Waikato Regional Transport Model
External Vehicle Model

Technical Note 13 Final
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1. INTRODUCTION

The purpose of this note is to document the external vehicle model. There are two types of travel encompassed within this model, referred to as “external” and “through”. External trips are those with one end outside the study area and one end within the study area. These are also commonly referred to as external-internal and internal-external trips. Through trips, as suggested by the name, are those that travel through the study area and are also known as external-external trips.

The external vehicle model estimates light and heavy vehicle travel. Similar to the Goods Vehicle Model, “heavy” is used generically for both medium and heavy vehicles.

Medium and heavy vehicles, the definitions of which are shown in Table A2.1 of Land Transport New Zealand’s Economic Evaluation Manual (EEM), include any vehicle over 3.5 tonnes in gross laden weight. In this technical note, these are referred to as “heavy” vehicles for simplicity, although medium commercial vehicles are included.

In this technical note, the following topics are covered in turn:

- processing the observed travel pattern data;
- the resulting through trip matrix for light and heavy vehicles, with data validation checks;
- development of the internal trip end models for light and heavy external trips; and
- development of the distribution models for external light and heavy vehicle trips; and
- application of the models with comparisons to observed data.

2. PROCESSING THE OBSERVED DATA

The main data sources for model development were the Household Interview Survey (HIS) and the Roadside Interview (RSI) Surveys.

The HIS by definition was household-based within the study area, and while travel outside the study area was collected and processed, this represents a small sample.

The roadside interview surveys collected data on travel by all vehicles across specified screenlines, including sites identified as the external cordon. Figure 1 illustrates the location of the RSI's (in yellow) selected to construct the observed external/through matrix, while the external model zones are shown in blue and the study area boundary in red.

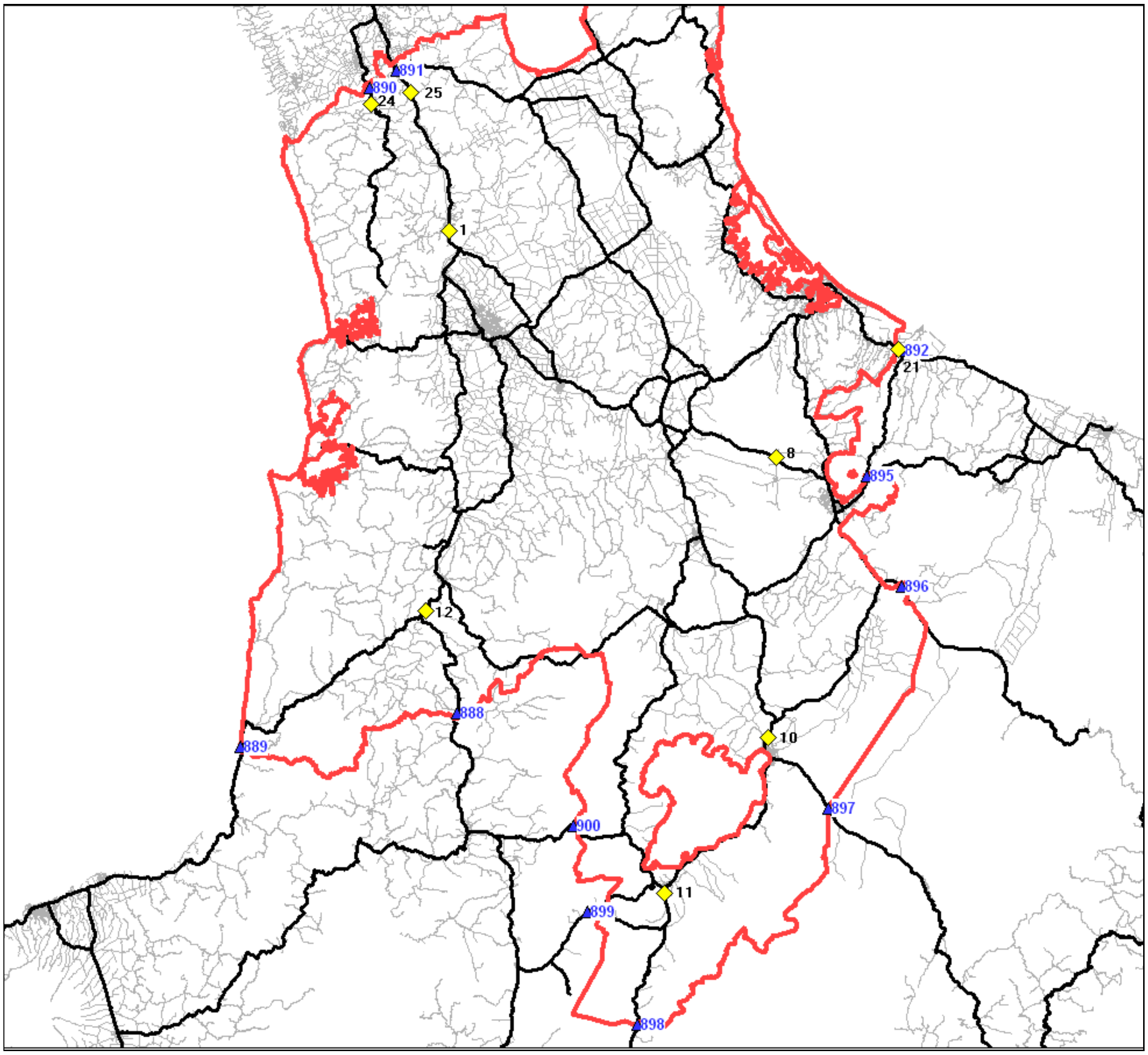


Figure 1: Location of RSI's for External/Through Travel

Of these seven RSI sites, five were surveyed for the WRTM build while the remainder were conducted for the development of adjacent models (one each for the Auckland and Tauranga Models). The processing of each dataset is summarised briefly in turn below.

The roadside interview surveys conducted for the WRTM were expanded to 12 hour manual classified counts as part of the separate data collection contract. These were then factored to daily (24 hours) by increasing the interpeak (9am to 4pm) to represent the unobserved overnight travel. This factoring was undertaken separately for light and heavy vehicles using Automatic Traffic Counts (ATC) undertaken at the same time as the interview surveys.

The Auckland and Tauranga survey databases were re-expanded to ensure consistency. These were initially factored to the interview period using seasonally adjusted ATC's for light and heavy vehicles. The ATC data were obtained from 2006 counts at the nearest NZTA monitoring site. The expansion considered time period, with expansion by hour for light vehicles and because of the smaller sample, expansion by peak period (AM, interpeak and PM peak) for heavy vehicles. The final step was factoring to daily, for which the interpeak trips were increased to represent the overnight travel.

To obtain the opposite direction of travel to the survey, each RSI site was transposed and daily expansion factors calculated for the non-survey direction.

The RSI data, including the non-survey direction, needed to be combined in such a way as to avoid double counting. For example, trips from Auckland to Wellington could have travelled through the Auckland RSI on State Highway 1 (immediately south of State Highway 2), the Waikato site (site 10) north of Taupo and the Waikato site (site 11) south of Turangi, all on State Highway 1. In this case, these trips would be triple counted when all the RSI sites were combined.

The process to combine the data and remove the double counting was to identify and use only one site for each external movement. The site selected was the one most suitably located for that movement, therefore giving the most reliable data. Daily through trips were calculated from an alternative site as a cross-check, which is reported in section 3 of this technical note.

The resulting estimate of observed external/through trips is shown below for light and heavy vehicles combined on a daily basis.

Observed Daily External/Through Trips (Light + Heavy) **Table 1**

Origin		Zones	Destination 1-849	888	889	890	891	892	895	896	897	898	Total
Internal		1-849	-	573	353	302	13,306	5,192	197	52	395	1,122	21,493
SH4		888	522	0	0	19	177	0	0	0	0	0	718
SH3 to New Plymouth		889	321	0	0	6	132	0	0	0	0	2	461
Auckland	SH22	890	321	20	6	0	0	0	0	0	7	15	370
	SH1	891	13,145	184	145	0	0	130	61	34	235	258	14,192
SH2 Te Puke		892	5,363	0	0	0	134	0	0	0	0	2	5,499
SH30		895	190	0	0	0	59	0	0	0	17	30	296
SH38		896	50	0	0	0	33	0	0	0	2	5	89
SH5 to Napier		897	384	0	0	7	228	0	17	2	0	2	640
SH1 South of Turangi		898	1,115	0	2	15	256	2	30	5	2	0	1,428
Total			21,411	777	506	349	14,325	5,324	305	93	659	1,437	45,186

Note that the total RSI heavy vehicle trip values for through movements for zone 888 in raw form exceeded the traffic counts at that location by 4% (from 888) and 30% (to 888). They have therefore been scaled down to match the counts, effecting a reduction of 15 vehicles over the 24 hour period.

Summing across all the external zones, as shown in the next table, reveals that there are 2,000 vehicle trips travelling through the study area on a daily basis (light and heavy combined) compared with 43,000 external trips. As suspected, travel through the study area is a very small component.

Observed Daily External/Through Trips (Light + Heavy) – Internal vs External **Table 2**

Origin	Destination Internal	External	Total
Internal	-	21,493	21,493
External	21,411	2,282	23,693
Total	21,411	23,775	45,186

The through trips are an input to the model and further validation checks are described in the next section.

Mathematical formulae will be derived to estimate the external trips, for which the matrix presented in this section forms the observed travel and the basis for model development. The derivation of the models (trip generation and trip distribution) that estimate external travel are described in sections 4 and 5 of this technical note.

3. THROUGH TRIPS

The daily through trips were provided in Table 1, while the methodology for their derivation was provided in the preceding text. For each through movement, one RSI site was selected to extract the demand. In this section, the demands from alternative sites are tabulated and compared. This is, in fact, a validation of the observed through matrix.

The through trips in Table 1 are replicated in the following table but with both directions of travel combined. This enables the most significant movements to be easily identified.

Daily Through Trips (Light + Heavy) – Combined Directions							**Table 3**				
		Zones	**888**	**889**	**890**	**891**	**892**	**895**	**896**	**897**	**898**
SH4		**888**									
SH3 to New Plymouth		**889**	0								
Auckland	**SH22**	**890**	39	12							
	SH1	**891**	362	276	0						
SH2 Te Puke		**892**	0	0	0	264					
SH30		**895**	0	0	0	119	0				
SH38		**896**	0	0	0	67	0	0			
SH5 to Napier		**897**	0	0	14	463	0	34	4		
SH1 South of Turangi		**898**	0	4	31	514	4	61	10	4	

The most significant through movements are associated with Auckland, with the largest being to/from State Highway 1 (Turangi), followed by to/from State Highway 5, the route to Napier.

In the following table, demands from alternative RSI sites are tabulated for these major movements and compared with the through trips included in the model.

Comparison of Key Through Movements at Different Survey Sites							**Table 4**
		Selected RSI Site		**Alternative RSI Site**		**Diff**	**% Diff**
		Site No	**Daily Trips**	**Site No**	**Daily Trips**		
Auckland	SH5 Napier	10	477	24 & 25	432	45	10%
Auckland	SH1 Turangi	11	545	24 & 25	749	-204	-27%

For Auckland to/from Napier, the number of trips from the alternative site is similar to the trips from the chosen site.

The number of Auckland to/from Turangi trips, however, is 204 vehicles larger using the sites south of Auckland (Sites 24 and 25) than using Site 11 (north of Turangi). This difference may be due to trips through the Auckland RSI sites headed for a destination (or from an origin) approximately south of Turangi, which are therefore allocated to that movement, but in reality took a different route and passed through a different external zone. It is exactly this possibility (and the reverse of it) that is the basis for the site selection. Trips through the RSI site north of Turangi (Site 11) headed for (or coming from) Auckland or north of Auckland are, in contrast, very likely to pass through the Auckland external zones (890 and 891). Using the RSI site north of Turangi (Site 11) for this movement, therefore, minimises the probability of trip misallocation.

Of note, this analysis includes sites surveyed for the Auckland model as well as for the Waikato model – undertaken at different times of the year and by different contractors.

Overall, this comparison demonstrates that the through matrix input to the model is sufficiently robust.

4. EXTERNAL TRIPS – INTERNAL TRIP END MODEL

This model estimates the internal trip location of external trips, that is, those with one end inside and one end outside the study area. Models were developed separately for light and heavy vehicles. Both models estimated daily vehicle (not person) trips.

The approach to developing the models was to estimate a linear relationship using regression techniques. The procedure for calibrating the model was:

- Internal trip origins and trip destinations were averaged, to produce a single value for the internal trip end. This further assisted with smoothing out the data;
- All explanatory land use variables were initially included;
- Statistical software was used to regress the independent and dependent datasets with a zero constant;
- Variables were then omitted from each model in a stepwise fashion. Variables were omitted if they had a negative coefficient, should not be present from a planning perspective, or the t-statistics were low. A t-statistic of two or greater indicated that the variable was statistically significant;
- This exclusion of variables continued until a satisfactory model was obtained. A satisfactory model must be logically acceptable from a transportation planning point of view as well as statistically significant.

The main explanatory dataset was employment by ANZSIC (Australia and New Zealand Standard Industry Classification) industry type from the 2006 Census. Total households from the Census were also considered, with employment and households both provided at meshblock level by Statistics New Zealand. The employment and household data was then aggregated from meshblock to model zones.

The composite zone system, defined as fine zones within Greater Hamilton and more aggregate zoning for the rest of the study area, was initially tested. But the sparseness of the observed data produced poor results. The next stage was to aggregate the explanatory land use data and the observed trip ends to the regional model zone system and rerun the regressions. Since the trip end models are linear in form, this is an acceptable approach as the model can subsequently be applied to any disaggregate (or aggregate) zone system.

The results of the regressions at regional model zoning were considerably more robust than at composite zoning, although a few outliers were noted. These outliers represented a small number of observed trips compared with a significant level of employment, which were subsequently identified as zones within Tauranga. Zoning within and around Tauranga has since been refined substantially, but in the regression process the best solution was to remove the internal Tauranga zones from the dataset; this ensured that statistical outliers did not skew the estimated models.

The resulting models of daily external trip ends for light and heavy vehicles are shown in the following table. The adjusted R-Squared values are provided with the t-statistics which indicate the explanatory power of each independent variable.

Internal Trip End Model for External Travel (Daily Vehicles)			**Table 5**
Daily External Trip End Models			**Adj R^2**
Light Vehicles	=	0.0408*TOT + 0.0396*HH	0.540
		T = 11.022 T = 4.788	
Heavy Vehicles	=	0.0042*OtherJobs + 0.0394*PrimSecJobs	0.569
		T = 3.913 T = 12.794	

Where:

TOT = Total Jobs (all 19 ANZSIC06 categories)

HH = Households

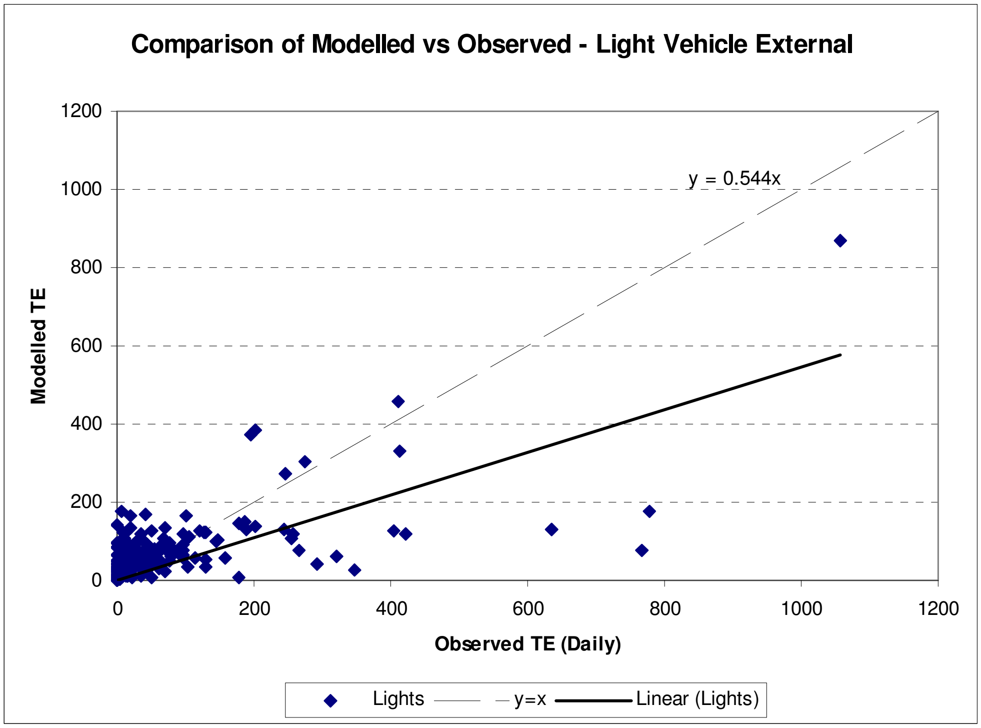
PrimSecJobs = Primary and secondary employment, defined as the sum of the ANZSIC categories: Agriculture, Forestry and Fishing; Mining; Manufacturing; Electricity, Gas, Water and Waste Services; and Construction.

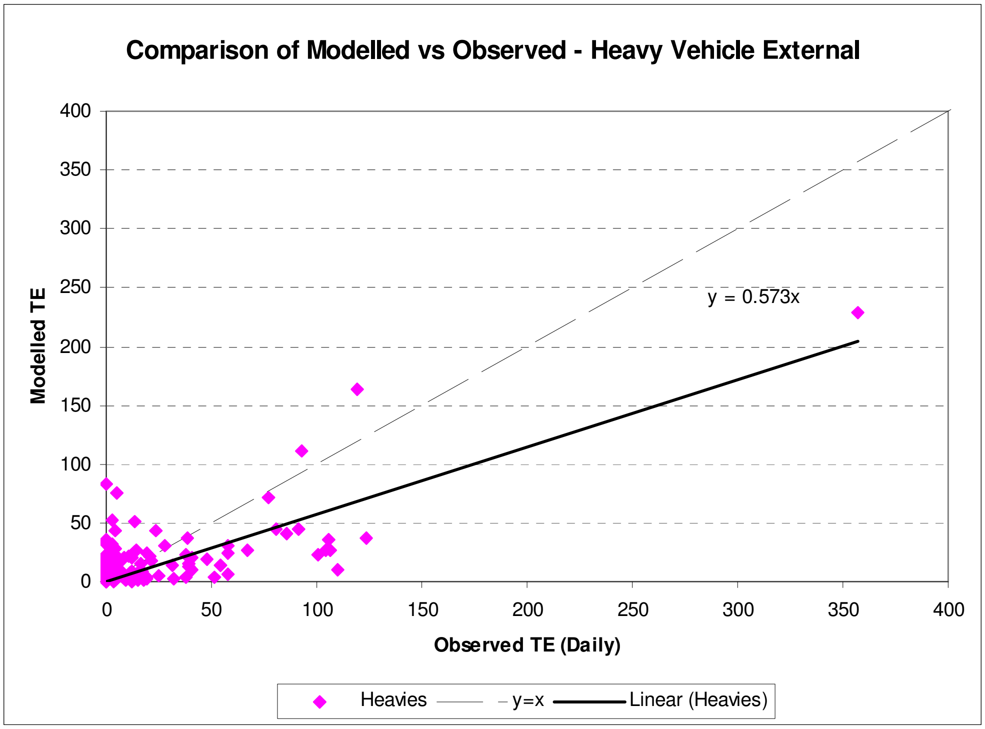
OtherJobs = Total jobs minus the primary and secondary jobs as defined above. This represents tertiary and quaternary sector employment.

The light vehicle model includes total employment and households as explanatory variables, both of which have strong t-statistics, while the model has an overall R-Squared value of 0.540. The predictive power of the model and the explanatory variables are both considered robust from a transportation planning perspective.

The strongest predictive variable in the heavy vehicle model is primary and secondary employment, which has a t-statistic of over 12. The other variable is remaining employment, so that all types of employment are represented, which also has a good t-statistic. The model has an R-Squared value of 0.569, indicating a strong relationship.

The application of the daily trip end models are shown below for light and heavy vehicles respectively. The observed trip ends from the RSI's are plotted on the x-axis with the modelled estimate on the y-axis. The trend line is also provided along with the dashed y=x line that indicates a perfect fit.





The line of best fit is below the y=x line for light and heavy vehicles, indicating that both models underestimate observed. This is not significant for the external trip model which is controlled to traffic counts at the external locations.

The degree of scatter reflects the sampling and the lumpiness of the observed data. The synthetic models effectively smooth out the results ensuring modelled trip estimates for each zone are relative to the level of employment and residential development, depending on the combination of the variables in each model.

5. EXTERNAL TRIPS – DISTRIBUTION MODELS

This model distributes the daily external vehicle trips, linking the origin and destination trip ends to form a matrix.

For the trip end outside the study area, automatic traffic counts were used to produce the base year (defined as 2006) daily light and heavy vehicle flows at the external points of the model. The trip ends for the external-internal and internal-external movements were found by subtracting the sums of through movements from the total traffic counts at the external locations.

For the internal end of each trip, these were calculated using the synthetic trip generation model described in the previous section.

Separate trip distribution functions have been calibrated for light and heavy vehicles.

The model form selected was a gravity model denoted by:

$$T_{ij} = L_i K_j P_i A_j F(C_{ij}),$$

where

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

P_i = productions/origins from zone i

A_j = attractions/destinations to zone j

L_i, K_j = row/column balancing factors

$F(C_{ij})$ = cost deterrence from zone i to zone j, and is represented mathematically by:

$$F(C_{ij}) = \exp(-\alpha C_{ij}),$$

where

Cij = generalised cost of travel from zone i to zone j

α = calibrated coefficient

The TRACKS program DISCAL has been used to calculate the distribution function coefficients. The inputs to DISCAL are time and distance matrices plus an observed trip matrix. In the case of external travel, the trips are distributed using time only (i.e. excluding distance), which is consistent with the approach for the three stage model. The time matrix was derived from the all day assignment of the surveyed light vehicle trips from the Household Interview Survey (HIS). This is consistent with the application of the heavy vehicle internal model described in Technical Note 14. The trip matrix was obtained from selected RSI sites, separately for light and heavy vehicles.

The calibration process involves inverting the gravity model so that it is expressed in terms of the distribution function

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

The function value is calculated for each origin/destination pair, and allocated to a 5 minute cost band k. The final value of the function in each cost band is the weighted average of the individual cells in that band.

The natural logarithms of these averages are then plotted against time to calibrate the α Gravity parameter value for use in the negative exponential function form, as shown in Figures 2 and 3.

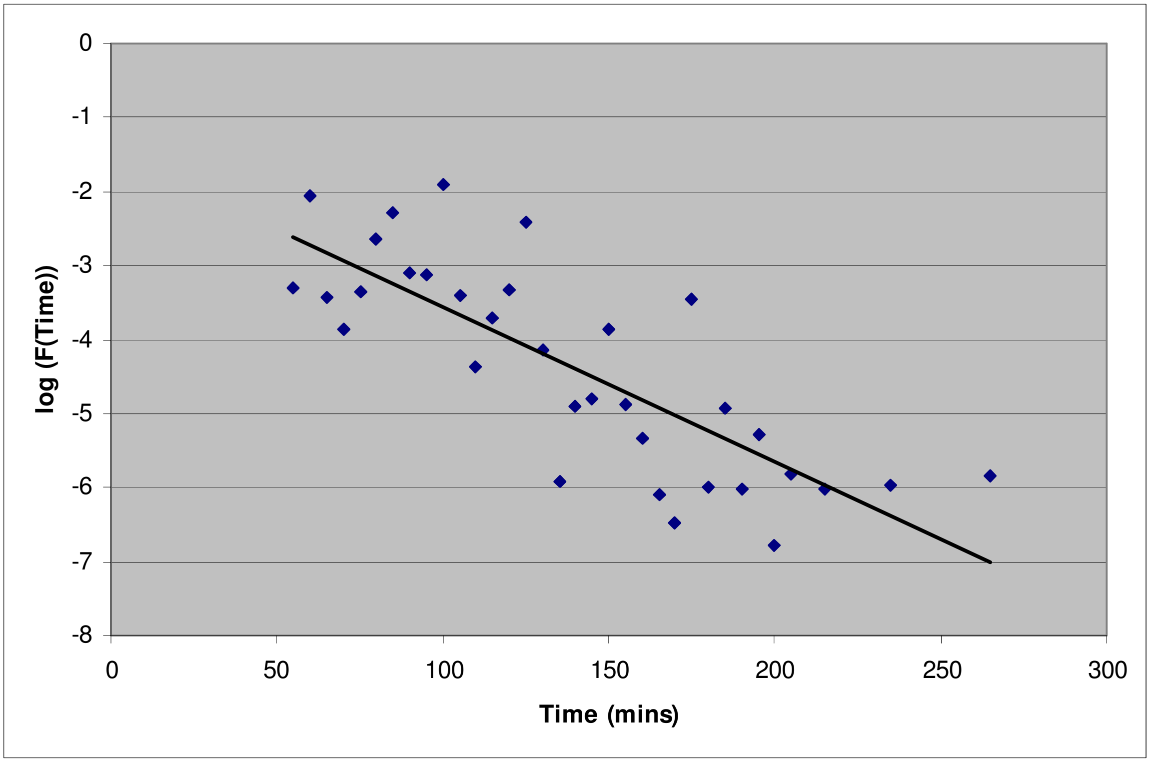


Figure 2: Distribution Calibration: Light Vehicles

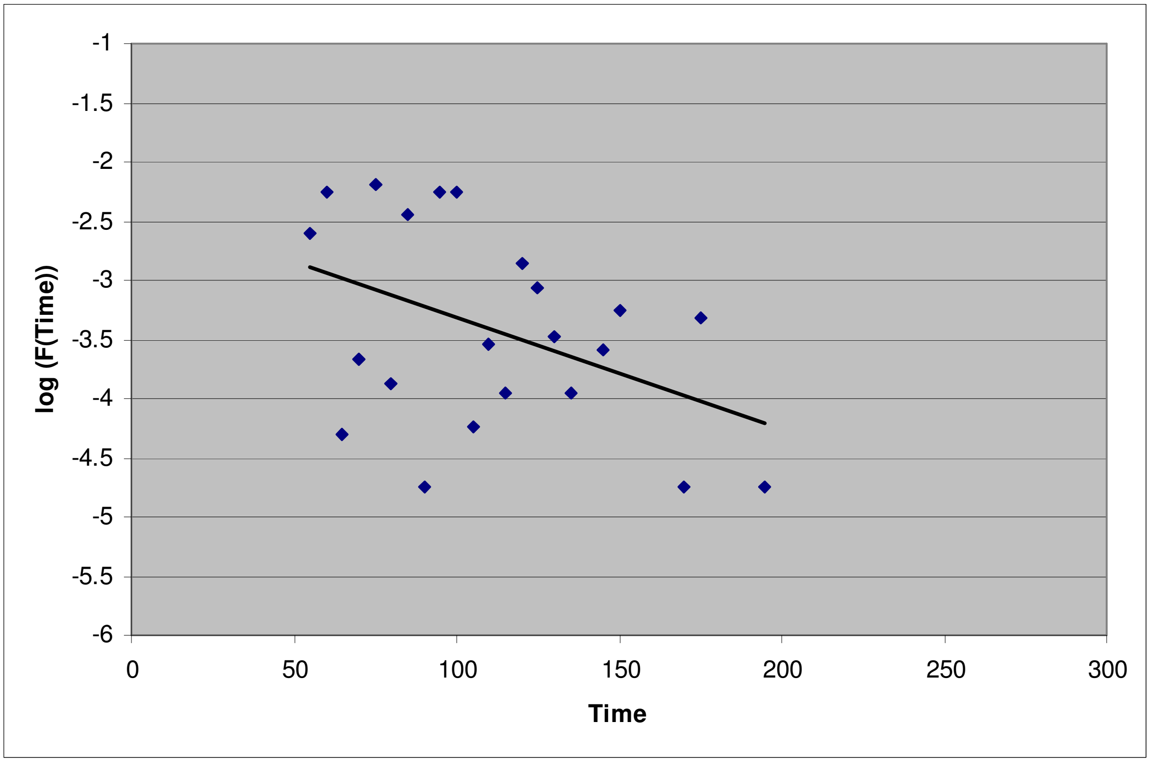


Figure 3: Distribution Calibration: Heavy Vehicles

Results are summarised in the following table.

Distribution (Gravity) Function Parameters		Table 6
Vehicle Class	**Gravity Parameter (min^{-1})**	**R-Squared**
Light	0.0210	0.6344
Heavy	0.0094	0.1826

The R-squared value for heavy vehicle trips is relatively low, due to the lower number of observed trips compared with light vehicles.

These calibrated parameters will be the starting point in the distribution validation process, which may have to be revised so that times and distances in the final model for these external movements match observed.

6. PERIOD MODELS

The AM Peak (0700-0900), Inter-Peak (1100-1300) and PM Peak (1600-1800) period models are derived from the 24 hour model described in the preceding sections based on hourly traffic counts at the external locations. The generation and distribution models were fitted at daily level because the RSI external trip data were too sparse to derive separate peak period models. The daily models were then factored to peak periods using counts. External and through trips are a small proportion of total travel, so this approach is considered appropriate.

The trip ends calculated for the peak periods are listed in Table 7.

Trip Ends; External + Through Trips (Light + Heavy) **Table 7**

Zone			24hr		AM		IP		PM	
			From	To	From	To	From	To	From	To
SH4		**888**	837	896	77	92	119	102	135	124
SH3 to New Plymouth		**889**	1022	961	92	75	167	133	140	145
Auckland	**SH22**	**890**	3793	3793	429	782	480	433	864	469
	SH1	**891**	15708	14979	1610	1703	1606	1470	2430	1946
SH2 Te Puke		**892**	7047	7080	1024	1005	918	914	1164	1238
SH30		**895**	1446	1415	268	139	174	172	224	277
SH38		**896**	1356	1316	202	156	169	141	228	202
SH5 to Napier		**897**	1876	1841	192	158	307	237	279	274
SH1 South of Turangi		**898**	1570	1523	76	108	229	243	233	166

The proportions of the 24 hour trip ends that are through trips are listed in Table 8. These proportions are retained in the period models.

Proportion of Trip Ends that are Through Trips **Table 8**

Zone			From	To
SH4		**888**	23.4%	22.8%
SH3 to New Plymouth		**889**	13.6%	15.9%
Auckland	**SH22**	**890**	1.3%	1.2%
	SH1	**891**	6.7%	6.8%
SH2 Te Puke		**892**	1.9%	1.9%
SH30		**895**	7.3%	7.6%
SH38		**896**	2.9%	3.1%
SH5 to Napier		**897**	13.6%	14.3%
SH1 South of Turangi		**898**	19.9%	20.7%

7. CONCLUSIONS

Trip end and distribution models have been calibrated at daily level and factored to peak period for both light and heavy vehicles.

Daily through movements were directly obtained from RSI data, then factored to peak periods using counts. Daily external-internal and internal-external movements were distributed based on:

- Observed data for the external trip ends;
- Synthetic generation models for the internal trip ends; and
- Calibrated gravity models.

The derived generation models are based on employment and household landuse categories. The models fit the observed data well, with R-Squared values of between 0.5 and 0.6 for the internal trip end calibration.

The calibrated distribution model for light vehicles fits the data well, with an R-squared value of 0.6344. There is not a strong regression for the heavy vehicle distribution model due to the sparseness of RSI data for heavy vehicles. Gravity parameters for both light and heavy vehicles may be revised during the validation process.