented within the model by the speed on each modelled link. It is important to recognise that this is not an actual speed, as the model does not consider travel times, delays or congestion. It does however allow the Relative Attractiveness classification assigned to each link to affect route assignment within the model: modelled trips assign not necessarily via the most direct route, but via an optimal route based on a weighting of each route's comfort, safety, inclusiveness and gradient (its Relative Attractiveness) and its distance. This reflects known cyclist behaviour, where user tend to be willing to cycle a slightly longer distance in order to access a safe and comfortable route, or to avoid a particularly dangerous route.

It is noted that the assignment within the model is 'all or nothing', rather than stochastic distribution.

The Relative Attractiveness classification is also important in the derivation of forecast demands for each route (refer Section 5).

In addition to physical cycling infrastructure, links have been included within the model representing the Devonport, Bayswater and Birkenhead/Northcote ferries. These links have been assigned lengths that correspond to a $5 ferry fare[2], plus the respective journey times and wait/transfer times (depending on the frequency of sailings), converted to distance by assuming a 15 km/h average cycle speed and standard EEM values for travel time[3].

4 2013 BASE MODEL

4.1 Methodology

A base model has been developed to represent March 2013 network conditions. March 2013 has been used as it aligns with both:

- The 2013 Census, carried out in March that year, and

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[2] Noting that the 2013 adult cash fare for each ferry was $6 and the AT Hop fare was $4.20
[3] $22.78/hour, including EEM update factors appropriate in 2013

- Auckland Transport's annual cycle count programme, also carried out in March.

The number of cyclists within the base model has been derived from the 2013 census journey to work data. This data includes 5,904 one-way bicycle trips to work within the Auckland region that was first reduced to 5,679 trips by removing trips in areas outside the model extent. This has been transposed to develop a matrix of the journeys home from work, used to develop evening peak demands.

The census data represents daily trips to work (or from work when transposed). These matrices were factored down to represent two-hour peak periods using the UK DoT's National Travel Survey statistics for commute trip types. Factors applied were 0.6 and 0.49 in the morning and evening peaks, respectively[4], resulting in a morning peak matrix total of 3,407 trips and 2,783 evening peak trips.

These matrices represented only those cycle trips that were undertaken as trips to or from work, so have been factored up to reflect all trip types undertaken by bicycle. For the morning peak, this factor (1.25) has been obtained by comparing data from the Household Travel Survey, which provided the number of cycle-to-work trips undertaken per person in Auckland with the number of cycle trips per person for all purposes. The resulting all-trip matrix contained 4,259 morning peak trips. A higher factor (1.43) was applied to the evening peak, reflecting the higher proportion of trips being undertaken for purposes other than commuting in the evening period, and resulting in 3,975 evening peak trips.

The above procedures have been used as a part of the calibration process, to scale the March 2013 cycling demands to match observed March 2013 cycle count data.

The census travel to work data contains a small number of cycle trips across the Waitemata Harbour, despite there being no existing cross harbour walking or cycling facility. This corresponds to cyclists who cycle to ferry (or bus) terminals or those who cycle 'the long way around' via the Upper Harbour Bridge. Cross harbour census trips have been calibrated to better reflect the observed cycle counts on the Devonport, Bayswater and Northcote/Birkenhead ferries, as well as those across the Upper Harbour Bridge.

While the census home-to-work trip data was manipulated as above to include all trip types, the modelled number of cyclists predicted to educational institutions and major schools was notably lower than observed. To correct for this, school trips have been manually added to the model for schools that recorded 50 or more daily cycle trips according to 2013 Auckland Transport cycle count data[5]. These trips have been distributed equally among residential zones within each school's enrolment area. This correction has been made to the morning peak period model only, as the return school trips will generally occur before the evening peak period. Similarly, inbound cycle trips into the University of Auckland and Auckland University of Technology city campuses in the morning peak, and outbound cycle trips in the evening peak, have been factored up to better reflect observed count data.

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[4] Factors of 0.50 and 0.45 could alternatively have been applied, using data from the NZ Transport Agency's Research Report 340. This would have then required higher factors when building the matrices to include all trip types, in order to achieve appropriate matrix calibration outcomes.

[5] Nine schools included, being: Belmont Intermediate, Takapuna Intermediate, Takapuna Grammar, Remuera Intermediate, Orewa College, St Cuthbert's, Western Springs College, Auckland Grammar and Westlake Boy's. All other Auckland schools had surveyed cycle volumes of less than 50 students

The final pre-estimation matrices contained 4,856 and 3,952 trips, in the morning and evening peak periods, respectively.

Recreational cyclists are a noticeable occurrence on the network, particularly during daylight saving months (typically October to March). It was noted that the model was under-representing cyclist trips on key recreational corridors along Auckland's waterfront, particularly Tamaki Drive, and particularly in the contra-peak directions (away from the city in the morning, and the reverse in the evening). To account for these trips, a series of fixed route trips have been manually added to the model between various inner west suburbs (such as Pt Chevalier and Westmere) and various inner east suburbs (Orakei, St Heliers and Glen Innes), via Quay Street and Tamaki Drive. This calibration factor has allowed a more acceptable comparison of observed and modelled cyclist numbers on Tamaki Drive, Quay Street and through the Wynyard Quarter.

The recreational trip process above is supported by Strava cycle heat maps for Auckland, which show trips undertaken by cyclists using smartphone apps and fitness equipment that logs their trips. The Strava data is not a representative sample of all cycle trips, being instead weighted towards recreational/fitness cyclists. The heat maps however show a concentration of such trips on Auckland's central waterfront that the base model did not fully represent without the above corrections.

4.2 Matrix Estimation

The process above has developed a 'prior' matrix for each peak period that was a fairly coarse approximation of actual cycle trips in March 2013, and which did not align with cycle count data from that period as well as it could. To better improve this fit, the prior matrices were run through a matrix estimation process. This process used approximately 410 cycle count data points from across Auckland, for each modelled period. The process used predominantly data from fine days in March 2013, but additional data collected in 2012, 2013 and 2014 were used, with these latter data points corrected for seasonality and annual growth as appropriate. Individual counts have also been corrected for weather as appropriate.

The estimation process was tempered by applying the following controls:

- Preventing the estimation process from 'seeding' demands in origin-destination pairs that had zero trips in the prior matrix. This prevented the estimation process from generating cycle trips to and from unlikely origin-destination pairs, such as Albany to Manukau.
- Limiting the factoring that the estimation process could apply to individual origin-destination pairs, and to each link, to five times the value in the prior matrix.

The changes in trip totals due to the estimation process are shown in Table 2, which details the total cycling demands in the prior matrices and the final estimated matrices.

Table 2: Matrix Totals, Before and After Estimation

	Morning Peak Period	Evening Peak Period
Prior Matrix Demand	4,856	3,952
Final Estimated Matrix Demand	4,644 (-4%)	3,739 (-5%)

The above table illustrates that the estimation process has reduced demands across the modelled network by 4% to 5%.

Plots showing comparisons of the prior and post estimation matrices are included in Appendix A. In these plots, green bands represent links where the estimation process has increased modelled demands, while blue bands represent reductions. The plots show that the estimation process has increased demands on Tamaki Drive in the morning peak and on Great North Road through Grey Lynn in the evening peak, but to have generally reduced demands overall.

As a second check of the estimation process, the trip length distribution has been compared between the prior and post estimation process. These distributions are also shown in Appendix A, and show a good level of agreement between the two demand sets. The process has resulted in an increase in trips of three to four km in length, which is a sensible result. The average trip length in the prior matrix was 5.9 km, and that in the post estimation process was 5.7 km.

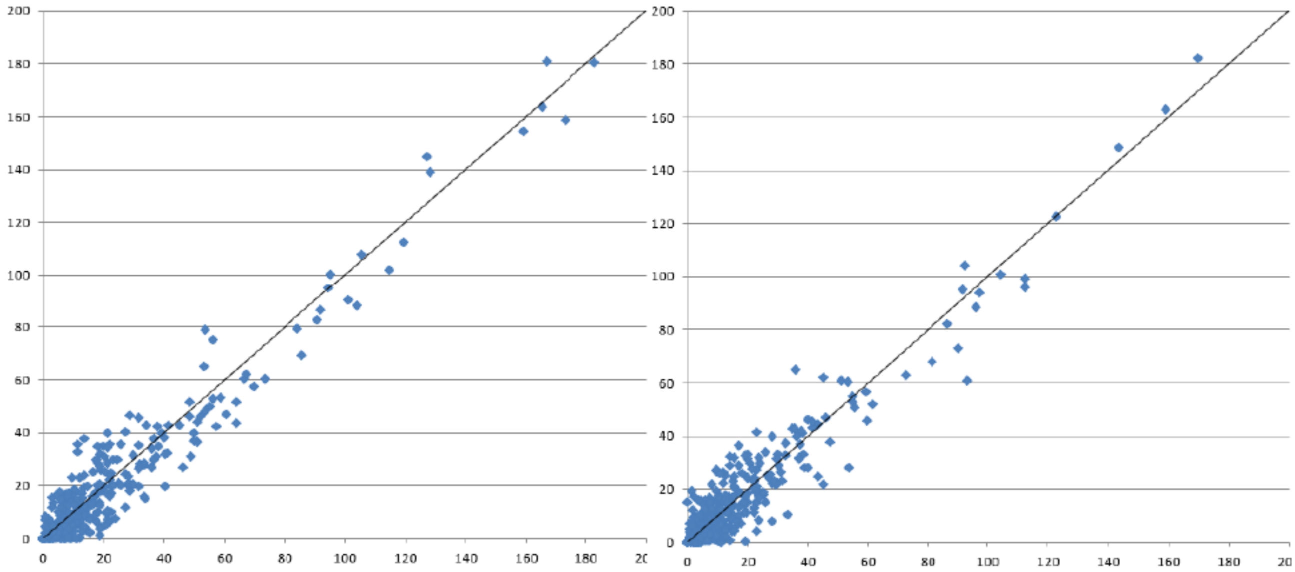
As a final check, a sector analysis has been carried out on the pre and post estimation matrices, with this process documented in Appendix A.

4.3 Model Validation

The March 2013 post estimation cycle trip matrices were applied to the 2013 base network model to enable sensibility checks to be undertaken on the model outputs at key locations, comparing these with existing weekday cycle count data. Count data was again predominantly taken for the month of March 2013, with additional data from 2012 to 2014 corrected as appropriate. The validation process used approximately 340 data points for each modelled period, each independent of the data used in the matrix estimation process.

Plots of the observed counts against the modelled volumes are shown in Figure 2 below.

Figure 2: Observed Counts (X axis) versus Modelled (Y axis), Morning (left) and Evening Peak Periods (right)



It is noted at this stage that a traditional traffic model would be validated against criteria from the NZ Transport Agency's Transport Model Development Guidelines. The criteria within this document were developed for application to traditional traffic models and have not generally been found to be appropriate to the cycle model. The criteria relating to GEH statistics[6] for example were found to be a poor measure of cycle model validity, as GEH criteria are too easy to meet when dealing with low value data points (over 40% of counts used in the validation are under 10 cyclists per two-hour period).

Model validation criteria applied to the model include those listed below. The Transport Agency's validation criteria relate to the 'Type B – Strategic Network Traffic Assignment Model' classification, which the Auckland Cycle Model most resembles. The Percent Mean Absolute Error is also provided in the table below, which is not a validation criterion documented in the NZ Transport Agency's Transport Model Development Guidelines.

Table 3: Link Count Validation Criteria

Link Count Criteria	Transport Agency Model Validation Guidelines	Auckland Cycle Model Morning Peak Period	Auckland Cycle Model Evening Peak Period
Coefficient of determination (R^2)	0.90	0.94	0.93
Line of best fit	Y = 0.9x to 1.1x	Y = 0.96x	Y = 0.97x
Percentage-Root-Mean-Square Error (RMSE)	◆ Acceptable: <25% ◆ Requires clarification: 25-35% ◆ Unlikely to be appropriate: >35%	35%	39%
GEH statistic	◆ >75% GEH <5.0 ◆ >80% GEH <7.5 ◆ >85% <10.0	◆ 99% GEH <5.0 ◆ 100% GEH <7.5 ◆ 100% GEH <10.0	◆ 99% GEH <5.0 ◆ 100% GEH <7.5 ◆ 100% GEH <10.0
Percent Mean Absolute Error	n/a	27%	30%

The comparisons for R^2 and the line of bets fit are generally very good, while the RMSE and GEH criteria are considered potentially unsuitable for cycle models.

Plots showing the locations of validation count data are included in Appendix B, as is a full tabulation of count data versus model outputs.

5 FORECAST MODEL DEMANDS

5.1 Methodology

The forecast demand methodology has considered two fundamental drivers of increases (or decreases) in cycle demands between any two zones:

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[6] The GEH statistic is a form of Chi-squared statistic, commonly used to compare observed and modelled count data.

- Changes in cycle demands as a result of future changes in land use, and
- Changes in cycle demands as a result of future cycle infrastructure improvements.

The first of the above may be considered ‘organic’ growth that would occur if the physical cycle network remained unchanged from its March 2013 state (ie the base model). The second relates to mode shift and behaviour change resulting from investment. This process is summarised in Equation 1 below.

Equation 1: Future Demand Calculation

$$\begin{array}{c}\text{Future}\\ \text{demands}\end{array} = \begin{array}{c}\text{Existing demands, factored}\\ \text{to reflect land use growth}\end{array} + \begin{array}{c}\text{Mode shift in response to cycle}\\ \text{infrastructure investment}\end{array}$$

Each of the factors used in the above equation are explained in more detail below.

5.2 Accounting for Land Use Growth

The base model’s demand set represents March 2013 cycle demands, while each of the forecast years represent annual average daily cyclists. To correct this, the base model demand set has been factored down by 26%, to convert to average annual daily cyclists. This factor was obtained by comparing March 2013 count data to annual count 2013 data from six Auckland automated cycle count locations[7].

The annualised 2013 demand sets were then factored up to account for land use growth from Auckland Council’s most recent land use forecasts (Scenario I11). This factoring has been carried out on a zonal basis, to ensure the growth has an appropriate geographic distribution. For the morning peak demand set, the growth applied to each origin-destination pair is the average of the forecast population growth for the origin zone and the forecast employment growth for the destination zone. The reverse has been applied to the evening peak demand set.

The fixed recreational trips documented in Section 4.1 have been factored up at this stage, by the forecast regional population growth.

This process of factoring base model demands has in effect developed future ‘Do Nothing’ demand sets that represent a hypothetical future scenario where there is no improvement in cycle infrastructure compared to the March 2013 network.

Some manual corrections have been made to the resulting future ‘Do Nothing’ demand sets, most notably in the Whenuapai area. This area had a large number of cycle trips in the 2013 base model, due to a high cycle to work mode share among employees of the Whenuapai Airforce Base. This semi-rural area is currently being urbanised however, with very high land use growth predicted. If the high cycle mode share was factored up by the high land use growth, disproportionately high cyclist demands would result. Existing cycle demands within the Whenuapai area have been zeroed accordingly.

The ‘Do Nothing’ demands consider the background growth in cyclist numbers through population and employment growth, and inherently assume that cycle mode share will remain the same; that is, they

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[7] Lagoon Drive, SH20 cycleway at Dominion Road, Upper Harbour Bridge, Tamaki Drive, Northwestern Cycleway at Te Atatu and Northwestern Cycleway at Kingsland

do not reflect any increased cycle trips due to people choosing to change mode, particularly where new infrastructure is introduced. Taking cross-harbour trips as an example, the March 2013 demand matrices include relatively few cross-harbour cycling trips, as currently these trips are difficult, being via the Upper Harbour Bridge or requiring a transfer to ferry. Upon completion of SkyPath however, there will clearly be some existing cross-harbour trips by non-cycling modes converting to cycling trips. It would not be appropriate to factor up the existing cross-harbour cycling trips to represent this mode shift, as their distributions would likely differ significantly. These mode shift trips have been added in to the 'Do Nothing' forecast trips, and the methodology used to estimate these trips is documented below.

5.3 Accounting for Mode Shift

5.3.1 General Methodology

The methodology for representing future mode shift resulting from investment in cycle infrastructure has followed the process summarised in Equation 2:

Equation 2: Future Mode Shift Calculation

$$\text{Mode shift in response to cycle infrastructure investment} = \text{'Potential Cycle Trips' from ART model} \times \text{Distance Conversion Factor, based on distance between O-D pairs} \times \text{Improvement Conversion Factor, based on improvements to cycle network between O-D pairs}$$

Each term is addressed in turn below.

5.3.2 Potential Cycle Trip Matrices

Future 'potential cycle trip' matrices have been developed by summing forecast person trips from each of the ART forecast models. The ART model is based on seven trip types however, and not all of these are suitable for conversion to cycle trips (such as heavy vehicle trips). Accordingly, only some trip types have been included in the process. Table 4 documents those trips types that have been included within this process, for the 2026 morning peak period. The same proportions have been applied to the evening peak period, but the trip totals differ.

Table 4: Trip Types Included in Pool of 'Potential Cycle Trips', 2026 Morning Peak Period

Trip Types	Total Trips	Proportion Included	Trips Included
Home-based work trips	221,500 car trips 59,400 public transport trips	100% of car trips 100% of public transport trips	280,900 trips
Home-based education trips	96,500 car trips 28,500 public transport trips	1000% of car trips 100% of public transport trips	125,000 trips
Home-based shopping trips	28,300 car trips 5,500 public transport trips	25% of car trips 100% of public transport trips	12,600 trips
Home-based other trips	198,500 car trips 11,600 public transport trips	25% of car trips 100% of public transport trips	61,200 trips
Employer's business trips	82,400 car trips 2,500 public transport trips	0% of car trips 100% of public transport trips	2,500 trips

Table 4: Trip Types Included in Pool of 'Potential Cycle Trips', 2026 Morning Peak Period

Trip Types	Total Trips	Proportion Included	Trips Included
Non home-based other trips	102,400 car trips 5,600 public transport trips	0% of car trips 100% of public transport trips	5,600 trips
Medium/heavy commercial vehicle trips	35,300 heavy commercial vehicle trips	No trips	0 trips
Totals	**878,000 trips**		**487,700 trips (56% of all trips)**

While trips associated with employers' business may be an area where short trips could be made by bicycle, the likely change is not considered to be significant compared to the other types of trips and therefore for this modelling has not been included. Similarly, cargo bicycles may replace certain heavy vehicle movements given appropriate future conditions, but this has been assumed not to be significantly so.

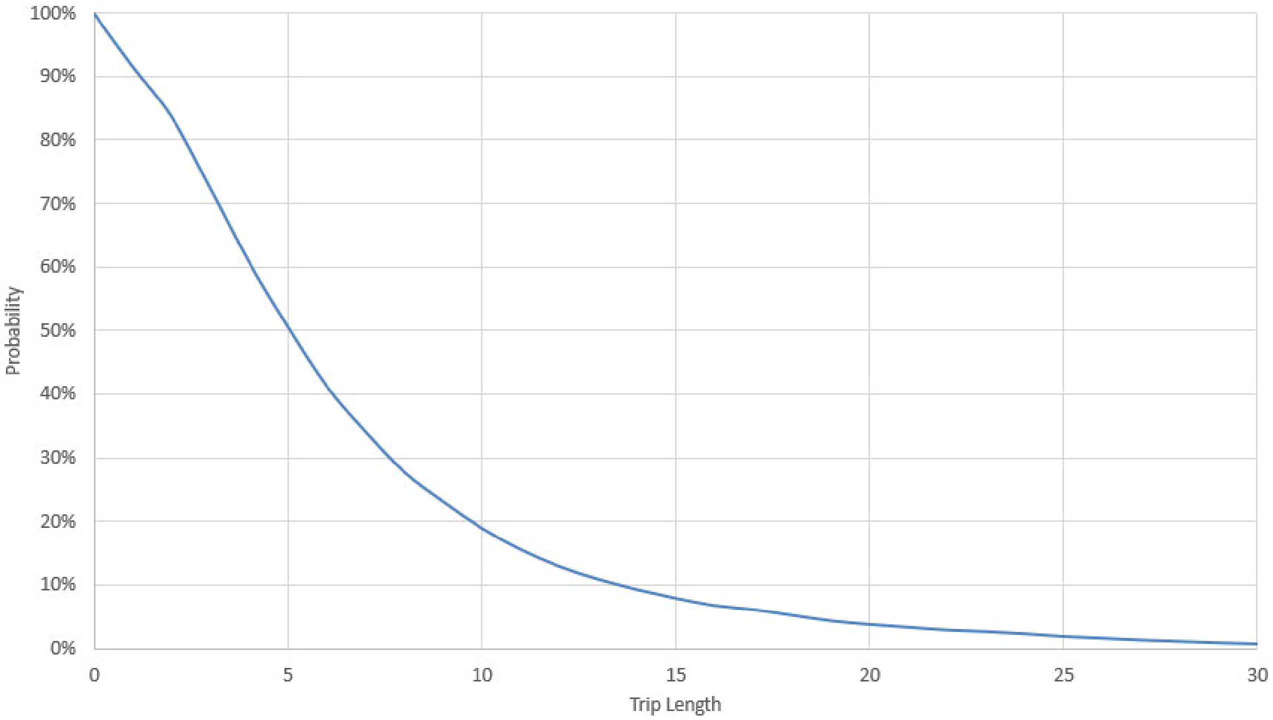
The resulting future morning and evening period trip matrices include most of the car and public transport person trips within the modelled area that might potentially convert to cycling. Their likelihood of shifting to bicycle depends however on a number of factors, most significantly the distance between each origin and destination, and the provision of cycle infrastructure between each origin and destination.

5.3.3 Distance Conversion Factor

As noted above, the likelihood of each potential trip being converted to cycling will depend on the distance between each origin-destination pair, with shorter trips being more conducive to cycling than longer distance trips. To account for this, a trip length probability function has been applied to the future potential cycle trips.

To estimate this underlying function, the census data trip length distribution has been converted to a probability function, which is best illustrated by way of an example. Taking the census cycle trip length distribution, 84% of cycle trips are of 2 km length or longer. It has been assumed then that 84% of trips of length 2 km might potentially be converted to bicycle. Similarly, 72% of cycle trips are 3 km or longer, so by extension a 72% conversion factor has been applied to each trip of 3 km length. This function is shown in Figure 3.

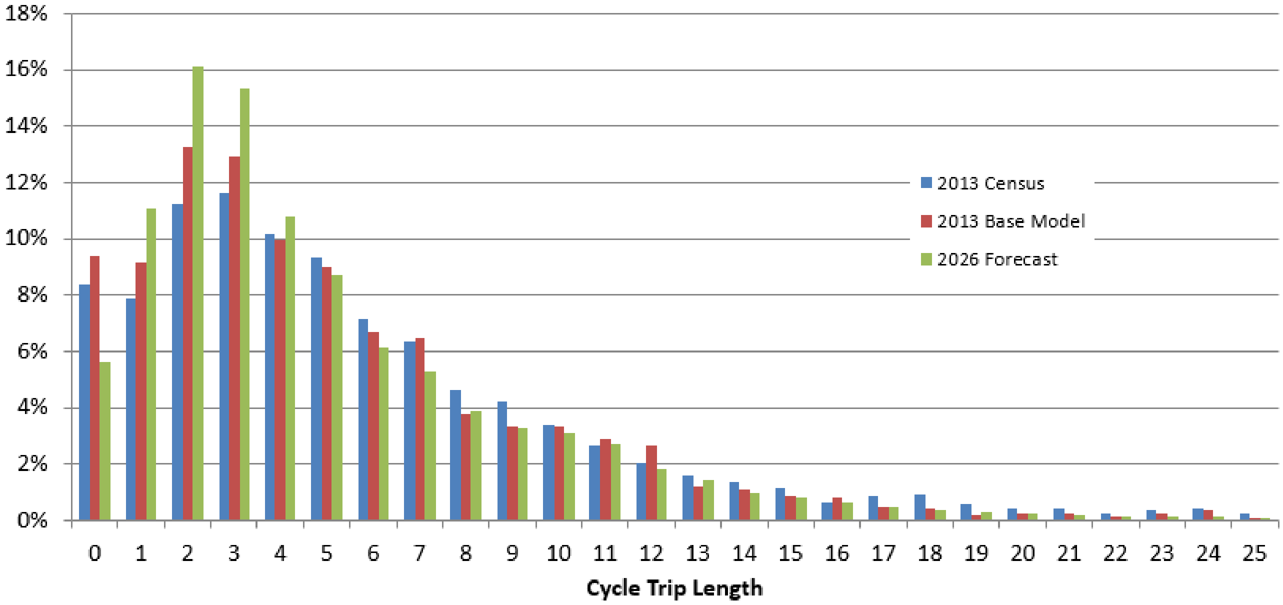
Figure 3: Trip Length Probability Function



This process has been applied to the 'potential trip' matrices, based on the distance between each origin-destination pair within the modelled network. This has in effect dampened down trips between more distant pairs of zones, while trips between two very close zones have remained relatively unchanged.

As a sensibility check, the final 2026 modelled morning period cycle trip length distribution has been plotted alongside the 2013 census data in Figure 4 below. The comparison shows that the forecast 2026 trip length distribution follows the census data distribution appropriately.

Figure 4: Cycle Trip Length Distribution



5.3.4 Improvement Conversion Factor

An improvement conversion factor has been applied to the future potential cycle trip matrices. This acknowledges that conversion from motorised modes to bicycle will only occur in areas where cycle infrastructure is improved, either in terms of reduced cycle distance or improved Relative Attractiveness. This conversion factor has been based on demand elasticity principles, and has been determined according to Equation 3.

Equation 3: Improvement Conversion Factor

$$\text{Improvement Conversion Factor} = \frac{\text{Change in distance between O-D pair (due to infrastructure improvements)}}{\text{Distance between O-D pair}} \times \text{Distance Elasticity} + \frac{\text{Change in average Relative Attractiveness between O-D pair (due to infrastructure improvements)}}{\text{Average Relative Attractiveness between O-D pair}} \times \text{Relative Attractiveness Elasticity}$$

Elasticity factors of 0.35 have been applied in relation to distance changes, and 0.65 in terms of Relative Attractiveness changes. These factors were calibrated during the initial 2014 model build to result in forecast demands that align with international research and result in a sensible long term mode share should the full Auckland Cycle Network (ACN) be built. They were then recalibrated in 2016 against post-implementation data from several major cycleway projects. This calibration process is documented further in Section 5.3.5.

As a simple example, the route between a particular origin-destination pair may be 10 km long via a minor arterial road without cycle infrastructure in 2013; this would correspond to a Relative Attractiveness of 12 if applying the Relative Attractiveness scale documented in Section 3. If a new dedicated cycleway of Relative Attractiveness 15 was built along this route, additionally shortening the distance to 8 km, the resulting Improvement Conversion Factor would be 0.23, as shown below:

Equation 4: Example Improvement Conversion Factor

$$\begin{aligned}\text{Factor} &= (10-8)/10 \times 0.35 + (15-12)/12 \times 0.65 \\ &= 0.23\end{aligned}$$

Conversely, an origin-destination pair with an unimproved route (in terms of both distance and Relative Attractiveness) would be assigned an Improvement Conversion Factor of zero.

In reality, trips between any given origin-destination pair will generally assign via a series of different roads with varying levels of cycle infrastructure, and a weighted average of the Relative Attractiveness along the route has been used to reflect this. This means that most origin-destination pairs are only partially affected by improvements by a given project. As a result, most conversion factors applied to the model are very low, typically in the order of 0.01 to 0.05.

This process has been applied to each origin-destination pair, resulting in non-cycle trips from the ART model being converted to cycle trips only if that trip has been improved by new or improved infrastructure. Further, the level of conversion is proportional to the degree of improvement on that route (in terms of shortened distance, improved route attractiveness, or both).

5.3.5 Initial Development of Elasticity Factors

As documented above, elasticity factors of 0.35 and 0.65 have been adopted, with regard to changes in route distance and Relative Attractiveness, respectively. The higher latter rate acknowledges that improvements in route attractiveness (eg cycle route safety) are likely to have a greater impact on cyclist demands than reductions in cycle distances. This reflects cyclists' priorities for more safe cycle routes[8], and aligns with the fundamental premise of the model network build, which assumes cyclists are willing to cycle somewhat greater distances in order to use a more favourable route.

The elasticity factors were originally developed for the evaluation of the Auckland Urban Cycleways Programme (UCP) in 2015, and were set at 0.35 for distance and 0.75 for Relative Attractiveness. These values were calibrated to result in sensible cycle demand predictions, and this calibration is documented in the following section. It should be recognised that the current elasticity factor for Relative Attractiveness of 0.65 results in more conservative demand estimates than those documented below from the 2015 process. It should also be appreciated that the international experience referenced below may no longer represent the most up to date research, as it did during the model's early development in 2015.

The first means of determining values for the elasticity factors compared the modelled effects of the Auckland UCP to international case studies on the effects of cycle infrastructure improvements on cycle mode share. Studies reviewed have included:

- Research from 35 US cities with populations over 250,000, which concluded that every mile of on road bicycle lane per square mile of city corresponds to a 1% increase in cycle mode share among commuters[9]
- In Montreal, improved cycle infrastructure investment including 67 km of separated cycle facilities has been matched by a 35 to 40% increase in cycle use between 2008 and 2010[10]
- The Minneapolis Greenway project, which is an 8.8 km shared path on a former rail corridor linking employment and residential areas, resulted in an 89% increase in cycle trips among residents living within three miles, and a 33% increase among those living within six miles[11]
- Sydney recorded a 132% increase in the number of cycling trips in the city centre, between 2010 and 2014, led by separated cycleway and shared path infrastructure improvements.

Table 5 below compares the outputs from the 2026 Auckland UCP model (relative to a 2026 Reference Case without the Auckland UCP) with the relevant international study.

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[8] Auckland Transport Cycling Research, 2013 https://at.govt.nz/media/981846/AT-Active-Modes-Research-Report-June-2013.pdf

[9] Dill, J and Carr, T. Bicycle Commuting and Facilities in Major US Cities: If You Build Them, Commuters Will Use Them – Another Look. Portland State University. 2003

[10] http://old.cycleto.ca/protected-bike-lanes/safety-ridership

[11] http://www.prnewswire.com/news-releases/study-shows-bicycle-friendly-city-infrastructure-in-us-significantly-increases-cycling-to-work-by-residents-which-can-improve-health-of-locals-281451471.html

Table 5: Comparison of Model Outputs and International Experience

Measure	Modelled Outcome from 2026 Auckland UCP Model	International Comparison
Auckland cycle to work mode share	0.32% increase predicted as a result of the 28 km of Project infrastructure	0.16% increase expected if applying research from 35 US cities where a 1% increase in mode share was seen for every mile of bicycle lane per square mile of city. This research is thought to underestimate the effects of the Project as it: 1) Relates to on-road cycle lanes, whereas the Project generally consists of facilities separated from traffic 2) Represents the average effects of cycle infrastructure across an urban area, whereas the Project is focussed on the CBD, where a greater effect on mode share per mile of bicycle facility can be expected.
Increases in cycle trips across Auckland urban area	16% increase in cycle trips across the Auckland urban area predicted due to the 28 km of cycle infrastructure assessed	35 to 40% increase in cycle trips in Montreal, due to significant investment including 67 km of separated cycle facilities
Local increases in cycle trips	51% increase in cycle trips predicted among origin-destination pairs with improved routes (generally within 3 km of infrastructure improvements)	89% increase in cycle trips among those living with three miles of Greenway project, Minneapolis; 33% increase among those living within six miles
City centre increases in cycle trips	51% increase in cycle trips to/from the city centre predicted	132% increase in cycle trips within Sydney city centre

The second means of determining values for the elasticity factors involved developing a hypothetical set of 2026 cycle demands that represent a scenario where a complete cycle network has been constructed Auckland wide. This has been approximated by converting all urban arterials into routes with separated cycle facilities, and it represents a network similar to a completed ACN. The resulting ACN demand set resulted in an Auckland wide cycle mode share for commute to work trips of 6.5% (compared with 1.2% in 2013[12]). This is considered an appropriate, if conservative, estimate of Auckland's long term cycling potential, should a complete network be built (see comparator cities, following section5.3.6).

Finally, the model outputs were compared to the forecast reference case 2026 model demands across SkyPath documented in the Transportation Assessment Report for this project[13]. This document gives an annual demand for SkyPath of 1.385 million trips in its fifth year of operation, counting both cyclists and pedestrians, corresponding to a daily average of 3,800 trips. Many of these trips are predicted to

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[12] New Zealand Census data

[13] Traffic Design Group. SkyPath Transport Assessment Report. October 2014

be outside the commuter peaks however, and the SkyPath Patronage Research[14] upon which SkyPath demands are based on estimates that 60% of weekly SkyPath use will be on weekends, with weekday making up 8% each. This 8% factor has been applied to result in a weekday daily demand on SkyPath of 2,130 trips. The SkyPath Transportation Assessment goes on to estimate that 85% of SkyPath users will be cyclists, giving a total weekday daily cycle demand of 1,810 trips.

The elasticity factors assumed in the model have resulted in modelled 2026 demands on SkyPath of 1,840 weekday daily cyclists[15], which agrees well with the estimated 1,810 daily cyclists derived from the SkyPath Transportation Assessment.

A discussion on elasticity factors can be found in the US National Cooperative Highway Research Program's "Estimating Bicycling and Walking for Planning and Project Development: A Guidebook". This study refers to distance elasticities for cycling trips of between 0.41 and 0.75. These elasticities are higher than the 0.35 applied to the Auckland Cycle Model, and would result in significantly greater forecast demands if they were applied. The Guidebook offers no suitable elasticities for application to route quality (ie Relative Attractiveness).

The elasticity factors and overall demand process have resulted in a maximum conversion of non-bicycle mode trips to cycling trips of 29%. This has been achieved in the case of closely spaced origin-destination pairs with the greatest improvement in distance and infrastructure. This 'trader factor' agrees well with the Christchurch Strategic Cycle Model[16], where a factor of 30% was applied, following a review of international stated preference literature quoting factors between 9% and 80%.

5.3.6 Network Effects

It is important to recognise that the demand forecast process documented above is linear. For a given cycle infrastructure improvement, say a cycleway, the demand process will generate a number of new cycle trips, say x. For a second piece of connecting infrastructure, the demand process may generate y new trips and if the two cycleways are assessed collectively, the demand process will generate x+y new trips.

This differs from expectations however, where the effects of cycle network investment are thought to be non-linear: the demand responses from incremental improvements to the cycle network are expected to accelerate as the network approaches completion. This 'network effect' phenomenon is related to the 'safety in numbers' and 'critical mass' effects, where increasing numbers of visible cyclists encourage more users to take up cycling, and is documented by Macmillan et al (2014)[17].

As such, provision of a complete cycle network would likely generate more new trips than the sum of its individual parts, and the cycle demand elasticities are unlikely to be linear. Recognising this, a 'Network

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[14] Angus & Associates. Patronage Research for the Auckland Harbour Bridge Pathway Project. June 2014

[15] Applying a weekday Annual Daily Traffic (ADT) factor of 2.8 to the morning and evening peak period demands (summed), based on automated cycle count data across six Auckland locations

[16] Quality Transport Planning; Christchurch Strategic Cycle Model Background Report, August 2012

[17] The Societal Costs and Benefits of Commuter Bicycling: Simulating the Effects of Specific Policies Using System Dynamics Modelling; *Macmillan, Connor, Witten, Kearns, Rees and Woodward*; April 2014

Factor' has been applied to the demand elasticities documented in Section 5.3.4. This Network Factor has been developed by:

- Assessing the average Relative Attractiveness from each zone to all other zones with a cycle-able distance of 5 km
- Where the above average Relative Attractiveness is 12 or less, the Network Factor has been set at 1.0 (ie. There are no network effects at this level of network development)
- Where the above average Relative Attractiveness is 15 or more, the Network Factor has been set at 2.0 (ie. Where all possible trips within a 5 km trip length from a given zone can be carried out on 'best practice' cycle infrastructure, 'network effects' are assumed to apply to that zone)
- For average Relative Attractiveness ratings of 12 to 15, a sliding scale has been used.

In practice, the above process has no effect on forecast cycle demands when applied to Auckland's existing cycle network, as there are no areas of Auckland where the average Relative Attractiveness threshold of 12 to 15 is met. That is to say, the existing demand response to cycle infrastructure investment in Auckland continues to be linear. Similarly, when evaluating individual future cycle investment projects, such as SkyPath or the Glen Innes to Tamaki Drive cycleway, the Network Factor has no effect. Only when evaluating a significant long term investment programme such as the completed Auckland Cycle Network, does the Network Factor have an impact.

It has not been possible to calibrate the Network Factor process, as this is not a phenomenon currently experienced on Auckland's existing cycle network, and nor is it a process that has been well documented internationally. However, when assessing a 'complete network' of 'best practice' cycle infrastructure across the extent of Auckland (eg separated cycle infrastructure on all Auckland arterial roads), the model predicts an approximate 14% mode share for cycle trips to work. In terms of comparator cities against which this forecast may be benchmarked:

- Christchurch has an existing cycle to work mode share of 7%[18], despite having a far from complete network
- Portland has a comparable geography, climate and land use density and has a 6% cycle mode share, with a target mode share of 25%[19]
- Munich and Tokyo have comparable climates, partially complete cycle networks, and 17% and 14% mode shares[20], respectively.

5.4 2016 Forecast Model Calibration

The initial development of the elasticity factors applied in the Auckland Cycle Model were developed in 2015, but subsequent modifications have been made to the process to better align the model's performance with observed trends. Chiefly among these, a model calibration process was carried out in February 2017[21].

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[18] Sustainable Cities; Benchmarking Cycling and Walking in Six New Zealand Cities, Pilot Study; 2015

[19] Portland 2035 Transportation System Plan; May 2018

[20] Auckland Transport; Auckland Cycling Programme Business Case; 2017

[21] Michael Jongeneel; Evaluating the Auckland Cycle Model; February 2017

In the three years since the network represented by the 2013 base model, a significant investment had been made in cycle infrastructure in Auckland to the end of 2016, including the:

- Grafton Gully and Beach Road cycleways
- Westhaven Promenade
- Nelson Street cycleway and Te Ara I Whiti (LightPath)
- Carlton Gore Road protected/buffered cycle lanes
- Improvements to the existing Northwestern cycleway
- Upper Harbour Drive buffered cycle lanes
- Mt Roskill Safe Routes
- Dominion Road parallel cycle route
- Quay Street cycleway.

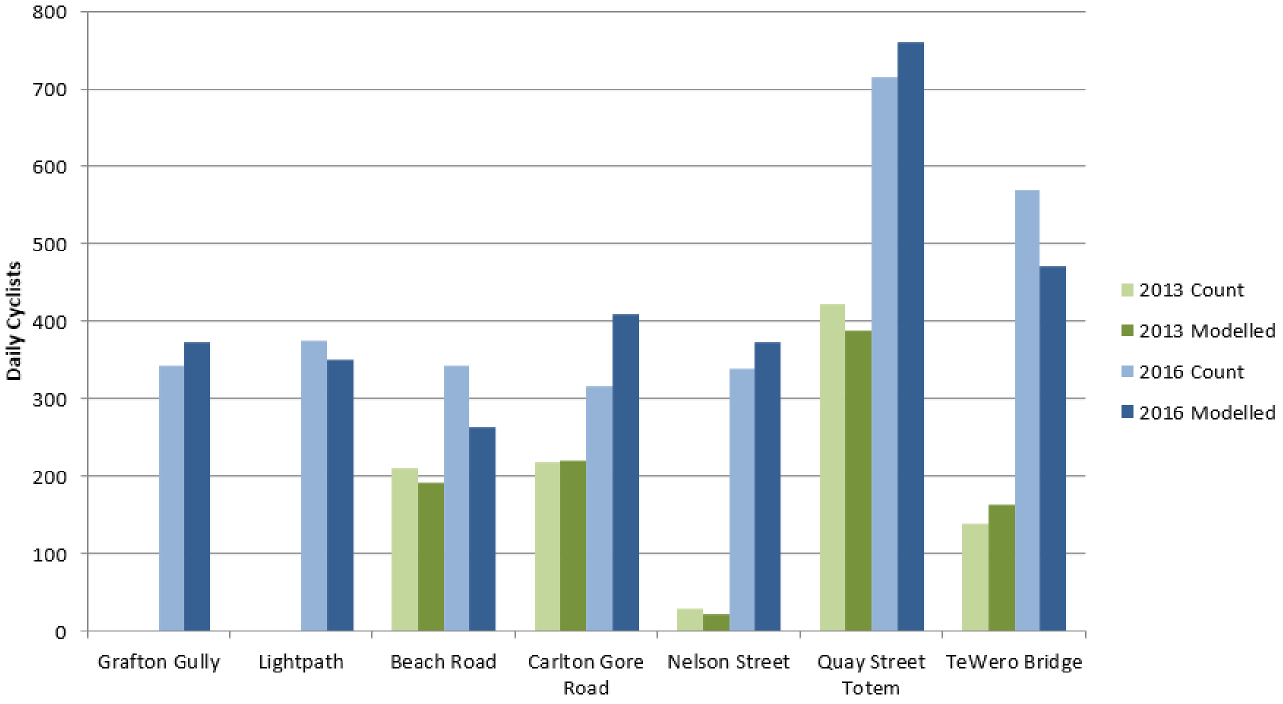
The calibration process allowed outputs from the 2016 Auckland Cycle Model to be compared to post implementation count data on the above routes, and others. In total, data was available from 21 automated cycle count sites across Auckland, providing 41 separate data points with which to compare. The comparison sites included a mixture of new routes, improved routes, and routes that had remain unchanged.

As a result of the forecast calibration process, three adjustments were made to the model process to better align the model forecasts with the observed trends:

- The Relative Attractiveness elasticity was reduced from 0.75 to 0.65
- Evening peak period growth was dampened down by 10%
- A new Relative Attractiveness category was applied to routes that have an exceptionally high appeal to cyclists, such as LightPath.

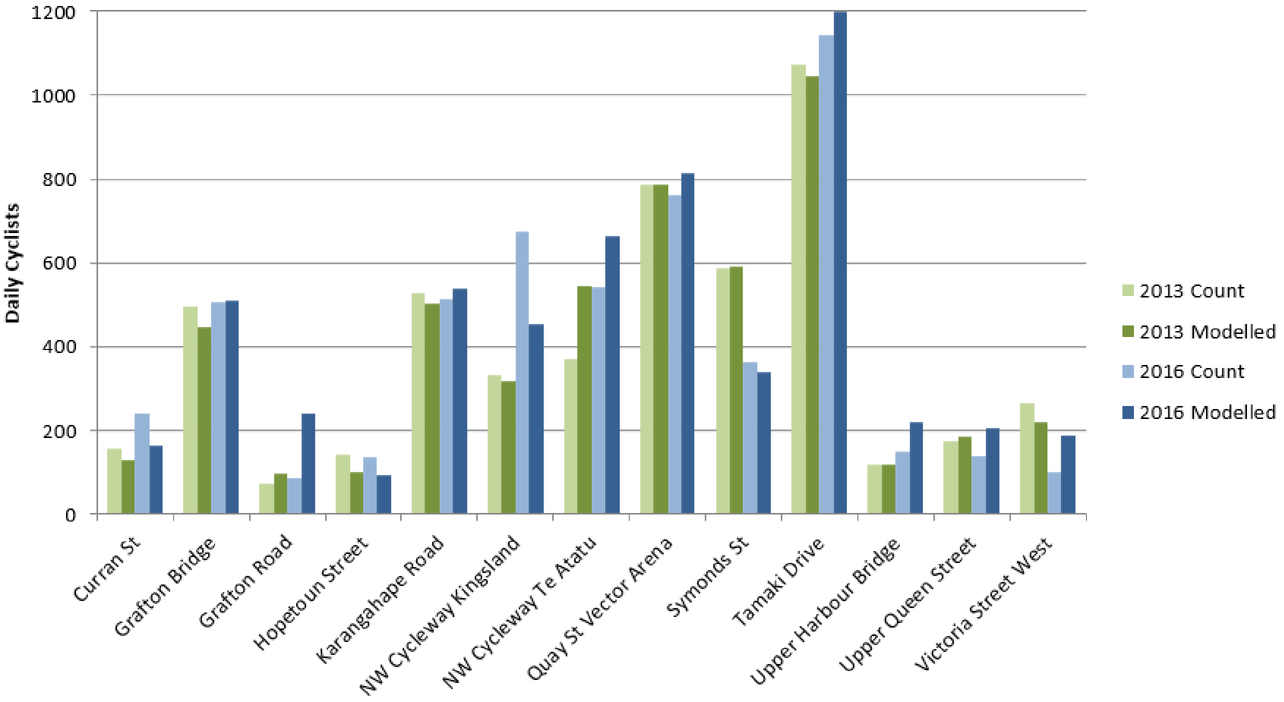
Figure 5 and Figure 6 show comparisons of the Auckland Cycle Model's 2016 forecasts (after the above adjustments were made) against the observed 2016 data, for new/improved routes and unimproved routes, respectively. A comparison of 2013 observed and modelled cyclists is also shown for completeness.

Figure 5: Observed vs Modelled Daily Cyclists, New and Improved Routes



The above comparison shows how daily cycle demands on Auckland's improved cycle routes had increased significantly between 2013 and 2016, with for example 300 more daily cyclists recorded on Nelson Street after the completion of stage 1 of this facility. The model forecasts generally agree well with these increases. In the case of the new routes, again the model agrees well with the observed data.

Figure 6: Observed vs Modelled Daily Cyclists, Unimproved Routes



In the case of the above routes that were not improved between 2013 and 2016, again the model generally agrees well with the observed data. Notably in the case of Symonds Street where the construction of the parallel Grafton Gully cycleway has resulted in a 38% reduction in daily cyclists, the model has produced a comparable reduction.

A final stage in the 2017 model calibration was to compare the Auckland Cycle Model's 2016 forecasts to the two alternative existing methods of forecasting cycle demands. This comparison is summarised below.

Table 6: Comparison of 2016 Cycle Demand Predictions – Three Methods (two-way, average annual daily cyclists)

Route	**Observed Cyclists (2016)**	**2016 Auckland Cycle Model**		**Research Report 340**		**EEM Simplified Procedures 11**	
		Cyclists	**Error**	**Cyclists**	**Error**	**Cyclists**	**Error**
Beach Road	343	263	-23%	392	+14%	1,158	+237%
Carlton Gore Road	317	410	+29%	423	+33%	1,067	+237%
Grafton Gully	344	373	+8%	465	+35%	1,660	+383%
Nelson Street	340	373	+10%	64	-81%	1,535	+352%
LightPath	375	351	-6%	248	-34%	1,594	+325%
Quay Street	715	761	-6%	628	-12%	956	+34%
Average Error		**±14%**		**±35%**		**±261%**	

6 MODEL LIMITATIONS

The Auckland Cycle Model represents a broad range of cycle trip types including commuter trips, trips to education (schools and higher education), shopping trips and 'other trips'. This final trip type category in particular will include some reasonable number of future recreational trips. However, the model is unable to represent any significant future change in recreational use on key routes, such as those that may be specifically drawn to future infrastructure such as SeaPath, SkyPath or improvements to Tamaki Drive. While the daily effect of these recreational trips can be estimated by using an appropriate daily cyclist factor (refer Section 3), the routes used by these recreational cyclists are unable to be accurately forecast.

Similarly, while the fixed recreational routes that have been manually added to the 2013 base model have been factored up to reflect forecast population growth, the model does not reassign these trips to new routes following infrastructure change.

SkyPath in particular is expected to attract a very high proportion of both recreational and tourist trips, with many of these trips taking place outside of the commuter peak periods. As a result, care must be taken when factoring the commuter peak model outputs to generate estimates of daily demands on this facility.

The model includes background growth in cyclist numbers reflecting both forecast population growth and also future infrastructure improvements. It does not however predict other factors that may influence road users' future travel choices, such increasing general traffic congestion, fuel costs, road pricing, or the impact of increasing uptake in electric bicycles.

The mode shift component of forecast cycle trips within the model are developed using person-trips from the ART model. The zones within the ART model are relatively large and many short trips such as trips to primary schools and to local shops will be intra-zonal trips in this regional model. These short, intra-zonal trips will not be accurately represented within the Auckland Cycle Model, and consideration should be given to manually evaluating these trips for projects where the focus is short trips to schools or local destinations.

The ART model version on which the Auckland Cycle Model is based does not exclusively consider trips to park and ride facilities; as a result, the current version of the Auckland Cycle Model will also exclude possible short cycle trips to public transport. It should be noted however that a recent update to the ART model (now the Macro Strategic Model, MSM) does incorporate car trips to park and ride facilities. Should the Auckland Cycle Model be updated to reflect the MSM's outputs, it too will incorporate these trips accordingly (at least in the case where the public transport facility has a park and ride component).

APPENDIX A matrix estimation

Figure 7: Matrix Estimation Count Locations

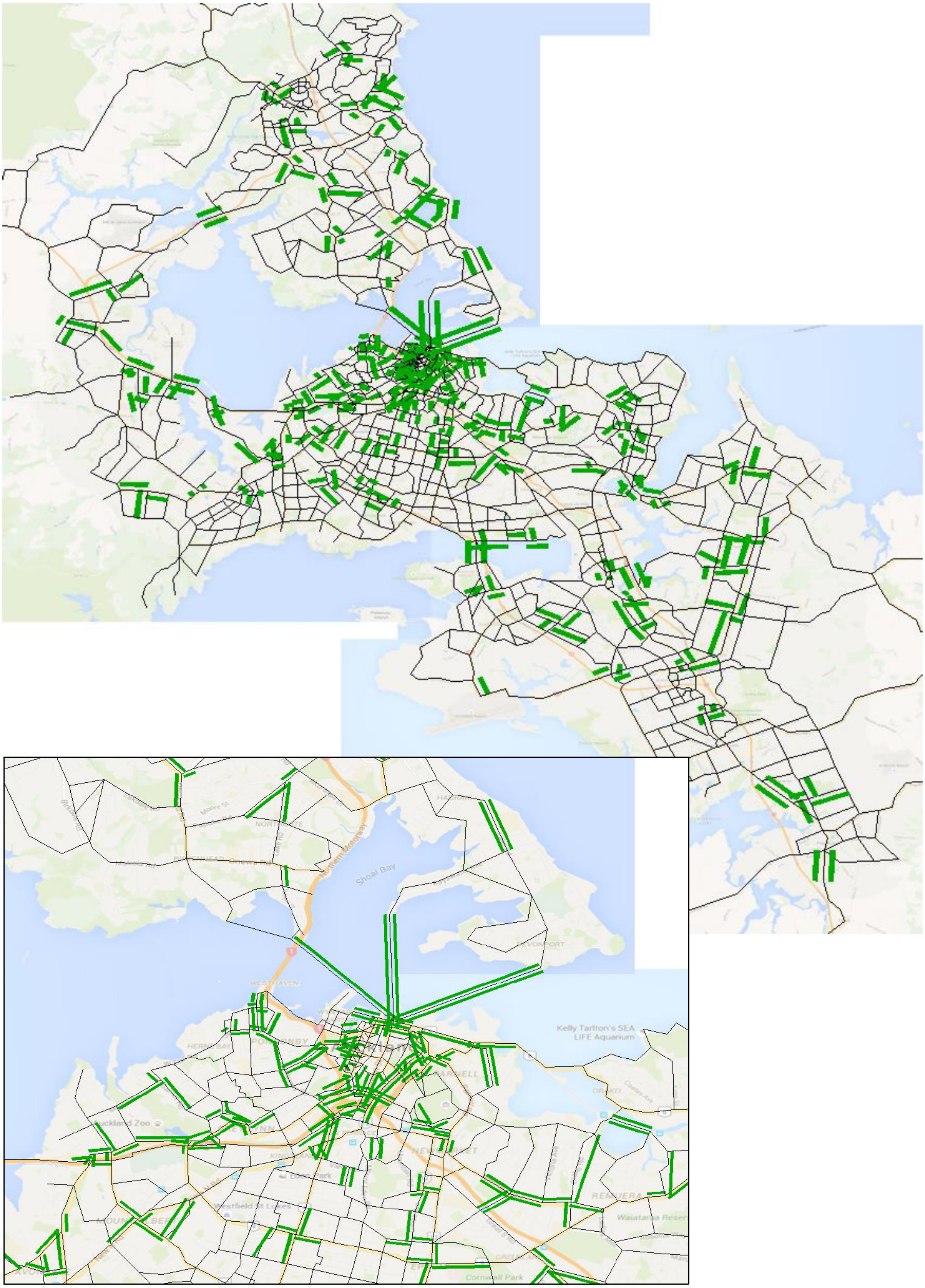


Figure 8: Prior vs Post Estimation Matrices, 2013 Morning Peak Period

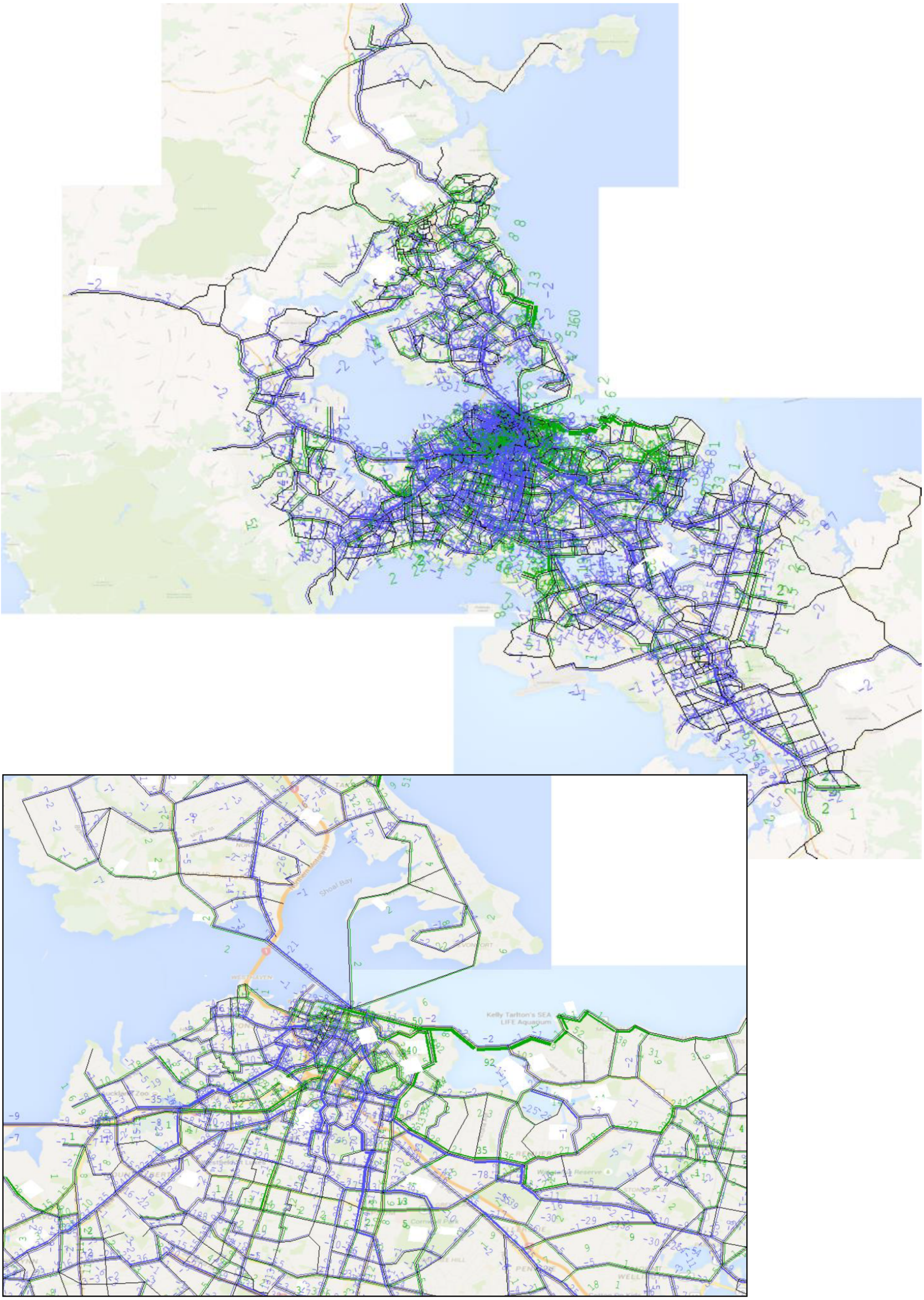


Figure 9: Prior vs Post Estimation Matrices, 2013 Evening Peak Period

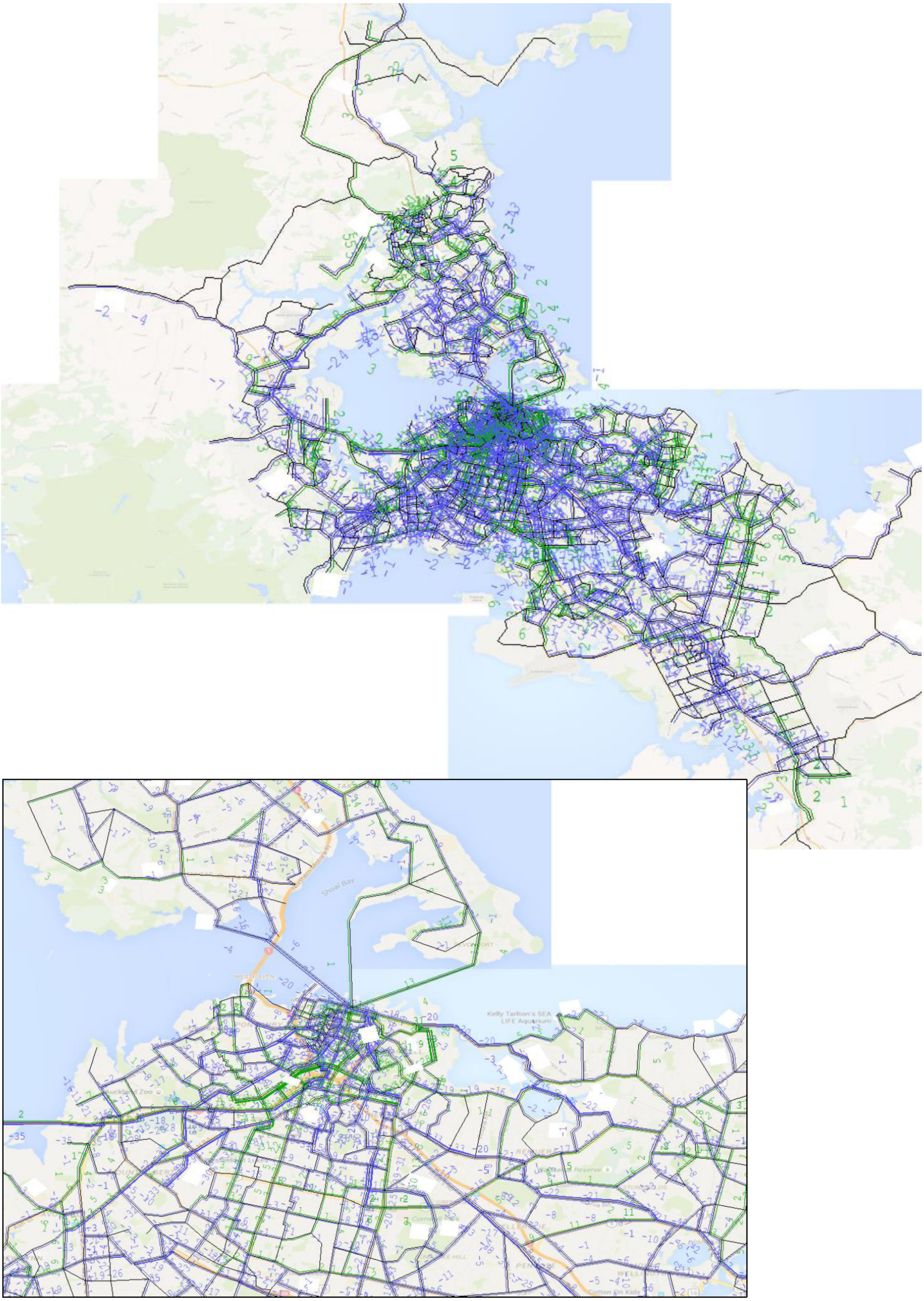


Figure 10: Prior vs Post Estimation Trip Length Distribution, 2013 Evening Peak Period

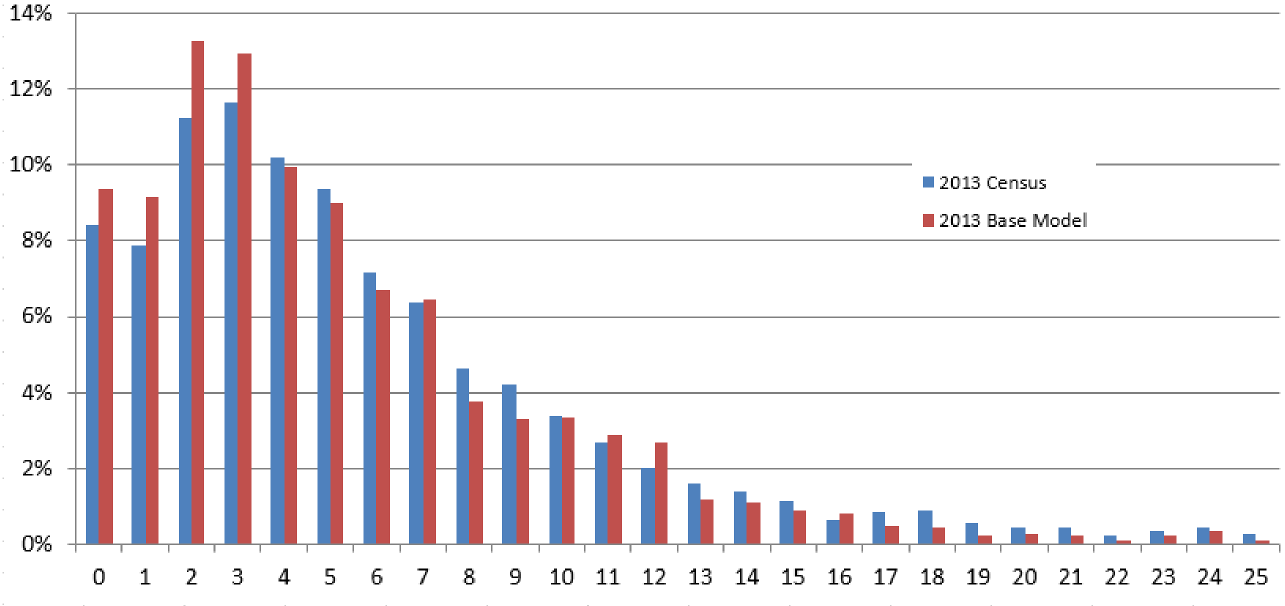


Table 7: 2013 Morning Peak Pre-Estimation Matrix Sectors

	North	West	Central	CBD	East	South
North	992	9	54	42	1	9
West	40	304	169	71	7	5
Central	9	46	1,611	722	36	83
CBD	0	7	31	36	0	0
East	0	0	49	11	137	45
South	0	2	75	10	28	215

Table 8: 2013 Morning Peak Post-Estimation Matrix Sectors

	North	West	Central	CBD	East	South
North	1,043	10	42	47	0	3
West	13	281	143	43	1	0
Central	12	49	1,530	693	27	70
CBD	1	12	31	62	0	0
East	0	0	30	5	127	45
South	0	0	95	5	16	209

Table 9: 2013 Morning Peak Estimation Sector Changes

	North	West	Central	CBD	East	South
North	51	1	-12	6	-1	-6
West	-27	-23	-26	-28	-6	-4
Central	3	3	-81	-29	-9	-13
CBD	1	5	-1	26	0	0
East	0	0	-19	-6	-10	-1
South	0	-2	20	-5	-12	-6

Table 10: 2013 Evening Peak Pre-Estimation Matrix Sectors

	North	West	Central	CBD	East	South
North	565	37	9	0	0	0
West	8	284	43	6	0	2
Central	50	158	1,283	29	45	70
CBD	39	66	674	34	10	9
East	1	6	34	0	128	26
South	8	4	78	0	42	200

Table 11: 2013 Evening Peak Post-Estimation Matrix Sectors

	North	West	Central	CBD	East	South
North	546	11	9	1	0	0
West	14	288	39	18	0	1
Central	41	144	1,255	60	27	93
CBD	47	34	585	56	1	2
East	0	4	16	0	123	17
South	4	0	65	0	38	197

Table 12: 2013 Evening Peak Estimation Sector Changes

	North	West	Central	CBD	East	South
North	-20	-26	0	0	0	0
West	6	4	-4	12	0	-1
Central	-9	-14	-28	30	-18	23
CBD	8	-32	-89	23	-9	-7
East	-1	-3	-18	0	-5	-9
South	-4	-4	-12	0	-4	-3

APPENDIX B Model validation

Figure 11: Base Model Validation Count Locations