Waikato Regional Transport Model

Mode Split Validation

Technical Note 29

March 2015

TDG Ref: technical note 29 mode split calibration_v5.docx

Waikato Regional Transport Model

Mode Split Validation

Technical Note 29

Prepared by:

Grant Smith

Principal Consultant

Reviewed by:

Julie Ballantyne

Technical Director

Approved for Issue by:

Julie Ballantyne

Technical Director

Status: Final report

Date: 16 March 2015

PO Box 8615, Riccarton 8440
New Zealand

P: +64 3 348 3215

www.tdg.co.nz

Table of Contents

1. Introduction

1.1 Purpose of this Report

The purpose of this note is to document the procedure followed to calculate the mode choice parameters and check the validation of the mode choice sub model.

1.2 The Logit Model

In the mode choice phase of the analysis the aim is to calculate how many people, travelling between a particular origin and destination would use each of the available modes. The most common form of discrete choice model applied to mode choice is a multinomial logit model. This model is derived by assuming that people have a choice between a number of discrete alternatives or modes, e.g. car versus bus versus train. The characteristics (times, costs etc) of each alternative determine the satisfaction that people get from each mode. The logit model predicts the probability that an individual will choose a particular alternative (mode m). The logit function takes the general form:

For any i,j pair

$$\rho_m = \frac{\exp(-\lambda c_m+\beta_m)}{\sum_{k=1}^{n} \exp(-\lambda c_k+\beta_m)}$$

Where:

ρ_m	=	probability of choosing mode m
$-c_m$	=	cost of mode m
λ, β_m	=	logit model coefficients
n	=	the set of available modes

Note that $(-\lambda c_m+\beta_m)$ = the utility u_m (or more correctly the dis-utility) of mode m

The model incorporates four modes:

- Car driver
- Car passenger
- Bus passenger
- Active (walking/cycling modes combined)

The utility function u_m incorporates variety of variables that influence mode choice and is usually formulated as a linear function of variables reflecting the attributes of the modes (e.g. time, parking cost, bus fare, transfer cost etc). As the utility of a particular mode improves, reflecting, for example, a reduction in travel time, the model will predict an increase in the probability that a person trip will be made using that mode.

If the probability of choosing mode m is ρ_m and the total number of people travelling between an origin and a destination is T_{ij} the number predicted to use mode m will be:

$$T_{ij}^m = \rho_m * T_{ij}$$

where the value for T_{ij} is obtained from the outputs of the trip distribution model

The weighting of the generalised cost components are usually calibrated from stated preference survey data. This data was not available in this project and the weightings were taken from generally accepted practice and are detailed in section 2.

1.3 The 2009 Version of the WRTM Mode Split

When building the original version of the WRTM in 2009, a decision was made to develop a nested logit model as a series of binary choices using the formulation:

$$\rho_\iota = \frac{e^{-\lambda ci+\beta}}{e^{-\lambda ci+\beta} + e^{-\lambda cj}}$$

with three mode choice steps as shown in Figure 1 below:

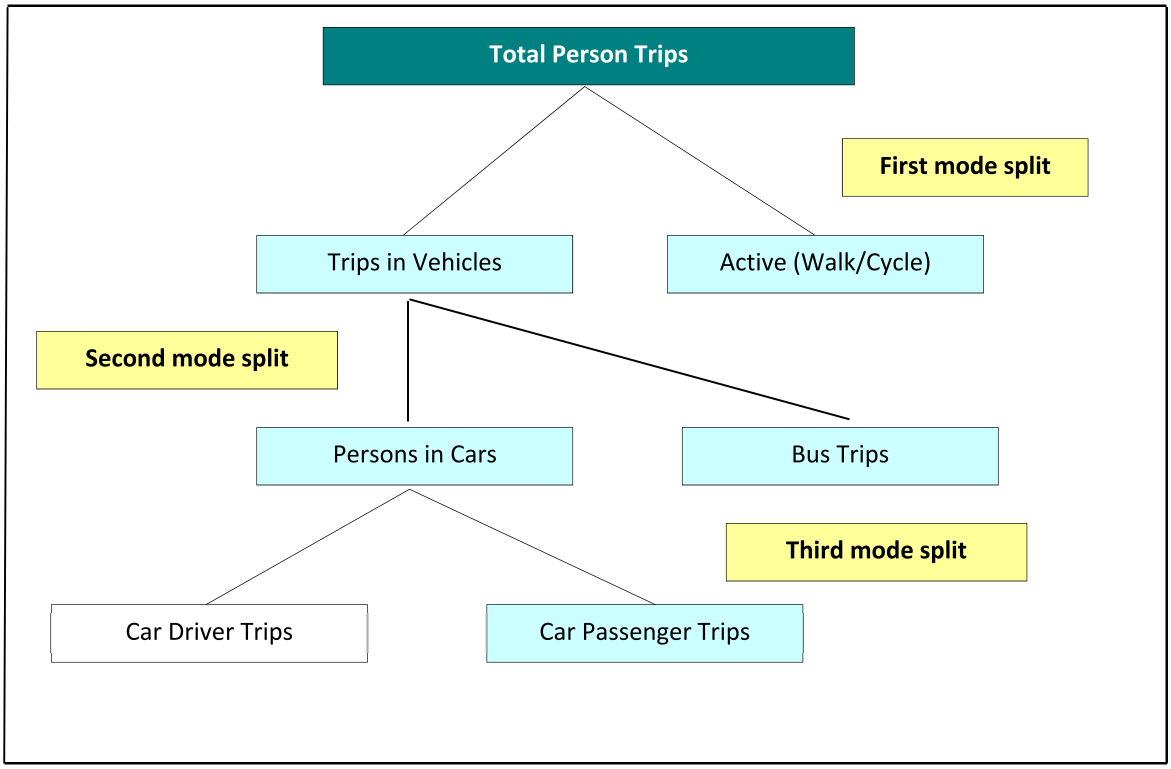


Figure 1: Structure of the Nested Logit Mode Choice Model (2009)

This structure was followed for Home to work and Home to education with all of the other purposes combined in the morning peak, and Home based work, Home based other and non-home based in the inter-peak.

For the 2013 update a different process was followed using a multinomial logit model, as documented below. There were good technical reasons for doing this and these are also documented in the following sections.

2. Generalised Cost Weighting Values

The generalised cost components are the same as in the original model and in the distribution step and are included here for completeness.

The components that make up the generalised cost and in turn contribute to the utility of travel are:

- For bus, walk time from origin to bus stop and from stop to destination;
- For bus, wait time at the stop or for a transfer;
- For bus, fare paid;
- For any bus, car, or walking / cycling, the travel time;
- For bus, transfer penalty.

Of these, the only cash item is the fare paid – all the others are expressed in minutes multiplied by a weighting factor to convert them into cents, relative to the fare which (by definition) has a weighting of 1.0.

The values used are shown in Table 1.

	Value		Comment
Component	AM Peak	Inter Peak	
Car in Vehicle Time	28.69 c/min	35.49 c/min	In car cost from TN27 Table 5
Car Distance	17.06 c/km	17.06 c/km	In car cost from TN27 Table 1
PT Ride Cost	17.41 c/min	15.92 c/min	As per TN15 with no “Work travel” costs in formulation
Walk Cost	34.82 c/min	31.84 c/min	Twice the ride cost
Wait Cost	34.82 c/min	31.84 c/min	Twice the ride cost
Transfer Penalty	174.10 cents	159.20 cents	10 min penalty

Table 1: Generalised Cost Components

The derivation of the mode inter-zonal costs has been set out in Technical Note 15 – The Four Step Distribution Model.

According to literature, walk and wait costs for public transport trips are typically twice the ride costs with a transfer penalty being in the order of a five minute penalty. For the WRTM four step validation process, in order to get a closer fit against the number of public transport patrons transferring between services (as recorded in the Bus Intercept Survey) the transfer penalty needed to be increased to 20 minutes in the morning peak and reduced to four minutes in the interpeak. The peer reviewer[1] was not comfortable with that level of penalty, nor was he comfortable with a different penalty in each period. Accordingly a 10 minute penalty has been adopted for each period, and this report reflects that decision.

[1] We are not unhappy with that decision.

3. Validation Criteria

The Model Specification Report contained the following criteria for Mode Split:

Model Output: Proportion by mode
Check: That the observed mode split is matched by the model
Criteria: All modes within ± 2% over the model area

However, while that criterion applies to both the λ and β values, a further check on the response is required for the lambda value. Generally that is achieved by investigating the response or elasticity of the model to a cost change. There are two tests that are commonly used, being a doubling of fares, and halving the headway (or doubling the frequency). The elasticity equation is shown below.

$$e = \frac{Ln(1 + \partial Q/Q)}{ln(\partial P/P)}$$

Where:

Q = quantity (demand)

P = costs or price (fare, headway, etc)

The best source document on fare elasticity that could be found is a publication by the American Public Transport Association[2]. They concluded that as city size decreased, elasticity to fare changes increased. For cities below 1 million population they concluded that the fare elasticity was -0.27 for peak hour travel and -0.46 for off peak travel.

Ian Wallis (Ian Wallis and Associates) has provided us with typical values from his literature review which were used in a recent Dunedin study. He suggests -0.21 for the morning peak and -0.35 for the inter-peak.

With Waikato at around 350,000 people, values of around -0.20 to -0.30 for peak and -0.35 to -0.5 for inter-peak would be anticipated for the fare elasticity.

While there is some consistency in the results of fare elasticity, there is a high degree of inconsistency in the values for headway (or frequency) elasticity. A Transport Research Board publication[3] cites headway elasticities between -0.22 to -0.58. Two examples – in Toronto found -0.47 in the peak and -0.29 in the off peak, and in Norway, -0.26. It also made the comment that the Toronto values (peak higher than off peak) were not typical.

Ian Wallis suggests that the headway response should be -0.3 for the peak, and -0.50 for the inter-peak.

Accordingly we would expect the Waikato response to be in the -0.2 to -0 .6 range for the headway elasticity.

---

[2] Pham LH and Linsalata J. (1991) *The Effects of Fare Changes on Bus Ridership*. APTA
[3] Traveler Response to Transportation System Changes Handbook, Third Edition: Chapter 9, Transit Scheduling and Frequency

The table below summarises the expected elasticities by peak period and test.

Period	Double the Fares	Half the Headway
Peak	-0.20 to -0.30	-0.20 to -0.60
Inter-peak	-0.35 to -0.50	

Table 2: Expected Elasticities

4. Logit Parameter Initial Calibration

4.1 The Approach

As noted above, there are two coefficients in the logit model, namely λ and β. These combined with the generalised cost produce the utility function for each mode, which determines the mode split. The β coefficient is often called the mode specific constant (MSC) which explains why, all things being equal, there is a higher preference for one mode over another – it is the constant that adjusts for the unquantifiable.

When the model is applied, λ determines the sensitivity of the model – that is the response of the model to changes in cost, and β is a cost adjustment. There should be one λ for each tier of the modal split, (unless there is a reason to believe that the value of time is perceived differently by each mode), but each mode can have a different β.

Accordingly, it is quite possible for the model to re-produce a surveyed mode split, but not produce the expected elasticity to a cost change. Both parameters have to be validated separately.

Rather than the iterative process used in the 2010 calibration, a purpose written calibration program, Biogeme[4], was used to estimate the model. Biogeme is an open source freeware designed for the estimation of discrete choice models.

The inputs to Biogeme are:

- Interzonal trips for each mode, purpose and time period;
- Interzonal costs for each mode, purpose and time period;
- Specification of the utility functions; and
- Identification of any special or 'flagged' zones – for example zones in Hamilton City, or the University.

The outputs are estimates of λ for the particular model/tier being estimated, and β for each mode, together with the 't' statistic for each estimated variable.

The calibration process is iterative. It involves repeated calibration of the logit parameters, application of the mode split model, and assignment to the road and public transport network. The mode split / assignment process is iterated until there is little or no change in both the mode share proportions and the network vehicle minutes between successive iterations.

The output costs from the assignments are then fed back into the logit parameter calibration, and the process repeated until there is little or no change in the λ and β values.

The variables that were initially input to the calibration were λ and the mode specific constants (MSC) for the four modes (MSC for car driver fixed at zero). There were then a

[4] Bierlaire, M. (2003). BIOGEME: A free package for the estimation of discrete choice models, *Proceedings of the 3rd Swiss Transportation Research Conference*, Ascona, Switzerland.

further set of coefficients that were added to the MSCs for the appropriate mode to form the final β if the coefficient was significant. These were:

- A weighting on trips to or from zones in Hamilton City;
- A weighting on trips to or from the university zones;
- Weightings for trips from zero car owning households; and
- Weightings on trips from car owning households.

Initially all variables were permitted to enter the calibration, including λ. Several variables failed the 't' test, and the one of those with the highest standard error eliminated from the permitted set, and the calibration re-run. This process was repeated until only statistically significant variables remained.

4.2 Initial Calibration

Initially, attempts were made to estimate models using the nested binary formulation adopted for the 2009 model, and using the matrices by mode, purpose and time period derived from the Home Interview Survey (HIS) data. No statistically significant relationship was found.

As a result of that work, the following process was adopted to see if that data would enable any model to be estimated:

- The data was aggregated to include all trips between 0700 and 1800 hours regardless of purpose;
- Bus passenger trips were excluded from the HIS data and replaced with the matrices from the Bus Passenger Intercept Survey;
- A multinomial model form was adopted rather than the nested binary; and
- The cost data was based on the original 2006 validated model (900 zones). If a model couldn't be estimated at that level, there is little chance that it could be estimated at the new 2,500 zone level. It also meant that the initial costs were from a stable (converged) model significantly shortening the calibration process and more robust producing parameters values.

This was the highest degree of aggregation possible and a statistically significant model was able to be calibrated. As a result, the following disaggregation was tried:

- The data was disaggregated into the two hour morning peak, and a seven hour (0900-1600) inter-peak;
- Trips were flagged as being generated separately from households with 0, 1, 2, and 3+ cars;
- Zones were identified as being within Hamilton City, and trips were flagged as having the origin, or the destination or both ends within those zones;
- Costs were derived from the 2006 validated two hour morning peak, and two hour inter-peak models.

A statistically significant morning peak model was estimated from this approach, but there was little difference between the β values for trips from the three car owning categories.

Accordingly those three categories were combined, resulting in trips from households with no cars and trips from households with cars.

Initially, in both periods, λ was estimated at about 0.0004, but when the model was applied and the fare elasticity tested, the response was only -0.068. Accordingly, a value of λ that gave the expected response was imposed on the model, and the β values calculated accordingly.

5. Morning Peak Calibration and Validation Results

5.1 Morning Peak Calculation of λ

As noted earlier, there are two components to validation. The first is whether the surveyed mode split is being replicated, and that the model has converged. The second is whether the model is giving the right response to a change in costs – in other words is λ correct?

It is appropriate to deal with λ first.

The simplest check on λ is a doubling of fares, and in the morning peak as noted earlier an elasticity of around -0.27 (target range -0.20 to -0.30) might be expected.

The λ estimated by Biogeme was 0.0004, and when the model was applied with the fares doubled, the elasticity response was only -0.067. As a result, a series of values for λwere imposed. Figure 2 shows the response to a doubling of fares for λvalues between 0.0004 and 0.005.

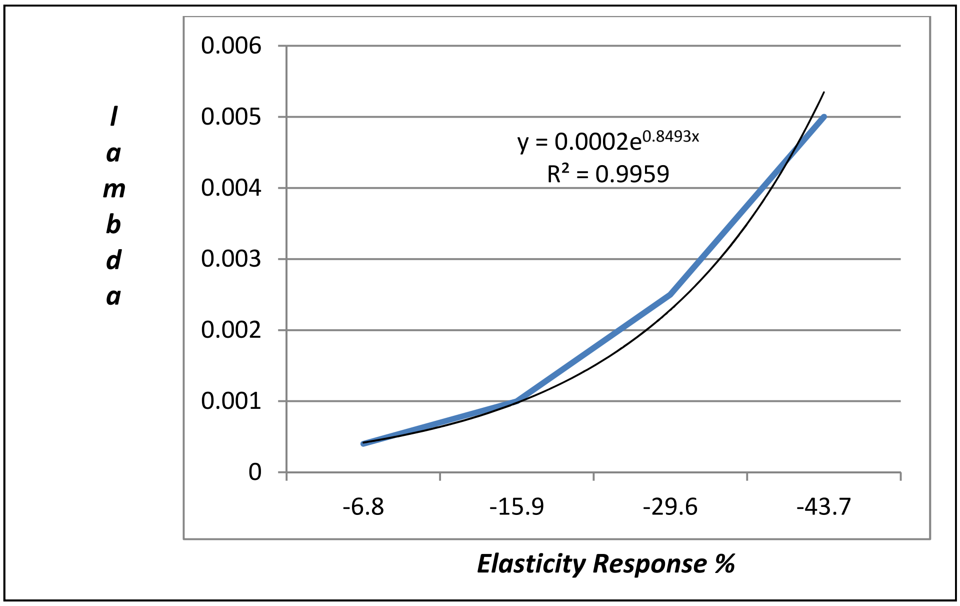


Figure 2: Elasticity Response vs λ- Morning Peak

The thin line is a best fit exponential curve. On the basis of this a λ of 0.0025 was imposed on the model and the β values re-estimated to give a response of around -0.30.

The results are shown in Table 3 after the model has converged (one iteration).

Mode	Model – Double Fares				Difference to Base			
	1+ Cars	0 Car	Total	% Share	Diff %	1+ Car	0 Car	Total
Active	38,498	3,784	42,284	11.5%	0.6%	134	132	266
Bus Pass	2,651	1,301	3,879	1.1%	-22.7%	-966	-192	-1,158
Car Pass	98,964	683	99,669	27.0%	0.3%	272	18	290
Driver	221,878	1,314	223,238	60.5%	0.3%	560	42	602
Total	**361,991**	**7,082**	**369,070**	**100.0%**		**0**	**0**	**0**

Table 3: Model Response to a 100% Fare Increase – Morning Peak

The final response is a 22.7% reduction in bus patronage which produces an elasticity of -0.37. This is a little outside the expectations from the literature discussed in Section 3 above; however this elasticity is consistent with the inter-peak period.

5.2 Morning Peak Calculation of the βValues

The β values estimated by Biogeme with a λ of 0.0025 (imposed) are given below.

Mode Specific Constant	Coefficient	t-Test	Significant
Active	-0.724	-37.74	Yes
Bus Passenger	4.59	15.53	Yes
Car Driver	0		Forced
Car Passenger	-1.270	-8.90	Yes
Households with 0 Car			
Bus Passengers at University	5.04	46.09	Yes
Active mode additional	3.24	92.22	Yes
Households with 1 or More Cars			
Bus Passengers	-5.73	-235.09	Yes
Bus Passengers at University	5.04	46.09	Yes

Table 4: β Values with λ Set to 0.0025 – Morning Peak

	City Zones	University	Non – City Zones
Active	2.516	2.516	2.516
Bus Passenger	4.59	9.63	4.59
Car Driver	0	0	0
Car Passenger	-1.27	-1.27	-1.27

Table 5: Total β Values – Households with 0 Cars - Morning Peak

	City Zones	University	Non – City Zones
Active	-0.724	-0.724	-0.724
Bus Passenger	-1.14	3.9	-1.14
Car Driver	0	0	0
Car Passenger	-1.27	-1.27	-1.27

Table 6: Total β Values – Households with Cars – Morning Peak

5.3 Morning Peak Mode Split Validation

Tables 7 and 8 below show the surveyed and modelled mode splits, and the change in trips and vehicle minutes assigned between the last and previous iterations for the morning peak period. Note that the total number of trips between the survey and the model are different – this is because the "surveyed' trips are sourced from the Household Interview Survey, whereas the model covers a larger geographic area.

Bus passenger trips were included from the Bus Passenger Intercept survey which is a better data set than the passenger trips recorded in the HIS. The PT comparison is against the absolute number of surveyed PT trips, and the proportion in the HIS for the other three modes.

The key metric therefore to compare is the percentage of trips by mode, and not the magnitude of the trips (which are not directly comparable).

Mode	Model - Base				Surveyed			
	1+ Car	0 Car	Total	%	%	1+ Car	0 Car	Total
Active	38,364	3,652	42,016	11.5%	12.2%	29,297	2,582	31,879
Bus Pass[5]	*3,617*	*1,493*	*5,110*			*3,267*	*1,521*	*4,788*
Car Pass	98,692	665	99,357	27.3%	28.5%	74,318	51	74,369
Driver	221,318	1,272	222,590	61.2%	59.2%	154,208	237	154,445
Total	358,374	5,589	363,963	100.0%	100.0%	257,823	2,870	260,693

Table 7: Mode Split Comparisons – Morning Peak

[5] Bus Passenger trips not included in the totals

Variable	Previous Iteration	This Iteration	Difference	%
Active Trips	42,007	42,016	9	0.02%
Bus Passengers	*5,123*	*5,110*	-13	-0.25%
Car Passengers	99,352	99,357	5	0.01%
Drivers	222,589	222,590	1	0.00%
Vehicle Minutes	2,198,105	2,198,080	-25	-0.00%

Table 8: Convergence Checks – Morning Peak

The morning peak model is within the target limits of +/-2% for each mode and the convergence checks between iterations are well within the expected range. The Economic Evaluation Manual (EEM) and the NZTA Transport Model Development Guideline provide minimal guidance on this.

Given that λ was forced to achieve the mode split, the validation test for it is a test on a change in headway. The results of halving the headway (twice the frequency) are shown in Table 9 below.

Mode	Model – Half Headways				Difference to Base			
	1+ Car	0 Car	Total	% Share	Diff %	1+ Car	0 Car	Total
Active	38,275	3,570	41,845	11.3%	-0.4%	-89	-82	-171
Bus Pass	4,364	1,625	5,989	1.6%	17.2%	747	132	879
Car Pass	98,471	649	99,120	26.9%	-0.2%	-221	-16	-237
Driver	220,880	1,238	222,118	60.2%	-0.2%	-438	-34	-472
Total	**361,990**	**7,082**	**369,072**	**100.0%**		**-1**	**0**	**-1**

Table 9: Model Response to Halving the Headways – Morning Peak

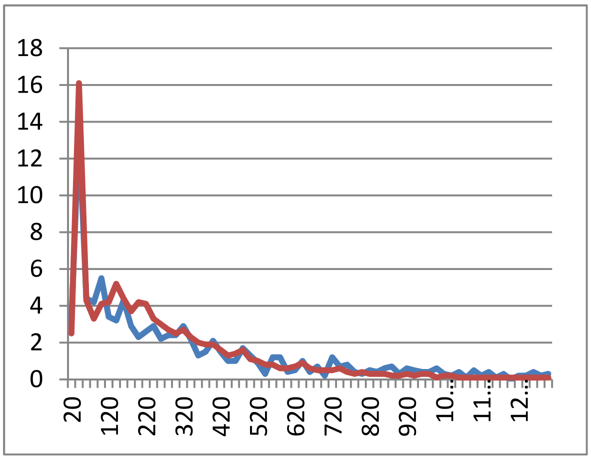
The response of 17.2% increase in bus patronage produces an elasticity of -0.23 and is within the expected range.

A summary of the morning peak elasticity responses are provided below, with the targets from Table 2. These results demonstrate that the morning peak period responds as expected to changes in input, although slightly over sensitive when doubling the fare but consistent with the sensitivity of inter-peak period.

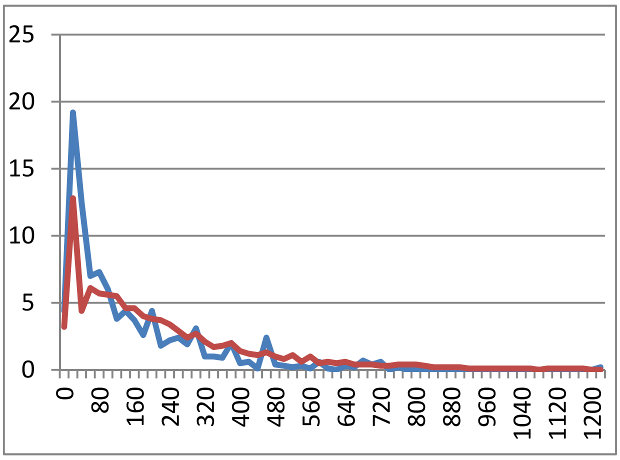
	Target	Modelled Response	Within Range?
Double Fares	-0.20 to -0.30	-0.37	No, but maximum response from data
Half Headway	-0.20 to -0.60	-0.23	Yes

Table 10: Summary of Elasticity Tests – Morning Peak

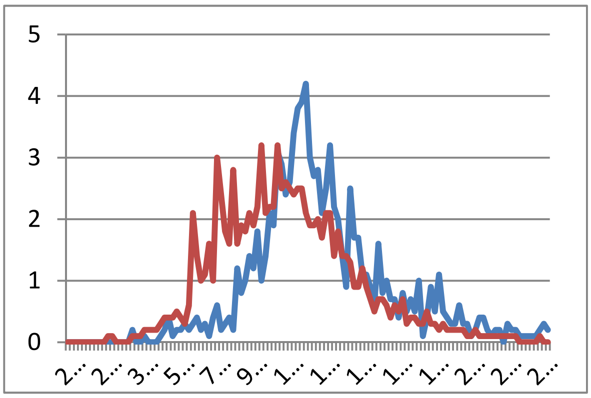
The next checks are on the distribution to ensure that the ‘shapes’ of the observed and measured matrices are similar by comparing the trip cost frequencies as shown in Figure 3.



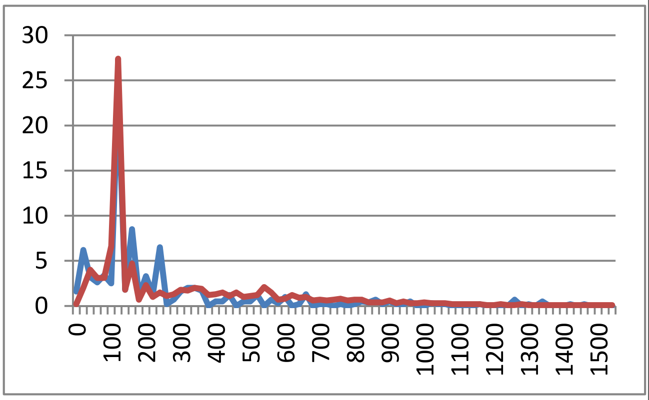
Car Driver



Car Passenger



Bus Passenger



Active Modes

These match reasonably well, except for the bus passengers where the model has tended to shorten the average trip cost. However, the observed trips are from a 30% sample over one day.

Observed and Modelled Trip Cost Frequencies after Mode Split – AM Peak

3

6. Inter-peak Calibration and Validation Results

6.1 Inter-peak Calculation of λ

As with the morning peak, the initial estimate of λ by Biogeme in the inter-peak was 0.0004. No attempt was made to check the response at that value (as it was known that this would not produce an appropriate sensitivity), and values ranging from 0.0025 to 0.05 imposed and the response checked, with the results shown in Figure 4 below.

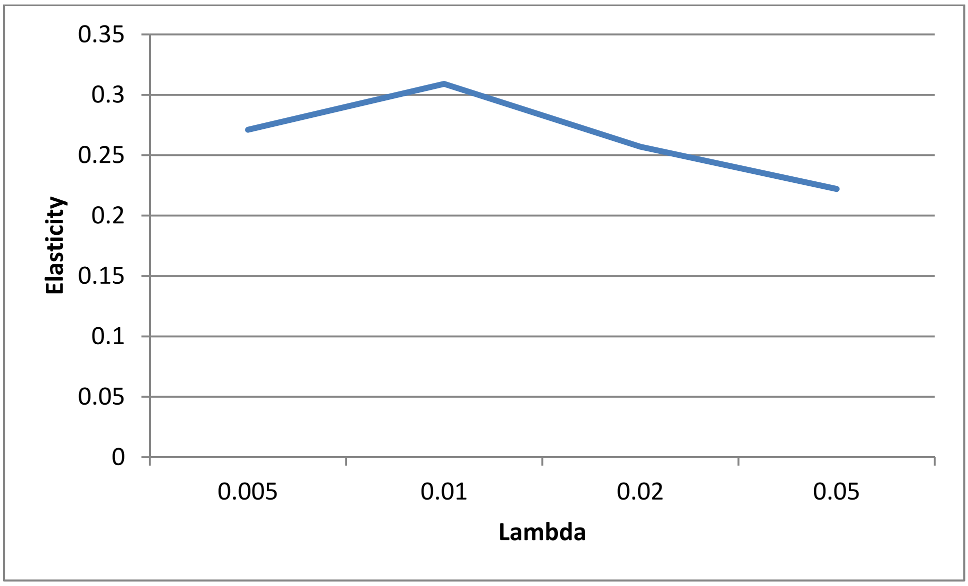


Figure 4: Elasticity Response vs λ Inter-peak

The shape of the curve was somewhat unexpected. A λ value that gave an inter-peak response of around -0.50 was sought, but clearly that is not going to be achieved. Accordingly, the λthat gave the highest response (0.01) was chosen for the model.

Initially, the model was estimated using costs averaged over the seven hour interpeak, but when the frequency test was applied, the elasticity was -0.669 - much higher than the literature would suggest.

Accordingly the model was re-estimated using costs from a two hour period (nominally between 09:00 and 11:00). The results are shown in Table 11 after the model has converged.

Mode	Model – Double Fares				Difference to Base			
	1+ Car	0 Car	Total	% Share	Diff %	1+ Car	0 Car	Total
Active	25,619	4,771	30,390	10.0%	0.6%	96	93	189
Bus Pass	1,392	98	1,490	0.5%	-22.4%	-302	-133	-435
Car Pass	63,852	3,399	67,251	22.1%	0.1%	50	22	72
Driver	203,415	1,499	204,914	67.4%	0.1%	156	17	173
Total	**294,278**	**9,767**	**304,045**	**100.0%**		**0**	**-1**	**-1**

Table 11: Interpeak Model Response to a 100% Fare Increase – Inter-peak

The final elasticity of -0.37 (22.4% reduction in bus patronage divided by a 100% increase in fares) is less than expectations from the literature for the inter-peak (although it does fall within the peak period expected response). It is, however, the highest elasticity that can be derived from the data and is not considered an inappropriate response. Again, the CBD shuttle may be affecting this.

6.2 Inter-peak Calculation of the βValues

The β values estimated by Biogeme with a λ of 0.01 (imposed) are given below.

Mode Specific Constant	Coefficient	t-Test	Significant
Active	-0.921	-7.74	Yes
Bus Passenger	5.7	15.53	Yes
Car Driver	0		Forced
Car Passenger	-3.18	-8.9	Yes
Households with 0 Car			
Bus Passengers City zones (incl Uni)	1.81	38.85	Yes
Bus Passengers at University	16.8	46.09	Yes
Active Mode Additional	4.03	92.22	Yes
Car Passengers Additional	2.13	87.58	Yes
Households with One or More Cars			
Bus Passengers City zones (incl Uni)	1.81	38.85	Yes
Bus Passengers at University	16.8	46.09	Yes
Bus Passengers Additional	-5.94	-235.09	Yes

Table 12: β Values with λ Set to 0.01 – Inter-peak

	City Zones	University	Non – City Zones
Active	3.109	3.109	3.109
Bus Passenger	7.51	24.31	5.70
Car Driver	0	0	0
Car Passenger	-1.05	-1.05	-1.05

Table 13: Total β Values – Households with 0 Cars – Inter-peak

	City Zones	University	Non – City Zones
Active	-0.921	-0.921	-0.921
Bus Passenger	1.57	18.37	-0.24
Car Driver	0	0	0
Car Passenger	-3.18	-3.18	-3.18

Table 14: Total β Values – Households with Cars – Inter-peak

6.3 Inter-peak Mode Split Validation

Tables 15 and 16 below show the surveyed and modelled mode splits, and the change in trips and vehicle minutes assigned between the last and previous iterations for the inter-peak period. Note that the total number of trips between the survey and the model are different – this is because the "surveyed' trips are sourced from the Household Interview Survey, whereas the model covers a larger geographic area. The key metric therefore to compare is the percentage of trips by mode, and not the magnitude of the trips. Because public transport usage is centred on Hamilton City, the metric to compare for PT is the absolute number of trips – since increasing the geographic coverage (HIS to model) should have minimal impact on the number of PT trips.

Mode	Model - Base				Surveyed			
	1+ Car	0 Car	Total	%	%	1+ Car	0 Car	Total
Active	25,471	4,675	30,146	10.0%	11.9%	22,205	2,885	25,090
Bus Pass[6]	*1,718*	*223*	*1,941*			*1,095*	*472*	*1,567*
Car Pass	63,792	3,383	67,175	22.2%	21.7%	45,548	472	46,020
Driver	203,296	1,488	204,784	67.8%	66.4%	140,159	422	140,581
Total	**292,559**	**9,546**	**302,105**	**100.0%**	**100.0%**	**207,912**	**3,779**	**211,691**

Table 15: Inter-peak Model Validation – Inter-peak

[6] Bus Passenger trips not included in the totals

Variable	Previous Iteration	This Iteration	Difference	%
Active Trips	30,193	30,146	-47	-0.16%
Bus Passengers	1,927	1,941	-14	-0.73%
Car Passengers	67,161	67,175	-14	-0.02%
Drivers	204,763	204,784	-21	-0.01%
Vehicle Minutes	1,836,806	1,838,539	-1733	0.09%

Table 16: Convergence Checks – Inter-peak

The inter-peak model has proved to be very difficult to calibrate given the data that is available. The active mode split is a little low in the model, with car passengers compensating. Nevertheless the convergence checks are well within acceptable ranges.

Given that λ was forced to achieve the mode split, the validation test is a change in headway. The results of halving the headway (twice the frequency) are shown in Table 17 below.

Mode	Model – Half Headways				Difference to Base			
	1+ Car	0 Car	Total	% Share	Diff %	1+ Car	0 Car	Total
Active	25,284	4,545	29,829	9.8%	-1.1%	-187	-130	-317
Bus Pass	2,214	436	2,650	0.9%	36.5%	496	213	709
Car Pass	63,669	3,337	67,006	22.0%	-0.3%	-123	-46	-169
Driver	203,109	1,450	204,559	67.3%	-0.1%	-187	-38	-225
Total	**294,276**	**9,768**	**304,044**	**100.0%**		**-1**	**-1**	**-2**

Table 17: Model Response to Halving the Headways – Inter-peak

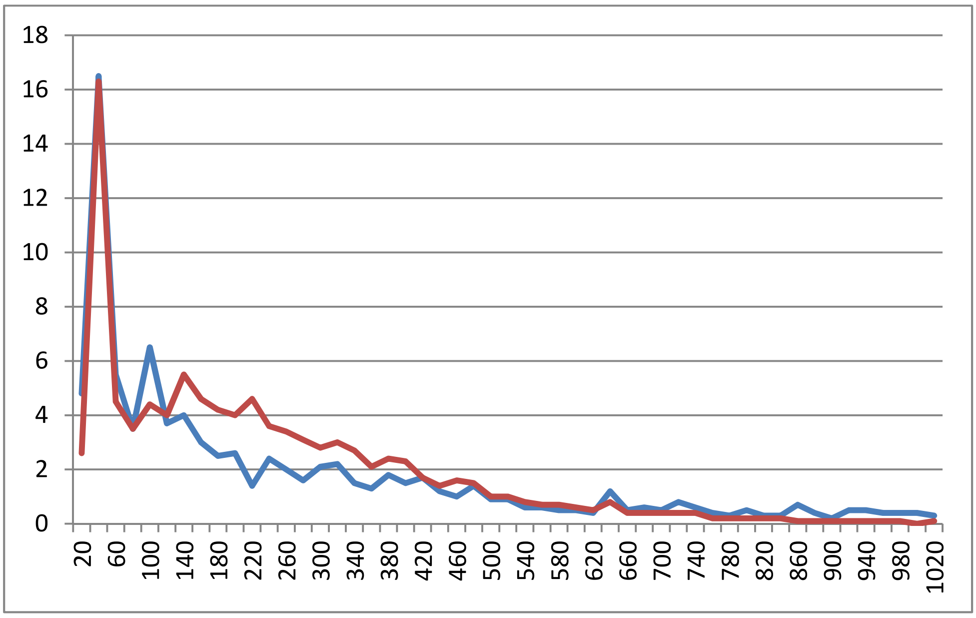
The model response to a halving the headways produces a 36.5% increase in trips, which is an elasticity of -0.45 - within the expected range.

A summary of the inter-peak elasticity responses are provided below, with the targets from Table 2. These results demonstrate that the inter-peak, both half headway and double fare scenarios responses are within the expected range.

	Target	Modelled Response	Within Range?
Double Fares	-0.35 to -0.50	-0.37	Yes
Half Headway	-0.20 to -0.60	-0.45	Yes

Table 18: Summary of Elasticity Tests – Inter-Peak

The modelled and observed trip cost frequencies are shown in Figure 5.



Car Driver

The car driver frequency matches reasonably well, but the observed data in the other modes is too sparse for a meaningful comparison.

Observed and Modelled Car Driver Trip Cost Frequencies after Mode Split – Inter Peak

5

7. Patronage by Service

The final test of the model is the comparison of passenger boardings when the surveyed and modelled trip matrices are assigned to the public transport network. The assignment of surveyed matrices is compared to patronage by route data counted during the Bus Intercept Survey ("count") in the following section; with the next section providing a similar comparison but based on a modelled estimate of public transport trips.

7.1 Surveyed Data

Table 19 below shows the surveyed matrices compared with observed patronage – routes are numbered such that one particular direction has the actual route number allocated, with the reverse direction denoted with the route number and the letter 'a'. There is no guidance in the EEM as to what would be an acceptable match but there is in the NZTA Transport Model Development Guidelines. These contain screenline and boarding criteria, and the boarding criteria have been reported here.

It is worth noting that there is generally considerable day-to-day variation in passenger boardings, and the boarding counts are for a single day.

Route	Route Name	Morning Peak				Inter Peak			
		Counts	AM Model	Diff	GEH	Counts	IP Model	Diff	GEH
1	Pukete In	166	105	-61.4	3.7	13	33	20	2.9
1a	Pukete Out	21	31	9.5	1.3	49	79	30	2.7
2	Silverdale In	153	127	-26.2	1.6	36	24	-12	1.5
2a	Silverdale Out	51	89	38.1	3.2	15	80	65	6.7
3	Dinsdale In	156	155	-0.6	0.0	33	21	-12	1.6
3a	Dinsdale Out	18	35	17.4	2.4	50	70	20	1.8
4	Flagstaff In	134	127	-6.9	0.4	30	34	4	0.5
4a	Flagstaff Out	52	47	-5.2	0.5	16	51	35	4.3
5	Chartwell In	79	83	3.8	0.3	11	41	30	4.2
5a	Chartwell Out	23	23	-0.2	0.0	28	0	-28	5.3
6	Mahoe In	144	160	16.2	0.9	58	73	15	1.3
6a	Mahoe Out	23	54	31.2	3.6	59	34	-25	2.6
7	Glenview In	153	91	-61.7	3.9	53	13	-40	4.9
7a	Glenview Out	56	55	-1	0.1	59	78	19	1.6
8	Frankton In	147	112	-35.5	2.2	38	71	33	3.2
8a	Frankton Out	87	47	-39.8	3.4	53	84	31	2.6
9	Nawton-TC IN	101	96	-5.1	0.4	36	32	-4	0.5
9a	Nawton-TC OUT	77	78	1.1	0.1	32	36	4	0.5
10	Hillcrest-TC IN	82	76	-5.7	0.5	47	23	-24	2.9

Route	Route Name	Morning Peak				Inter Peak			
		Counts	AM Model	Diff	GEH	Counts	IP Model	Diff	GEH
10a	Hillcrest-TC OUT	112	125	13.1	0.9	52	59	7	0.7
11	Fairfield-TC IN	113	69	-43.6	3.2	45	59	14	1.4
11a	Fairfield-TC OUT	33	33	-0.2	0.0	27	36	9	1.1
12	Fitzroy-TC IN	169	121	-48.5	2.9	78	15	-63	6.5
12a	Fitzroy-TC OUT	25	35	9.5	1.2	63	30	-33	3.4
13	University-TC IN	87	123	35.9	2.5	33	46	13	1.5
13a	University-TC OUT	95	194	98.5	5.8	43	48	5	0.5
14	Claudelands-TC IN	103	66	-36.7	2.8	36	20	-16	2.1
14a	Claudelands-TC OUT	33	34	1.3	0.2	26	55	29	3.2
15	Ruakura-TC IN	33	63	30.1	3.1	11	28	17	2.7
15a	Ruakura-TC OUT	36	54	18.1	1.9	4	40	36	5.4
16	Rototuna-TC IN	189	268	78.9	3.7	64	41	-23	2.2
16a	Rototuna-TC OUT	55	129	73.9	5.4	45	71	26	2.4
17	Hamilton East Uni-TC IN	62	76	14.2	1.2	11	16	5	1.0
17a	Hamilton East Uni-TC OUT	167	129	-37.8	2.2	61	17	-44	5.0
18	Te Rapa-TC IN	142	118	-23.7	1.5	52	62	10	0.9
18a	Te Rapa-TC OUT	77	61	-15.6	1.3	20	80	60	6.0
26	Bremworth/Temple View-TC IN	104	94	-9.6	0.7	34	25	-9	1.2
26a	Bremworth/Temple View-TC OUT	54	63	8.6	0.8	54	32	-22	2.4
30	Northerner-TC IN	25	25	0.4	0.1	5	8	3	0.8
30a	Northerner-TC OUT	10	5	-5.2	1.4	8	15	7	1.5
16rd	Rototuna Direct In	137	77	-60.3	4.1		0	0	0.0
16rda	Rototuna Direct Out	9	60	51.1	6.1		0	0	0.0
51	CBD Shuttle		92	-158.5	9.6		164	164	12.8
20	Hamilton to Cambridge	0	0					0	0.0
20	Cambridge to Hamilton	25	53	28.4	3.2	0	0	0	0.0
24	Hamilton to Te Awamutu	3	7	4	1.3	0	0	0	0.0
24a	Te Awamutu to Hamilton	55	43	-12.3	1.2	0	0	0	0.0
52a	OrbiterC: University-Base	574	565	-8.7	0.3	227	259	32	1.5
52	OrbiterA: University-Base	422	537	114.6	3.7	199	153	-46	2.5
1pd	Pukete Direct In	37	148.6	111.6	8.2	0	0	0	0.0
1pda	Pukete Direct Out	22	25.7	3.7	0.5	0	0	0	0.0
3dd	Dinsdale Direct In	3	83.5	80.5	8.7	0	0	0	0.0

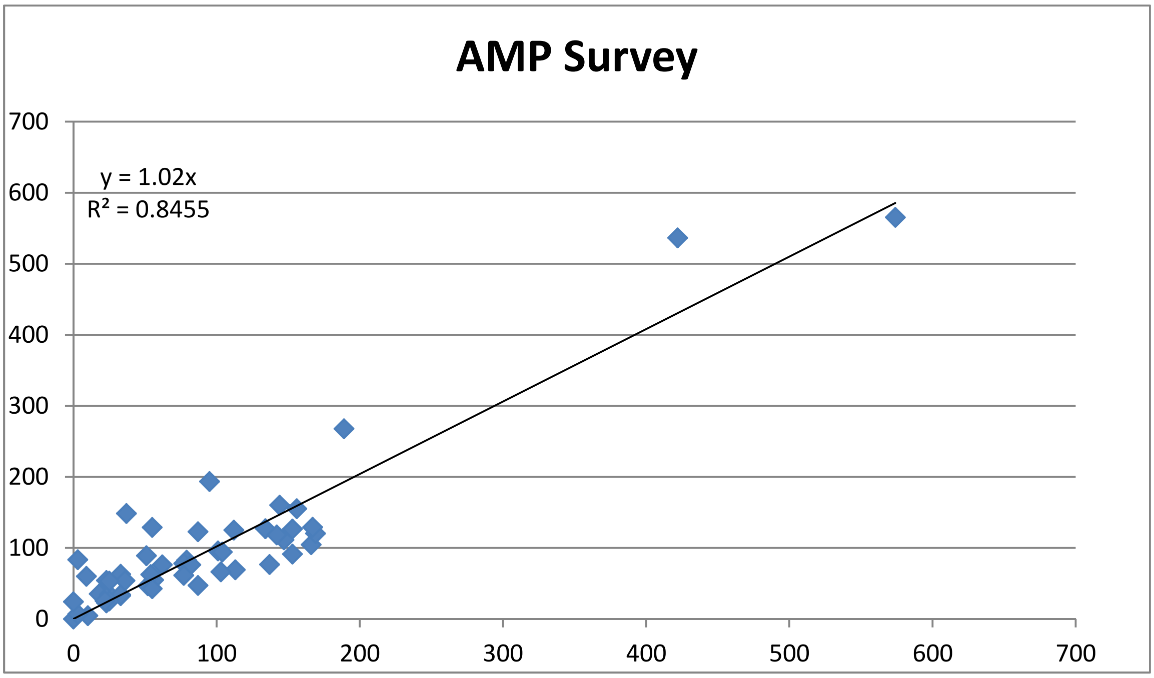
Route	Route Name	Morning Peak				Inter Peak			
		Counts	AM Model	Diff	GEH	Counts	IP Model	Diff	GEH
3dda	Dinsdale Direct Out	0	24.3	24.3	4.9	0	0	0	0.0
Trips with no transfer		4436	3513			1999	2085		
Trips with transfer		251	820			83	86		
TOTAL TRIPS		4687	4333			2082	2171		
Boardings		4734	5192			1914	2256		

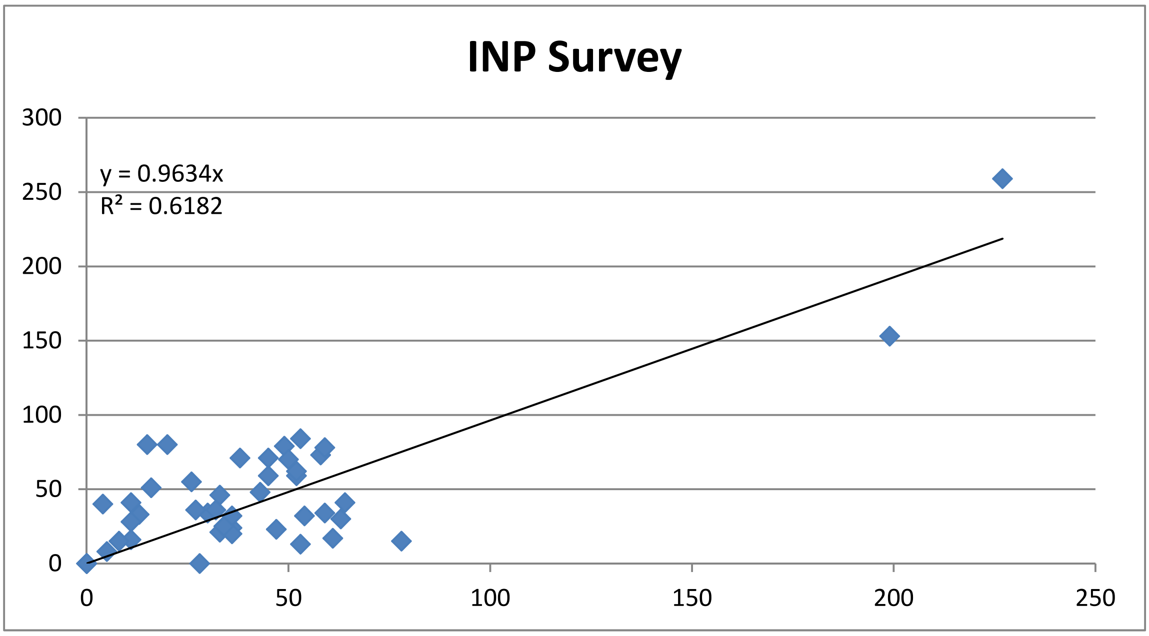
Table 19: Comparison of Assigned Survey Boardings against Surveyed Boarding Counts

When the morning peak surveyed assignment is compared against the NZTA guidelines, 90% have a GEH less than 5.0 (cf NZTA 50%), 96% less than 7.5 (NZTA 60%) and 100% less than 10.0 (NZTA 70%).

The inter-peak results are that 90% have a GEH less than 5.0, and 100% are less than 7.5.

These results are plotted as scattergrams on Figure 6. The morning peak slope and R^2 are within NZTA guidelines. The inter-peak slope is just outside the NZTA guideline of 0.85, but the R^2 complies.





Assigned Observed Passenger Boardings vs Boarding Counts - Peak and Inter-peak

6

7.2 Modelled Volumes

Modelled boardings compared against boarding counts are shown on Table 20 below.

Route	Route Name	Morning Peak				Inter Peak			
		Counts	AM Model	Diff	GEH	Counts	IP Model	Diff	GEH
1	Pukete In	166	82	-84	5.3	13	12	-1	0.3
1a	Pukete Out	21	50	29	3.4	49	11	-38	4.9
2	Silverdale In	153	207	54	2.8	36	27	-10	1.2
2a	Silverdale Out	51	139	88	6.4	15	36	21	3.0
3	Dinsdale In	156	142	-14	0.8	33	18	-15	2.1
3a	Dinsdale Out	18	35	17	2.3	50	6	-44	6.0
4	Flagstaff In	134	121	-13	0.8	30	26	-4	0.5
4a	Flagstaff Out	52	45	-7	0.7	16	4	-12	2.7
5	Chartwell In	79	34	-45	4.2	11	4	-7	1.8
5a	Chartwell Out	23	23	0	0.0	28	6	-22	3.8
6	Mahoe In	144	143	-1	0.1	58	19	-39	4.5
6a	Mahoe Out	23	49	26	3.0	59	22	-37	4.1
7	Glenview In	153	45	-108	7.7	53	18	-35	4.1
7a	Glenview Out	56	67	11	1.0	59	17	-42	4.8
8	Frankton In	147	83	-64	4.2	38	2	-36	5.7
8a	Frankton Out	87	54	-33	2.8	53	4	-49	6.5
9	Nawton-TC IN	101	110	9	0.6	36	16	-20	2.7
9a	Nawton-TC OUT	77	93	16	1.2	32	9	-23	3.5
10	Hillcrest-TC IN	82	121	39	2.7	47	14	-33	4.2
10a	Hillcrest-TC OUT	112	74	-38	2.8	52	19	-33	3.9
11	Fairfield-TC IN	113	98	-15	1.0	45	7	-38	5.2
11a	Fairfield-TC OUT	33	52	19	2.1	27	7	-20	3.5
12	Fitzroy-TC IN	169	69	-100	6.5	78	40	-38	3.5
12a	Fitzroy-TC OUT	25	43	18	2.1	63	11	-52	6.0
13	University-TC IN	87	175	88	5.4	33	158	125	9.0
13a	University-TC OUT	95	277	182	9.4	43	89	46	4.0
14	Claudelands-TC IN	103	76	-28	2.1	36	6	-30	4.7
14a	Claudelands-TC OUT	33	31	-2	0.3	26	5	-21	3.9
15	Ruakura-TC IN	33	186	153	10.4	11	69	58	6.5
15a	Ruakura-TC OUT	36	218	182	11.4	4	80	76	8.3

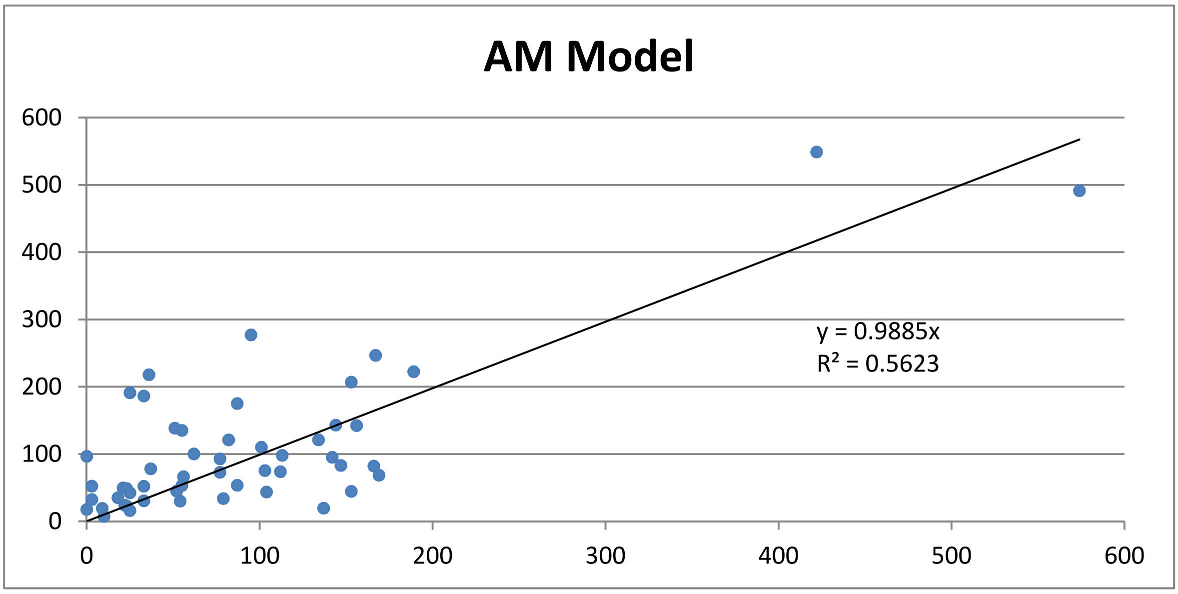
Route	Route Name	Morning Peak				Inter Peak			
		Counts	AM Model	Diff	GEH	Counts	IP Model	Diff	GEH
16	Rototuna-TC IN	189	223	34	1.7	64	76	12	1.0
16a	Rototuna-TC OUT	55	135	80	5.8	45	30	-15	1.7
17	Hamilton East Uni-TC IN	62	100	38	3.0	11	99	88	8.4
17a	Hamilton East Uni-TC OUT	167	247	80	3.9	61	65	4	0.4
18	Te Rapa-TC IN	142	95	-47	3.0	52	21	-32	3.7
18a	Te Rapa-TC OUT	77	73	-4	0.3	20	29	9	1.3
26	Bremworth/Temple View-TC IN	104	44	-60	5.0	34	5	-29	4.6
26a	Bremworth/Temple View-TC OUT	54	30	-24	2.6	54	6	-48	6.1
30	Northerner-TC IN	25	16	-9	1.4	5	7	2	0.5
30a	Northerner-TC OUT	10	7	-3	0.6	8	1	-7	2.4
16rd	Rototuna Direct In	137	20	-117	9.4			0	0.0
16rda	Rototuna Direct Out	9	19	10	2.0			0	0.0
51	CBD Shuttle								
20	Hamilton to Cambridge	0	97	97	9.8			0	0.0
20	Cambridge to Hamilton	25	191	166	11.3	0	44	44	0.0
24	Hamilton to Te Awamutu	3	32	29	4.9	0	0	0	0.0
24a	Te Awamutu to Hamilton	55	54	-2	0.1	0	2	2	0.0
52a	OrbiterC: University-Base	574	492	-83	2.5	227	230	3	0.1
52	OrbiterA:University-Base	422	549	127	4.1	199	236	37	1.8
1pd	Pukete Direct In	37	78	41	3.8	0	0	0	0.0
1pda	Pukete Direct Out	22	24	2	0.3	0	0	0	0.0
3dd	Dinsdale Direct In	3	53	50	6.6	0	0	0	0.0
3dda	Dinsdale Direct Out	0	18	18	4.2	0	0	0	0.0
Trips with no transfer		4436	4281	-155	1.7	1999	1774	-225	3.7
Trips with transfer		251	701	450	14.6	83	106	23	1.7
TOTAL TRIPS		4687	4982	295	3.0	2082	1880	-202	3.2
Boardings		4734	5537			1914	1610		

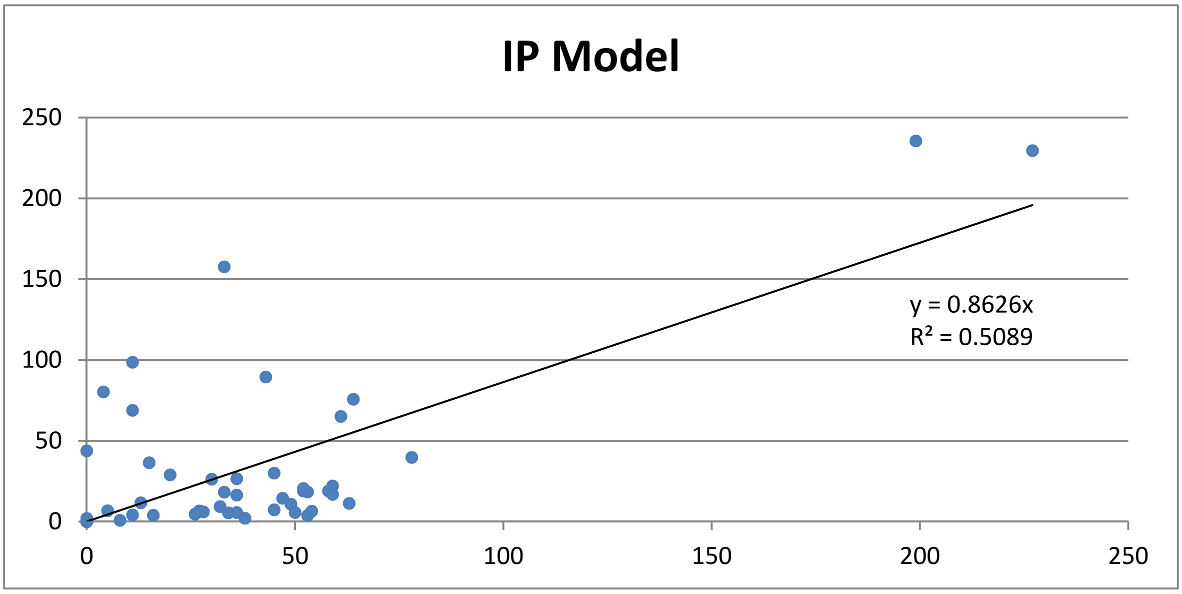
Table 20: Comparison of Assigned Modelled Boardings against Surveyed Boarding Counts

When the morning peak modelled assignment is compared against the NZTA guidelines, 75% have a GEH less than 5.0 (cf NZTA 50%), 86% are less than 7.5 (NZTA 60%), 94% is less than 10.0 (NZTA 70%) and 100% are less than 12.0 (NZTA 80%). This demonstrates that the morning peak results exceed the NZTA guidelines for PT assignment.

The inter-peak results are 81% less than 5.0, 94% less than 7.5, and 100% less than 10.

These results are plotted as scattergrams in Figure 7. The slopes in both periods comply with NZTA guidelines, but the R^2 values fall outside the >0.80 guideline.





Modelled Passenger Boardings vs Boarding Counts
Peak And Inter-Peak

TDG

7

8. Conclusion

The mode split process has proved to be challenging and tested the boundaries of the data, but that is not unexpected when calibrating four step models in places with a very low PT mode split. Nevertheless, the model is performing reasonably well in replicating existing mode splits and PT boardings, given the variability that is inherent in day-to-day bus usage.

The model has been built using the 900 zone system and has been applied to the new 2500 zone system. The result of that process is reported in Technical Notes 34 and 35.