Tour-Based Travel Model Estimation:

for Oahu Metropolitan Planning Organization

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Introduction

This document describes the estimation of the Oahu Metropolitan Planning Organization (OahuMPO) Tour-Based Model (TBM) system. This model will serve as the major travel forecasting tool for Oahu. The model system has been developed to ensure that the regional transportation planning process can rely on forecasting tools that will be adequate for new socioeconomic environments and emerging planning challenges. It is equally suitable for conventional highway projects, transit projects, and various policy studies such as highway pricing and HOV analysis. The models were estimated based upon a set of household and visitor travel surveys collected by NuStats in 2012; a total of 4,000 households and 950 visitors were surveyed using state-of-the-art surveying methods including real-time geocoding.

The OahuMPO travel models are designed as simple tour-based models, which are characterized by the following considerations:

1) A micro-simulation of travel using a fully-disaggregate population and a Monte Carlo discrete choice application paradigm wherein a database of residents are explicitly represented, and travel choices are modeled explicitly for each household and person.

2) Tours are used as fundamental unit of travel. A tour is a series of trips starting and ending at home. Tours have an anchor location (home), a primary destination (work, school, or some other dominant out-of-home activity) and zero or more intermediate stop locations. The use of a tour as the unit of travel allows the model system to predict activity locations, modes, and times of trips on tours consistently.

3) The tour-based modeling approach is simple, in that tours are modeled independently of each other. They are not scheduled into a daily activity pattern at a person level, nor are there interactions among household members. This is a key differentiating characteristics between a tour-based model and an activity-based model. In an activity-based model, tours or activities are scheduled such that no person can be in more than one place at the same time, and typically the number and schedule of higher-priority activities influence the number and schedule of lower-priority activities. Activity-based models also seek to coordinate travel across household members. Activity-based models offer many advantages over tour-based models, but require greater time and budget to develop.

The tour-based models micro-simulate the travel patterns of Oahu residents and visitors. The tour-based framework retains many of the advantages of an activity-based model (ABM) while greatly simplifying the model system (see Figure 1). In this model system, people generate tours and then tours are modeled independently without fitting them into an over-arching daily activity schedule. Many model components are statistically estimated based upon the data collected (green shaded boxes), while other model components utilize observed frequency distributions from the survey data in order to reduce development cost and time required (blue shaded boxes). Finally, some models are asserted and calibrated to match the travel patterns revealed in the Oahu travel survey (orange shaded boxes). This approach offers the following advantages as compared to a traditional trip-based model:

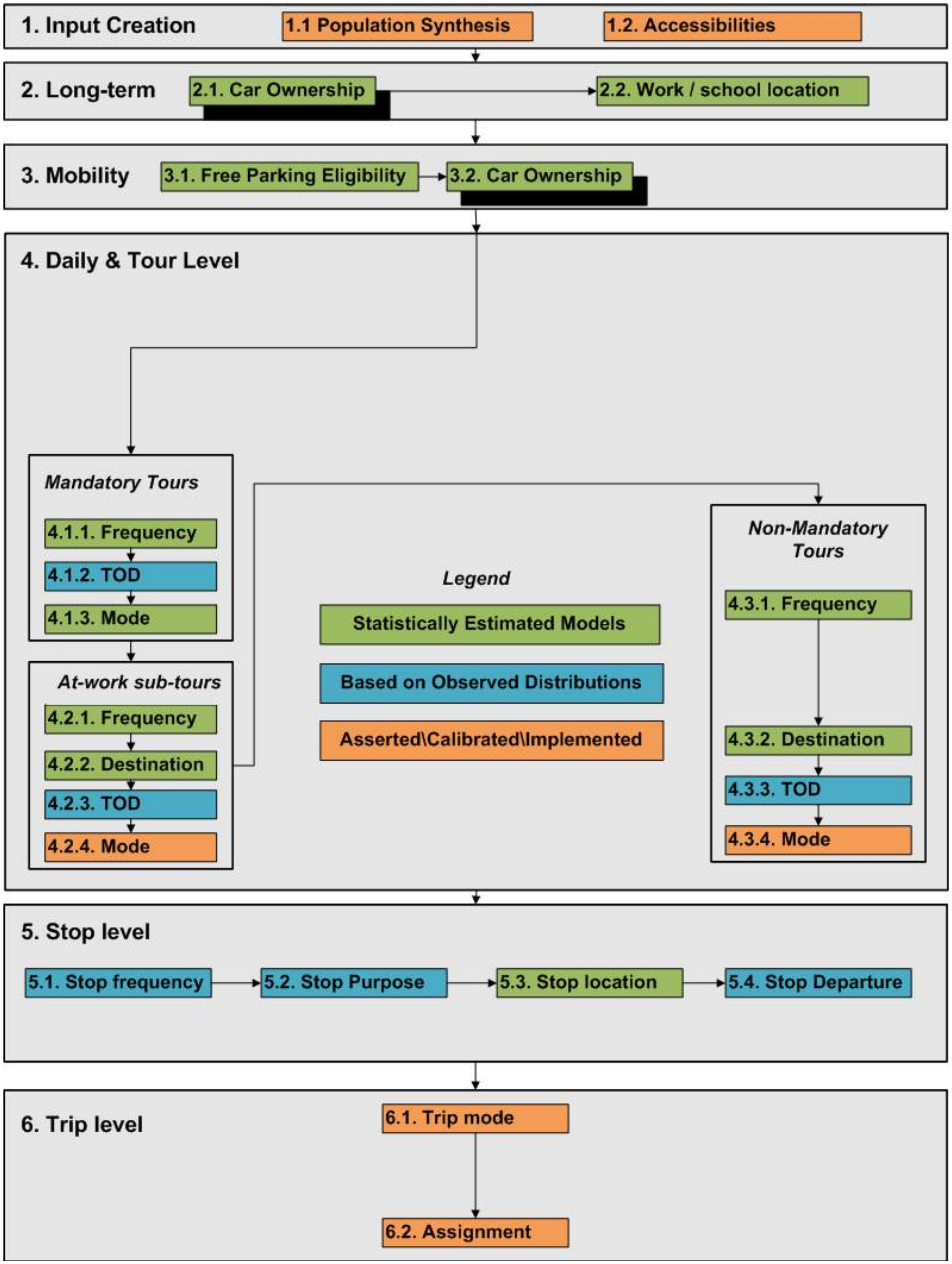
a. Sensitivity of tour generation to accessibility: The resident tour models take into account the travel time and cost to work and school for workers and students, as well as a general accessibility of each household to non-mandatory activities such as shopping and recreation.
b. Consistency of activity locations and modes used on tours: The models incorporate constraints such that the locations of intermediate stops on tours are consistent with the chosen tour mode.

c. Consistency between home and out-of-home locations on tours: The intermediate stop locations are selected based on out-of-direction cost based upon the home and primary activity location.
d. The tour-based model system contains a number of components (residential location choice, tour and stop destination choice, tour mode choice) that can be easily integrated with an activity-based model such as the Coordinated Travel – Regional Activity-Based Model Platform (CT-RAMP).

e. The model system incorporates and responds to many socio-economic and level-of-service variables due to the use of micro-simulation of tours as opposed to an aggregate four-step model framework

The model is implemented in Java using Parsons Brinckerhoff's Common Modeling Framework, a library of Java classes written specifically to implement travel demand models. The resident models are multi-threaded to take advantage of multiple processors, and micro-simulate a population of 1 million in approximately 30 minutes on a 12-core Intel Xeon workstation, while the visitors run in approximately 10 minutes. The survey data NuStats delivered was durable enough to support the rigorous demands of regional transportation models and detailed enough to support analysts seeking answers to local transportation problems.

Figure 1. OahuMPO Tour Based Model Structure



Model Components

The general description of each model component follows the flow chart in Figure 1

1. Input creation: A synthetic population is created for the region.
   1.1. Population synthesis: A synthetic population is generated by UrbanSim for the model scenario (some specific land-use\year combination).
   1.2. Accessibilities: A set of origin-based accessibilities are calculated for each TAZ and segment to be used in tour generation models. These accessibilities take the form of destination-choice logsums, but can be segmented by specific modes (walk or transit-only for example) as well as market segment (0 auto versus auto insufficient versus auto sufficient) and tour purpose (maintenance versus discretionary).
2. Long Term Models
   2.1. Auto ownership: The number of autos is determined for each household.
   2.2. Work\School location choice: The work TAZ for each worker and the school TAZ for each student is predicted.
3. Mobility Models
   3.1. Free parking eligibility: It is determined for each worker whether they have their parking paid for by their employer. This is determined by simulating from observed probabilities that were created from analysis of household survey data.
   3.2. Auto ownership: The number of autos model is re-run with exact accessibilities for each workplace and school location.
4. Daily and Tour Level Models: These models predict tour frequency, primary destination, outbound/return time period, and general or preferred tour mode. They are segmented into mandatory and non-mandatory models.
   4.1. Mandatory tour models: Mandatory purposes are tours made for work or school.
      4.1.1. Tour frequency: The exact number of work and school tours is predicted for each worker and student, based on the coefficients estimated through a multinomial logit model. Alternatives are 0 tours, 1 work\0 school, 2 work\0 school, 0 work\1 school, 0 work\2 school, 1 work\1 school.
      4.1.2. Tour Destination choice: Each tour is assigned a primary destination, based on the coefficients estimated through a multinomial logit model.
      4.1.3.Tour Time of Day: Each tour is assigned a departure and arrival half-hour period, based on probability distribution that varies by tour purpose.
      4.1.4.Tour Mode Choice: Each tour selects a preferred primary tour mode, based on the coefficients in an asserted nested logit model.
   4.2. At-work sub-tour models: At-work sub-tours are tours with an anchor location at work. These typically include lunch tours, personal business, and work-related tours.
      4.2.1.Tour frequency: The exact number of at-work sub-tours is predicted for each work tour, based on the coefficients estimated through a multinomial logit model. Exact alternatives are 0, 1, or 2 at-work sub-tours.
      4.2.2. Tour Destination choice: Each at-work sub-tour tour is assigned a primary destination TAZ, based on the coefficients estimated through a multinomial logit model.

4.2.3. Tour Time of Day: Each at-work sub-tour is assigned a departure and arrival half-hour period, based on probability distribution.

4.2.4. Tour Mode Choice: Each tour selects a preferred primary tour mode, based on the coefficients in an asserted nested logit model.

4.3. Non-Mandatory tour models: Non-mandatory purposes are tours made for purposes other than work or school, such as escort, shopping, recreational, or eating-out.

4.3.1. Tour frequency: The exact number non-mandatory tours is predicted for each person, based on the coefficients estimated through a multinomial logit model. The alternatives are 0, 1, or two tours for each purpose, with a maximum of four non-mandatory tours in total which covers 99% of all observed daily patterns.

4.3.2. Tour Destination choice: Each tour is assigned a primary destination TAZ, based on the coefficients estimated through a multinomial logit model.

4.3.3. Tour Time of Day: Each tour is assigned a departure and arrival half-hour period, based on probability distribution that varies by tour purpose.

4.3.4. Tour Mode Choice: Each tour selects a preferred primary tour mode, based on the coefficients in an asserted nested logit model.

5. Stop Models
   5.1. Stop Frequency Choice: Each tour is attributed with a number of stops in the outbound direction and in the inbound direction, based upon sampling from a distribution.
   5.2. Stop Purpose: Each stop is attributed with a purpose, based upon sampling from a distribution.
   5.3. Stop Location Choice: Each stop is assigned a location based upon an estimated multinomial logit model
   5.4. Stop Departure Choice: Each stop is assigned a departure time-period (half-hourly) based upon sampling from a distribution.
6. Trip Level Models
   6.1. Trip Mode Choice: Each trip within the tours selects a preferred trip mode, based on an asserted nested logit model.
   6.2. Trip Assignment: Each trip is assigned to the appropriate time-of-day specific network.

Estimation of Long Term-Models

This section describes the estimation of each long term model component including the estimation dataset, the coefficients and t-statistics of the main explanatory variables used, the utility structure if applicable, and a summary of the findings of the estimation results.

Car Ownership Model

The household car ownership model predicts the number of autos (including motorcycles, vans, and trucks for personal use) available to a household. The model was estimated in a logit form using the ALOGIT software. In this model, household car ownership is a dependent variable derived from the activity needs of the household based on household characteristics, and the characteristics of persons within the household. The car-ownership model is applied twice. In the pre-location choice mode, origin-based accessibilities and household and person socio-economic variables are used, while in the post-location choice mode, actual mandatory accessibilities for each worker and student are also considered.

Estimation Dataset

The estimation dataset included 4,001 observed households from the Oahu Household Travel survey. Table 1 shows surveyed households by number of owned cars and by each of four districts used to sample households. The survey observations were joined with TAZ-based mandatory and non-mandatory accessibilities as well as other land-use data to create the estimation file. Mandatory and non-mandatory activity accessibilities are the logsum/utility measures calculated using asserted mode and destination choice models. Mandatory accessibilities reflect the actual workplace and/or school location for each worker and student in the household, while non-mandatory accessibilities reflect the general accessibility of the household to all potential non-mandatory destinations.

Table 1: Household Survey Observed Household Vehicles

District	N	Household Vehicles				Total	Mean
		0	1	2	3+		
PUC and East Honolulu (Pearl City to Hawaii Kai)	2,167	12.46%	41.16%	33.32%	13.06%	100 %	1.54
Koolauloa, Koolaupoko, Kaneohe, and Kailua	584	3.94%	27.40%	44.35%	24.32%	100 %	2.01
Central Oahu (includes Waipahu), Wahiawa, Haleiwa and Northshore	833	4.44%	28.57%	42.26%	24.73%	100 %	2.00
Ewa, Kapolei, and Waianae	417	7.91%	25.18%	44.60%	22.30%	100 %	1.92
Total	4,001	9.07%	34.87%	37.97%	18.10%	100 %	1.74

Main Explanatory Variables and Utility Structure

The following variables have been examined and proved to be significant in the utility functions:

Household composition:

- Ratio of workers (full time and part time) to driving age household members
- Ratio of pre-driving age school children to driving age household members
- Ratio of retirees to driving age household members

Household income group:

- Low income (less than $30,000)
- High income ($100,000 and more)

Household residence type:

- Detached or attached single family dwelling unit.

Zonal accessibility indices from residential zones to potential destinations:

- Non-motorized accessibility to maintenance activities in off peak period
- Difference between auto accessibility and transit accessibility to maintenance activities in off peak period.

Household mandatory activity auto dependency indices:

- Workers' mandatory activity auto dependency

The zonal accessibility indices for maintenance activities take the form of destination choice logsums and represent a result of summation of attractions across all destinations. They are calculated across destination zone attractions by mode (auto, transit, and walk) and time-of-day period. Off-peak skims are used for creation of maintenance accessibilities.

The worker's mandatory activity auto dependency variable is calculated using the difference between the single-occupant vehicle (SOV) and the walk to transit mode choice logsum. The logsums are computed based on the household TAZ and the work TAZ (for workers). The household auto dependency is obtained by aggregating individual mandatory auto dependencies (MandatoryAutoDependency) of workers in the household, according to the following formulas:

$$\text{WorkAutoAdvantage} = \text{Logsum}_{SOV} - \text{Logsum}_{WalkTransit} \text{ if } \text{Logsum}_{SOV} > \text{Logsum}_{WalkTransit}\text{, else } 0$$

$$\text{WorkNonMotorizedFactor} = 0.5 * (\min(\max(\text{workDistance}, 1.0), 3.0)) - 0.5$$

$$\text{MandatoryAutoDependency} = \min(\text{WorkAutoAdvantage} /3.0, 1.0) * \text{workNonMotorFactor}$$

The WorkAutoAdvantage measures the relative attractiveness of SOV compared to walk transit. The measure is greater the more accessible the workplace is to home by auto compared to transit with walk access. If transit has a greater accessibility than auto, the difference is capped at 0 (auto has no advantage). The non-motorized factor measures how accessible the workplace is from home by walk. It ranges between 0 and 1, where 0 is very accessible and 1 is not accessible. The first part of the MandatoryAutoDependency equation scales the difference in utility between auto and transit to a measure between 0 and 1, where 0 is very auto dependent and 1 is not auto dependent. This is then multiplied by the non-motorized factor, to reflect that even if transit accessibility is poor relative to auto, the auto dependency is lower if the workplace is within walking distance of home.

Results

The car ownership estimation results are summarized in Table 2.

Table 2: OahuMPO Car Ownership Model Estimation Results

Observations:	4001
Final log likelihood:	-3489.5185
Rho-Squared (0):	0.3709
Rho-Squared (constant):	0.3090

Variable	Relevant types	Coefficient & T-Stat by Choice Alternative							
		0 car		1 car		2 cars		3 + cars	
		coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat
#of driving age members	1	ref	ref	(0.907)	(1.038)	(3.179)	(3.418)	(5.648)	(5.561)
	2	ref	ref	(0.601)	(0.692)	(0.761)	(0.827)	(3.644)	(3.650)
	3+	ref	ref	(1.226)	(1.375)	(1.085)	(1.156)	(2.069)	(2.049)
HH compositions									
#worker/#driver		ref	ref	0.461	2.288	0.759	3.115	1.063	3.529
# pre-driving age school children/#driver		ref	ref	0.471	1.193	0.726	1.764	0.827	1.915
# retiree/#driver		ref	ref	(0.454)	(2.438)	(0.611)	(2.630)	(0.826)	(2.651)
Single Family Dwelling HH		ref	ref	0.585	3.488	1.779	9.347	2.716	10.645
HH Income	Less than $30,0000	ref	ref	(1.386)	(9.974)	(2.028)	(11.030)	(2.411)	(8.035)
	More than $100,000	ref	ref	1.284	2.724	1.956	4.117	2.292	4.749
Zonal accessibility	Non-motorized maintenance	ref	ref	0.028	0.408	(0.062)	(0.850)	(0.079)	(0.965)
	auto-transit discretionary	ref	ref	1.267	4.705	1.327	4.800	1.379	4.863
Man auto dependency	worker	ref	ref	1.402	3.794	2.069	5.484	2.438	6.344

Red font: t-stat not significant

Findings

- The number of driving-age adults has a strong impact on household car ownership. Though the coefficients for owning more than one car are negative, they are much less negative for households with multiple driving-age adults. The workers to drivers ratio coefficient increases with increasing number of autos in the household. The higher the ratio, the higher the probability is of owning a car as workers in the household need enough cars to commute to work.
- The pre driving age school children to drivers ratio has similar coefficient patterns as those of the workers to adult household members ratio. This shows that households with school children need sufficient cars to transport both parent and children to work and school activities.
- The retirees to drivers ratio has negative coefficients for all car ownership choices. This shows that retirees tend to be less mobile and therefore tend to own less cars compared with younger households.
- Low income households are less likely to own cars as shown by the negative coefficients for all 1, 2, 3+ cars per household. The high income households have an opposite pattern compared with the low income households. The residence type variable has a strong impact on car ownership. Households that live in a single family dwelling unit have a large positive coefficient for 1, 2, 3+ car households. This is probably because single family dwelling units are more likely to be in suburban areas and have garage space for cars.
- The non-motorized variable represents the zonal accessibility of maintenance (e.g. shopping) activities by non-motorized travel modes, such as walking and biking, or in other words the ease of travel by walking and biking. The increasingly negative coefficient with increasing car ownership is consistent with the expectation that the more accessible a household is to maintenance activities by walking or biking, the more likely the household is to own less autos.
- The difference between auto and transit accessibility to discretionary (e.g. recreation) activities has an increasingly positive coefficient with increasing car ownership, and this is consistent with the expectation that households with relatively better auto access than transit access to discretionary destinations are more likely to own cars.
- The work tour auto dependency variable represents how much a household member's work tours are dependent on the auto mode. This variable has an increasingly positive coefficient with increasing car ownership. This shows that a household is more likely to own cars if workers in the household have a strong dependency on using the auto mode for commuting to work.

Mandatory Tour Location Choice Models

A destination choice model was estimated for each of the three mandatory tour purposes; Work, University, and School. The destination choice model predicts the location of where the traveler is going based on mode choice logsums, distance terms, zonal employment and household and person attributes as explanatory variables. These models were estimated in a multinomial logit form using the ALOGIT software. The utility structure of the model is described below.

Utility Structure

The utility (U_{ijn}) of choosing a destination (j) for an individual (n) in zone (i) is given by

$$U_{ijn} = S_j + \alpha \times L_{ij} + \sum \beta^k \times D_{ij}^k + \sum \beta^k \times D_{ij}^k N_n^k$$

Where, S_j is the size variable for destination zone *j*, L_{ij} is the mode choice logsum between zone pair *ij*, D_{ij}^k represents the various distance terms (linear, log, and squared), and N_n^k represent person or household characteristics for individual n and is used for creating interaction variable with distance terms.

Work Location Choice

The work destination choice model predicts the usual work location for full-time and part-time workers. This model is one of the first models applied in the model chain.

Estimation Dataset

In the 2012/2013 Oahu Household Travel Survey there are 4,863 observed worker records including both full-time and part-time workers. Table 3 below shows the working adults in surveyed households by worker status, gender and income group.

***Table 3**: Frequencies on Working Adults*

	Count	Percentage
Worker status		
Full-time	3,559	73.2%
Part-time	1,195	24.6%
Unknown	109	2.2%
Gender		
Male	1,565	51.0%
Female	1,483	48.3%
Unknown	23	0.7%
Income group		
Less than 30K	343	7.1%
30K to 60K	1093	22.5%
60K to 100K	1495	30.7%
100K to 150K	1113	22.9%
More than 150K	589	12.1%
Unknown	230	4.7%
Total	**4,863**	**100%**

Main Explanatory Variables

The following variables have been examined and proved to be significant in the utility functions:

- Mode choice logsum
- Impedance between the home and potential work destinations:
  - Linear distance
  - Distance squared
  - Natural Log of Distance
- Household income group interacted with distance terms:
  - Low Medium income ($30,000-$60,000)
- Household auto ownership interacted with distance terms:
  - Zero Auto Households
- Person Characteristics interacted with distance terms:
  - Age group interacted with distance terms"
    - Age 20 years and younger
    - Age 65+
  - Gender – Female vs. Male
  - Work Status – Full-time vs. Part-time.
- Size Terms: There are 7 work occupation segments and each segment has different sensitivities to employment that determine a person's work location choice
  - (1)Management, Business, Science, and Arts
    - Government Employment
    - Hotel Employment
    - Agriculture Employment
    - TCU Employment
    - Industry Employment
    - FIRE Employment
    - Service Employment
  - (2) White Collar Service
    - Government Employment
    - Service Employment
  - (3) Blue Collar Service
    - Government Employment
    - Hotel Employment
    - Agriculture Employment
    - TCU Employment
    - Industry Employment
    - FIRE Employment
    - Service Employment
    - Retail Employment
  - (4) Sales and Office Support
    - Government Employment
    - Hotel Employment
    - Agriculture Employment
    - TCU Employment
    - Industry Employment
    - FIRE Employment
    - Service Employment

        - Retail Employment
    - (5) Natural Resource, Construction
        - Government Employment
        - Hotel Employment
        - Agriculture Employment
        - TCU Employment
        - Industry Employment
        - FIRE Employment
        - Service Employment
        - Retail Employment
        - Construction Employment
    - (6) Products, Transportation, Material Moving
        - Hotel Employment
        - Agriculture Employment
        - TCU Employment
        - Industry Employment
        - FIRE Employment
        - Service Employment
        - Retail Employment
        - Construction Employment
    - (7) Military
        - Military Employment
        - Service Employment

A combination of distance terms were used in the utility such that the composite distance utility function is monotonically decreasing within the maximum chosen work distance (55 miles) range. Table 4 shows the frequency of distance to work location for 3,071 workers in the dataset.

***Table 4**: Frequency of Distance to Chosen Work Destinations*

Bin (miles)	Frequency
5	1,097
10	577
15	626
20	438
25	208
30	66
35	37
40	18
45	4
Total	3071

Results

The work destination choice results are summarized in Table 5.

Table 5: Oahu Out-of-Home Usual Work Location Choice Model Estimation Results

Observations: 3061
Final log likelihood: -17454
Rho-Squared (0): 0.1411
Rho-Squared (constant): -0.0244

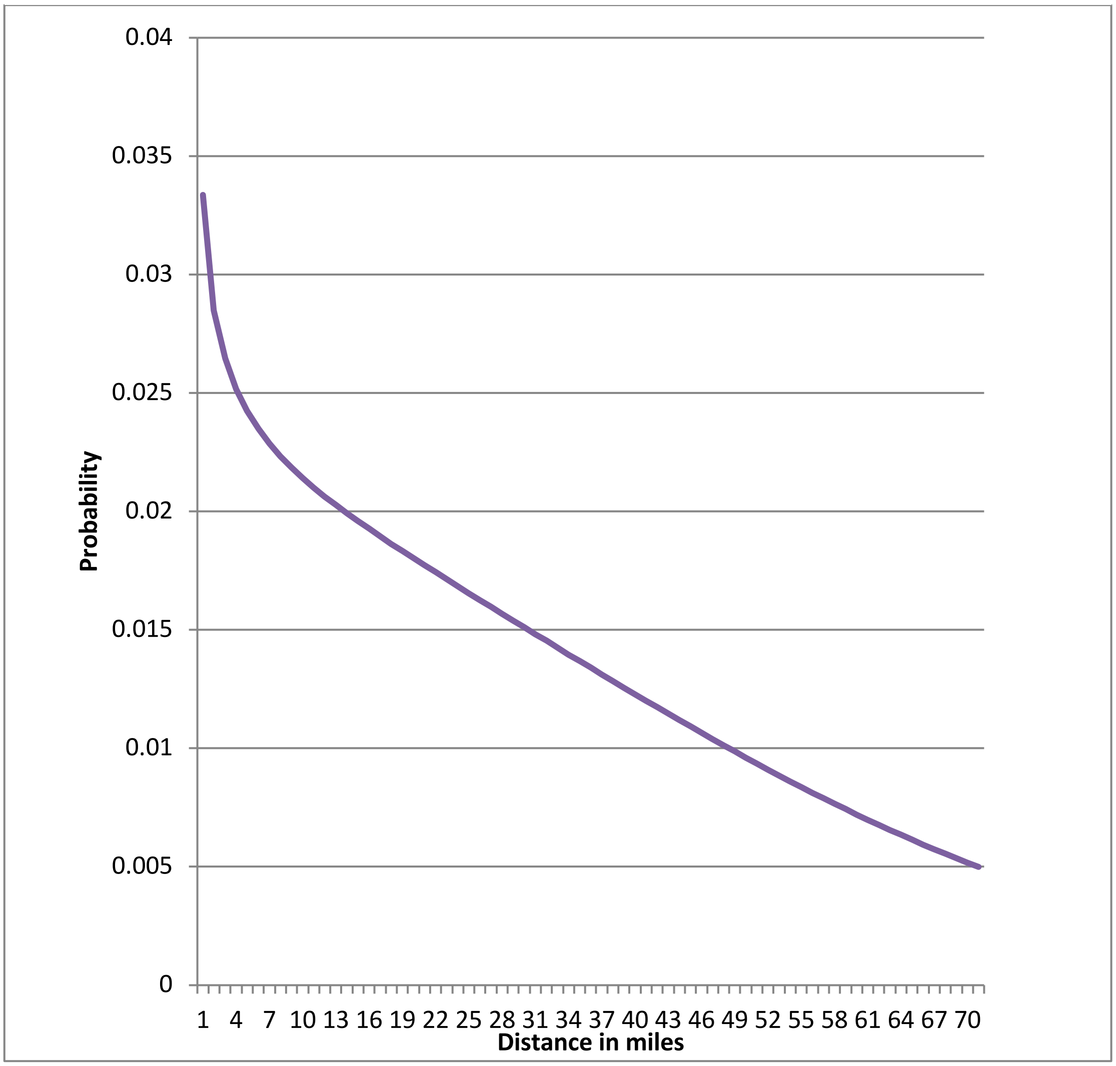
Utility Function Variables	Coeff	T-Stat
Mode Choice Logsums	0.343	4.95
Distance	0.000	
Distance Squared	0.000	-1.13
Distance Natural Log	-0.330	-6.40
Part-time worker		
Distance	-0.06101	-6.40
Female		
Distance	-0.03936	-6.32
Low Medium Income Group ($30K-60K)		
Distance	-0.01846	-2.42
Age 20 Years and Younger		
Distance	-0.04432	-1.53
Age 65 and Up		
Distance	-0.01624	-1.25
0 Auto Households		
Distance	-0.08710	-2.77
Size Function		
Service Employment (Total Emp)	1.000	
Management, Business, Science, and Arts		
Government	1.833	4.20
Hotel	0.000	-0.02
Financial, Real Estate, Insurance	0.909	-0.31
Retail	0.000	-0.04
Industry, TCU	1.128	0.64
White Collar Service		
Government	1.336	2.23
Hotel	0.000	-0.01
Financial, Real Estate, Insurance	0.000	-0.07
Retail	0.000	-0.06
Industry, TCU	0.000	-0.07
Blue Collar Service		
Government	0.530	-1.05
Hotel	2.843	2.24
Financial, Real Estate, Insurance	0.000	-0.01
Retail	1.672	1.20

Industry, TCU	0.089	-0.95
Sales and Office Support		
Government	2.208	4.06
Hotel	0.387	-0.99
Financial, Real Estate, Insurance	2.615	4.01
Retail	1.271	0.82
Industry, TCU	1.179	0.60
Nat Resource, Constr, Maintenance		
Government	2.280	1.14
Hotel	2.812	0.96
Financial, Real Estate, Insurance	0.000	-0.01
Retail	0.000	-0.02
Agriculture, Construction	13.376	3.81
Industry, TCU	12.490	4.56
Prod, Trans, Material Moving		
Government	0.000	-0.02
Hotel	17.193	2.27
Financial, Real Estate, Insurance	0.000	-0.02
Retail	4.640	1.06
Agriculture, Construction	23.040	2.33
Industry, TCU	32.990	3.04
Military		
Military	6.643	9.76
Unknown		
Tot Non-Service Employment	4.229	2.36

Findings:

- The coefficient on mode choice logsum is positive and between 0 and 1 as expected.
- *Composite distance function* (or distance decay factor) has been defined as a combination of linear, squared and natural logged distance terms with different coefficients. This term should be analyzed as a composite term and the coefficient (positive or negative) of individual terms should not be looked at. For example, the coefficient on linear distance is positive but it does not mean that workers choose distant locations as work places. But, we should look at the combined effect of all terms. Figure 2 shows the distance decay factor. This function is monotonously decreasing in within the maximum chosen work distance range.
- The effects of work status (full-time vs. part-time), gender (females vs. males) and household income was found siginificant on distance to work location. The findings are below:

Figure 2. Work Distance Decay Factor



- *Part-time workers* are most sensitive to longer commute than full-time workers. The sensitivity increases with longer distances. In other words, part-time workers are more likely to choose a workplace closer to home than full-time workers.
- *Females* are more likely to choose a workplace close to home compared to males. This could be due to household responsibility and children at home.
- *Income group:* Low income workers are more sensitive to commuting longer distances. Longer distances would increase the cost of commuting and it could be the reason low income workers prefer to work close to their homes.

- Size term effects:
  - There are 7 work segments and each have different employment categories that determine a person's work location choice.
    - For workers in the *Management, Business, Science, and Arts* occupation segment, government employment is twice as attractive as service, financial/insurance/real estate TCU, industry and retail employment.
    - For workers in the *White Collar Service* occupation segment, government employment is nearly one third more attractive than service employment.

- For workers in the *Blue Collar Service* occupation segment, hotel employment is nearly 3 times more attractive than service employment, retail employment is 1.7 times more attractive than service employment, government employment is half as attractive as service employment, and TCU, industry employment was not as attractive as service employment.
- For workers in *Sales and Office Support* occupation segment, government and financial/insurance/real estate and retail employment was 2 times more attractive than service employment, retail, TCU, industry employees are 1.2 times more attractive than service employment, and hotel employment was one-third less attractive as service employment.
- For workers in *Natural resources, construction and maintenance* occupation segment, government and hotel employment are over 2 times more attractive service employment, and agriculture, construction, TCU, industry employment are over 12 times more attractive than service employment.
- For workers in the *Production, Transportation, and Material Moving* occupation segment, hotel, agriculture, construction, TCU, industry employment are over 17 times more attractive than service employment, retail employment are 5 times more attractive than service employment.
- For workers in the *Military* occuption segment, military employment was nearly 7 times more attractive than service employment.

Oahu University Location Choice

The university destination choice model predicts the usual school location for all college students. This model is applied very early in the model chain with the work destination choice model.

Estimation Dataset

In the 2012/2013 Oahu Household Travel Survey there are 517 university students. However, it should be noted that the survey did not capture university students living on campus, and it is likely that the survey under-represents students living in off-campus non-family households. Table **6** below shows the student in the surveyed households by income group, person type and age categories.

Table 6: Frequencies on Students

	University	
	Count	%
Age		
Under 25 years	190	37%
Income Group		
Less than 30K	62	12%

30K to 60K	155	30%
60K to 100K	138	27%
100K to 150K	102	20%
More than 150K	40	8%
Unknown	20	4%
Total	517	100%

Main Explanatory Variables

The following variables have been examined and were significant in the utility functions:

- Mode choice logsum
- Household income group interacted with distance terms:
    - Low income <$20,000)
- Household size interacted with distance terms:
    - Single Person household
- Person Characteristics interacted with distance terms:
    - Age group interacted with distance terms"
        - Age 20 years and younger
        - Age 65+
    - Gender – Female vs. Male
    - Work Status – Full-time vs. Part-time.
- Size Terms: Total Enrollment, and service employment

Table 7 shows the frequency of distance to 174 university or college locations in the dataset.

Table 7: Frequency of observed distance to usual university/college location

Bin(miles)	University(4)
5	59
10	41
15	18
20	24
25	15
30	12
35	3
40	2
Total	174

Results

The university destination choice results are summarized in Table 8.

Table 8: Oahu Usual University Location Choice Model Estimation Results

Observations: 172
Final log likelihood: -553.7504
Rho-Squared (0): 0.5150
Rho-Squared (constant): -0.3483

Utility Function Variables	Coeff	T-Stat
Mode Choice Logsums	0.684	5.84
Low Income Group (<$20K)		
Distance	-0.048	-1.75
Household Size 1		
Distance	-0.163	-1.07
Size Function		
Total University Enrollment	1.000	
Service Employees	0.073	-14.53

Findings:

- The coefficient on mode choice logsum is positive and between 0 and 1 as expected.
- The effects ofhousehold size and household income was found significant on distance to university location. The findings are below:
    - Students in *low income households* are less likely to to travel longer commutes than students inhigher income households.
    - *Single person households* are less likely to travel longer distances as compared to larger households. This is likely due to the flexibility of single-person households to locate close to their university, or perhaps due to a greater number of apartments near universities..
- Size term effects:
    - University enrollment is the dominant size term effect. However, service employment also attracts some university tours; probably because some portion of service employment is continuing education or trade-oriented education services.

Oahu School K-12 Location Choice

The school destination choice model predicts the usual school location for all students. This model is applied very early in the model chain with work destination choice model.

Estimation Dataset

In the 2012/2013 Oahu Household Travel Survey there are 1,157 observed student records including 123 preschoolers, 694 kindergarten to 8th graders, and 340 9th -12th graders. Table 9 below shows the student in the surveyed households by income group, and age categories.

Table 9: Frequencies on Students

	Preschool		K to 8th		9th to 12th	
	Count	%	Count	%	Count	%
Age						
0 to 3 years	61	49.6%	2	0.3%	0	0.0%
4 to 5 years	59	48.0%	55	7.9%	0	0.0%
6 to 13 years	0	0.0%	594	85.6%	12	3.5%
14+ years	0	0.0%	17	2.4%	317	93.2%
Unknown	3	2.4%	26	3.7%	11	3.2%
Income Group						
Less than 30K	8	6.5%	42	6.1%	20	5.9%
30K to 60K	19	15.4%	145	20.9%	64	18.8%
60K to 100K	37	30.1%	259	37.3%	131	38.5%
100K to 150K	30	24%	130	19%	76	22%
More than 150K	27	22%	102	15%	40	12%
Unknown	2	2%	16	2%	9	3%
Total	123	100%	694	100%	340	100%

Main Explanatory Variables

The following variables have been examined and significant in the utility function:

- Mode choice logsum
- Impedance between the home and potential school destinations:
    - Natural Log of Distance
- Household auto ownership interacted with distance terms:
    - Zero Auto Households
- Person Characteristics interacted with distance terms:
    - Age group interacted with distance terms
        - Age 5 years and younger
        - Age 6 through 13
- Size Terms: Total Enrollment

Table 10 shows the frequency of distance to 930 school locations in the dataset.

Table 10: Frequency of Distance to Chosen School Destinations

Bin (miles)	Frequency
5	648
10	136
15	82
20	25
25	34
30	3
35	2
Total	930

Results

The school destination choice results are summarized in Table 11.

Table 11: Oahu Usual School Location Choice Model Estimation Results

Observations: 723
Final log likelihood: -2564.7274
Rho-Squared (0): 0.4656
Rho-Squared (constant): 0.2400

Utility Function Variables	**Coeff**	**T-Stat**
Mode Choice Logsum	0.515	3.70
Distance	0.000	
Distance Squared	0.000	
Distance Natural Log	-1.122	-12.45
Age 5 Years and Younger		
Distance	-0.087	-3.53
Age 6 through 13		
Distance	-0.077	-6.13
0 Auto Households		
Distance	-0.13512	-1.42
Size Function		
Total Enrollment	1.00	

Findings:

- The coefficient on mode choice logsum is positive and between 0 and 1 as expected.
- The effects of age and household auto ownership was found siginificant on distance to school location. The findings are below:
  - *Children age 5 and under* are most sensitive to longer distances than older children. This reflects the relatively shorter trips for daycare and pre-school as opposed to grade school or high school.

    - *Children ages 6 to 13 are also* less likely to travel longer distances compared to older children, but more likely to travel further for school than children under 5. The distance coefficients reflect a relatively longer trip length for high school students (children age over 13).
    - *Zero auto households:* Students in households with no cars are more sensitive to longer distances. These students are likely to go to schools closer to home, perhaps because they are less likely to go to private schools.
- Size term effects:
    - Public and private school enrollment is the only size term in the school location choice model. Zones with more enrollment have higher probability of being chosen.

Oahu Parking Costs

This section documents how parking costs and free parking eligibility shares were developed for model estimation. An existing data search was conducted to identify possible sources of parking cost data including number of available on-street and off-street parking spaces, parking rates, and utilization. The search revealed little useful, comprehensive parking cost data, so the household travel survey was used to analyze expected parking costs and percent parking for free.

Using the household survey, an averaging methodology was developed to calculate an average weighted parking cost for each zone. This averaging method was implemented because the survey did not capture parking in every zone that could have a parking cost, as it was a sample of parkers. Also, the average parking cost for a destination zone must take into account the parking cost paid by persons who park in other zones and walk to their destination. The algorithm calculates a weighted average of the parking costs for all zones that fall within a maximum walk distance of 0.5 miles from each zone. The following formula was used to calculate the weighted average parking cost:

$$AvgCost_j = \sum e^{\beta * distance_{kj}} * Cost_k * Obs_k \,/ \sum e^{\beta * distance_{kj}} * Obs_k$$

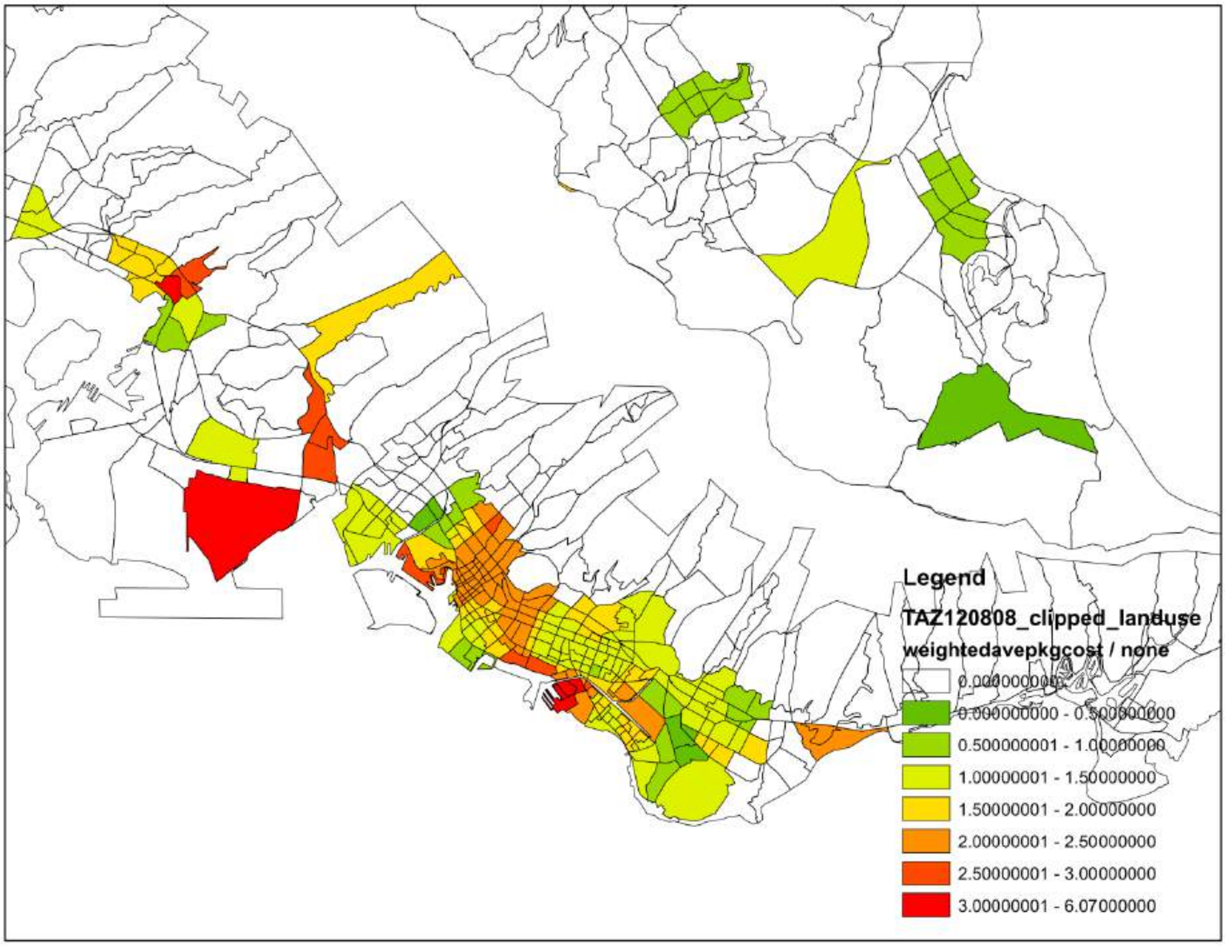
Where $\beta$is a coefficient on distance which was based on previous estimation performed in San Diego (-5), $distance_{kj}$is the distance in miles between parking zone k and destination zone j, $Cost_k$ is the cost of parking in zone k, and Obs_j is the number of people parking in zone k. The formula results in a weighted average parking cost where parking further from the destination zone j is discounted by the distance from the parking zone k to the destination zone j, across all potential parking zones k within the maximum half-mile buffer.

Two different parking costs were developed. One set was for non-work tours and one for work tours. Separate parking costs were developed for each because most non-work tours pay the full hourly or daily parking rate, while many workers pay monthly or annually parking rates, in order to obtain a lower parking cost than the daily rate.

Non-work related Hourly Parking Costs

The household survey data was tabulated for all persons that made a non-work tour and paid for parking. An hourly rate for each tour was calculated based on the tour duration if the person paid at a rate other than an hourly rate. Then an average hourly parking cost was calculated at each destination zone according to the formula above. Figure 3 shows the resulting average parking costs, which are higher in downtown and Waikiki than other parts of Oahu. Parking costs are free in most areas outside downtown and Waikiki.

Figure 3. Weighted Average Non-Work Hourly Parking Costs by TAZ



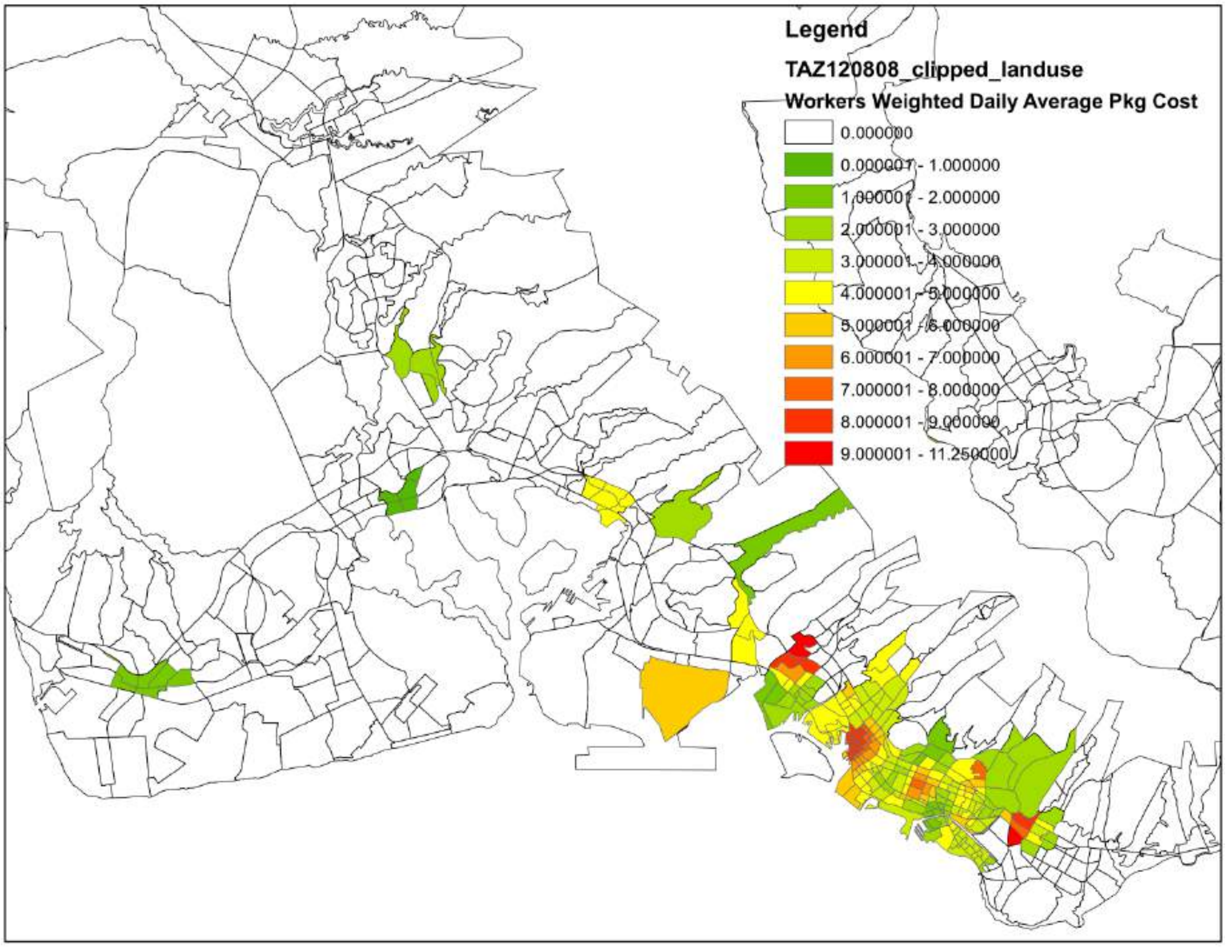
Work Daily Parking Costs

The household survey data was tabulated for all workers that made a work tour and paid for parking. A daily rate for each trip was calculated based on the following assumptions if the person paid at a rate other than a daily rate:

- Daily cost = weekly cost/5
- Daily cost = monthly cost/20
- Daily cost = yearly cost/210 (assumes 12 holidays, 12 vacation days, 12 sick days, and 12 travel\telecommute days per worker on average)

Then an average daily parking cost was calculated at each destination zone according to the formula above. Figure 4 shows the weighted average work parking cost by TAZ. Note the higher parking costs in downtown, and other small pockets where there are parking costs. Waikiki seems to have a relatively low parking cost, which could be because some workers pay a lower rate to park there.

Figure 4. Weighted Average Work Daily Parking Costs by TAZ



Estimation of Daily and Tour Level-Models

This section describes the estimation of the daily and tour level model components including the estimation dataset, the coefficients and t-statistics of the main explanatory variables used, the utility structure if applicable, and a summary of the findings of the estimation results.

Mandatory Tour Frequency

The mandatory tour frequency choice model predicts the number of mandatory (work and school) tours for each person. The model has six alternatives: 0 mandatory tours, one work tour, one school tour, two or more work tours, two or more school tours, one work tour plus one school tour. It was estimated in a multinomial logit form using the ALOGIT software.

Estimation Dataset

The estimation dataset included 6244 observations of workers and students. In order to evaluate the potential impact of workplace and school location on the number of mandatory tours, the survey observations were appended with distance, and mode choice logsums of work and school locations. Accessibilities at the work location (TAZ) and accessibilities for the escort purpose from the residence location (TAZ) were also tested in the estimation.

Observed Frequency of Mandatory Tours

Table 12 shows the frequency of mandatory tour patterns by person type and gender. For workers or students making mandatory tours, most have either 1 work tour or 1 school tour. Only around 4% have two or more tours of same type or different types.

Table 12: Frequency of Mandatory Tour Patterns by Person type and Gender

	0 Work, 0 School	1 Work, 0 School	2+ Work, 0 School	0 Work, 1 School	0 Work, 2+ School	Work & School	Total
Person Type							
Full-time Worker	856	2,472	82	0	0	0	3,410
Part-time Worker	604	347	24	0	0	0	975
University Student	186	180	9	177	3	15	570
Driving Age School Child	36	3	1	138	2	3	183
Pre-driving Age School Child	134	1	0	609	13	0	757
Pre-school Child	225	1	0	123	0	0	349
Gender							
Male	928	1,546	60	530	10	9	3,083
Female	1,095	1,437	56	498	8	9	3,103
Missing	18	21	0	19	0	0	58
Total	**2,041**	**3,004**	**116**	**1,047**	**18**	**18**	**6244**

Main Explanatory Variables

The following variables have been examined in the estimation process:

- **Personal characteristics stratified by person type**
  - Female
  - Age 18 through 35 for full time and part time worker
  - Age greater than 35 for university student
- **Household composition stratified by person type**
  - Zero cars
  - Cars not sufficient for drivers for worker, university student, and school age children
  - Cars sufficient for drivers for worker, university student, and school age children
  - Number of preschool children for full and part time workers, and university student
  - Number of children 6 through 18 for full and part time workers
  - Household income for full and part time workers, and university student
- **Mandatory tour destination location**
  - Workplace location within walking distance bins (0-1 and 1-3 miles)
  - School location within walking distance bin (0-1, 1-2, 0.5-3 miles)
  - Work and school mode choice logsums
  - Accessibility at workplace
- **Population accessibility to household**
  - Escorting accessibility by car ownership
  - A measure of the mixture of employment and households, as follows:

    Mix = (-1)*(Household Proportion * log(Household Proportion) + Employment Proportion * log(Employment Proportion)) /log(2),

    Where household proportion = total households/(total households + total employment), and employment proportion = 1-household proportion

Results

The final estimation results are presented in Table 13 below for all workers and students.

Table 13: Mandatory Tour Frequency Model Estimation Result

Observations:	6244
Likelihood – Constants only	-7022.6981
Final log likelihood:	-6781.1867
Rho-Squared (0):	0.3939
Rho-Squared (constant):	0.0344

Variable	Relevant person types	Coefficient and T-Stat by Choice Alternative (T-Stat)									
		1 Work		2+ Work		1 School		2+ School		Work & School	
		Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Constant	1=Full-time worker	1.697	13.685	-1.213	-2.535	N/A	N/A	N/A	N/A	N/A	N/A
	2=Part time worker	0.501	5.522	-2.231	-4.646						
	3=University student	0.410	1.257	-2.586	-5.616	-0.377	-2.449	-0.377	-2.449	-0.887	-2.729
	6=School child 16-17	-2.485	-4.135	-3.584	-3.535	1.096	4.539	-3.138	-4.227	-2.159	-3.583
	7=School child 6-15	N/A	N/A	N/A	N/A	2.810	29.497	-1.037	-3.571	N/A	N/A
	8=Preschooler <=5	N/A	N/A	N/A	N/A	0.967	8.628	0.000	0.000	N/A	N/A
Person is female (dummy)	1=Full-time worker			-0.287	-1.245						
	2=Part time worker			0.725	1.422						
	3=University student	-0.837	-3.581	-0.837	-3.581	-0.358	-1.704	-0.358	-1.704		
	6=School child 16-17					0.536	1.511	0.536	1.511		
	7=School child 6-15										
	8=Preschooler <=5										
Young adult (age <=35)	1=Part-time worker	0.845	3.809	1.338	2.483						
Age older than 35	3=University student	0.438	1.893	0.438	1.893						
Distance to Work 0 to 1 miles & Distance to School 0 to 1 miles (dummy)	1=Full-time worker									-2.267	-5.019
	2=Part time worker									-2.267	-5.019
	3=University student									-2.267	-5.019
	6=School child 16-17									-2.267	-5.019
Distance to Work 1 to 3 miles & Distance to	1=Full-time worker									-2.842	-6.911
	2=Part time worker									-2.842	-6.911
	3=University student									-2.842	-6.911

School 1 to 2 miles (indicator)	6=School child 16-17									-2.842	-6.911
No cars in household (dummy)	1=Full-time worker			-1.528	-2.062						
	2=Part time worker			-1.528	-2.062						
# of pre-school children in household	2=Part-time worker	-0.428	-1.952	-0.428	-1.952						
	3=University student	-0.281	-1.161	-0.281	-1.161	-0.351	-1.254	-0.351	-1.254		
# of children age 6-18 in household	1=Full-time worker			0.317	2.754						
Household income medium ($30-$100K) (dummy)	1=Full time worker	0.267	2.020	0.794	1.633						
	3=University student	0.571	1.790	0.571	1.790						
Household income high ($100K+) (dummy)	1=Full time worker	0.354	2.557	0.757	1.496						
	3=University student	0.996	2.826	0.996	2.826						
Work Logsum	1=Full time worker	-0.278	-8.548	0.507	4.142						
	2=Part-time worker	-0.181	-3.370	0.425	1.789						
	3=University student	0.004	7.153	0.004	7.153					0.003	3.224
School Logsum	3=University student					0.003	3.077	0.003	3.077	0.407	2.242

Findings

The following section summarizes the most important findings and impacts on mandatory tour frequency:

- Person-type constants are very significant showing that person type itself and the characteristics of the person explains the frequency and purpose of the tours. For example, a full time worker is more likely to make one work tour than no tours at all as noted by the positive significant coefficient. Also the constant for full time workers making 2+ work tours is negative and significant as this shows a full time worker spends most of the day at work and thus not likely to make 2+ work tours in a day.
- Gender has a certain impact on frequency and purpose of mandatory tours. Female full-time workers are less likely to make two or more work tours. However, a female part time worker is more likely to make two or more work tours compared to a male, which may be because female workers tend to work near their residence and need to take care of children related issues. Female university students are less likely to make one work tour or one or more school tours. And female drive age students are more likely to make one or more school tours.
- Part time workers of younger age (under 35) are more likely to make one or more work tours. This may be because they have more than one job. Older (greater than 35) university students are more likely to have one or more work tours.
- The number of preschool children in household has a negative impact on part time workers and university students making one or more work tours or one or more school tours. The pre-schoolers are keeping part-time workers and university students from going to work and school. The number of older children (6-18) in the household has a positive impact on full time workers making two or more work tours. Full time workers with older children are more likely to go to work.
- Zero car households reduce the probability of workers making two more work tours.
- The work location logsum coefficient is positive for full-time workers, part time workers, and university students to make more than one work or school tour.
- The school location logsum coefficient is positive for university students making one or more school tours, or a combination of work and school tours. So the more accessible the school location is, the more work and school tours university students make.

Non-Mandatory-Tour Frequency Estimation

The non-mandatory tour frequency model predicts the number of tours for each person who has at least one non-mandatory tour. The model is applied after the mandatory tour frequency model. The model has twenty three alternatives which include all combinations of 0,1, or 2 escort, maintenance and discretionary tours, with no more than four total tours allowed. A separate model was estimated for each person type: full time worker, part time worker, university student, retiree, driving age student, non-driving age student, and preschool student. All were estimated in a multinomial logit form using the ALOGIT software.

Estimation Dataset

The estimation dataset included 8,970 observations of non-mandatory tours. The observed frequency by choices are in Table 14 below. In order to evaluate the potential impact of varying accessibilities as well as zone-specific characteristics at the home locations (by TAZ), data containing accessibilities, logsums, and demographic information by zone was appended.

Table 14: Non-Mandatory Tour Frequency Available Alternatives

alt	escort	maintenance	discretionary	total	frequency
1	0	0	0	0	5882
2	0	0	1	1	855
3	0	0	2	2	127
4	0	1	0	1	1086
5	0	1	1	2	176
6	0	1	2	3	26
7	0	2	0	2	149
8	0	2	1	3	38
9	0	2	2	4	3
10	1	0	0	1	206
11	1	0	1	2	56
12	1	0	2	3	14
13	1	1	0	2	81
14	1	1	1	3	24
15	1	1	2	4	2
16	1	2	0	3	18
17	1	2	1	4	5
18	2	0	0	2	138
19	2	0	1	3	27
20	2	0	2	4	4
21	2	1	0	3	41
22	2	1	1	4	7
23	2	2	0	4	3

Main Explanatory Variables

The following variables have been examined in the estimation process. All variables were stratified by the number of tours by purpose (i.e., 1 or 2 escort tours).

- **Income of household:**
  - Low, medium, high, and very high income
- **Household characteristics stratified by tour purpose:**
  - Number of workers
  - Worker status (for university students)
  - Household size
  - Female
  - Age
- **Home location accessibility**
- **Mix of households and employment at home location**
- **Distance to work or school, depending on person type**

Due to the small number of observations for some of the alternatives, some of the variables did not have a significant effect. These were dropped from the estimation, except in a couple of cases where they were close to significance and the sign was in the correct direction.

Results

The final estimation results are presented in Table 15.

Table 15: Phase 1 Estimation Results for Non-Mandatory Tour Frequency Model

	Full Time Worker	Part Time Worker	University Student	Retiree	Non-Working Adult	Other Students
ASC						
one escort tour	-3.143 (-19.39)	-2.708 (-14.89)	-3.099 (-14.81)	-16.966 (-2.70)	-3.112 (-16.35)	-3.756 (-29.66)
two escort tours	-4.201 (-15.13)	-3.823 (-11.24)	-4.441 (-10.80)	-19.952 (-2.42)	-3.377 (-11.91)	-5.212 (-27.47)
one maintenance tour	01.346 (-12.13)	-0.505 (-4.27)	-0.977 (-2.32)	-3.818 (-2.46)	-4.567 (-2.57)	-0.672 (-9.14)
two maintenance tours	03.369 (-13.24)	-2.317 (-8.59)	-1.731 (-1.91)	-13.226 (-2.98)	-6.346 (-3.54)	-2.595 (-14.36)
one discretionary tour	-1.435 (-8.49)	-1.180 (-8.67)	-2.250 (-14.84)	-11.254 (-4.86)	-0.727 (-3.31)	-1.298 (-15.68)
two discretionary tours	-3.343 (-7.54)	-3.015 (-9.90)	-5.040 (-10.81)	-30.514 (-3.99)	-2.117 (-4.75)	-3.347 (-16.49)
two total tours	0.444 (2.90)	0.216 (1.24)	0.840 (2.74)	-0.378 (-2.58)	-0.068 (-0.40)	0.235 (3.12)
three total tours	0.908 (3.31)	0.424 (1.42)	1.699 (3.33)	-0.455 (-1.74)	-0.059 (-0.21)	0.732 (5.64)
four total tours	1.187 (2.13)	-0.589 (-0.85)	2.495 (2.65)	-1.173 (-1.96)	-0.173 (-0.34)	0.809 (3.02)
Low income						
discretionary, 1+ tours					-0.888 (-3.91)	
Medium Income						
discretionary, 1+ tours					-0.335 (-1.89)	
Accessibility						
escort, 1 tour				1.028 (2.11)		
escort, 2 tours				1.249 (1.96)		
maintenance, 1 tour				0.318 (2.27)		
maintenance, 2 tours				1.003 (2.55)		
discretionary, 1 tour				0.822 (4.31)		
discretionary, 2 tours				2.276 (3.66)		
maintenance, 1+ tours					0.329 (2.08)	
Logsum						
escort, 1+ tours						0.0003 (3.31)

maintenance, 1+ tours	0.199 (4.25)	0.185 (2.97)				0.001 (16.57)
discretionary, 1+ tours	0.187 (4.00)	0.088 (1.37)				0.001 (8.77)
HH size						
escort, 1 tour						0.291 (9.00)
escort, 2 tours						0.450 (11.68)
maintenance, 1 tour			-0.214 (-2.03)			-0.170 (-6.94)
maintenance, 2 tours			-0.823 (-2.70)			-0.263 (-4.25)
discretionary, 1 tour	-0.161 (-3.42)				-0.196 (-2.91)	-0.136 (-5.11)
discretionary, 2 tours	-0.265 (-1.88)				-0.261 (-1.79)	-0.185 (-2.75)
escort, 1+ tours				0.215 (2.86)		
maintenance, 1+ tours				-0.274 (-5.12)		
Workers in Household						
discretionary, 1 tour				-0.235 (-2.71)		
discretionary, 2 tours				-0.477 (-2.02)		
Distance to Work						
escort, 1+ tours						
Worker Status - Work						
maintenance, 1 tour			-0.870 (-2.94)			
maintenance, 2 tours			-1.264 (-1.99)			
Presence of Preschool children						
escort, 1 tour	0.300 (1.79)	0.789 (3.13)			0.410 (1.60)	
escort, 2 tours	0.688 (3.31)	0.993 (3.12)			0.979 (4.88)	
Presence of Non-driving age children						
escort, 1 tour	0.666 (7.16)	1.116 (7.81)			0.932 (5.56)	
escort, 2 tours	0.902 (6.62)	1.386 (7.22)			1.061 (6.48)	

Presence of Driving age children						
escort, 1 tour	0.536 (2.12)				1.180 (3.00)	
escort, 2 tours	0.873 (2.49)				0.963 (2.13)	
escort, 1+ tours		0.686 (1.89)				
Single Adult households						
escort, 1+ tours					-1.00 (-2.11)	
discretionary, 1 tour					0.521 (2.91)	
discretionary, 2 tours					0.749 (2.20)	
Number of Work Tours						
escort, 1 tour	-0.772 (-4.34)	-0.609 (-2.50)				
escort, 2 tours	-2.413 (-7.14)	-1.317 (-3.02)				
maintenance, 1 tour	-1.193 (-9.67)	-1.498 (-7.81)				
maintenance, 2 tours	-1.938 (-5.97)	-1.858 (-3.89)				
discretionary, 1 tour	-0.360 (-2.89)	-0.643 (-3.64)				
discretionary, 2 tours	-1.029 (-3.10)	-1.238 (-2.54)				
Number of School Tours						
maintenance, 1+ tours						-2.189 (-2.15)
Number of University Tours						
maintenance, 1+ tours			-1.011 (-2.86)			

Findings

The following section summarized the most important findings and impacts on non-mandatory tour frequency.

- **Full Time Worker**
  - Being in a low-income bracket means that a person is more likely than a higher income person to take one or two maintenance tours. The coefficient on two maintenance tours is higher than the coefficient on one, which could be because low income workers are not working a typical 8-5 shift, meaning they have more time during the work day to do maintenance activities.
  - The logsum term was significant and positive for maintenance and discretionary tours, as is expected.
  - Household size had a negative and significant coefficient on discretionary tours, which means that in a larger household a person is less likely to make discretionary tours during the day. This could be reflecting that other household members are participating in these tours, or that there is less time during the day for discretionary tours due to the time used for the escort tours.
  - The presence of children had a positive and significant effect on the number of tours of all three purposes. Children were grouped into three categories (preschool, non-driving age, and driving age) and all three groups had significant coefficients. The magnitude was larger for 2 tours than for one.
  - The number of work tours had a negative and significant effect on all three purposes. This is expected, because it reflects that the more mandatory tours the person is making, the less time they have for non-mandatory tours.
  - A mix variable was tested, which measures the density of households and employment at the household location. This variable was not significant.

- **Part Time Worker**
  - Part Time Worker estimation was based on the Full Time worker estimation.
  - The logsum coefficients were positive and significant.
  - The presence of children was significant and positive again. For the driving age children group, the number of escort tours was combined into a category for 1+ escort tours.
  - The number of work tours was negative and significant.

- **University Student**
  - Somewhat surprisingly, neither accessibility nor the mix variable were significant.
  - Household size was negative and significant for one and two maintenance tours, which means that as there are more household members, the university student is less likely to make maintenance tours during the day.
  - University students who are also workers have a negative and significant coefficient on maintenance tours. This means that if they work, they are unlikely to make one or two maintenance tours. This most likely reflects a lack of time in the day for additional tours.

- The number of university tours had a negative and significant coefficient for 1+ maintenance tours. This is a reasonable result, as it reflects that the more mandatory tours the person is making, the less time they have for non-mandatory tours.

- **Retiree**
  - Accessibility was positive and significant for all tour types for retirees. This may reflect a difference in mobility and auto ownership among retirees. The coefficients on two tours are higher than the coefficients on one tour, reflecting that higher accessibility means more tours are taken.
  - The mix coefficient was not significant.
  - Household size had a significant and positive term on two escort tours. It had a negative and significant coefficient for two maintenance tours. As discussed in the full time worker summary, this is an expected result.
  - The number of workers in the household had a negative and significant coefficient on the discretionary tour purpose. This could be reflecting that the retiree is not choosing to make those kinds of tours, as the working adult is doing them during the day.

- **Non-working Adults**
  - Low and medium income had a negative and significant coefficient on discretionary tours. This is a reasonable result because these persons have less income to spend on entertainment activities.
  - Household size had a positive and significant coefficient on one and two escort terms, as seen for other person types. There is a negative and significant coefficient on one and two discretionary tours and on one maintenance tour. The coefficient for two maintenance tours was not significant.
  - Accessibility had a positive and significant coefficient on maintenance tours, which means that in more accessible locations, more maintenance tours are chosen.
  - Household size had a positive and negative coefficient on discretionary tours. As discussed for other purposes, this could be reflecting that the non-working adult in the household is not making these tours because the working adult did them during the day.
  - Single adult households had a negative and significant term on escort tours, which means that these respondents are not driving other householders around and dropping them off. This could reflect smaller household sizes, lack of children in home (presence of children is explained by another coefficient), or that the single adult is doing the other mandatory tours and therefore unable to do escort tours. The coefficient was positive and significant for one and two discretionary tours, which is reasonable because the householder is solely responsible for the tours.

- **Students**
  - Estimation was attempted for students within three sub-groups: driving age students, non-driving students, and preschool students. Not all alternatives were represented in those subgroups. Additionally, it was not possible to estimate reasonable coefficients due to lack of

observations in many categories. Therefore, all student records were combined into one estimation.

- The logsum was significant and positive for all purposes.
- Age was estimated in order to determine differences in the driving age student’s tours, but was not significant for any purpose.
- Household size was positive and significant for one and two escort tours, and negative and significant for one and two discretionary and maintenance tours. This is the same pattern as seen for other person types.
- The number of school tours had a negative and significant coefficient on the number of maintenance tours. This reflects that the more mandatory tours the person is making, the less time they have for non-mandatory tours.

At-Work Sub-Tour Frequency Estimation

The at-work sub-tour frequency model predicts the number of tours for each person who has at least one work tour. The model is applied after the mandatory tour frequency model. The model has three alternatives: No at-work sub tours, 1 at-work sub tour, 2+ at-work sub tours. It was estimated in a multinomial logit form using the ALOGIT software.

Estimation Dataset

The estimation dataset included 3,399 observations of work tours. Of these, only 405 had one or more at-work sub tours.

Table 16: Observed Frequency of At-Work Sub-Tours

Alternative	Frequency
No tours	2994
1 at-work subtour	360
2+ at-work subtours	45
Total	**3399**

Main Explanatory Variables

The following variables have been examined in the estimation process:

Income stratified by alternative:

- Low, medium, high income

Person type stratified by alternative:

- full time
- part time
- university student

Household characteristics stratified by alternative:

- Number of adults (drivers 16 and up)
- Number of non-workers
- Number of workers
- Number of children (non-driving)
- Female, with pre-school children

Accessibility at work location stratified by alternative:

- At work walk accessibility
- At work walk to transit accessibility

Results

The final estimation results are presented in Table 17.

Table 17: Estimation Results for At-Work Sub-Tour Frequency Model

Initial likelihood (zero coefficients)	-3734.1832
Likelihood with constants only	-1382.7053
Final likelihood	-1337.8821
Rho-squared w.r.t. Zero	0.6417
Rho-squared w.r.t. Constants	0.0324

Variable	Alternative	Coefficient	T-Stat
Constant	No at-work subtours	0	reference
	1 at-work subtour	-2.842	-8.53
	2+ at-work tours	-5.541	-4.84
Part time worker	1 at-work subtour	-0.703	-3.00
Low income	1 at-work subtour	-0.694	-2.17
	2+ at-work tours	-1.298	-1.25
Medium income	1 at-work subtour	-0.322	-2.72
	2+ at-work tours	-0.658	-2.06
Number of Workers	1 at-work subtour	-0.228	-2.91
	2+ at-work tours	-0.296	-1.36
Number of non-workers	1 at-work subtour	-0.201	-1.47
	2+ at-work tours	-0.606	-1.32
Female	2+ at-work tours	-0.846	-2.54
At-work accessibility, non-motorized	1 at-work subtour	0.155	5.04
	2+ at-work tours	0.283	2.63

Findings

The following section summarized the most important findings and impacts on at-work tour frequency.

- Part time workers are not likely to make at-work sub-tours as noted by the significant negative coefficient. This makes sense as a full time worker with a longer day would result in more likelihood of these types of tours.
- A low or medium income household has a significant and negative effect on the number of at-work sub-tours. This is intuitively correct, since workers with money will make more tours to purchase food and other goods and services.
- A low income household for 2+ at-work sub tours was not statistically significant but does have a negative sign. This variable was left in the model even though it is not significant, because it is likely that lower income workers do not attend as many business meetings as their higher income counterparts.
- The number of workers and number of non-workers in the household has a negative and significant effect on the frequency of at-work sub tours. This is presumably because another adult could take the necessary other tours (for example, shopping). Another adult could also perhaps prepare a lunch for a working adult.

- Females are less likely to make 2+ at-work sub tours than males.
- The at-work walk accessibility is statistically significant and positive as expected. Workers in more accessible locations are more likely to take tours.

Non-Mandatory Tour Location Choice Models

A destination choice model was estimated for each of the non-mandatory tour purposes; Maintenance, Discretionary, and Escorting. The destination choice model predicts the location of where the traveler is going based on mode choice logsums, distance terms, zonal employment and household and person attributes as explanatory variables. These models were estimated in a multinomial logit form using the ALOGIT software. The utility structure is the same as the structure used for the mandatory tour location choice models described earlier.

Oahu Maintenance Location Choice

The maintenance purpose destination choice model predicts primary destination for maintenance tours, which include shopping and other maintenance purposes such as banking, medical appointments, and other personal business.

Estimation Dataset

In the 2012/2013 Oahu Household Travel Survey there were 1,874 tour records that were used to estimate the maintenance tour destination choice model.

Main Explanatory Variables

The following variables have been examined and proved to be significant in the utility functions:

- Mode choice logsum
- Impedance between the home and potential maintenance destinations:
    - Linear distance
    - Distance squared
    - Natural Log of Distance
- Person Characteristics interacted with distance terms
    - Age group
        - Age 20 years and younger
        - Age 65+
    - Gender – Female vs. Male
    - Work Status – Full-time vs. Part-time.
- Size Terms: Retail, Service, and Government employment

Table 18 shows the frequency of distance to maintenance locations for all persons in the dataset.

Table 18: Frequency of Distance to Chosen Maintenance Destinations

Bin (miles)	Frequency
5	1,377
10	305
15	187
20	74
25	53
30	19
35	6
40	2
45	0

50	0
55	2
Total	2,025

Results

The maintenance destination choice results are summarized in Table 19.

Table 19: Oahu Maintenance Location Choice Model Estimation Results

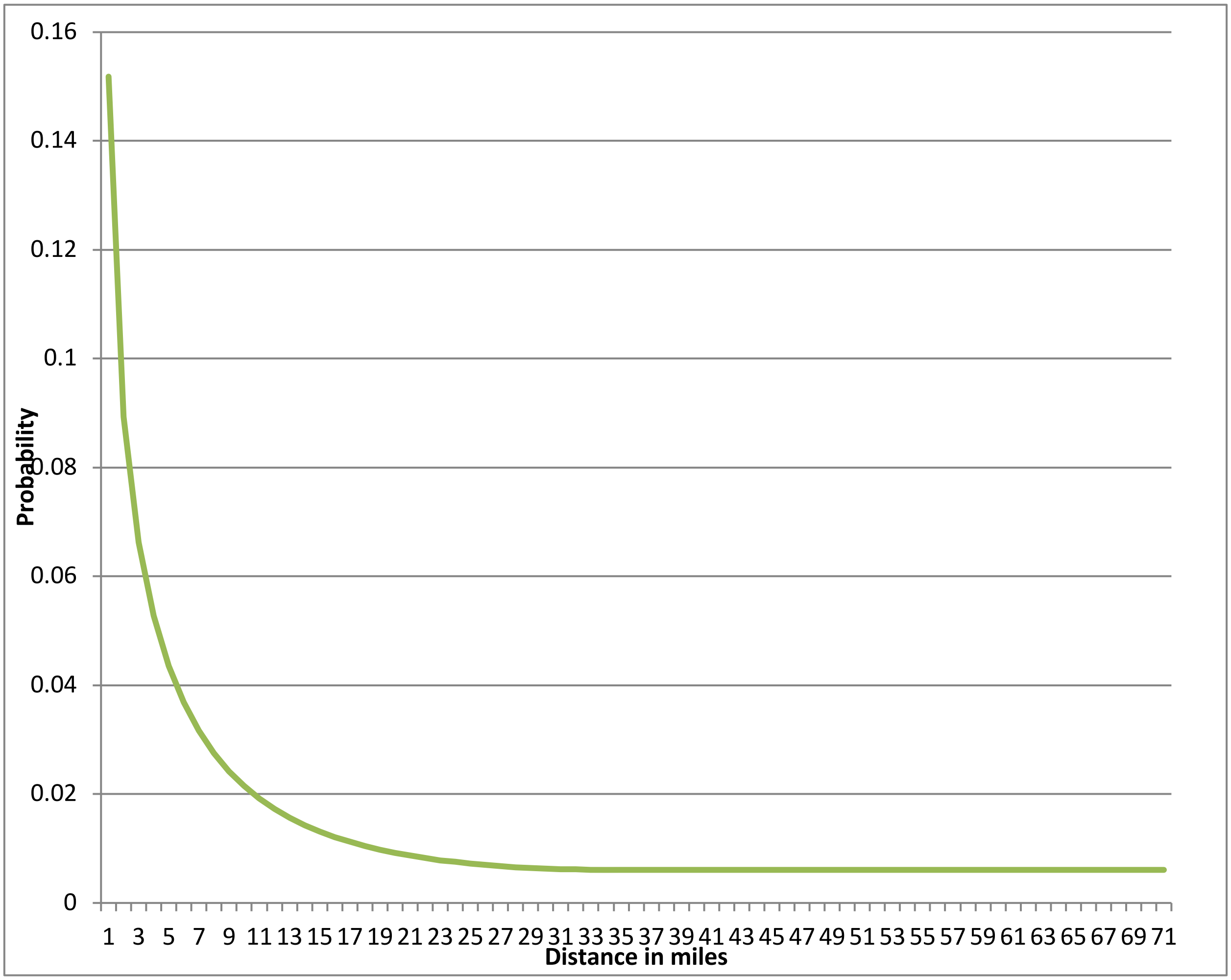
Observations: 1874
Final log likelihood: -9211.6361
Rho-Squared (0): 0.2596
Rho-Squared (constant): 0.0104

Utility Function Variables	Coeff	T-Stat
Mode Choice Logsum	0.444	2.89
Distance	-0.108	-3.86
Distance Squared	0.002	2.62
Distance Natural Log	-0.893	-12.12
Full-time worker		
Distance	-0.033	-2.68
Female		
Distance	-0.015	-1.67
Age 20 Years and Younger		
Distance	-0.031	-1.59
Age 65 and Up		
Distance	-0.034	-3.26
0 Auto Households		
Distance	-0.08710	-2.77
Size Function		
Retail Employment	1.000	
Service Employment	0.124	-24.17
Government Employment	0.017	-6.98

Findings:

- The coefficient on mode choice logsum is positive and between 0 and 1, as expected.
- A *Composite distance function* (or distance decay factor) has been defined as a combination of linear, squared and natural logged distance terms with different coefficients. This term should be analyzed as a composite term.. For example, the coefficient on linear distance is positive but it does not mean that people choose distant maintenance locations. But, we should look at the combined effect of all terms. Figure 5 shows the distance decay factor. This function is monotonously decreasing within the maximum chosen maintenance distance range.

Figure 5: Maintenance Distance Decay Factor



- The effects of work status (full-time vs. part-time vs. non-work), gender (females vs. males) and age was found siginificant on distance to maintenance location. The findings are below:
  - *Full-time workers* are most sensitive to longer distances to maintenance locations than those that are part timers or non-workers. This may be because full-time workers have less time to spend travelling for maintenance tours after allocating time to work tours.
  - *Females* are less likely to travel longer distances as compared to males.
  - *Age (young and old):* People less than 20 years old, and those older than 65 years old tend to travel shorter distances for maintenance activities than those age 21 to 64.
- Size term effects:
  - Retail employment has the highest size term coefficient, relative to service or government employment, and therefore will attract a relatively higher share of maintenance tours.

Oahu Discretionary Location Choice

The discretionary purpose destination choice model predicts the primary destination of discretionary tours. Discretionary tours include tours for recreation, visiting, eating out, and other discretionary activities.

Estimation Dataset

In the 2012/2013 Oahu Household Travel Survey there were 1,560 tour records that were used to estimate the discretionary tour destination choice model.

Main Explanatory Variables

The following variables have been examined and proved to be significant in the utility functions:

- Mode choice logsum
    - Distance
- Person Characteristics interacted with distance terms:
    - Age 20 years and younger
    - Work Status – Full-time vs. Part-time.
- Size Terms: Retail, Service, Hotel employment, and households

Results

The discretionary destination choice results are summarized in Table 20.

Table 20: Oahu Discretionary Location Choice Model Estimation Results

Observations: 1560
Final log likelihood: -8701.6417
Rho-Squared (0): 0.1598
Rho-Squared (constant): 0.0167

Utility Function Variables	Coeff	T-Stat
Mode Choice Logsum	1.000	
Natural Log of Distance	-0.835	-25.70
Full-time worker		
Distance	-0.041	-3.68
Age 20 Years and Younger		
Distance	-0.050	-3.77
Size Function		
Retail Employment	1.000	
Service Employment	0.264	-9.48
Hotel Employment	0.226	-3.74
Households	0.306	-11.77

Findings:

- The coefficient on mode choice logsum was set to 1 because the ALOGIT estimated the coefficient as slightly over one.

- The effects of work status (full-time vs. part-time vs. non-work), and age was found significant on distance to discretionary location. The findings are below:
    - *Full-time workers* are most sensitive to longer distances to discretionary locations than those that are part timers or non-workers. This is likely due to full-time workers having less time to travel to discretionary activities after allocating time to work tours.*Age (20 and younger):* People less than 20 years old tend to engage in discretionary activities that are closer to home compared to those older than 20.
- Size term effects:
    - Retail employment is the dominant size term, with service employment and hotel employment attracting about 25% as many discretionary tours. Households also attract discretionary tours.

Oahu Escorting Location Choice

The escorting purpose destination choice model predicts the primary destination for escorting tours, which involve picking up or dropping off household members, often at school locations.

Estimation Dataset

In the 2012/2013 Oahu Household Travel Survey there were 887 tour records that were used to estimate the escorting tour destination choice model.

Main Explanatory Variables

The following variables have been examined and proved to be significant in the utility functions:

- Impedance between the home and potential escorting destinations:
    - Linear distance
    - Distance squared
    - Natural Log of Distance
- Size Terms: total employment, service employment and households

Table 21 shows the frequency of distance to escorting locations for all persons in the dataset.

Table 21: Frequency of observed distance to escorting location

BIN (MILES)	FREQUENCY
5	627
10	164
15	75
20	30
25	12
30	4
Total	912

Results

The escorting destination choice results are summarized in Table 22.

Table 22: Oahu Escorting Location Choice Model Estimation Results

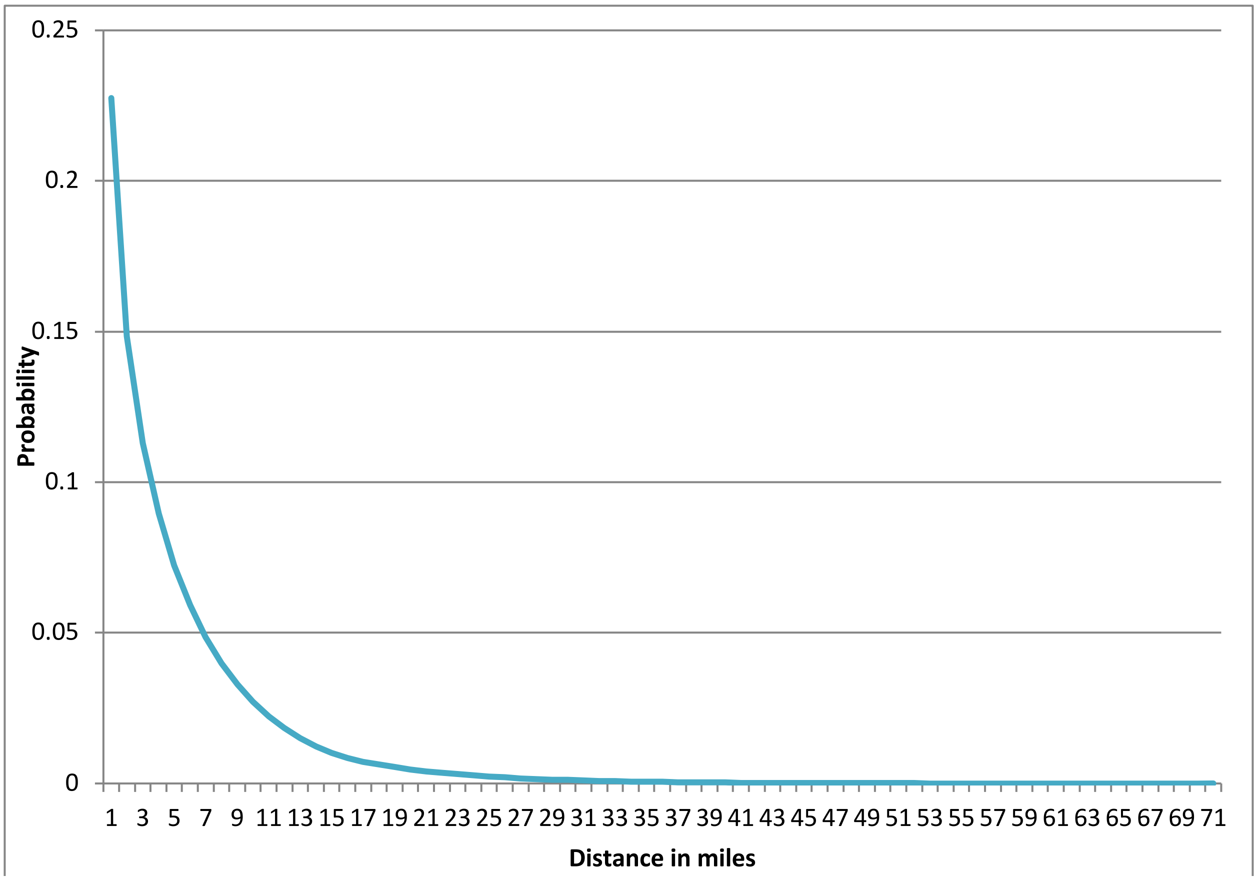
Observations: 887
Final log likelihood: -4364.1952
Rho-Squared (0): 0.2588
Rho-Squared (constant): 0.0534

Utility Function Variables	Coeff	T-Stat
Distance	-0.171	-4.81
Distance Squared	-0.0019	-0.85
Distance Natural Log	-0.6598	-8.22
Size Function		
Total Enrollment	1.000	
Households	0.353	-7.84
Service Employment	0.750	-2.71

Findings:

- The coefficient on mode choice logsum could not be estimated as it had a coefficient over 1.
- A *Composite distance function* (or distance decay factor) has been defined as a combination of linear, squared and natural logged distance terms with different coefficients. Figure 6 shows the distance decay factor. This function is monotonously decreasing within the maximum chosen escorting distance range.

Figure 6: Escorting ***Distance Decay Factor***



- Size term effects:
  - School enrollment has a much greater tour attraction rate than households or service employment.

At-Work Location Choice Model

The at-work sub tour purpose destination choice model predicts primary destination location for at-work subtours. At-work sub-tours are tours made for eating out (e.g. lunch), business, and other personal reasons, where the workplace is the tour origin.

Estimation Dataset

In the 2012/2013 Oahu Household Travel Survey there were 455 tour records that were used to estimate the at-work sub-tour destination choice model.

Main Explanatory Variables

The following variables have been examined were significant in the utility functions:

- Mode choice logsum
- Impedance between the workplace and potential at-work destinations:
  - Natural Log of Distance

- Size Terms: retail, service, military, government employment, and households

Table 23 shows the frequency of distance to escorting locations for all persons in the dataset.

Table 23: Frequency of observed distance to an at-work location

Bin(miles)	At-work(4)
5	359
10	50
15	23
20	13
25	7
30	6
Total	458

Results

The at-work sub tour destination choice results are summarized in Table 24.

Table 24: Oahu At-Work Sub Tour Location Choice Model Estimation Results

Observations: 455
Final log likelihood: -2319.2954
Rho-Squared (0): 0.2322
Rho-Squared (constant): -0.0117

Utility Function Variables	Coeff	T-Stat
Mode Choice Logsum	0.343	4.95
Natural Log of Distance	-0.6144	-7.56
Size Function		
Retail Employment	1.000	
Service Employment	0.745	-1.01
Military Employment	0.794	-0.61
Government Employment	0.963	-0.13
Households	0.418	-3.11

Findings:

- The coefficient on mode choice logsum is positive and between 0 and 1 as expected.

- Only the natural log of distance turned out significant for this purpose.
- Size term effects:
    - Retail employment has the highest tour attraction rate, but service and government employment is also a strong attractor of at-work sub-tours. Interestingly, military employment is a strong attractor of at-work sub-tours, perhaps due to at-work sub-tours being made for business reasons, or perhaps due to at-work sub-tours being generated bt military base employment. Households also attract at-work sub-tours, as some workers go home for their lunch hour.

Stop Level Models

Only the intermediate stop location choice model was estimated using the household survey data and is described below.

Intermediate Stop Location Choice Model

The intermediate stop location choice model predicts the location (TAZ) of each intermediate stop (each location other than the origin and primary destination) on the tour. In this model, a maximum of 3 stops in outbound and 3 stops in inbound direction are modeled for each tour. A number of variables were tested in the stop location choice models, including mode choice logsum, travel distance deviation for stop from the half-tour path, tour specific variables (purpose, mode, origin location, destination location), person and household attributes (gender, age, household income) and land use variables (employment, household, school enrollment and university enrollment). The models were estimated in ALOGIT software as a multinomial logit model.

Estimation Dataset

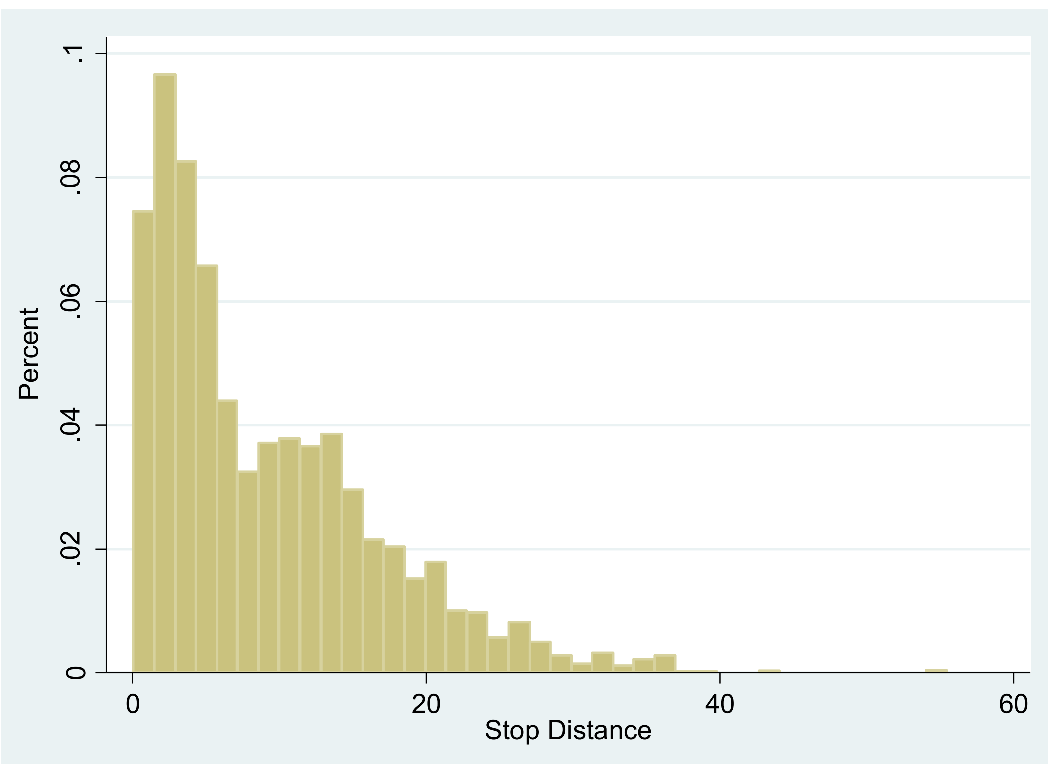
The estimation dataset included 6,659 observed stop records including up to 3 stops in each direction. Table 25 below shows the number and percentage of stop records by primary tour purpose and stop purpose. Most of the stops are made for escorting, maintenance and shopping activities comprising for more than 70% of all stops. Nearly 35% of the stops are made on work tours.

Figure 7 shows the proximity of a stop from the previous stop and the end location of the half-tour. A half-tour is the trip beginning from a tour/trip origin and ending at the primary destination of that tour. An outbound half-tour is from the tour origin to the primary destination of that **tour**. An inbound half-tour begins at the primary destination of a tour and ends at the **half-**tour destination (which was also the tour origin). In case of the first stop on the outbound half-tour, the previous location is home (or work for at-work subtours) and end location is the tour primary destination (or subtour destination for at-work subtours). In case of second or later **stops** on the same tour, the previous location is the previous stop on the half-tour and end location is the half-tour destination. Please refer to the section on "Processing of Stops" for more detail.

Table 25: Number of Stop Records by Stop Purpose and Tour Purpose

Purpose	# Stops on Tours by Tour Activity Purpose		# Stops by Stop Activity Purpose	
Work	2,313	35%	50	1%
University	112	2%	0	0%
School	481	7%	0	0%
Escorting	456	7%	1,760	26%
Shopping	1,249	19%	1,468	22%
Maintenance	642	10%	1,522	23%
Eating Out	137	2%	675	10%
Visiting	189	3%	382	6%
Discretionary	488	7%	422	6%
At Work	592	9%	380	6%
Total	6,659	100%	6,659	100%

Figure 7: Distribution of Stop Distance



Model Utility

The utility ($U^{tm}_{isjnkod}$) of choosing a stop MGRA (*s*) for an individual (*n*) for stop purpose (k) between the previous location MGRA (*i*) and half-tour destination MGRA (j) is given by Equation 1.

Equation 1

$$U^{tm}_{isjnkod} = S_{sk} + \alpha \times L^{tm}_{isj} + \sum_{g} \delta \times Fn[d_{os}, d_{sd}]T^{g} + \sum_{p} \beta^{p} \times d^{p}_{isj} + \sum_{q} \phi^{q} \times d_{isj} N^{q}_{n} + \sum_{g} \delta^{g} \times d_{isj} T^{g} + C_{s}$$

Where:

S_{sk} = the size function for stop mgra (s) and stop purpose (k)

L^{tm}_{isj} = the mode choice logsum for half-tour between zone pair ij via stop s, conditional upon tour purpose (t) and tour mode (m).

$Fn[d_{os}, d_{sd}]$ = function of distance from tour origin to stop (d_{os}) and distance from tour destination to stop (d_{sd}). The final function used is $d_{os}/ (d_{os}+d_{sd})$. This ratio shows if the stop location is closer to tour origin than tour destination.

d^{p}_{isj} = the various distance deviation terms (*p = linear, log, square root, squared, and cubed*) for stop *(s).*

N^{q}_{n} =the q[th] stop/tour/person /household characteristics (such as stop purpose, tour purpose, stop number, income, age group, person type) for individual n and are used for creating interaction variable with linear distance deviation term(d_{isj}),

T^{g} =the g[th] stop/tour characteristics (such as stop purpose, tour purpose, stop number, half-tour direction etc.) and are used for creating interaction variable with linear distance deviation term (d_{isj}),

C_{s} = a correction term to compensate for the sampling error in the model estimation (i.e. represent the difference between the sampling probability and final estimated probability for each alternative). The appendix explains how this correction factor is calculated.

The size function (S_{sk}) for stop location s, purpose k is a combination of different (*r*) size variables (S_{skr}) such as enrollment, employment by class, households, and their interaction with person/household characteristics. It is included in the utility function as a log term. The coefficients (γ_{rk}) on the size terms are constrained as positive in the estimation process. Note that the implied value of the coefficient on the first size term variable (r=1) is 1 for each stop purpose. This is to ensure that the size term is not over-specified; all other parameter values are interpreted as ratios of the impact of their corresponding independent variable to the first size term variable. Size term parameters are estimated simultaneously with other stop location choice parameters in ALOGIT. The final estimation results for size variables are shown in Table 3.

Equation 2

$$S_{sk} = \log(S_{sk1} + \sum_{d>1} \gamma_{dk} \times S_{skd})$$

A combination of distance deviation terms is used in the utility such that the composite distance deviation utility function is monotonically decreasing within the maximum chosen distance deviation range.

Main Explanatory Variables

It is not straightforward to segment the model by purpose because size (or attraction) variables are related to purpose of the stop activity while impedance variables are strongly related to the tour characteristics – primary tour purpose, primary mode used for the tour, etc. Therefore, a single model is estimated with size variables based on stop purpose and utility variables based on both stop and tour characteristics.

The following variables have been examined and proved to be significant in the utility functions:

1. Mode choice logsum
2. Distance deviation or "out-of-the-way" distance for stop location when compared to the half-tour distance without detour for any stop
    a. Linear distance
    b. Distance squared
    c. Distance logged
3. Distance of stop location from tour origin and destination is used to define closeness to tour origin or destination. This term is interacted with tour purpose, direction of half-tour and stop number.
4. Tour- and stop-specific variables interacted with distance deviation:
    a. Stop purpose
    b. Tour purpose
    c. Tour mode
    d. Dummy for 2^{nd} or 3^{rd} stop
    e. Direction of the half-tour
5. Household income group interacted with distance deviation:
    a. Low income (less than $30,000)
    b. Medium income ($30,000-60,000)
    c. High income ($60,000 and more)
6. Person characteristics interacted with distance deviation:
    a. Gender – female vs. male
    b. Age group
7. Size variables
    a. Employment by categories
    b. Number of households

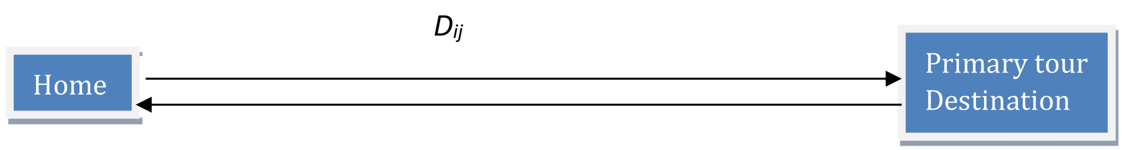
c. School enrollments – pre-school, K to 6 grade and 7^{th} to 12^{th} grade, based on type of school child in the household

d. University and other college enrollments

The model operates at a half-tour level using distance and level-of-service to get from half-tour origin to half-tour destination via stop location. In case of multiple stops on a half-tour, the stop locations are processed in a chronological order. The first stop is considered as the origin zone for the second stop, and second is considered the origin zone for the third stop. Detailed processing of stops is explained below.

Processing of Stops

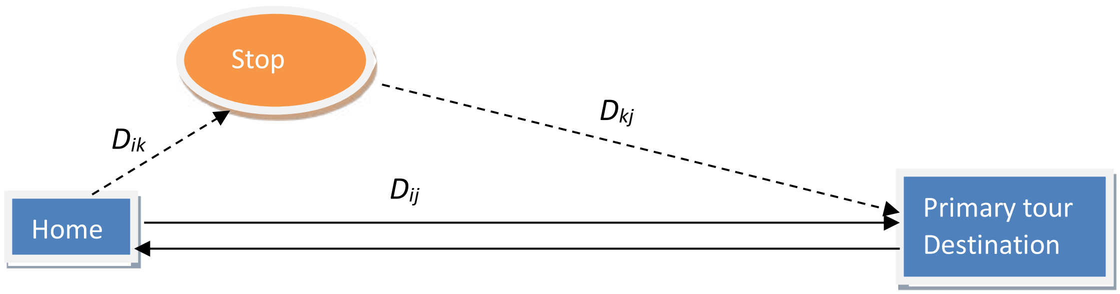
The example below explain show the stops are processed and how the distance deviation is calculated. Consider a tour from home (i) to primary tour destination (j) with distance D_{ij} between the two locations. Assume that this tour has two stops on the outbound half-tour and one stop on the inbound half-tour. The process described below applies to additional stops in any direction.



First, process the first outbound stop (k) for the half-tour. The absolute distance deviation (d_k) for stop k is given by $d_k = D_{ik} + D_{kj} - D_{ij}$ and relative distance deviation (R_k) is given by

$$R_k = \frac{[D_{ik}+D_{kj}-D_{ij}]}{D_{ij}},$$

where D_{ik} is the distance from home (i) to stop k and D_{kj} is the distance from stop k to primary destination (j).



Let's consider the second stop (m) on the half-tour. Since the location of stop (k) is already decided, the deviation for next stop is calculated based on stop (k) as the origin.

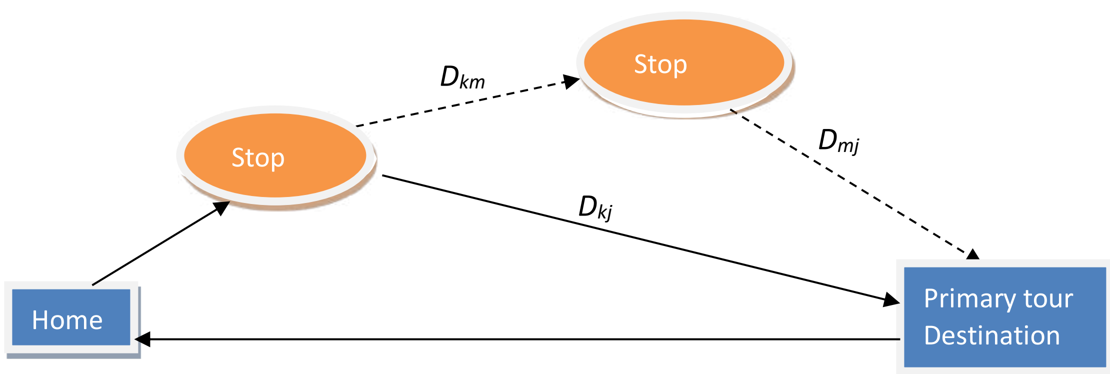
The absolute distance deviation (d_m) for stop m is given by:

$$d_m = D_{km} + D_{mj} - D_{kj}$$

The relative distance deviation (R_m) is given by:

$$R_m = \frac{[D_{km} + D_{mj} - D_{kj}]}{D_{kj}}$$

where D_{km} is the distance from stop k to stop m, and D_{mj} is the distance from stop m to primary destination (j).



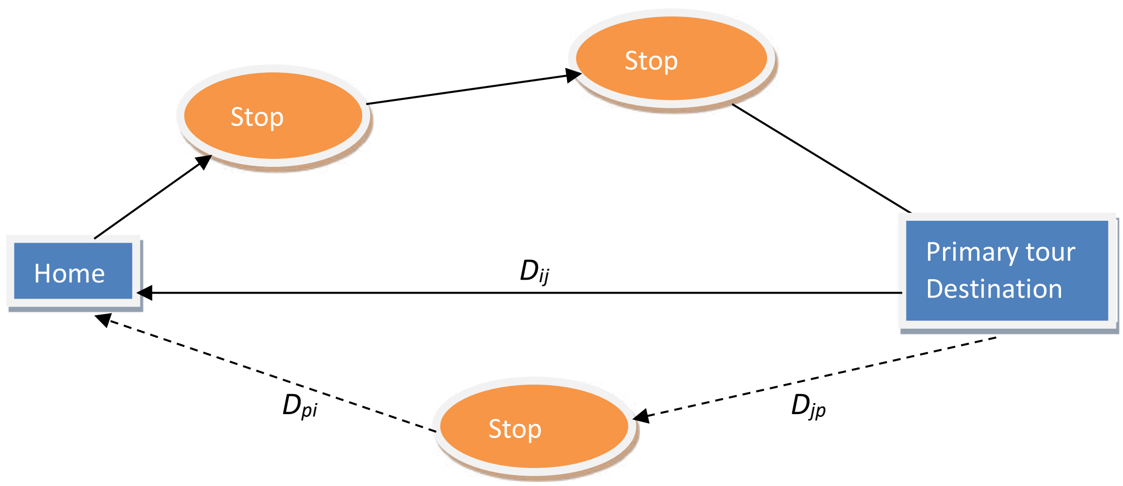
Multiple stops are processed along the half-tour using the same process. For inbound half-tour, the processing is carried out in the same way except that the primary tour destination (or previous stop on inbound half-tour) becomes origin location and home becomes destination location. The absolute distance deviation (d_p) for stop p on the inbound half-tour is given by:

$$d_p = D_{jp} + D_{pi} - D_{ij}$$

And the relative distance deviation (R_p) for stop p on the inbound half-tour is given by:

$$R_p = \frac{[D_{jp} + D_{pi} - D_{ij}]}{D_{ij}}$$

where D_{jp} is the distance from primary destination (j) to stop p and D_{pi} is the distance from stop p to home (i).



Results

Tables 26 and 27 show the estimation results for the intermediate stop destination choice model. The total number of observations is 6554. Some records were dropped due to unacceptable choices and errors in size variables during the estimation process.

Table 26: Intermediate Stop Destination Choice Model (Impedance Variables)

Number of Observations	6,554
Likelihood with Constants only	-38143.1120
Final likelihood	-31646.6037
ρ^2 w.r.t. zero	0.2625
ρ^2 w.r.t. constants	0.1703

Utility Function Variables	Coeff	T-stat
Mode Choice Logsum	1.3442	26.52
Closeness to Tour Origin		
Linear	-6.1616	-23.28
Square	5.1668	20.59
First outbound	0.1214	0.73
First Inbound Stop	0.9995	6.92
Mandatory Tour Purpose - Outbound	-0.3353	-1.90
Mandatory Tour Purpose - Inbound	0.6931	4.84
Absolute Distance Deviation		
Linear	-0.0948	-2.61
Square	0.0014	1.17
Log	-0.4941	-5.47
Absolute Distance Deviation - Stop Sequence		
Number of Stops on the half-Tour	0.0159	6.77
2nd Stop	-0.0402	-4.08
3rd Stop	-0.0501	-3.29
Absolute Distance Deviation - Stop Purpose		
Escort	0.0532	5.94
Discretionary	0.0502	5.44
Absolute Distance Deviation - Tour Purpose		
University	-0.1055	-2.52
School	-0.1859	-12.06
Escorting	-0.1678	-10.71
Maintenance	-0.1011	-9.96
Discretionary	-0.1007	-7.81
At-Work	-0.0525	-3.82
Household Variables		
Absolute Distance Deviation - Income - $29,999 or Less	0.0438	2.53

Utility Function Variables	Coeff	T-stat
Person Variables		
Absolute Distance Deviation - Female	-0.0153	-2.11
Relative Distance Deviation - Age 35 to 54 yrs	-0.0318	-3.17
Relative Distance Deviation - Age >=55	-0.0397	-3.95

*Table 27: Intermediate Stop Destination Choice Model (Size Variables)***

Stop Purpose	Escorting	Maintenance	Discretionary
	Coeff	Coeff	Coeff
Retail Employment		1.0000	1.0000
University Enrollments	1.0000		
Number of Households	0.3530		0.3064
Service Employment	0.7500	0.1240	0.2645
Government Employment		0.0174	
Hotel Employment			0.2256

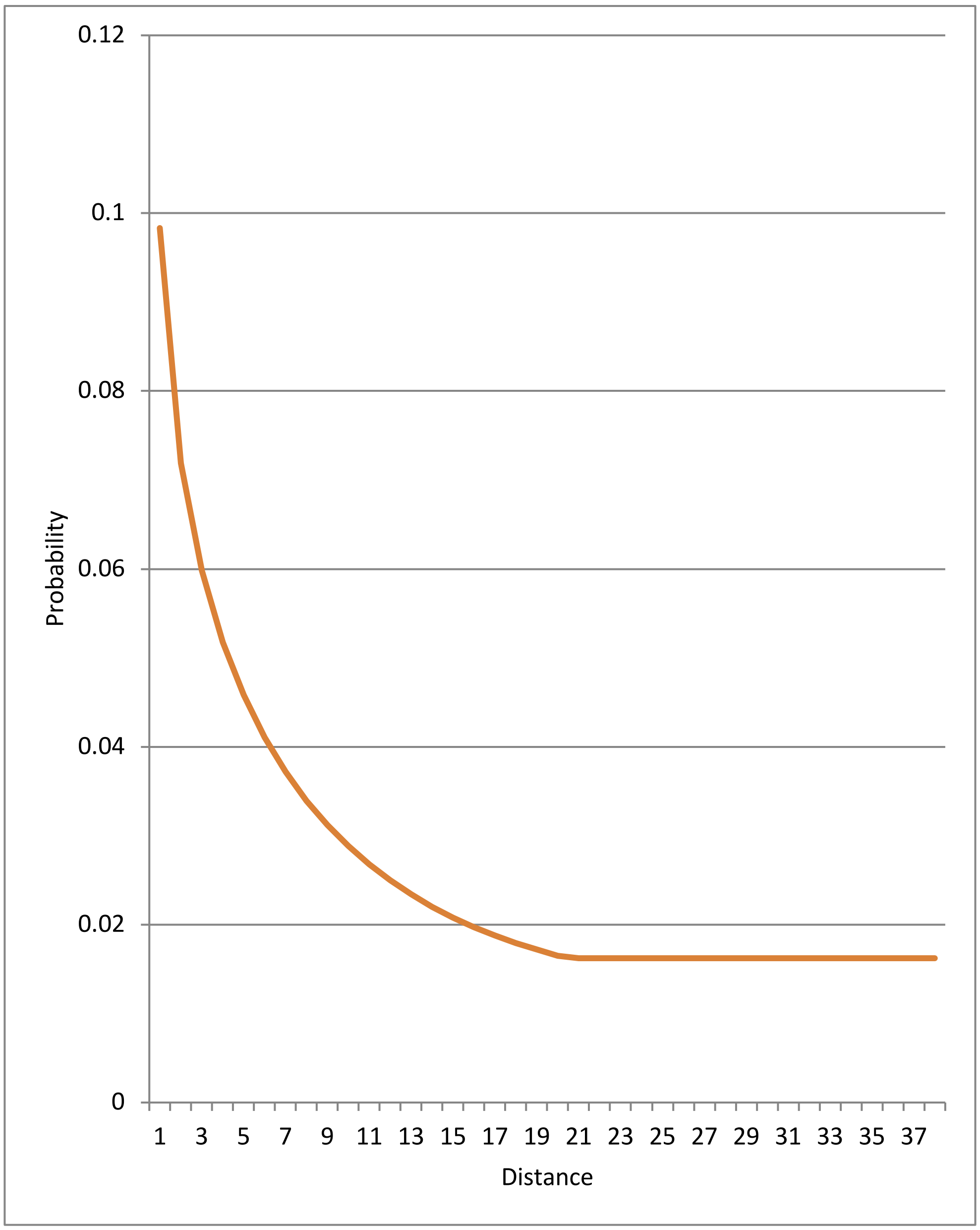
*****These coefficients were borrowed from the non-mandatory tour location choice models.***

Findings

The estimated mode choice logsum parameter is **1.34** and is very significant.

The distance deviation function measures how far "out-of-way" a stop location is compared to the half-tour path distance. There are two terms used in the utility expression: relative deviation and absolute deviation. Relative distance is more relevant for short distance tours where absolute deviation is small but its proportion to half-tour distance is significant. The composite function (with linear, log and square terms) defined for both terms are strongly negative, as shown in Figures 8.

Figure 8: Absolute Distance Deviation and Relative Distance Function in the Utility Function



Below are interesting findings for the interaction of distance deviation with stop, tour, household and person characteristics:

- *Tour Purpose:* Stops on at-work tours tend to be more out-of-the-way than on any other type of tours as noted by the negative terms on the other tour purposes while work tours is the base.
- Stop Purpose: Stops made for purposes other than escorting and discretionary tend to be larger deviation from the straight line half tour path with stops for mandatory purposes on the inbound direction having the largest deviation.
- Half-Tour Direction: Stops on the inbound half-tour tend to be more “out-of-the-way” than stops on the outbound half-tour for mandatory tours.
- Number of Stops and Stop Sequence: The deviation tends to be larger for multi-stop half-tours. However, second and the third stop tend to be less “out-of-the-way” compared to first stop.
- Person and Household characteristics: There are strong effects of gender, income and age group on distance deviation. Females and individuals 35 years or older tend to be more sensitive to longer deviations for the stop. Low income household members ($29,999 or less) tend to go more out-of-the-way for stops compared to high income household members.
- Closeness to Tour Origin or Tour Destination: The ratio of distance from tour origin to sum of distance from tour origin and tour destination is used as a measure of closeness of stop to tour origin. Overall, stops tend to be closer to tour origin (usually home).On a multiple stop half-tour, the first stop is closer to origin in the outbound direction and close to destination in the inbound direction. Also, the stops are closer to origin, more on the outbound direction than in the inbound direction, on mandatory tours as compared to non-mandatory tours.

The size variables in Table 3 were borrowed from the primary non-mandatory tour destinations of the same purpose.