Waikato Regional Transport Model

Trip Distribution Update (3 step model)

Technical Note 27

November 2014

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Technical Note

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1. Purpose

The purpose of this note is to describe the trip distribution methodology adopted for the study, and to report on the calibration and validation of the distribution functions for the three step model. The purpose for the update is to take into account the changes in the number and size of zones in the updated 2013 model. The new Waikato Regional Transportation Model (WRTM) has been expanded to approximately 2500 zones to create an improved level of land use precision. This change in zone detail has necessitated the recalibration of the distribution parameters following the attraction model updates.

The purposes used were:

- Home to work
- Home to education
- Home to business
- Home to shop
- Home to soc/rec
- Home to other
- Non home based
- Work to home
- Education to home
- Business to home
- Shopping to home
- Soc/rec to home
- Other to home

Note that some aggregation of trip purposes within each time period was undertaken due to data limitations.

2. Introduction

2.1 Trip Distribution Model Form

The gravity model form chosen for this model was:

$$T_{ij} = P_i.K_i\ A_j.L_i\ f(c_{ij})$$

subject to the double constraints of:

$$K_i = \frac{P_i}{\sum_j T_{ij}}$$

$$L_j = \frac{A_j}{\sum_j T_{ij}}$$

Where:

T_{ij}	=	Trips between zones i and j
P_i	=	Productions at zone I
A_j	=	Attractions at zone j
$f(c_{ij})$	=	Some function of the impedance between zones i and j
$K_i\ L_j$	=	Balancing factors

The balancing factors are successively applied until there is convergence. The notation has been ignored in the rest of this note as it can be shown that ΣK_i and ΣL_j tends to 1.0 over the balancing iterations.

2.2 The Distribution Function

The distribution function can be approximated to an exponential line of the form:

$$f(c_{ij}) = e^{-\alpha C_{ij}}$$

Where:

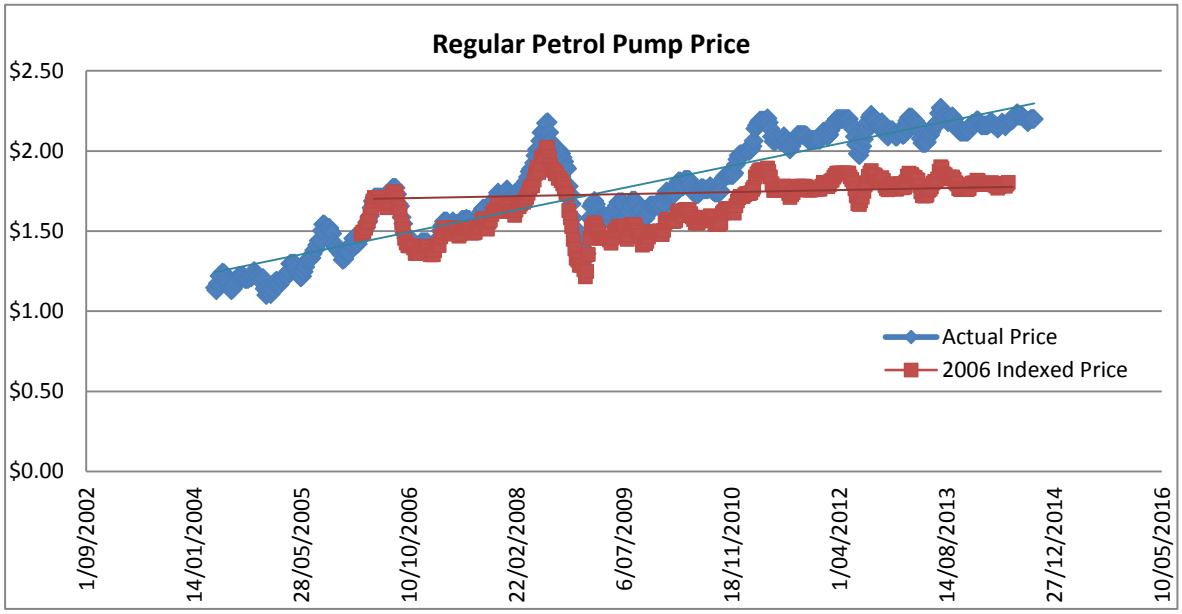
$f(c_{ij})$	=	function of cost of travel between zone i and zone j
C_{ij}	=	generalised cost of travel between zones i and j and is usually of the form $\beta t_{ij} + \gamma d_{ij}$ + tolls + parking charges
t_{ij}	=	time to travel between zone i and zone j (minutes)
d_{ij}	=	distance between zone i and zone j (kilometres)
β	=	generalised cost of travel per minute
γ	=	generalised cost of travel per kilometre
α	=	distribution model exponent to be calibrated

3. Calibrating the Generalised Cost Coefficients

The first step in the calibration is to evaluate the generalised cost coefficients, β and γ, for each purpose and time period. The time cost coefficient has been established using the values published in Table A4.1 of the New Zealand Transport Agency's (NZTA) Economic Evaluation Manual (EEM).

Only part of the running costs for cars is considered to be a perceived cost. It is assumed that most car drivers, when deciding to make a trip by car, consider as their vehicle operating costs only the cost of fuel. This is consistent with the guidelines for private vehicle operating costs in "Travel Behaviour Change Evaluation Procedures" prepared for Transfund NZ (now part of NZTA) in December 2004 by Maunsells Australia Pty Ltd.

Data from the Ministry of Economic Development of fuel prices from 2004 to 2014 is shown on the diagram below. The trend line shows a price of $1.70 early in 2006 and $2.16 for the first quarter of 2013 (in blue). When indexed to 2006 dollars it is clear there is no change in "real" fuel price between 2006 and 2013 (in red).



Graph 1: Fuel Prices

Accordingly, the distance cost for cars has been calculated as 17.068 cents per kilometre, which corresponds to 10 kilometres per litre at $1.71 per litre which has been indexed back to 2006 dollars as calculated from the Statistics New Zealand Consumer Price Index.

The resulting time and distance costs are detailed in Table 1.

Vehicle Class	In Work Travel		Commuting to / from Work		Other Non-Work Travel Purposes		Distance Cost
	$/Hour	Cents/min	$/Hour	Cents/min	$/Hour	Cents/min	Cents/km
Car	23.85	39.75	7.80	13.00	6.90	11.50	17.06

Table 1: Perceived Costs of Travel by Vehicle Class

The non-work time values were factored by 1.15 to convert to perceived costs (Table A11.1 of EEM), and then by 1.11 to bring into first quarter 2006 values from 2002 (Table A12.2 of EEM). The perceived costs are 2006 based because this is the year of the surveyed data used for the trip distribution and the fuel price has not changed in real terms between 2006 and 2013, as shown by the red coloured data in Graph 1.

The next stage was to determine the percentage of trips which fall into the broader work travel, commuting and non-work travel purposes by time of day for each modelled trip purpose, the average occupancy per vehicle, and then for assignment, the weighting of each purpose to form an overall generalised cost. It should be noted that Heavy Commercial Vehicles have been dealt with separately as that model has been imported from the 2006 Christchurch Transportation Model project.

A literature search to determine the percentage breakdowns between work and non-work travel proved fruitless and in the absence of any such guidelines, the proportions in Table 2 of trips classified as work, non-work, and commuting have been assumed for this analysis. These proportions have been used in numerous New Zealand applications since the early 1980s.

	Period	Work	Non Work	Commuting
Home Based Work	All	0.0	0.0	1.0
Home Based Ed	All	0.0	1.0	0.0
Home Based Business	All	0.8	0.2	0.0
Home Based Shop	All	0.0	1.0	0.0
Home Based Soc/Rec	All	0.0	1.0	0.0
Home Based Other	All	0.2	0.8	0.0
Non Home Based	All	0.5	0.5	0.0

Table 2: Proportion of Work and Non Work Trips

Table 3 includes the car occupancy values as calibrated from the Home Interview Survey (HIS). There is one anomaly in that Home To Education is a trip to an education facility for the purpose of study. The car driver trip for the purpose of dropping a person off at school is often classed as a 'serve passenger' trip or in this case as a Home To Other trip.

For the purpose of calculating occupancies, the Home To Work occupancy has been assumed for Home To Education car drivers (also applied for the To Home direction), and the Home To Education passengers have been included in the Home To Other purpose.

	Morning Peak	Inter Peak	Evening Peak
Home To Work	1.07	1.05	-
Home To Ed	1.07	-	-
Home To Business	1.07	1.28	-
Home To Shop	1.24	1.14	1.19
Home To Soc/Rec	-	-	1.76

	Morning Peak	Inter Peak	Evening Peak
Home to Other	1.71	1.73	1.52
Non Home Based	1.43	1.38	1.41
Work To Home	-	1.05*	1.09
Ed To Home	-	-	1.09
Business To Home	-	1.28*	1.52
Shop To Home	-	1.14*	1.19
Soc/Rec To Home	-	-	-
Other To Home	1.20	1.73*	1.90
Total	**1.33**	**1.37**	**1.37**

Table 3: Car Occupants by Time Period

Table 4 shows the proportion of trips by purpose for the trip purposes for each time period as obtained from the Waikato HIS. Note that for the home-based (i.e. home-to and to-home) purposes only one of the directions is included towards the total[1].

	Morning Peak	Inter Peak	Evening Peak
Home To Work	20.47	9.91	-
Home To Ed	23.02	-	-
Home To Business	1.73	5.32	-
Home To Shop	2.28	10.66	9.88*
Home To Soc/Rec	-	-	6.75
Home To Other	22.28	31.57	7.03
Non Home Based	22.25	42.53	27.44
Work To Home	-	9.91*	24.05
Ed To Home	-	-	4.79
Business To Home	-	5.32*	2.19
Shop To Home	-	10.66*	9.88
Soc/Rec To Home	-	-	-
Other To Home	7.98	31.57*	17.87
Total	**100.00**	**100.00**	**100.00**

Table 4: Purpose Proportions by Time Period

Table 5 contains the resulting generalised costs coefficients for time and distance. The time costs are evaluated by multiplying the cost in Table 1 by the proportions in Table 2, adjusting for perceived costs (1.15 factor for non work-related), scaling up to July 2006 dollars (1.11 factor for all) and then multiplying each by the occupancy rates in Table 3. Subsequently it represents the aggregated perceived time cost for all vehicle occupants.

[1] In Tables 3 and 4, trip purposes with an asterisk (*) do not get included to produce the total, i.e. the trip purpose proportions are home-based rather than home-to and to-home.

	Morning Peak		Inter Peak		Evening Peak	
	Time(c)	Dist(c)	Time(c)	Dist(c)	Time(c)	Dist(c)
Home To Work	17.72	17.08	17.49	17.08	-	-
Home To Ed	17.59	17.08	-	-	-	-
Home To Business	40.92	17.08	48.94	17.08	-	-
Home To Shop	18.24	17.08	16.70	17.08	17.42	17.08
Home To Soc/Rec	-	-	-	-	25.88	17.08
Home To Other	33.76	17.08	30.97	17.08	33.94	17.08
Non Home Based	41.97	17.08	40.71	17.08	41.49	17.08
Work To Home	-	-	17.49	17.08	18.15	17.08
Ed To Home	-	-	-	-	18.15	17.08
Business To Home	-	-	48.97	17.08	58.13	17.08
Shop To Home	-	-	16.70	17.08	17.42	17.08
Soc/Rec To Home	-	-	-	-	-	-
Other To Home	23.86	17.08	30.97	17.08	35.41	17.08
Total	**27.60**	**17.08**	**33.21**	**17.08**	**30.07**	**17.08**

Table 5: Generalised Costs by Time Period

4. Calibrating the Distribution Functions

The surveyed trip matrices were derived from the Household Interview Survey data for each purpose and time period. The purposes used were:

- Home to work
- Home to education
- Home to business
- Home to shop
- Home to soc/rec
- Home to other
- Non home based
- Work to home
- Education to home
- Business to home
- Shopping to home
- Soc/rec to home
- Other to home

The TRACKS program DISCAL has been used to calculate the distribution function coefficients. DISCAL uses as inputs a time and distance matrix with corresponding generalised cost coefficients (as derived above) and a trip matrix. To start the process the time and distance matrices were derived from the all-day assignment of the surveyed trips matrix used to determine expansion factors (see Technical note 4).

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

$$f(c_{ij}) = T_{ij} / P_i A_j$$

where $f(c_{ij})$ is assumed to be $e^{-\alpha cij}$

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

The natural log of this average is then calculated and plotted against cost to calibrate the α value for use in the negative exponential function.

The **first** stage in the process was to calibrate the α exponent using the surveyed matrices and the period time and distance matrices derived from assignment of the surveyed matrices. The results from this analysis for each purpose and time period are shown in the Figures below, including the number of trips in each of the matrices and the regression R^2 values.

The results of the calibration for the vehicle driver model (cost based) are included in Figures 2a-4c respectively. The original three step model used a time based distribution, but this update has used cost in order for the model to be sensitive to changes in fuel cost, and for consistency with the 4-step model.

Table 3 of Technical Note 26 contains a breakdown of the total number of expanded trips for each purpose as derived from the HIS. This and the relevant discussion in the corresponding section of Technical Note 26 provide some perspective regarding the level of sampling for each.

The goal is to produce R-squared values of greater than 0.8 where possible, which implies that the calibrated function coefficient explains at least 80% of the surveyed data. In some

cases this has not been possible due to the low number of sampled and expanded households at a trip purpose by period level. In some purposes the line of best fit approaches horizontal. This is particularly apparent for Education and Employers Business purposes where the choice of destination is relatively independent of the cost of getting there. In these instances, the R-squared calculation produces an apparently poor result even though the line of best fit reflects the data trend well.

Note that the total expanded trips are included on each plot, with the number of sampled trips in the HIS being approximately 1% of these values with an average expansion factor of approximately 100.

The **second** stage is to apply the gravity model using modelled trip ends, and confirm that the modelled and observed trip length frequencies still match. There is an iterative process between assignment and distribution that will eventually converge. Throughout this process the α values published in Figure 2 though Figure 4 are successively 'tuned' such that the modelled trip lengths match the HIS trip lengths as closely as possible. As such the α values in Figure 2 through Figure 4 are treated as a 'starting point' and the final validated α values, which are the outcome of this process, are reported in Table 6.

During the trip distribution calibration process it was deemed necessary to employ the bimodal distribution for the main urban area that had been used in various forms in previous versions of the model. The bimodal distribution calibrated trips to/from the main urban area in the WRTM (defined as Region 2 in Figure 1) independently from those trips which had both trip ends outside of the main urban area (defined as Region 1 in Figure 1). For ease of explanation these two areas are referred to as Urban and Rural, respectively. Only those purposes that had a significant number of trips were considered for bimodal coefficients since those with a low number of trips will make little change in the overall model.

Figure 5a though 7e show the results of using the calibrated functions in the AM/INT/PM 2006 models. These figures show the trip length frequency plots for cost for each statistically significant trip purpose. For each purpose, both the modelled and HIS frequency plots have been provided along with statistical measures for both.

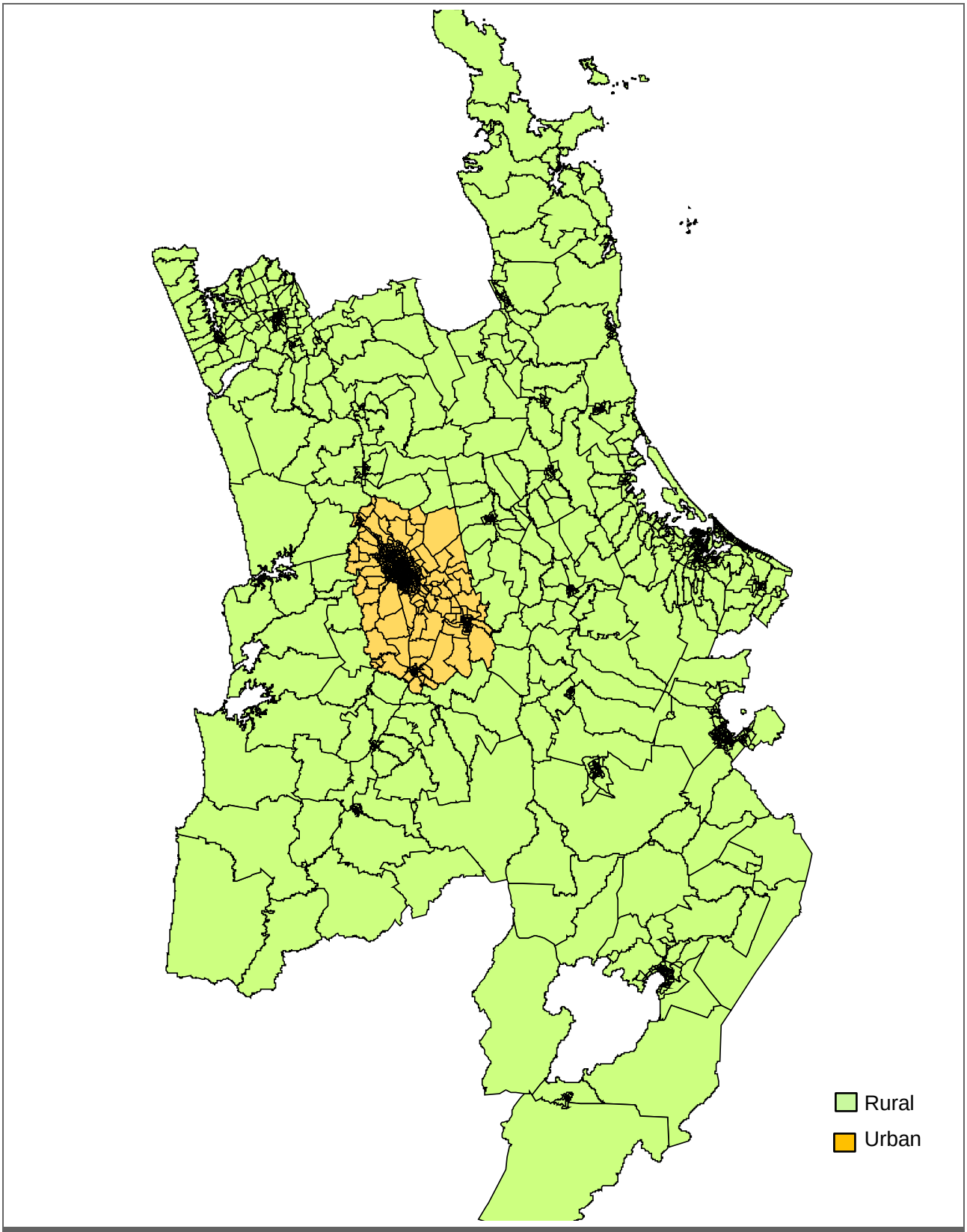
A full table of HIS and modelled averages and standard deviations has been included here to summarise the results published in Figure 5a though 7e as Table 7.

Note that trip chaining has not been taken into account in this analysis. The analysis focuses on trips only. This is consistent with all interpretation and analysis of the WRTM Household Interview Survey data.

	Morning Peak	Inter Peak	Evening Peak
URBAN REGION			
Home To Work	0.0039*	0.0059	-
Home To Ed	0.0045	-	-
Home To Business	0.0018	0.0014	-
Home To Shop	0.0054	0.0051	0.0350
Home To Soc/rec	-	-	0.0036
Home To Other	0.0049*	0.0021	0.0036
Non Home Based	0.0032*	0.0023*	0.0022*
Work To Home	-	0.0037	0.0039*
Ed To Home	-	-	0.0027
Business To Home	-	0.0082	0.0033
Shop To Home	-	0.0067	0.0140*
Soc/rec To Home	-	-	-
Other To Home	0.0059	0.0034	0.0046*
RURAL REGIONS			
Home To Work	0.0032*	0.0059	-
Home To Ed	0.0045	-	-
Home To Business	0.0018	0.0014	-
Home To Shop	0.0054	0.0051	0.0350
Home To Soc/rec	-	-	0.0036
Home To Other	0.0032*	0.0021	0.0036
Non Home Based	0.0021*	0.0020*	0.0020*
Work To Home	-	0.0037	0.0033*
Ed To Home	-	-	0.0027
Business To Home	-	0.0082	0.0033
Shop To Home	-	0.0067	0.0064*
Soc/rec To Home	-	-	-
Other To Home	0.0059	0.0034	0.0021*

* Dual distribution function exponent

Table 6: Validated Distribution Model Coefficients

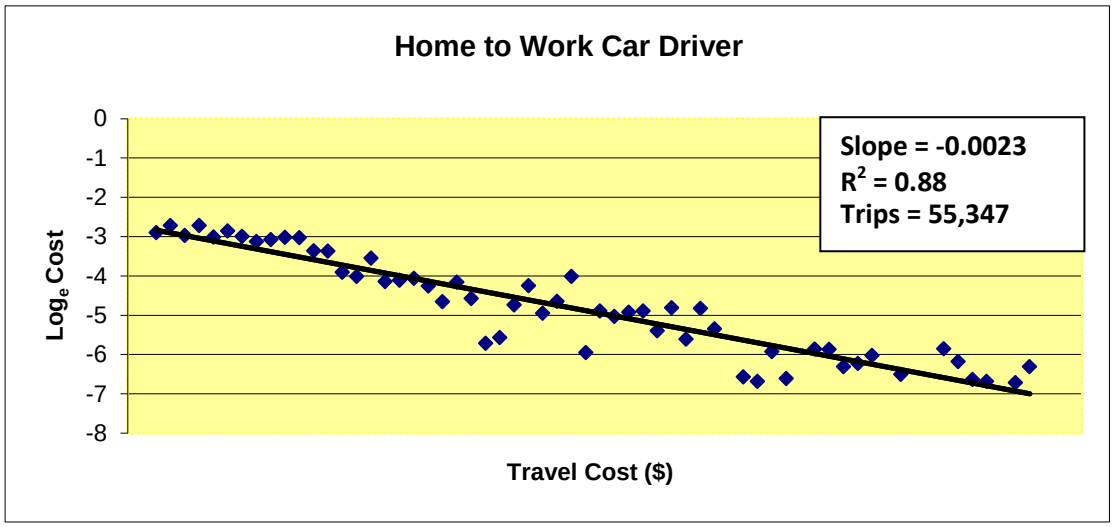


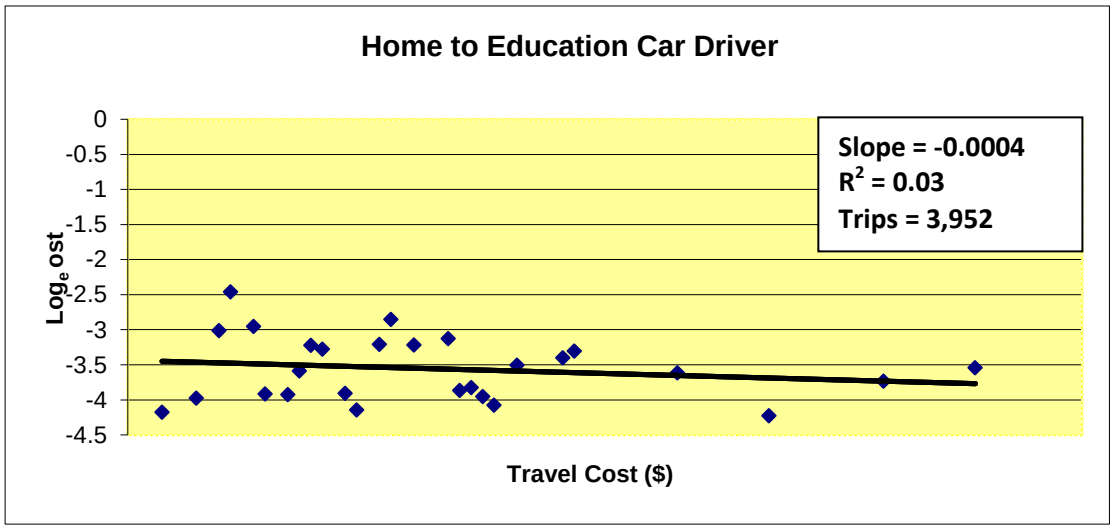
Urban and Rural Regions in Waikato

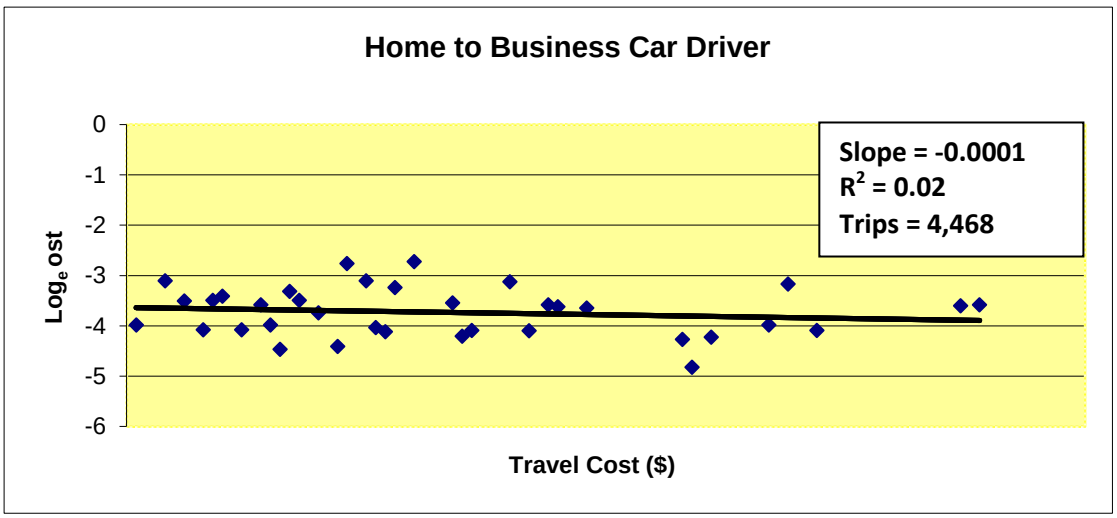
1

Period	Purpose	Figure	Trip Cost ($)			
			HIS		Model	
			Mean	SD	Mean	SD
Morning Peak	Home to Work – Urban	4A	3.42	2.39	3.42	2.30
	– Rural		5.14	5.88	5.23	5.06
	Home to Education	4A	3.96	3.22	4.00	3.98
	Home to Business	4A	8.31	10.71	8.46	7.82
	Home to Shop	4B	3.67	5.44	3.63	3.82
	Home to Other – Urban	4B	3.72	2.78	3.80	2.52
	– Rural		5.23	7.12	5.22	5.60
	Non Home Based – Urban	4C	4.44	3.38	4.43	3.14
	– Rural		6.68	10.90	6.57	7.31
	Other to Home	4C	2.99	4.40	2.97	2.91
Interpeak	Home to Work	6A	3.44	4.70	3.36	3.39
	Home to Business	6A	11.20	18.11	11.41	11.03
	Home to Shop	6B	3.27	4.18	3.42	3.58
	Home to Other	6B	6.54	9.05	6.55	5.97
	Non Home Based – Urban	6C	5.28	4.46	5.34	4.07
	– Rural		6.71	11.76	6.77	7.90
	Other to Home	6C	4.52	5.24	4.35	3.94
	Work to Home	6C	4.01	5.18	4.02	3.73
	Business to Home	6D	6.12	4.36	6.06	8.58
	Shop to Home	6D	3.07	3.90	3.13	3.37
Evening Peak	Home to Shop	8B	2.02	2.08	2.06	2.45
	Home to Social/Rec	8B	3.95	5.49	4.01	3.65
	Home to Other	8B	4.29	4.13	4.32	3.84
	Non Home Based – Urban	8C	4.88	4.03	4.87	3.87
	– Rural		6.03	10.43	6.23	7.43
	Other to Home – Urban	8C	3.97	3.07	4.00	2.54
	– Rural		8.64	12.64	8.62	8.03
	Work to Home – Urban	8C	3.52	2.44	3.53	2.34
	– Rural		5.48	5.86	4.90	4.82
	Education to Home	8D	5.86	5.06	6.13	6.04
	Business to Home	8D	10.12	8.18	10.07	10.27
	Shop to Home – Urban	8D	1.96	1.69	2.03	1.33
	– Rural		4.46	4.71	4.41	5.05

Table 7: Comparison of HIS and Modelled Trip Lengths

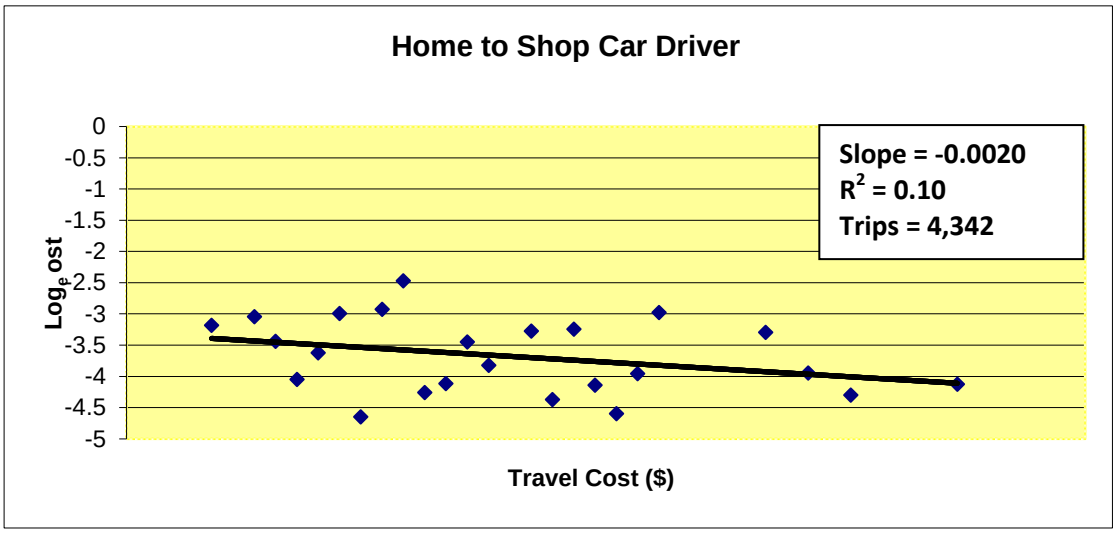


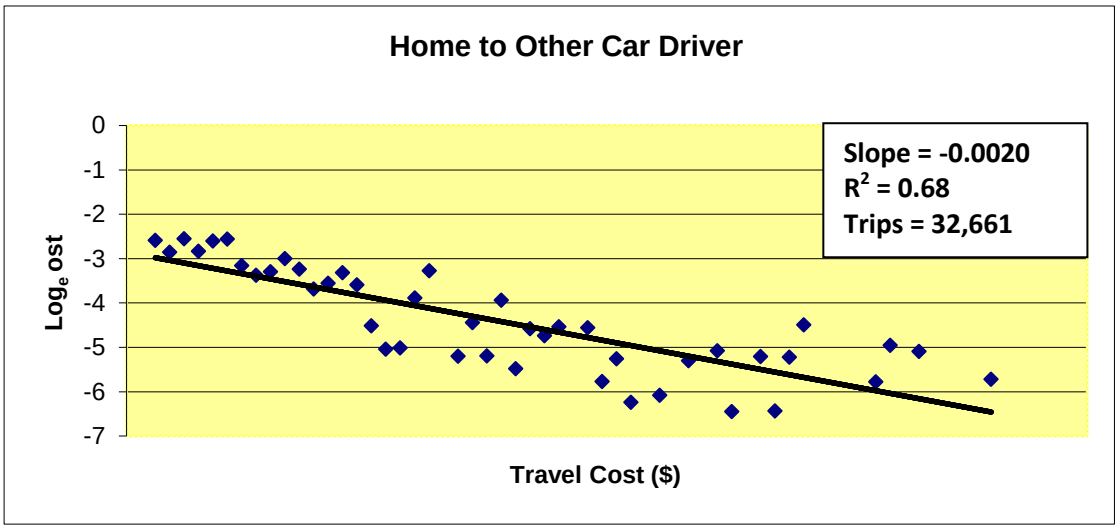


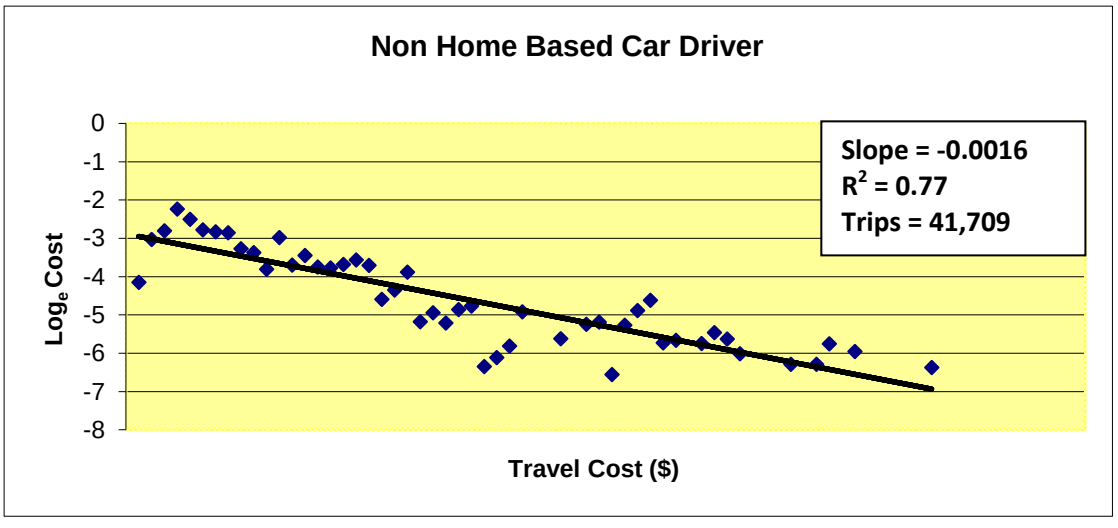


Distribution Functions (HTW/HTE/HTB)
Morning Peak Car Drivers

2a

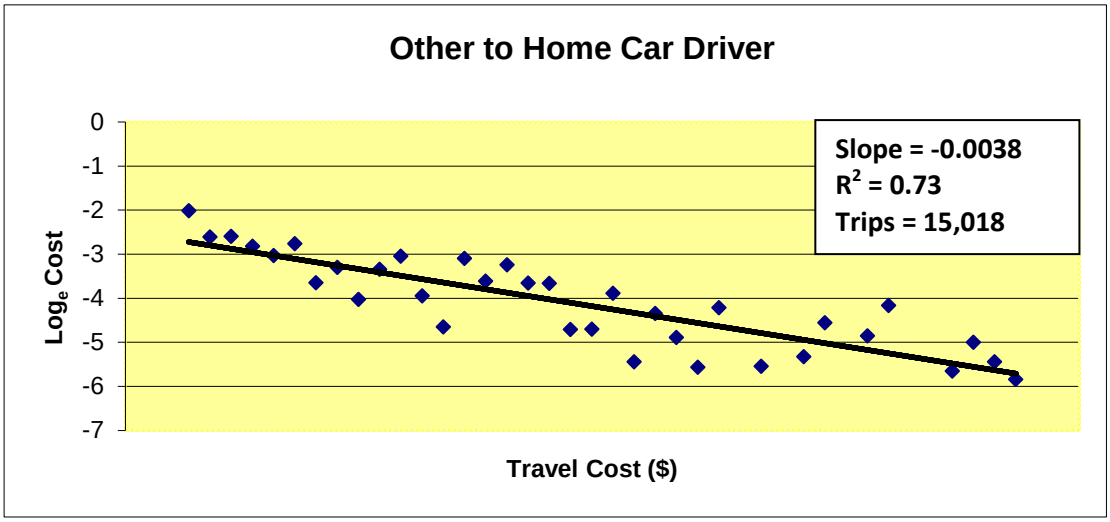






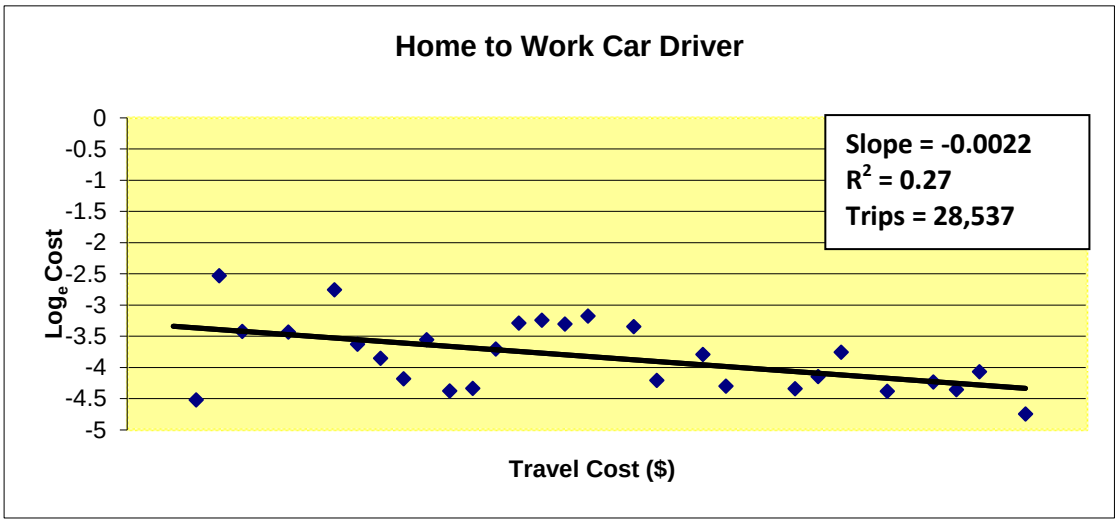
Distribution Functions (HTS/HTO/NHB)
Morning Peak Car Drivers

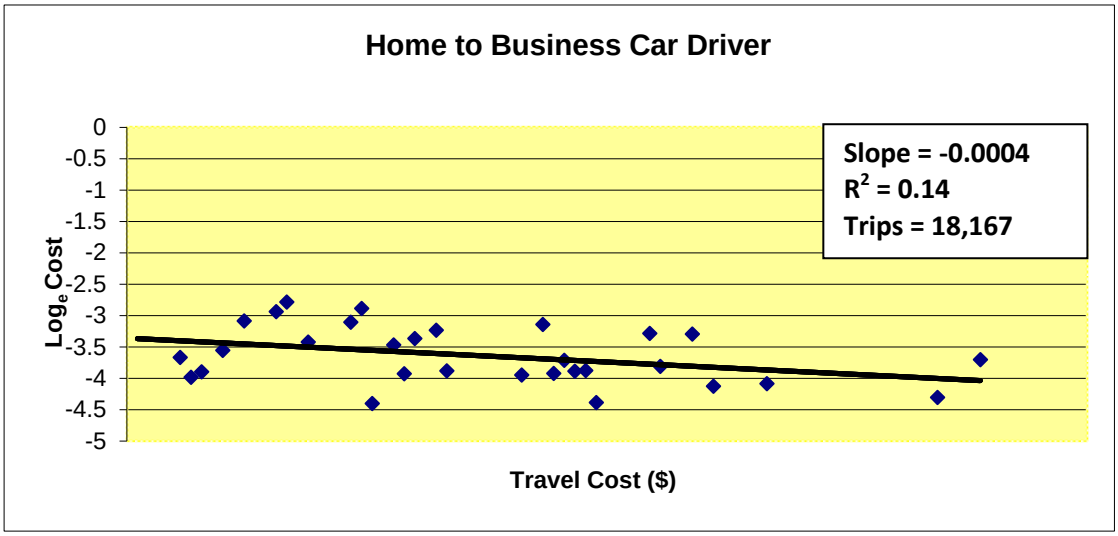
2b

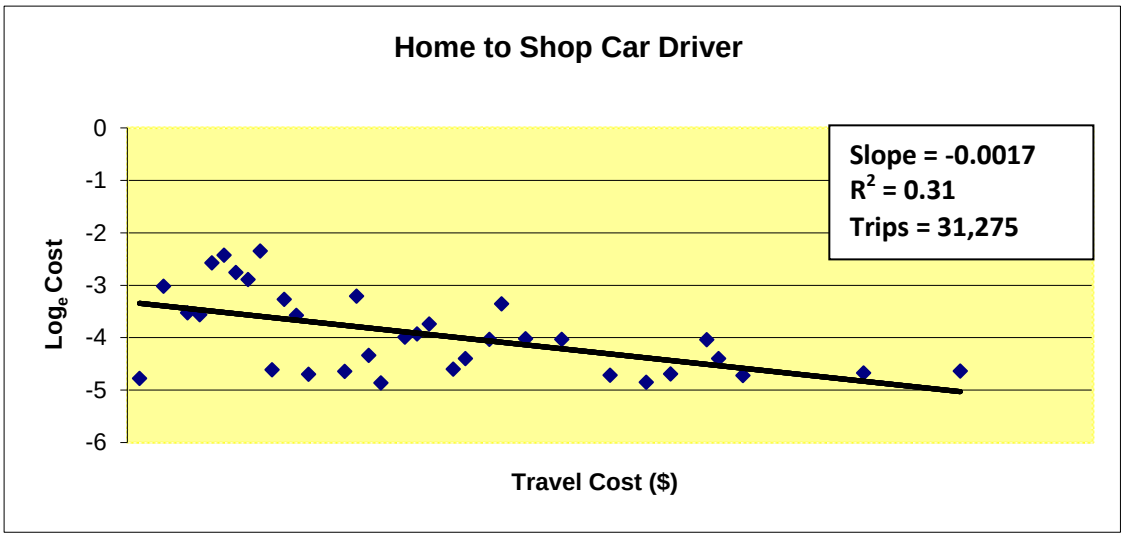


Distribution Functions (OTH)
Morning Peak Car Drivers

2c

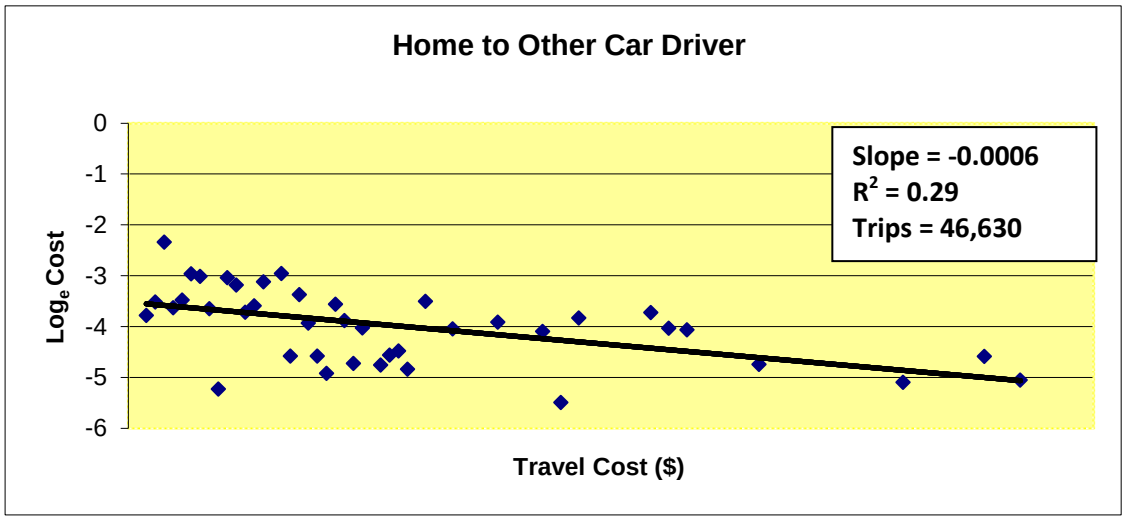


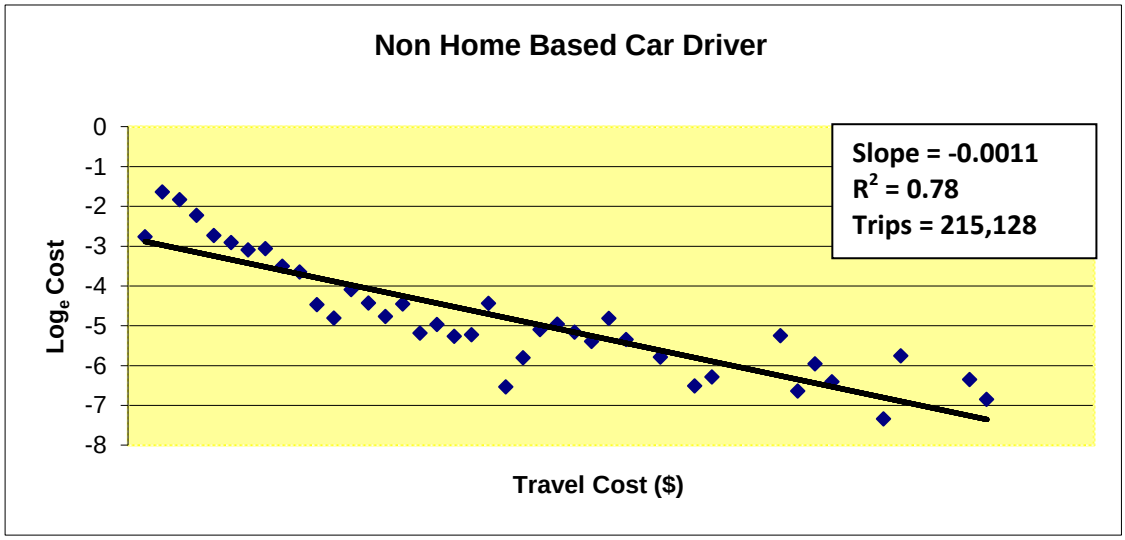


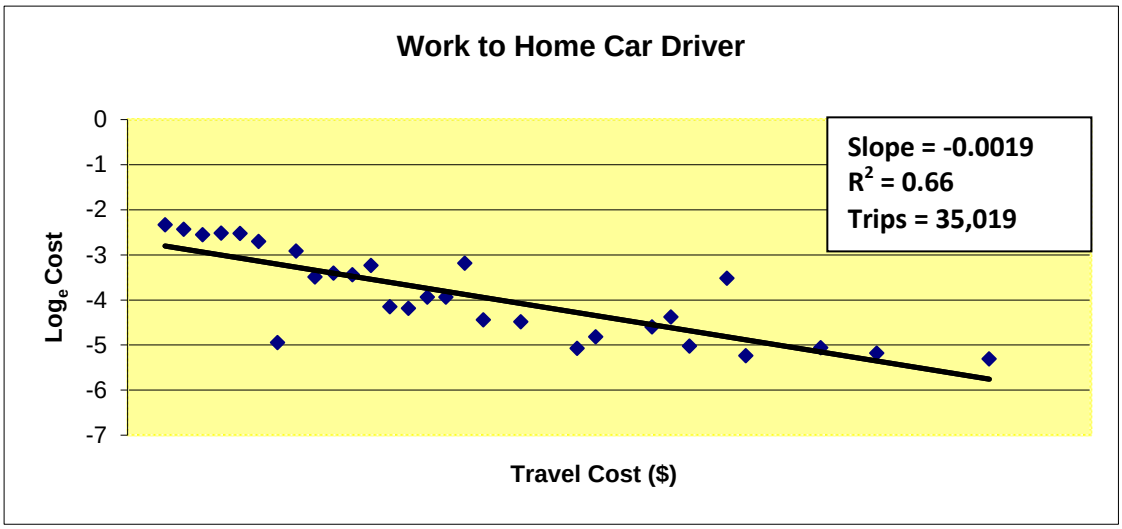


Distribution Functions (HTW/HTB/HTS)
Inter Peak Car Drivers

3a

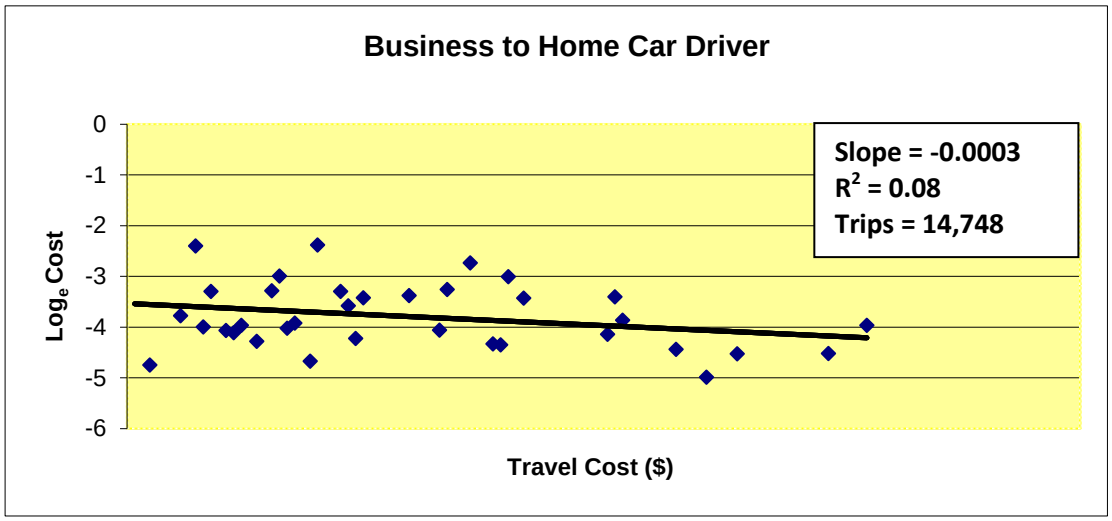


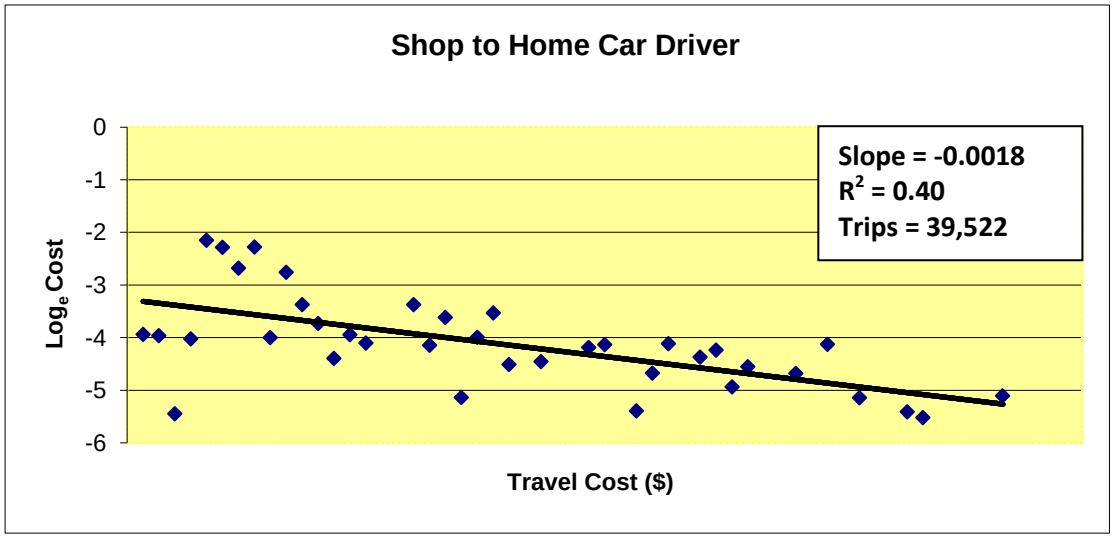


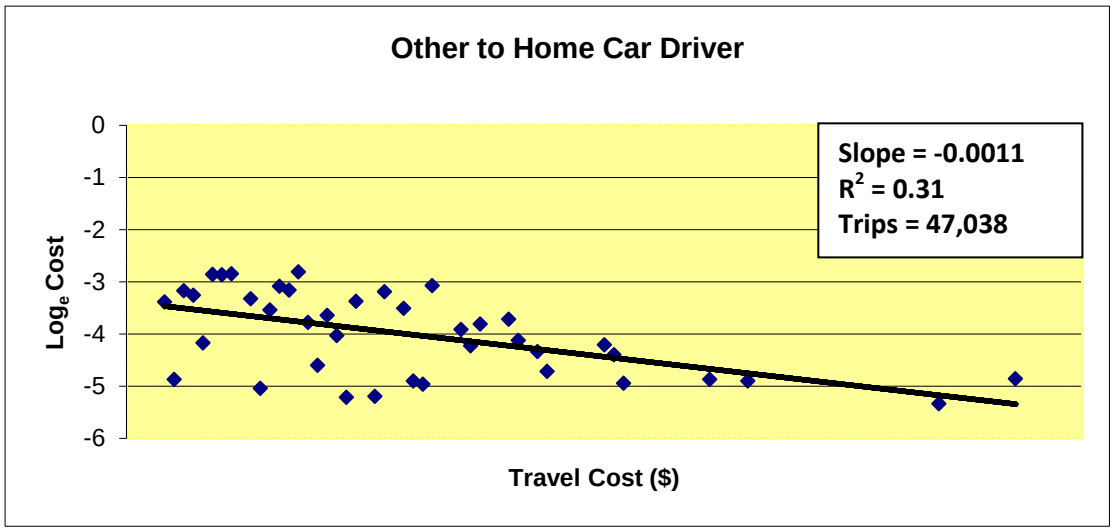


Distribution Functions (HTO/NHB/WTH)
Inter Peak Car Drivers

3b

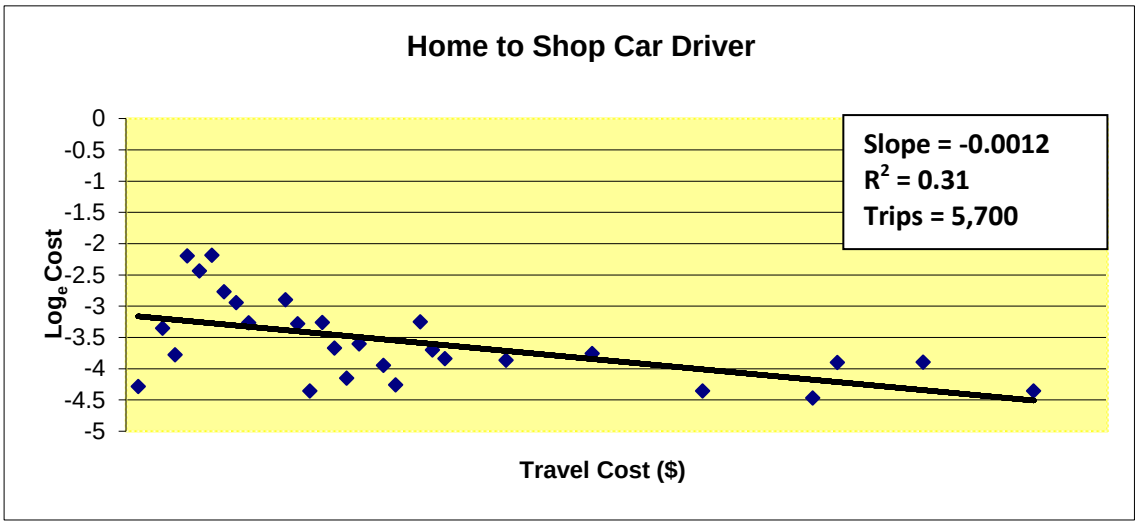


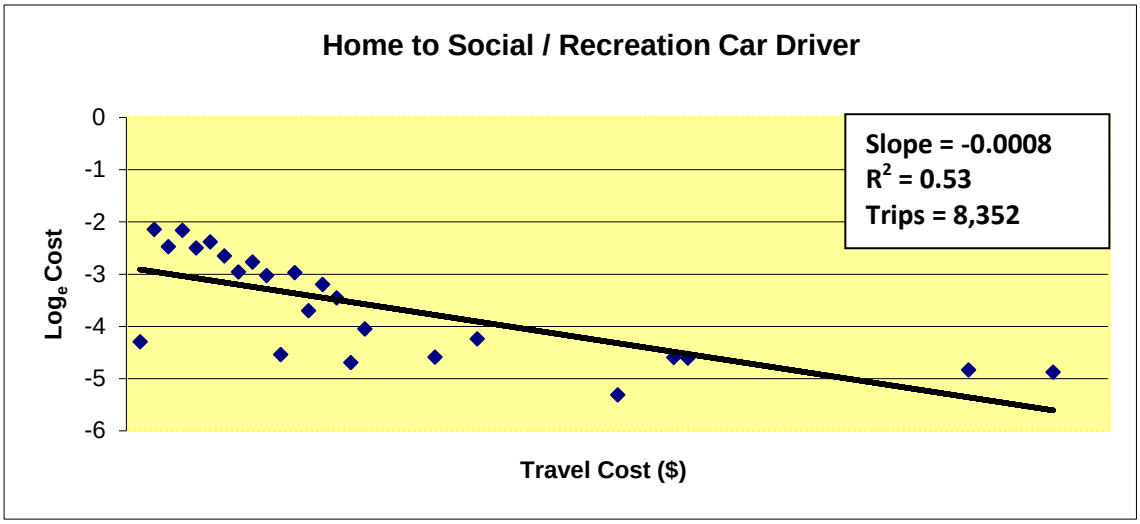


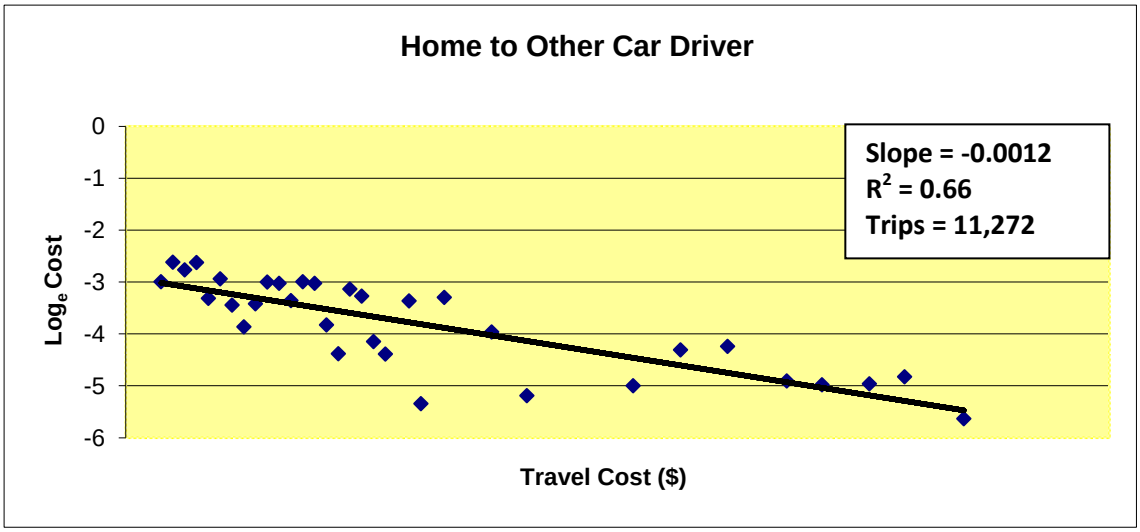


Distribution Functions (BTH/STH/OTH)
Inter Peak Car Drivers

3c

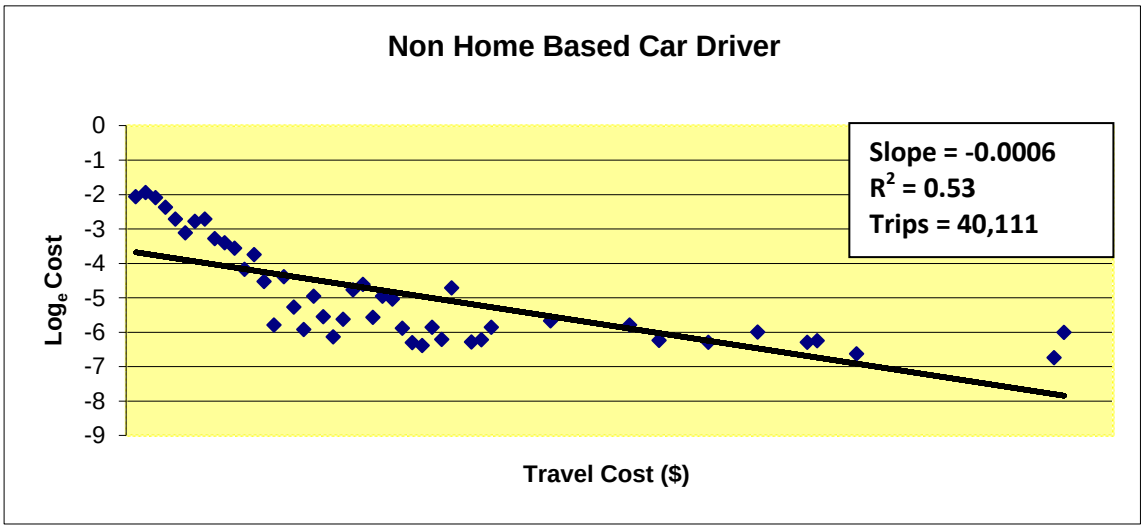


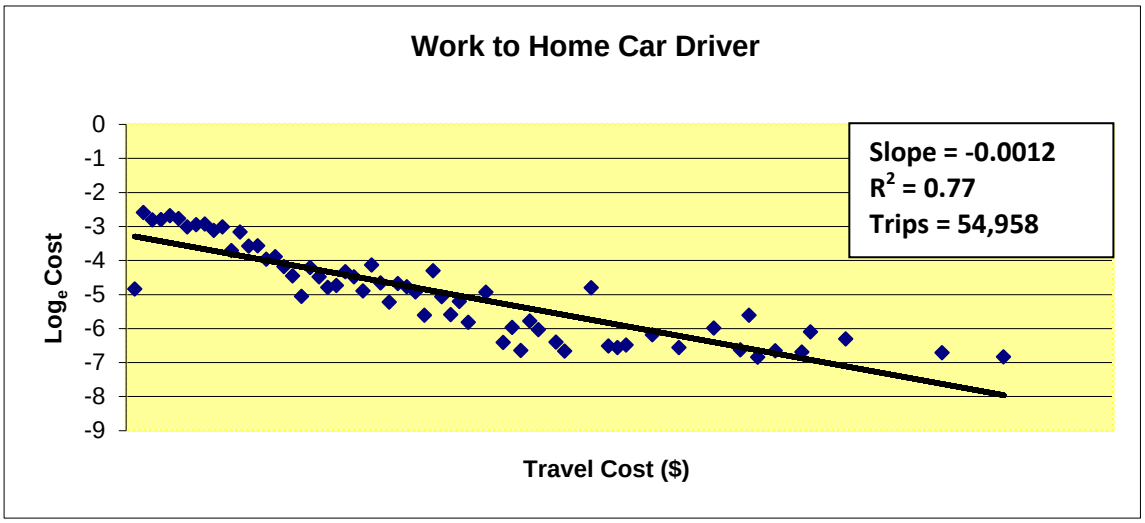


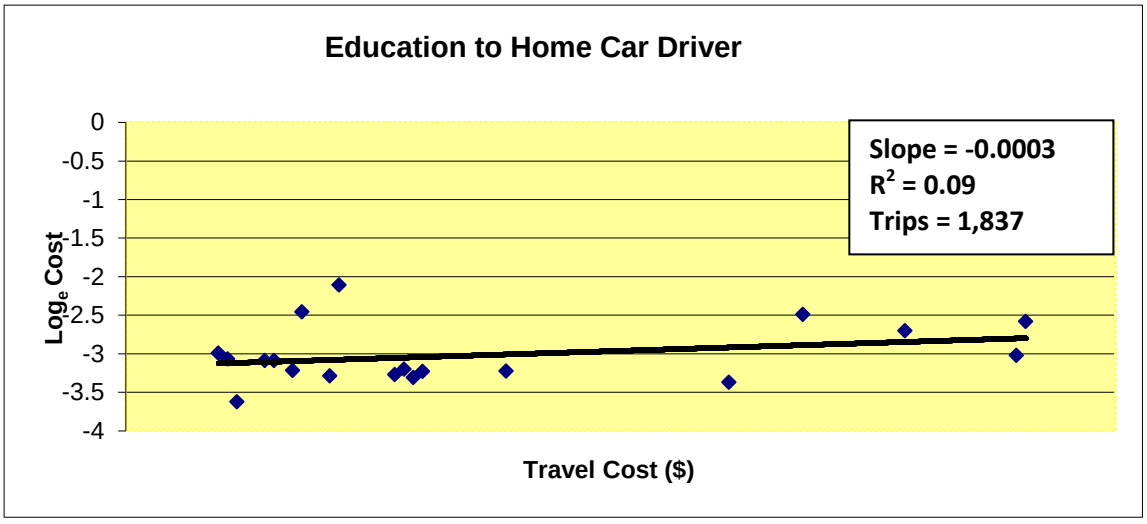


Distribution Functions (HTS/HTR/HTO)
Evening Peak Car Drivers

4a

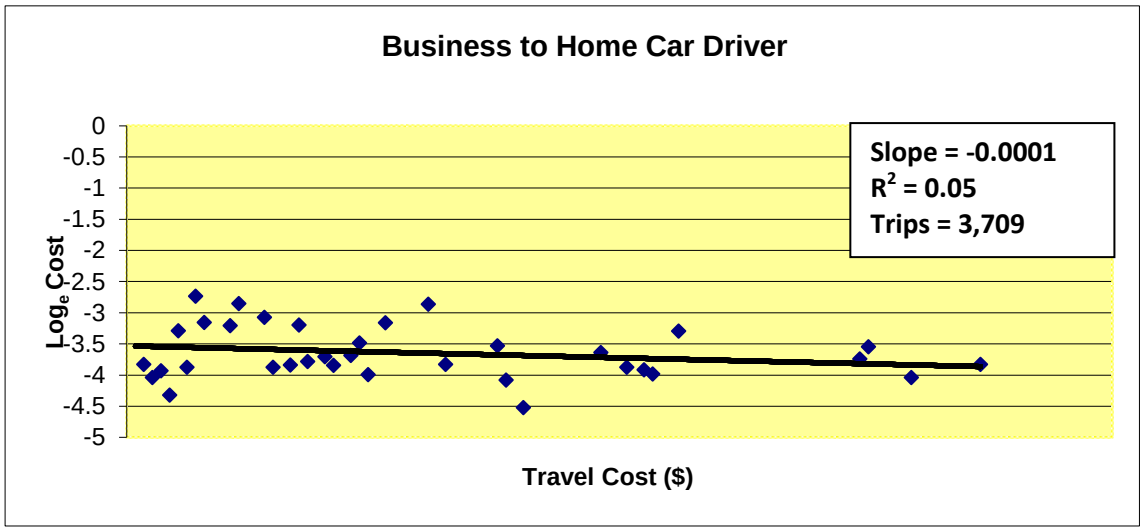


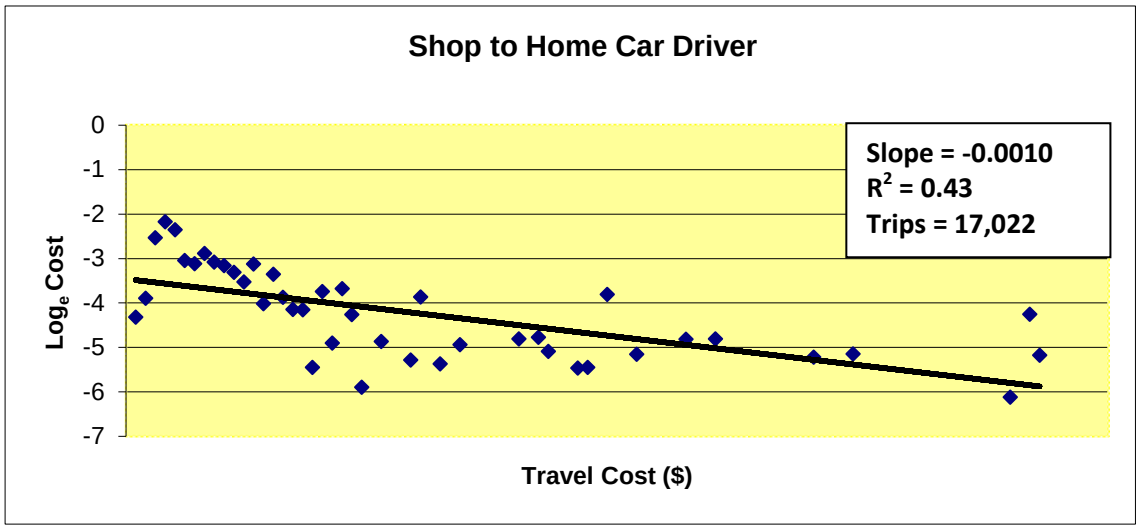


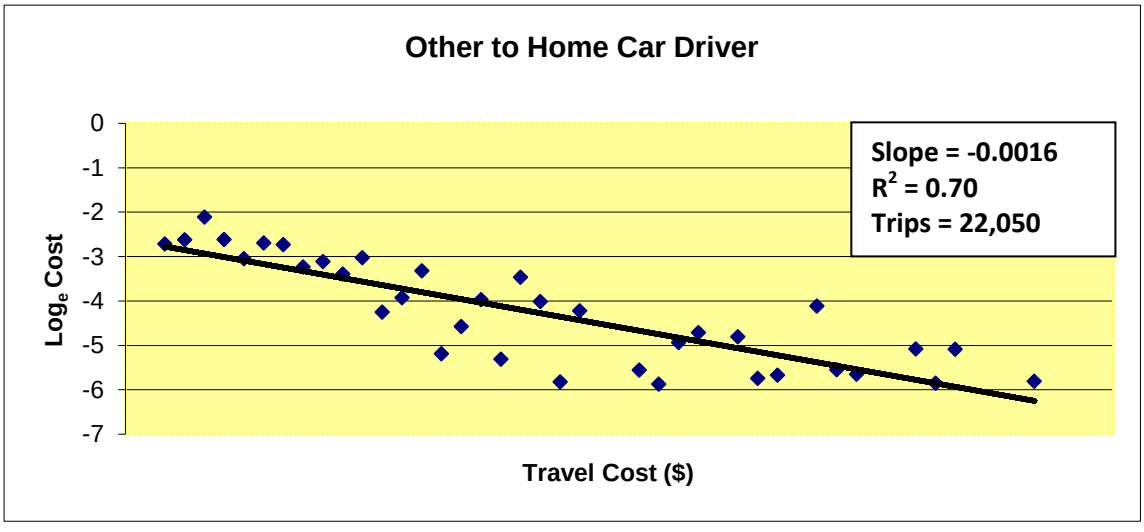


Distribution Functions (NHB/WTH/ETH)
Evening Peak Car Drivers

4b

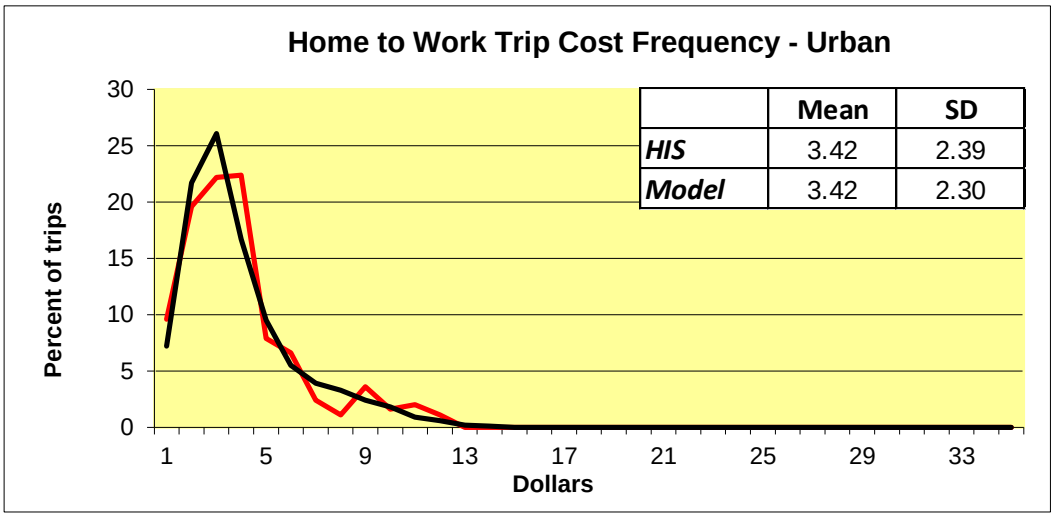


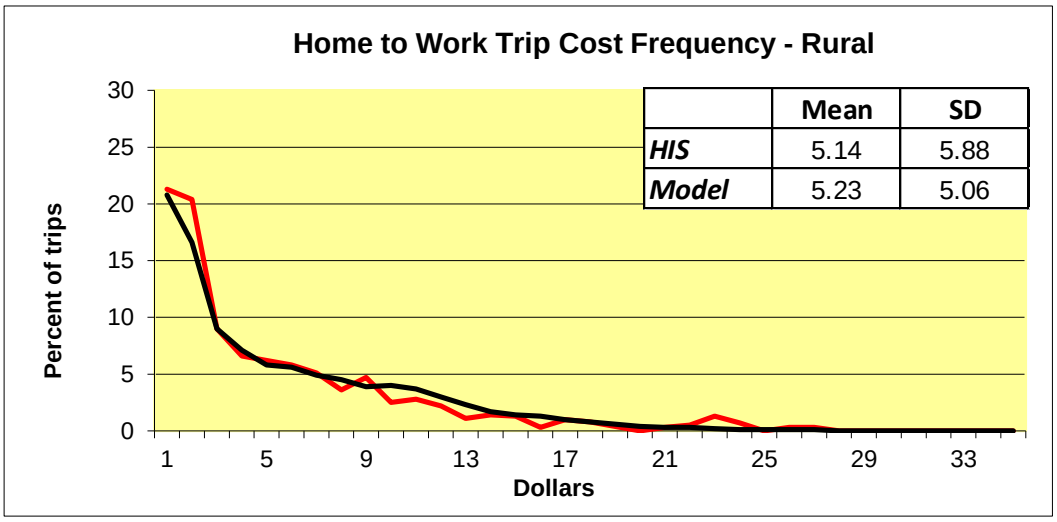


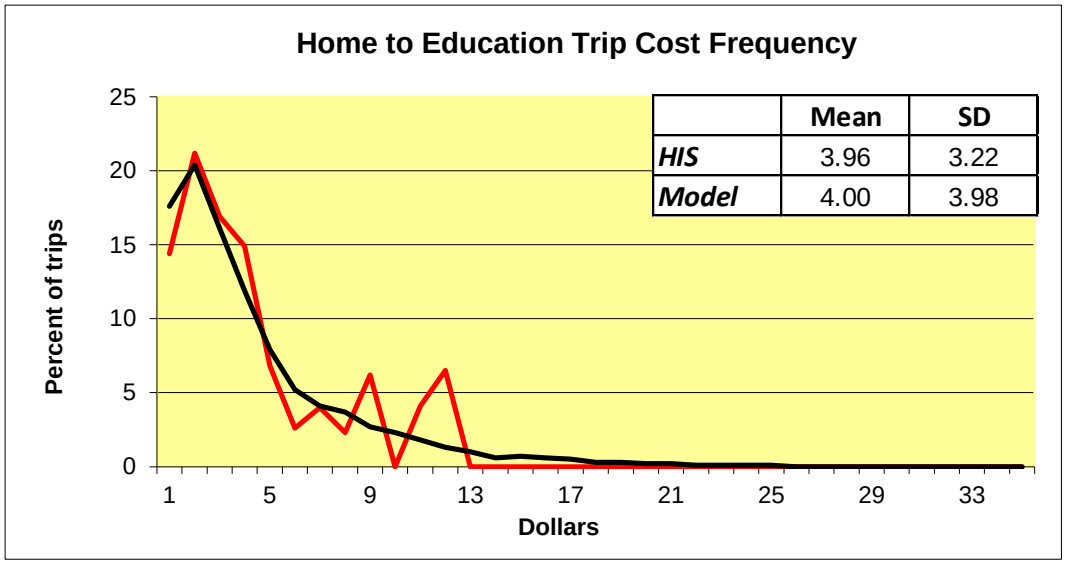


Distribution Functions (BTH/STH/OTH)
Evening Peak Car Drivers

4c

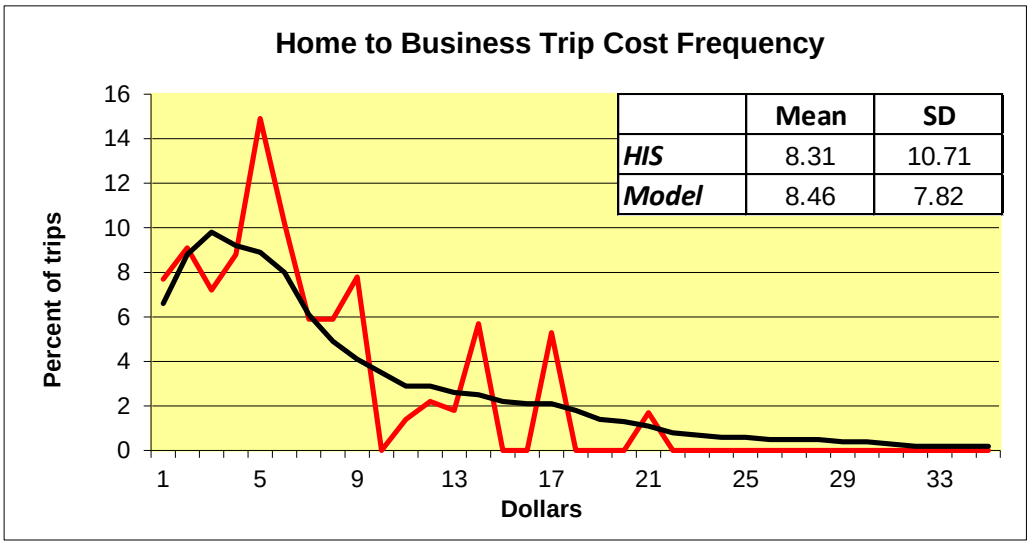


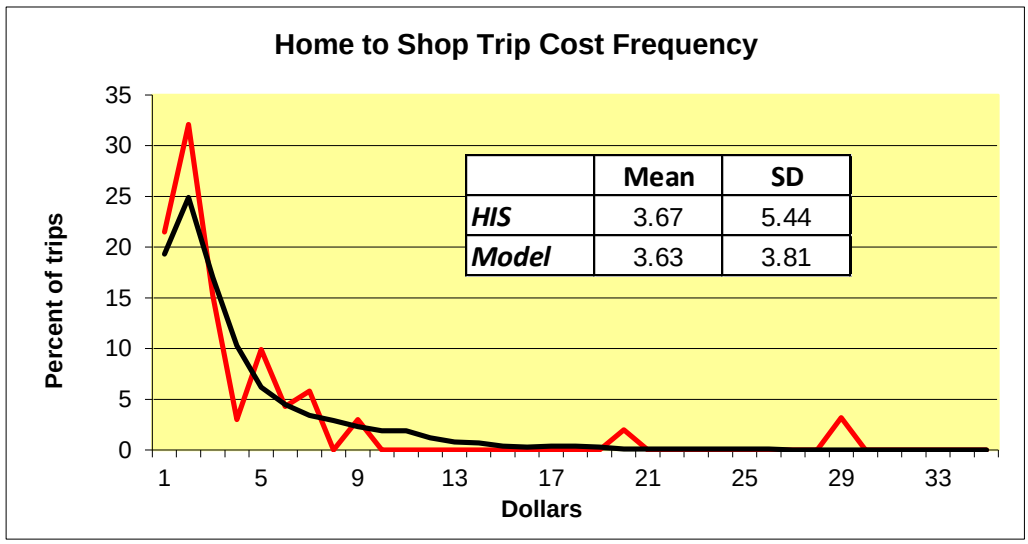


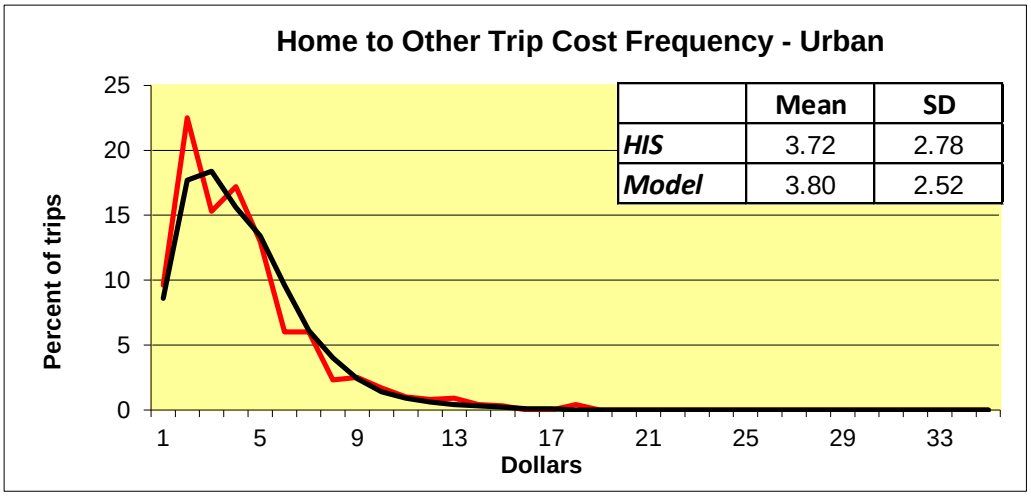


Trip Cost Frequency Plots (HTW/HTEd)
Morning Peak Car Drivers

5a

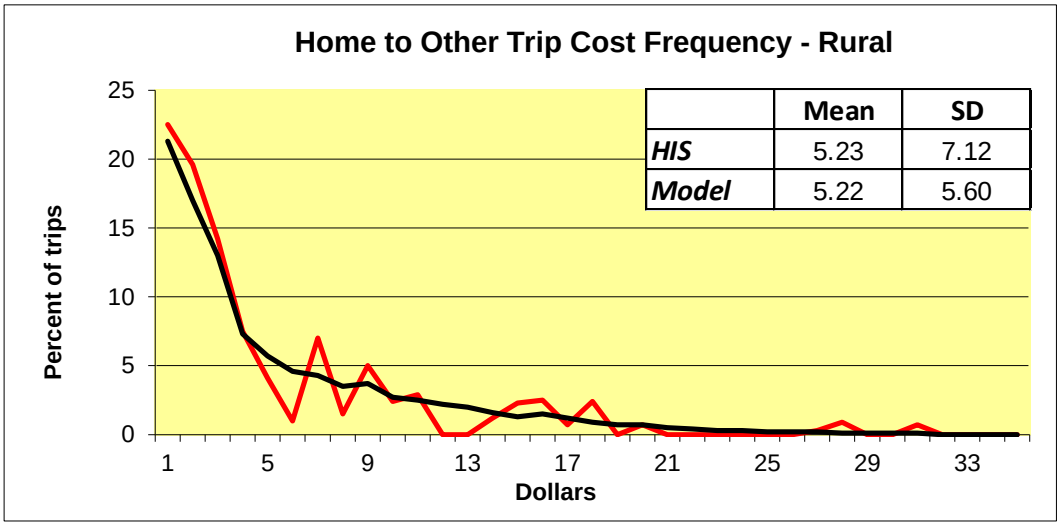


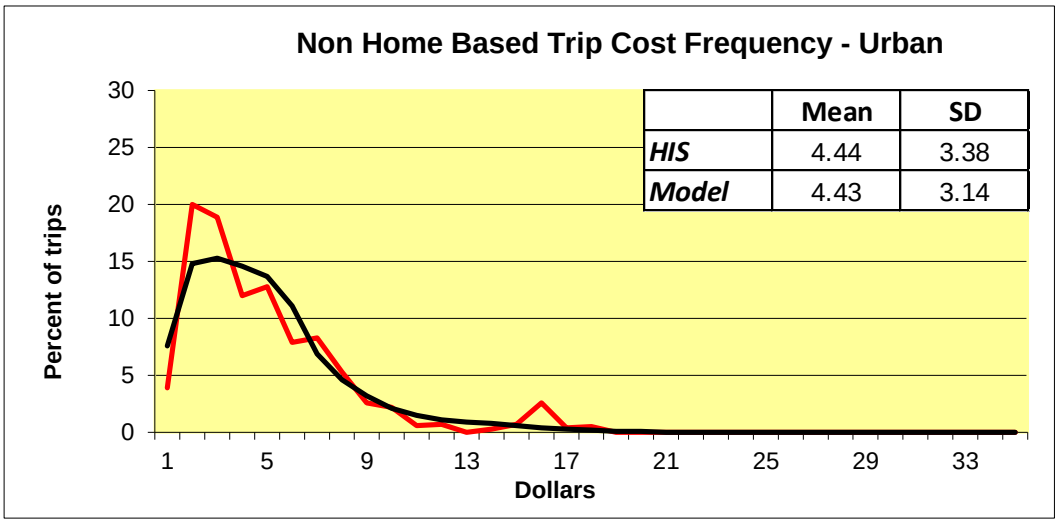


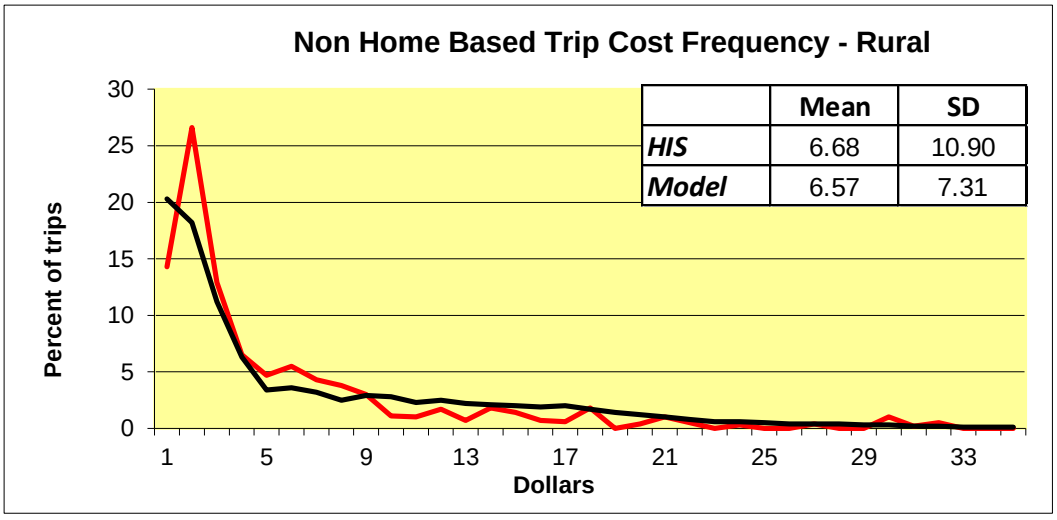


Trip Cost Frequency Plots (HTB/HTS/HTO)
Morning Peak Car Drivers

5b

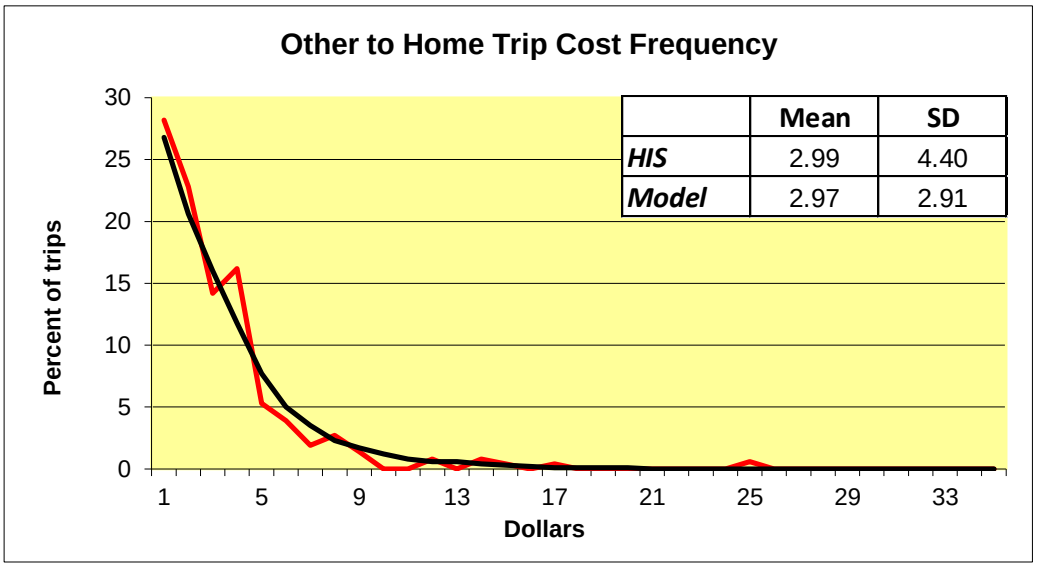






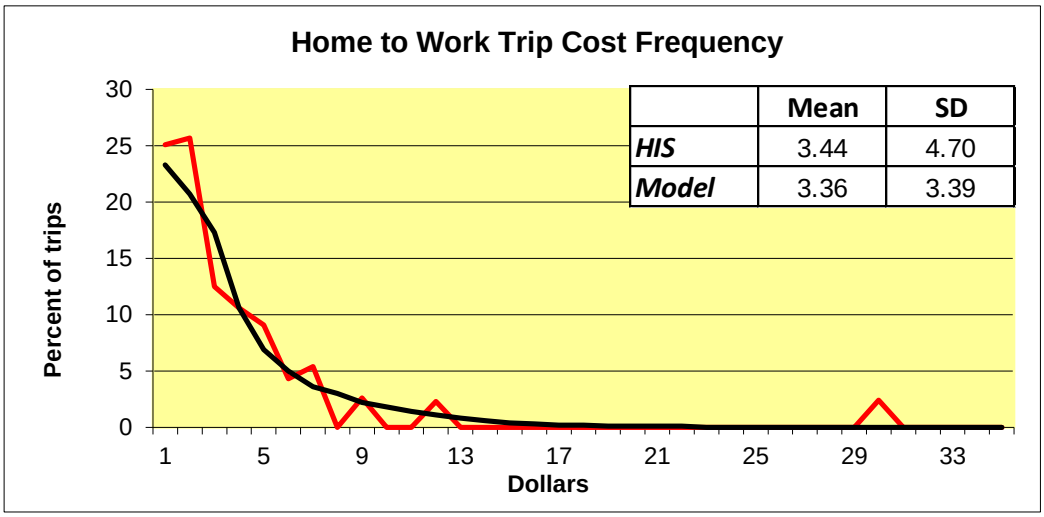
Trip Cost Frequency Plots (HTO/NHB)
Morning Peak Car Drivers

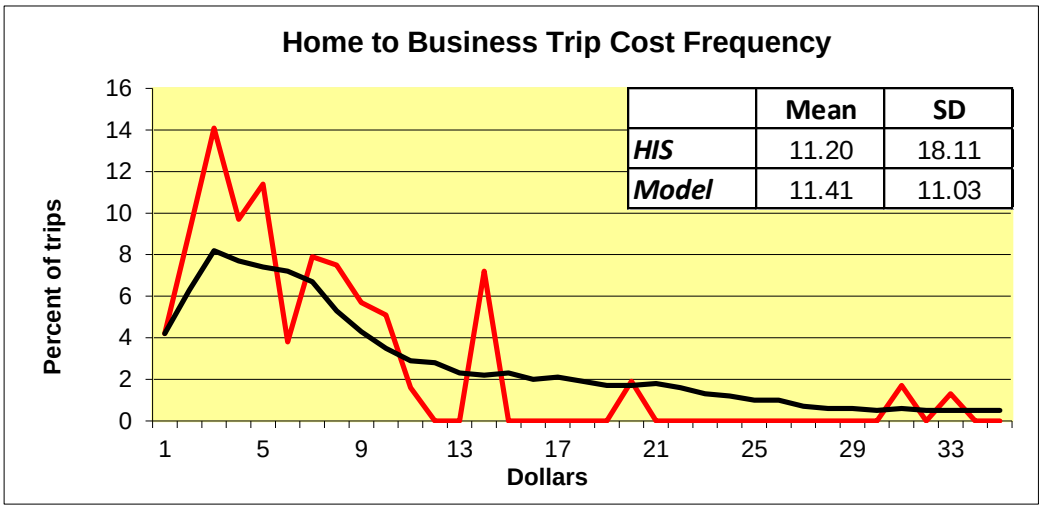
5c

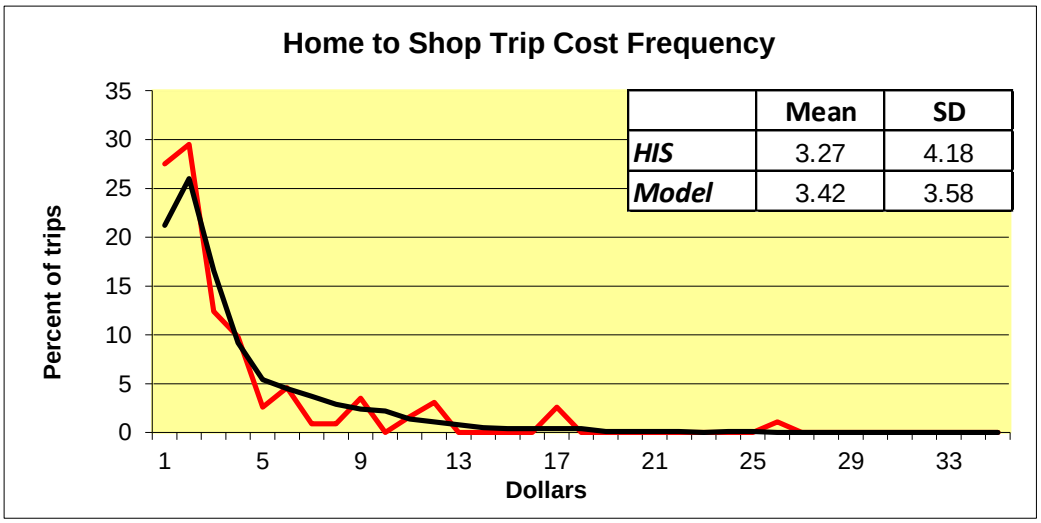


Trip Cost Frequency Plots (OTH)
Morning Peak Car Drivers

5d

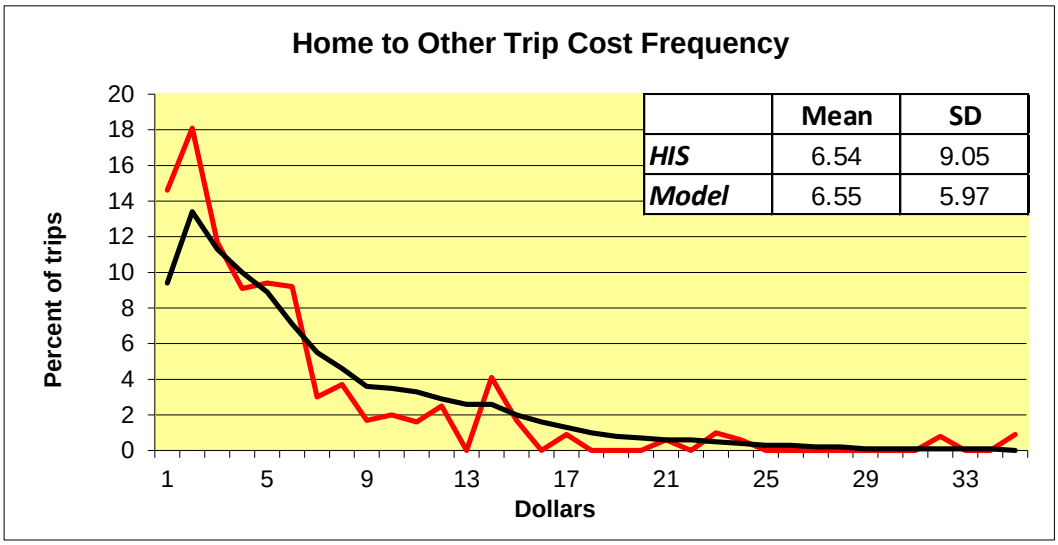




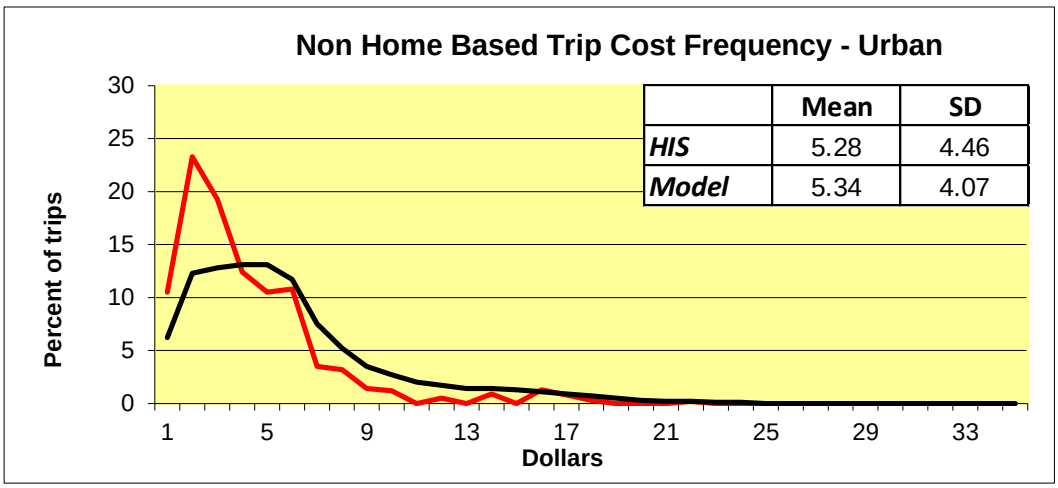


Trip Cost Frequency Plots (HTW/HTB/HTS)
Inter Peak Car Drivers

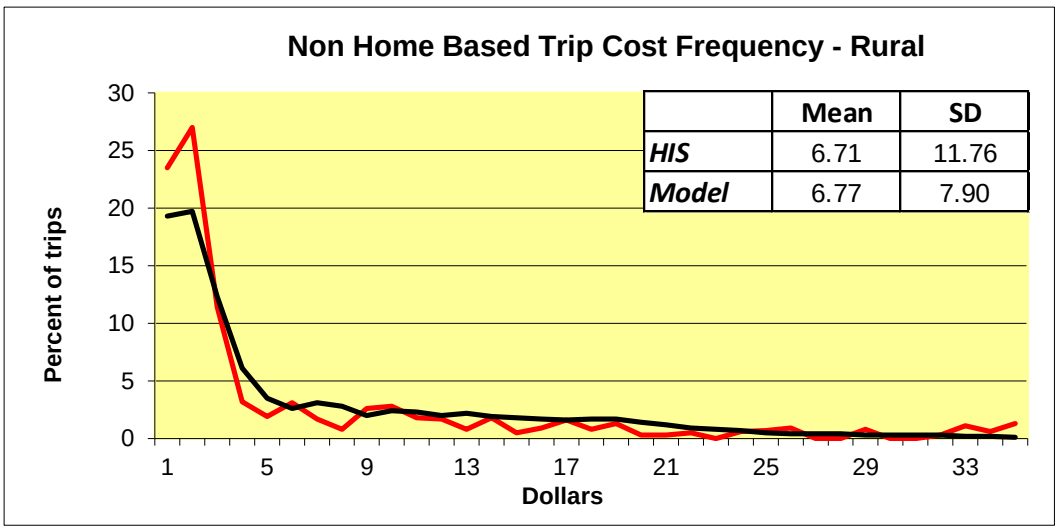
6a



	Mean	SD
HIS	6.54	9.05
Model	6.55	5.97



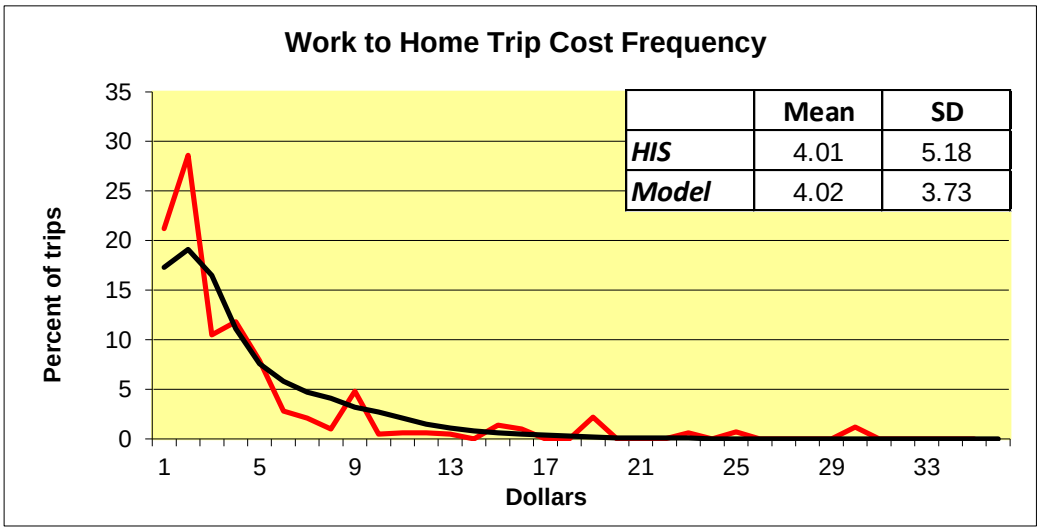
	Mean	SD
HIS	5.28	4.46
Model	5.34	4.07

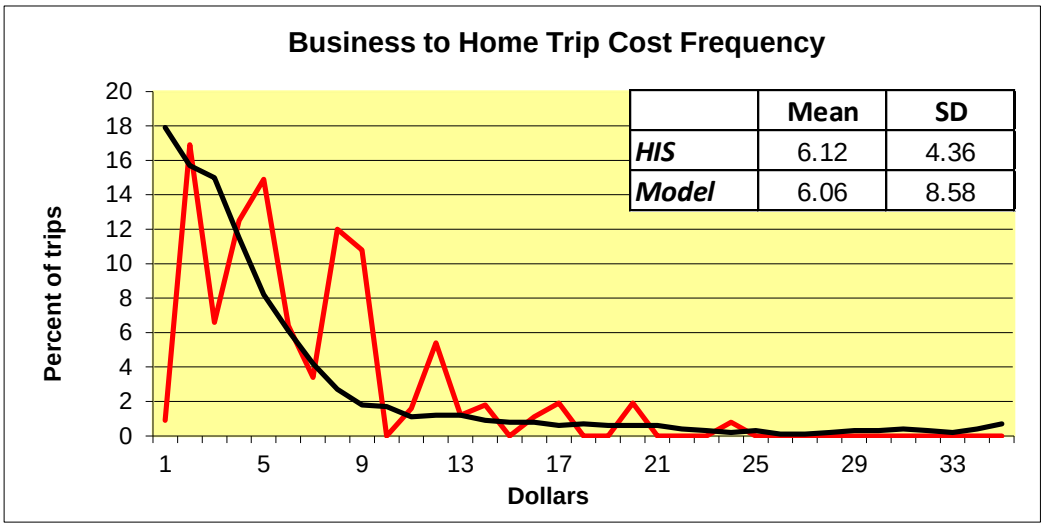


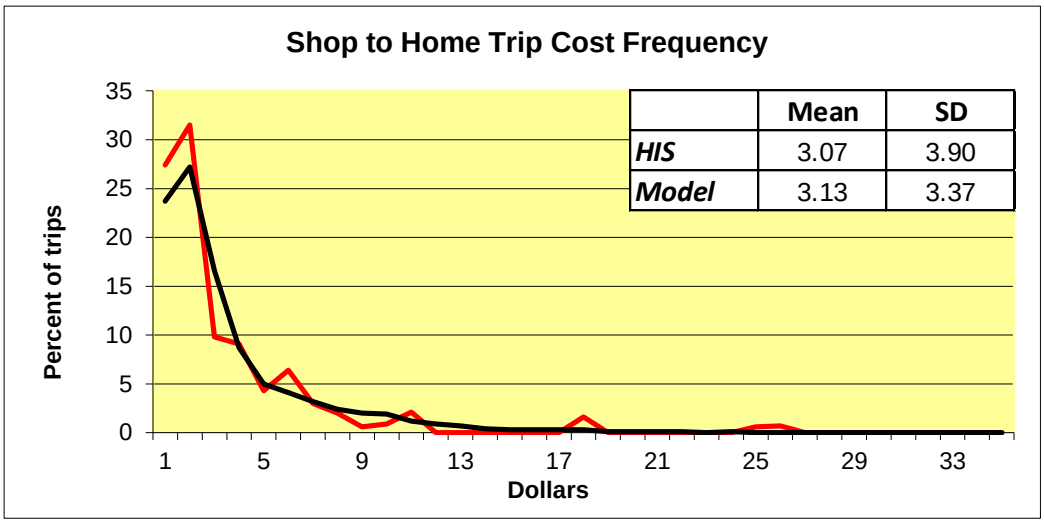
	Mean	SD
HIS	6.71	11.76
Model	6.77	7.90

Trip Cost Frequency Plots (HTO/NHB)
Inter Peak Car Drivers

6b

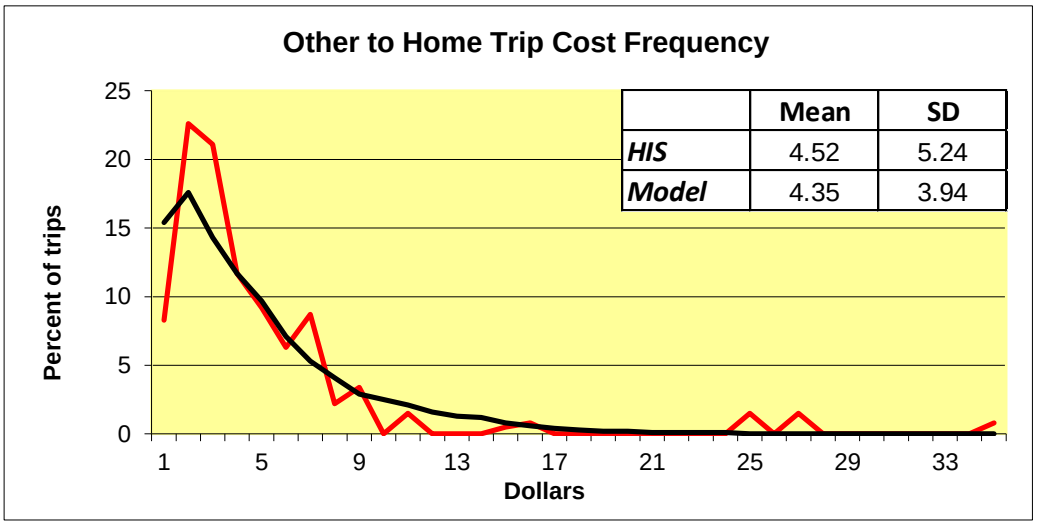






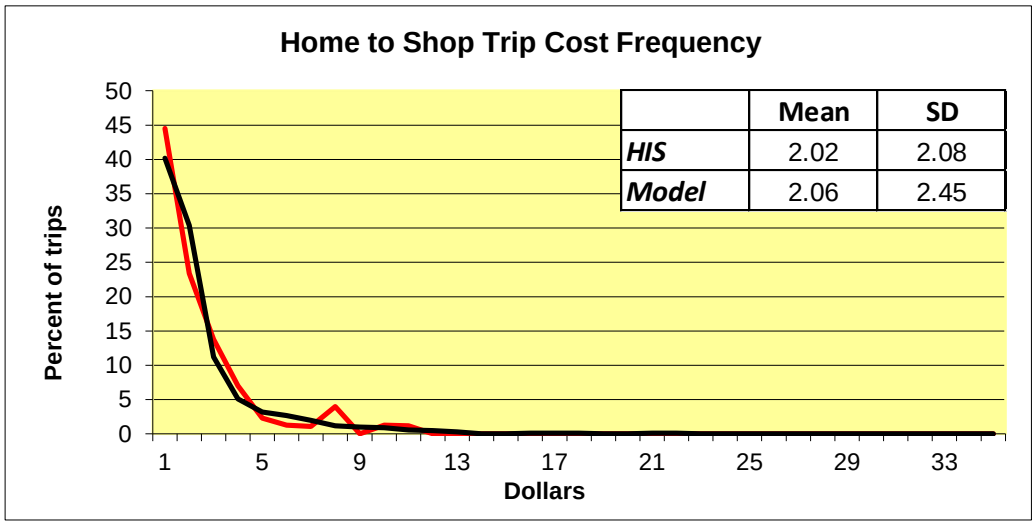
Trip Cost Frequency Plots (WTH/BTH/STH)
Inter Peak Car Drivers

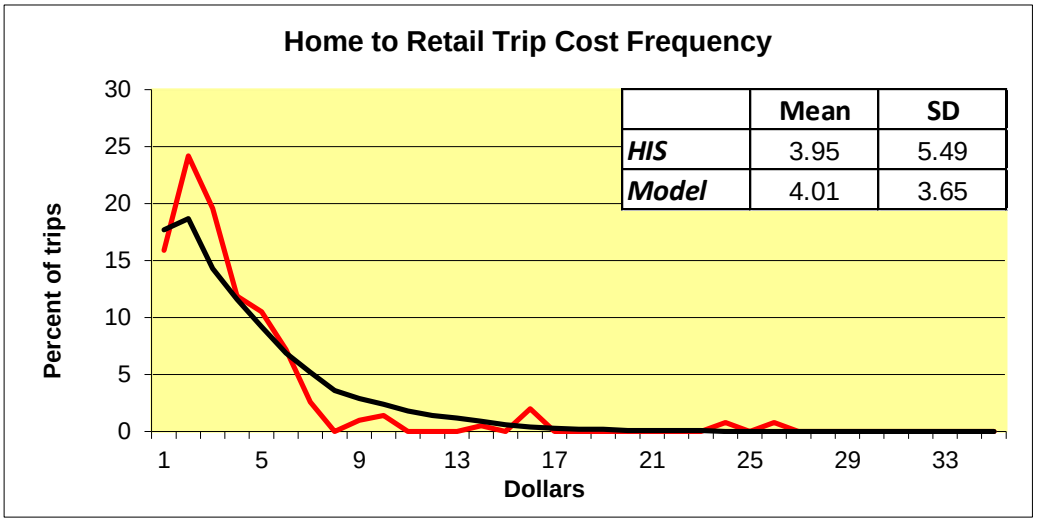
6c

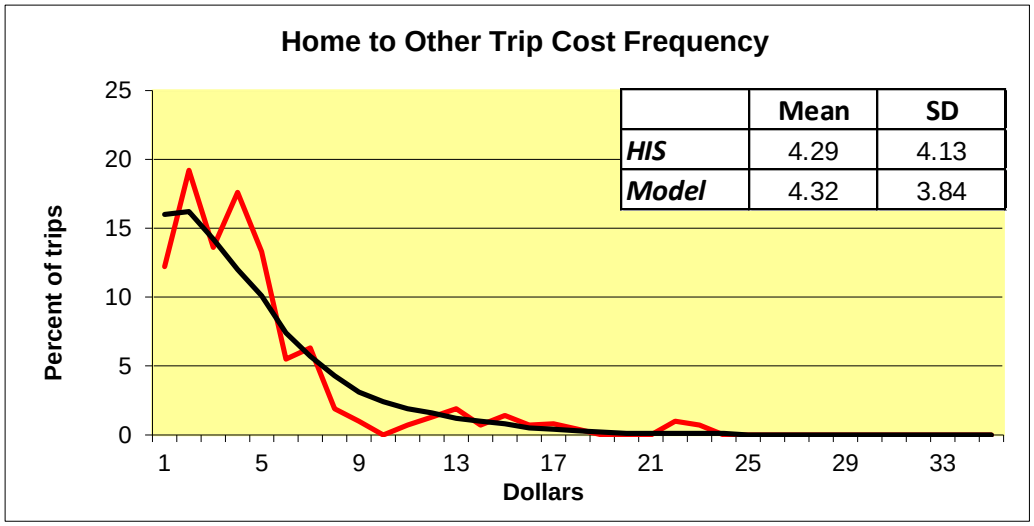


Trip Cost Frequency Plots (OTH)
Inter Peak Car Drivers

6d

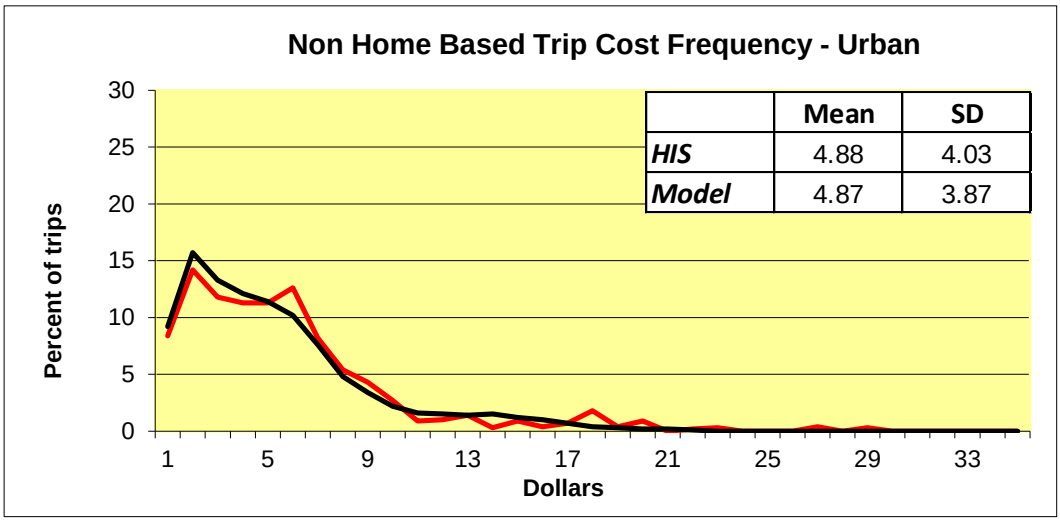


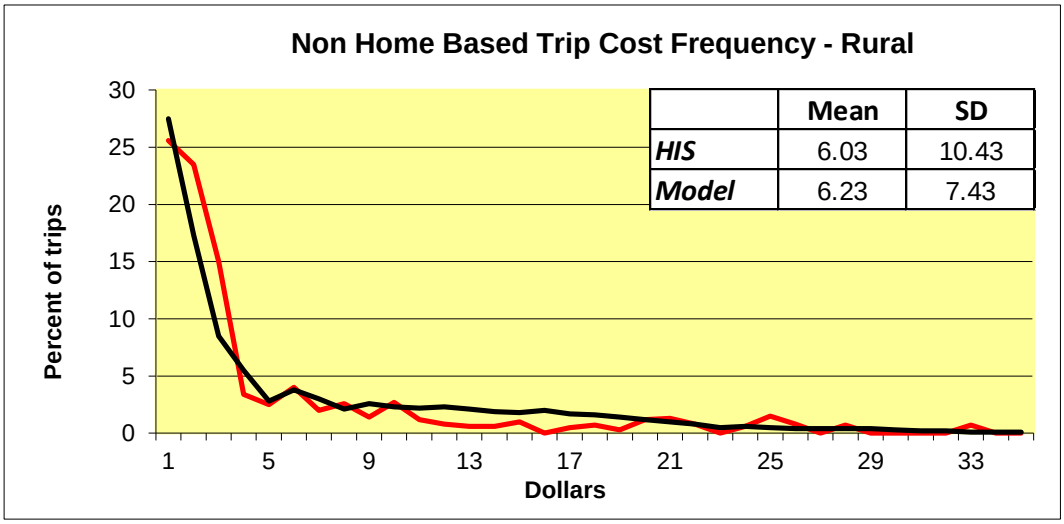


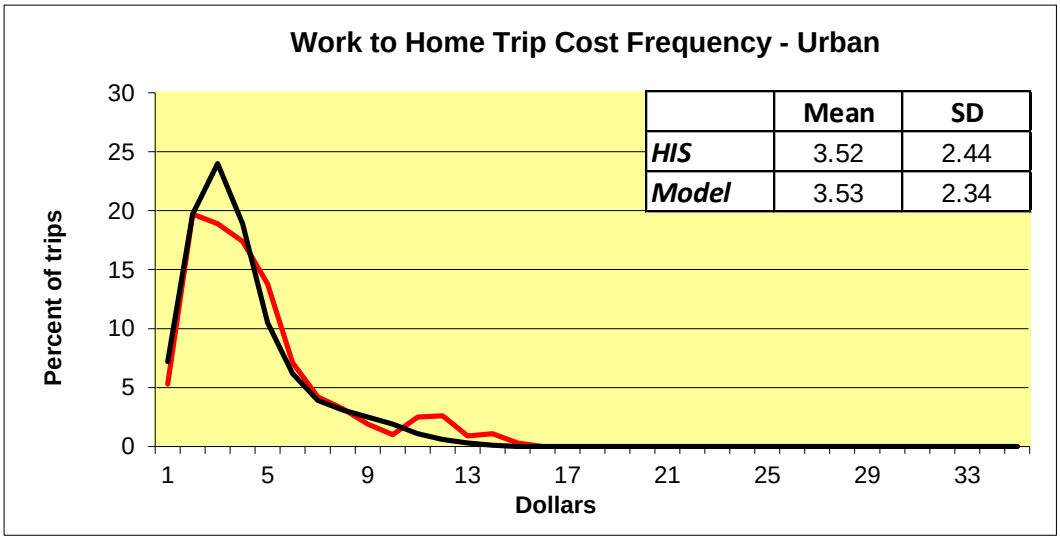


Trip Cost Frequency Plots (HTS/HTR/HTO)
Evening Peak Car Drivers

7a

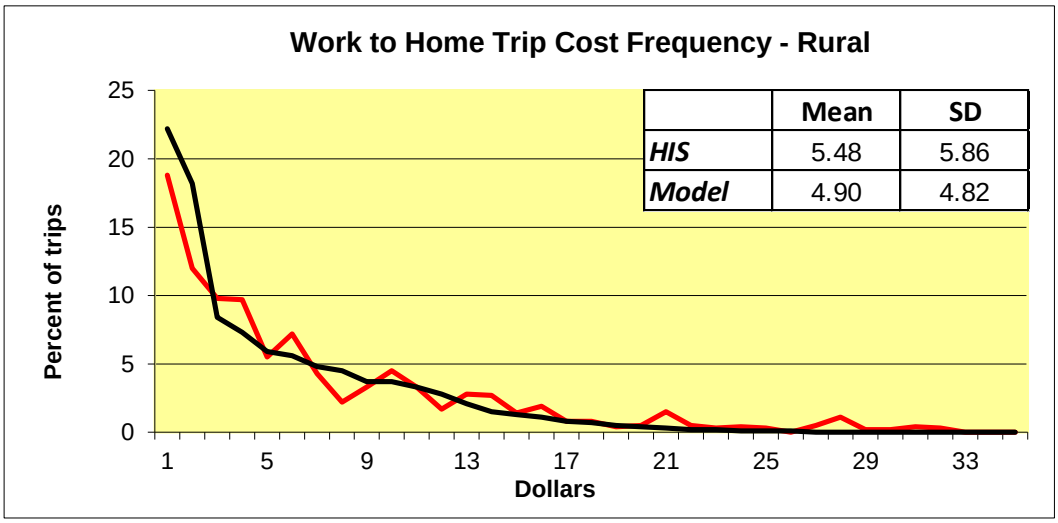


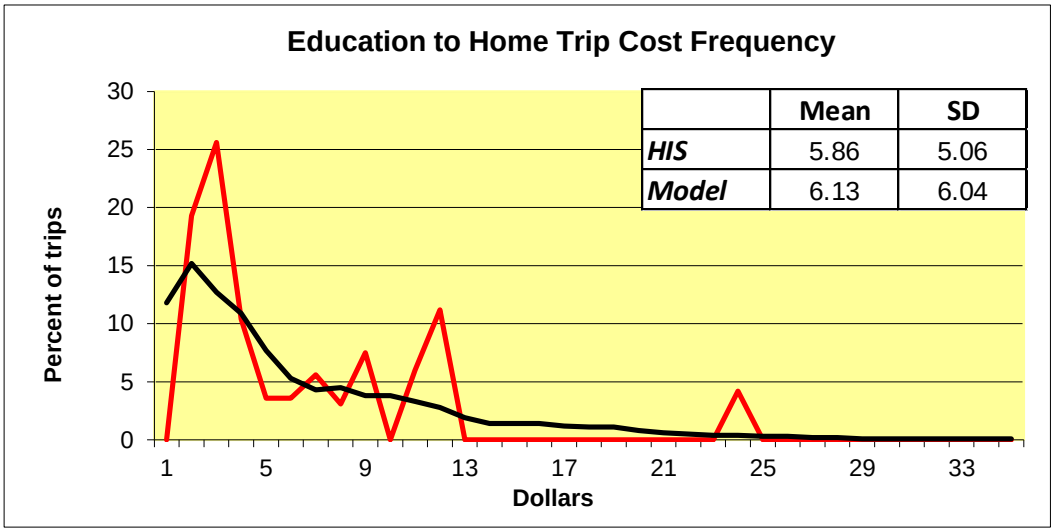


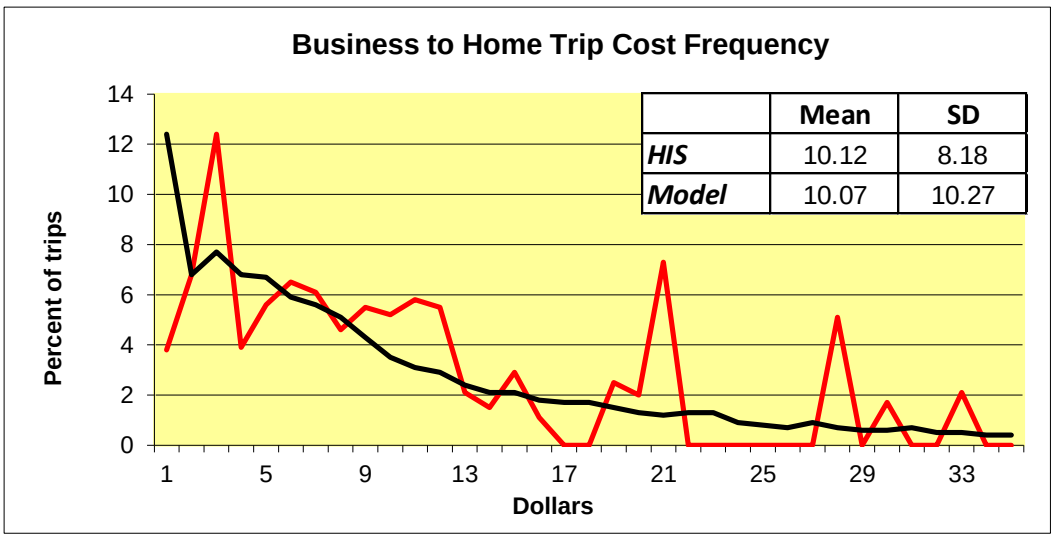


Trip Cost Frequency Plots (NHB/WTH)
Evening Peak Car Drivers

7b

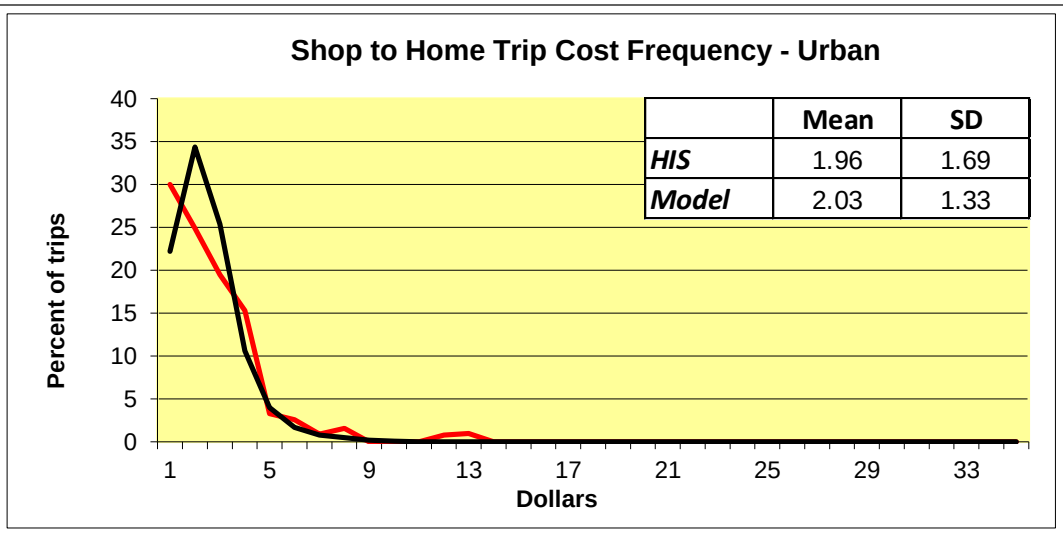


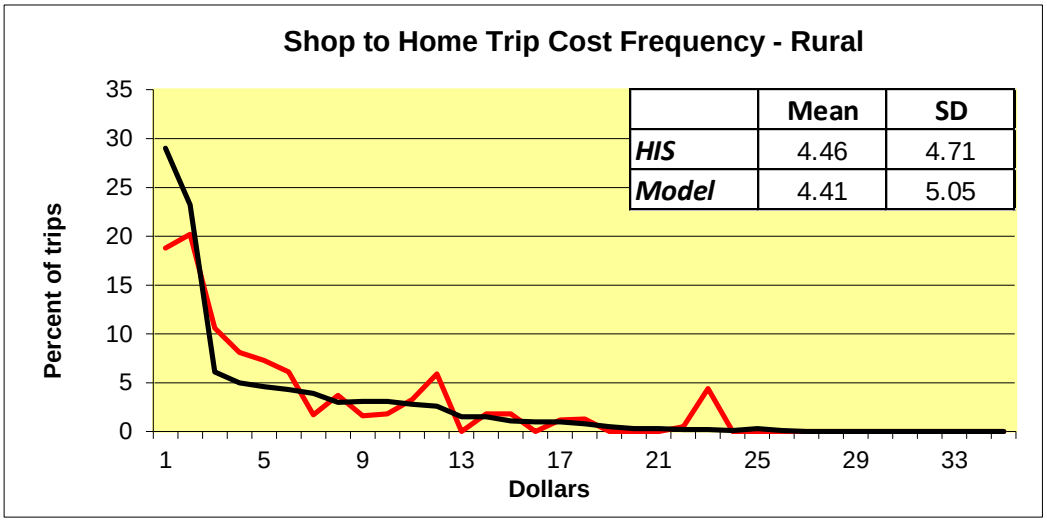


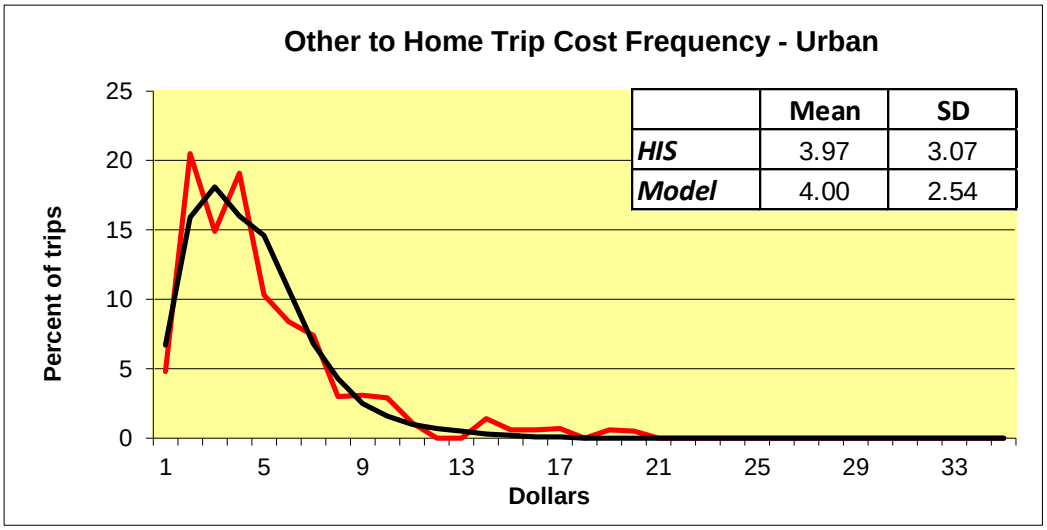


Trip Cost Frequency Plots (WTH/ETH/BTH)
Evening Peak Car Drivers

7c

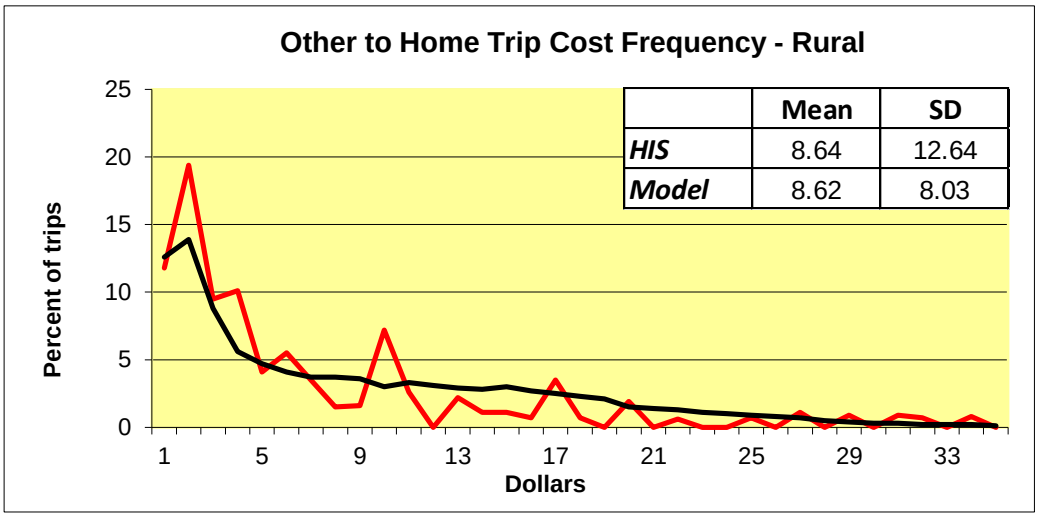






Trip Cost Frequency Plots (STH/OTH)
Evening Peak Car Drivers

7d



Trip Cost Frequency Plots (OTH)
Evening Peak Car Drivers

7e