# CSTDM09 – California Statewide Travel Demand Model

## Model Development

## Short Distance Commercial Vehicle Model

### Final System Documentation: Technical Note

ULTRANS
Institute of Transportation Studies,
UC Davis
Davis, CA

HBA Specto Incorporated
Calgary, Alberta

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# 1. Introduction

This technical note describes the Short Distance Commercial Vehicle Model (SDCVM) component of the California Statewide Travel Demand Model (CSTDM09).

THE CSTDM09 has defined two distinct models to be applied to forecast commercial vehicle travel generated by California business on a typical weekday in the fall. The Short Distance Commercial Vehicle Model will apply for all trips made up to 50 miles from the home business establishment. The Long Distance Commercial Vehicle Model (LDCVM) will forecast vehicle movements greater than 50 miles. This coverage is based on the observed spacing of depots for major delivery companies such as UPS, where vehicles and drivers are based at a home location and conform to a normal daily schedule and driver hours of operation requirements.

The SDCVM models developed by HBA Specto for the cities of Calgary and Edmonton in Alberta, Canada are being applied in the CSTDM09. The models were calibrated using data from Commodity Flow Surveys of over 8,000 business establishments, conducted to determine the characteristics of goods and service movements over a 24-hours period. All sectors of the economy were considered including industrial, wholesale, retail, service, transport and handling and “fleet allocator” (businesses where vehicles operate on regular (and thus relatively fixed) routes rather than making stops in response to individual requirements e.g. parcel delivery / pick-up).

These models are state-of-the-art micro-simulation tour-based models that explicitly predict both goods and service vehicle movements in a local context. They include light, medium and heavy commercial vehicle movements. They have been implemented in a practical modeling environment. The initial model formulations are based on the Alberta parameter values, adjusted as appropriate to match California conditions.

This Technical Note summarizes the form and parameter values of the SDCVM being implemented in the CSTDM09, the calibration of the model, and its implementation.

## 2. Short Distance Commercial Vehicle Model Overview

The tour-based SDCVM is a group of models that work in series. A basic schematic of the models is shown in Figure 1.

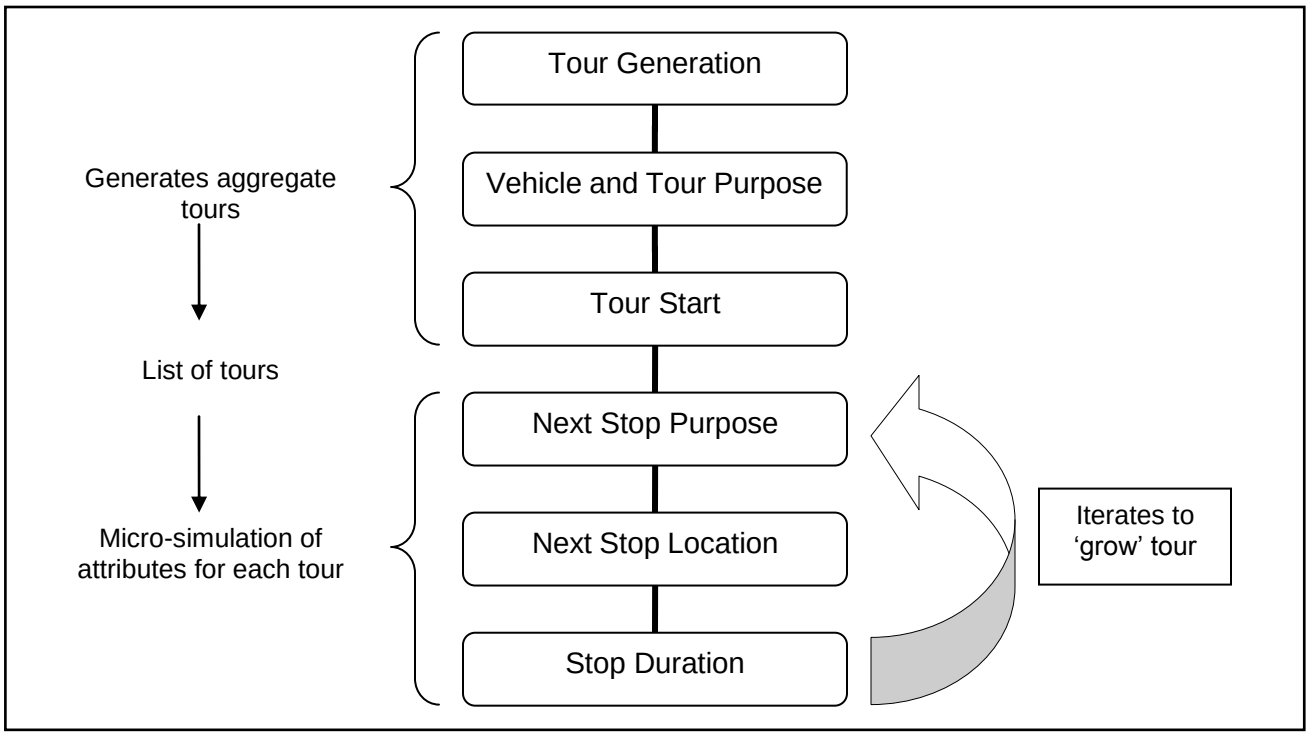


**Figure 1: Tour-Based Model Structure**

Tour generation quantities by vehicle type, tour purpose, and time of day are generated for each TAZ, using logit and regression equations applied with aggregate TAZ inputs and travel accessibilities, to create a list of tours.

Individual tours generated from each TAZ are then assigned a next stop purpose, next stop location and next stop duration using a micro-simulation process. In this process, Monte Carlo techniques are used to incrementally 'grow' a tour by having a 'return-to-establishment' alternative within the next stop purpose allocation.

If the next stop purpose is not 'return-to-establishment', then the tour extends by one more stop. The location and duration of the next stop are then estimated. These steps are repeated until the "return to establishment" next stop purpose is chosen.

Six establishment types are considered, based on aggregations of NAICS categories:

- (Industrial (IN) – NAICS 11, 21, 23, 31-33,;
- Wholesale (WH) – NAICS 42;
- Service (SE) – NAICS 51, 52, 53, 54, 55, 56, 61, 62, 71, 72, 81, 91;
- Retail (RE) – NAICS 44-45;
- Transport and Handling (TH) – NAICS 22, 48-49;
- Fleet Allocator (FA) - All.

Four commercial vehicle types are used:

- Light vehicle FHWA classes 1-3, 5;
- Medium truck < 9.6 short tons – FHWA classes 6-7;
- Medium Truck > 9.6 short tons – FHWA classes 6-7;
- Heavy Truck – FHWA classes 8-13.

In the Alberta urban environment there are designated truck routes – trucks 8 tons or heavier are required to use these designated routes. The commercial vehicle categorization is explicitly designed to incorporate this weight limit.

Five time periods are used:

- EARLY (Midnight – 7 AM;
- AM Peak (7AM – 9AM);
- MIDDAY (9AM – 4 PM);
- PM Peak (4 PM – 6 PM);
- LATE (6PM – Midnight).

These time periods do not exactly match the ones used in the CSTDM09. However the micro-simulation nature of the CVM model means that trip start and end times are forecast to the nearest minute. Trip midpoint times can be allocated to the relevant CSTDM09 time period, and thus all trips allocated to the correct time category for assignment. The CSTDM09 time periods are:

- EARLY (3AM – 6 AM;
- AM Peak (6AM – 10AM);
- MIDDAY (10AM – 3 PM);
- PM Peak (3 PM – 7 PM);
- LATE (7PM – 3AM).

Five TAZ level land use types are used in the model:

1. Low Density (<250 persons / square mile; AND <250 jobs / square mile);
2. Residential (>250 persons / square mile AND > 2 persons / job);
3. Commercial (>60% jobs are Service plus Retail AND > 1,500 jobs / square mile AND Retail jobs are >25% of Retail plus Service jobs);
4. Industrial (<15,000 jobs / square mile AND <80% of jobs are office-based)
5. Employment Node (if TAZ does not fall into the above categories).

This classification system will be used initially with the CSTDM09.

Additional zonal employment characteristics used are:

- percentage of employment in employment categories;
- 0-1 variable whether absolute zonal employment by industry > 3,000;
- 0-1 variable for Retail Zone (Retail Employment > 50% Total Employment)
- total jobs within 30 minutes travel time.

Travel utilities based on cost are used for travel for movements between zones.

These vary by vehicle type and are always a negative value. The values are determined using the following equation:

Travel Utility ***ij*** = A x Travel Time ***ij*** + B x Travel Distance ***ij*** + C x Travel Toll ***ij***

where A,B and C are shown in Table 1:

**Table 1: Travel Utility Coefficients**

| | Light Vehicles | Medium Vehicles | Heavy Vehicles |
|---|---|---|---|
| **A (Time - minutes)** | -0.313 | -0.313 | -0.302 |
| **B (Distance - miles)** | -0.138 | -0.492 | -0.580 |
| **C (Toll - $)** | -1.000 | -1.000 | -1.000 |

These values were established using industry data for vehicle operating costs and wages. The values in Table 1 have been converted to US$ and per mile equivalents. Tolls applying to truck origin-destination travel can be added to the time and distance $ cost equivalents established using the above parameters. Travel time, distance and toll can vary between time periods, resulting in separate utilities for each time period. The early and late time periods use the off-peak time period skim assignment results.

Zonal accessibilities are also used throughout the micro-simulation process. Both total employment and population accessibilities are determined using the following function:

$$\text{Accessibility}_i = \Sigma_j \left(\text{Opportunity}_j \times e^{(\lambda \times \text{travel utility } ij)}\right)$$

where:

Accessibility$_i$ = the accessibility for a given zone ***i*** to a particular factor

Opportunity$_j$ = the quantity of the factor in zone ***j***

$\lambda$ = 1.0 for heavy vehicles; 2.0 for medium; 3.0 for light

# 3 TAZ Tour Generation

The number of tours generated for a given zone, vehicle type, purpose and time period is determined using a sequence of nested logit models that start with the relevant total employment in the zone and calculate in order:

- **Ship or No Ship**: estimating out of the total employment in the type of firm for the segment in the zone, the proportion of employment and thus the aggregate employment at 'shippers' establishments;
- **Daily Tours Per Employee**: the tours per employee and hence the total number of tours originating in the zone; the range of alternatives goes from 0 to 10 tours per employee (The tours per employee model was estimated using aggregate multiple linear regression with the logarithmic transform of a binary logit expression for the alternatives 0 tours and 10 tours where the utility expression is associated with the 10 tours alternative. The maximum number of tours per employee was larger than 1 and much smaller than 10, which led to the selection of a maximum value of 10 for all segments);
- **Time of Day**: the allocation of the tours originating in the among start times in each of five time periods covering the 24 hours of a typical workday; and
- **Vehicle Type and Tour Purpose**: the allocations of the tours with a given start time period from a zone among vehicle types (among Light, Medium<9.6 tons, Medium>9.6 tons and Heavy) and tour purposes (among Goods, Service and Other).

Figure 2 illustrates the specific nesting structure for the sequence of models for the 'industry' firms segment. The nesting structures for the other segments are similar, with slight differences in the structures for the two 'lowest' level models concerning the allocations among start times, vehicle types and tour purposes.

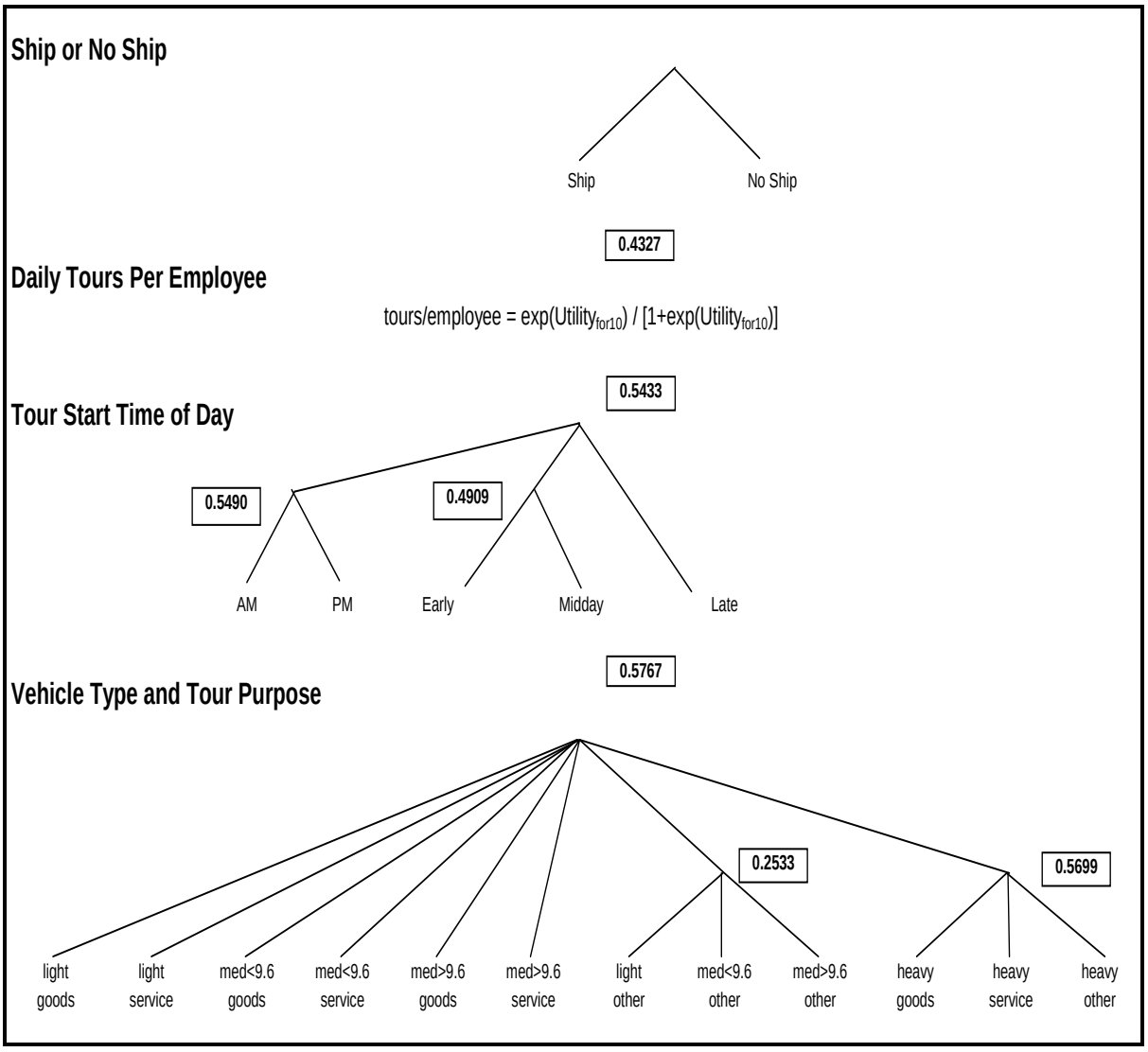


**Figure 2: Tour Generation Model Structure Example: Industry Tours**

As shown in Figure 2, the generation of tours is a multi-step process.

The general form of the daily tour generation equation for zone *i* is:

$$\text{Daily Tour Generation}_i = \text{Probability Ship}_i \times \text{Tours/Employee}_i \times \text{Employment}_i$$

### 3.1 Ship / No Ship Models

The probability of ship/no ship equation for zone *i* is:

Probability of $Ship_i$ = (exp (Utility $Ship_i$)) / (exp(Utility $Ship_i$) + exp(Utility No $Ship_i$))

Utility $Ship_i$ = Σ (Attribute of $zone_i$ x Attribute Coefficient) + Ship Constant

Utility No $Ship_i$ = 0

The utilities for ship by employment category are shown in Table 2.

**Table 2: Utilities for Ship/No Ship by Employment Category**

| Attribute | Industrial | Wholesale | Retail | Service / Fleet | Transport & Handling |
|---|---|---|---|---|---|
| Ship Constant | -0.9257 | 0.1680 | -1.8180 | -3.4360 | 2.6160 |
| Ship Constant Fleet | | | | -3.8660 | |
| Residential Land Use | 1.7417 | 1.5379 | 1.1836 | 0.1491 | -1.3431 |
| Commercial Land Use | 1.3815 | 1.5379 | 1.4773 | 0.1491 | -1.3431 |
| Res / Commercial Land Use : Fleet | | | | -2.1533 | |
| Industrial Land Use | 1.4262 | 0.2737 | 1.9255 | 0.5464 | 0.0199 |
| Industrial Land Use : Fleet | | | | -1.4907 | |
| Employment Land Use | -1.1420 | -0.6468 | -1.1980 | -0.7016 | -4.0396 |
| Employment Land Use : Fleet | | | | -4.4767 | |
| Retail Zone | -0.8298 | -1.0950 | -0.8221 | - | -0.8195 |
| % zonal employment INDUSTRIAL | 1.0710 | - | - | 3.0730 | - |
| % zonal employment WHOLESALE | - | -2.507 | 4.9340 | 5.1810 | - |
| % zonal employment RETAIL | - | - | -0.9041 | - | - |
| % zonal employment SERVICE | -1.2730 | -2.9870 | -0.5956 | 2.3220 | -2.2340 |
| % zonal employment TRANSPORT & HANDLING | 1.0250 | - | - | 3.0810 | - |
| Composite Utility – Tour Generation | 0.4327 | - | - | 0.5180 | - |

Note: Fleet Allocator category is applied to total zonal employment

The composite utility of Tour Generation is calculated by taking the “logsum” of the exponents of the utility of tours / employee AND the utility of making no tours (set at 0).

## 3.2 Daily Tour Generation Models

The utilities for daily tour generation by employment category are shown in Table 3.

**Table 3: Utilities for Daily Tour Generation by Employment Category**

| Attribute | Industrial | Wholesale | Retail | Service / Fleet | Transport & Handling |
|---|---|---|---|---|---|
| Generation Constant | -3.2310 | -3.5889 | -3.8589 | -0.0893 | -3.5589 |
| Generation Constant Fleet | | | | -0.8693 | |
| Low Density Land Use | 0.8356 | 1.3150 | 1.3379 | -0.0523 | -0.2097 |
| Low Density Land Use: Fleet | | | | -2.4960 | |
| Residential Land Use | 0.4257 | 0.3771 | 1.1971 | -0.8739 | 1.0238 |
| Residential Land Use: Fleet | | | | 1.7199 | |
| Commercial Land Use | 0.4257 | -0.1161 | 0.7039 | -1.5876 | 0.5306 |
| Commercial Land Use: Fleet | | | | 1.0062 | |
| Industrial Land Use | 0.0674 | 0.7762 | 0.5595 | -0.7796 | 0.1872 |
| Industrial Land Use: Fleet | | | | 1.2316 | |
| Employment Land Use | -0.4693 | -0.0407 | 0.0730 | -2.0166 | 0.7719 |
| Employment LU: Fleet | | | | 1.3792 | |
| % zonal employment INDUSTRIAL | -0.9668 | - | - | - | - |
| % zonal employment WHOLESALE | - | 0.6118 | 0.6118 | - | 0.6118 |
| % zonal employment RETAIL | - | - | - | 1.0441 | - |
| % zonal employment SERVICE | 0.8487 | 0.6922 | 0.6922 | - | 0.6922 |
| Log (Jobs within 30 minutes) | -0.1116 | -0.0752 | -0.0752 | -0.2441 | -0.0752 |
| Composite Utility – Time of Day | 0.5433 | 0.6078 | 0.3097 | 0.2308 | 0.4573 |

The daily tour generation per employee for zone *i* is calculated as follows:

Utility Tour Generation = ln((tours/employee/10)/((1-(tours/employee/10)))

Utility = ln((R/10) / ((1-(R/10))) where R = tours/employee

exp(Utility) = (R/10) / (1-R/10)

(1-R/10)*exp(Utility) = R/10

R = (10-R) * exp(Utility) =10*exp(Utility) - R*exp(Utility)

R + R*exp(Utility) = 10*exp(Utility)

R(1 + exp(Utility) = 10 * exp(Utility)

R = (10*exp(Utility))/(1+exp(Utility))

Tours/employee = (10*exp(Utility))/(1+exp(Utility))

### 3.3 Tour Time of Day Models

Once the number of daily tours is determined, the tours in each zone are split among each time period by establishment category.

The split among time periods is determined using a logit model formulation as follows:

Tour Generation by Time Period = Daily Tour Generation x Probability $U_T$

where:

Probability $U_T$ = exp ($U_T$ )/ Σ exp($U_T$ ) all time periods

$U_T$ = $ASC_T$ + Σ (Attribute of zone *i* x Attribute Coefficient)

where:

$U_T$ = utility function for a given time period

$ASC_T$ = alternative specific constant for a given time period

The nesting structures for each employment category are given in Figures 3a to 3E. estimated time period specific attribute coefficients and resulting calibrated values are shown in Table 4A to Table 4E below.

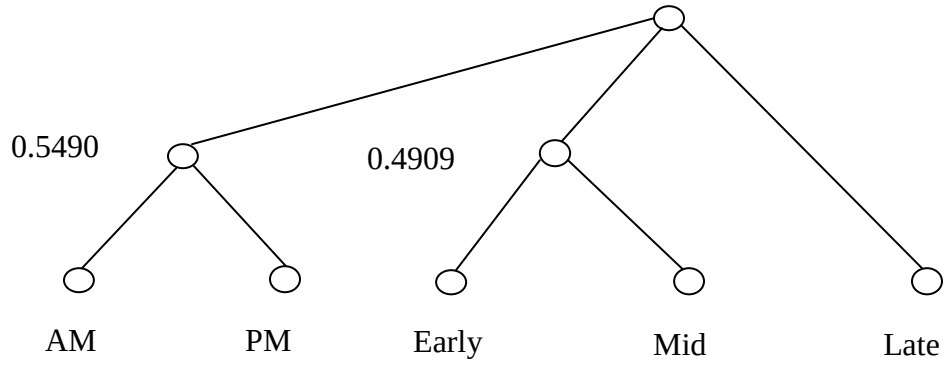


**Figure 3A: Tour Time of Day Nesting Structure: Industry Tours**

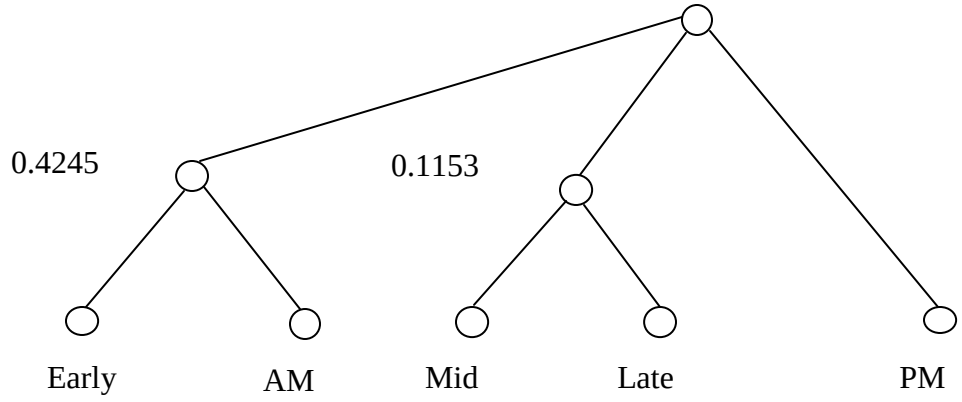


**Figure 3B: Tour Time of Day Nesting Structure: Wholesale Tours**

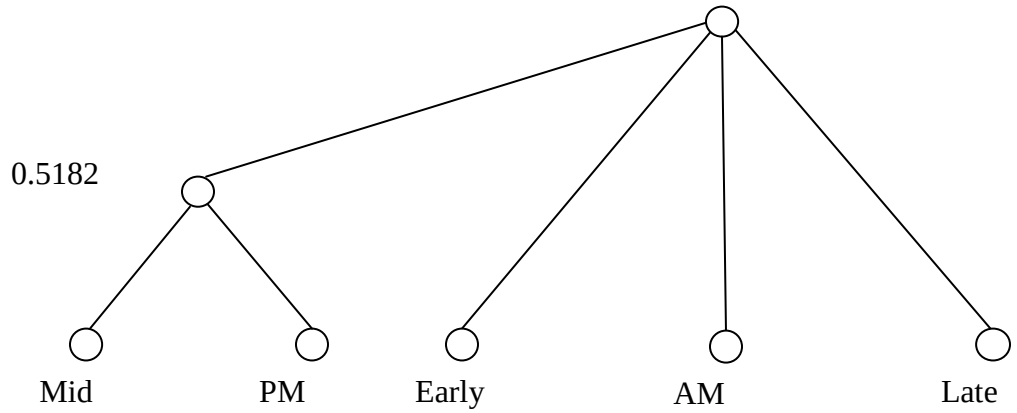


**Figure 3C: Tour Time of Day Nesting Structure: Retail / Fleet Tours**

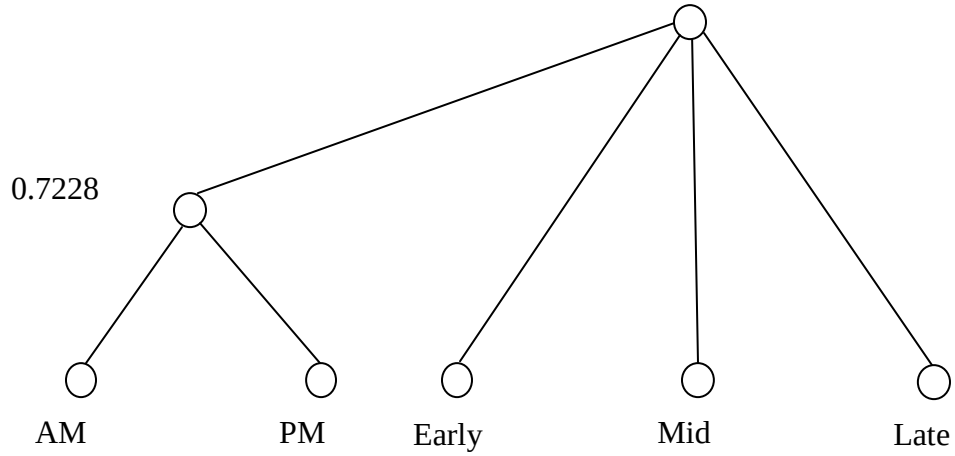


**Figure 3D: Tour Time of Day Nesting Structure: Service Tours**

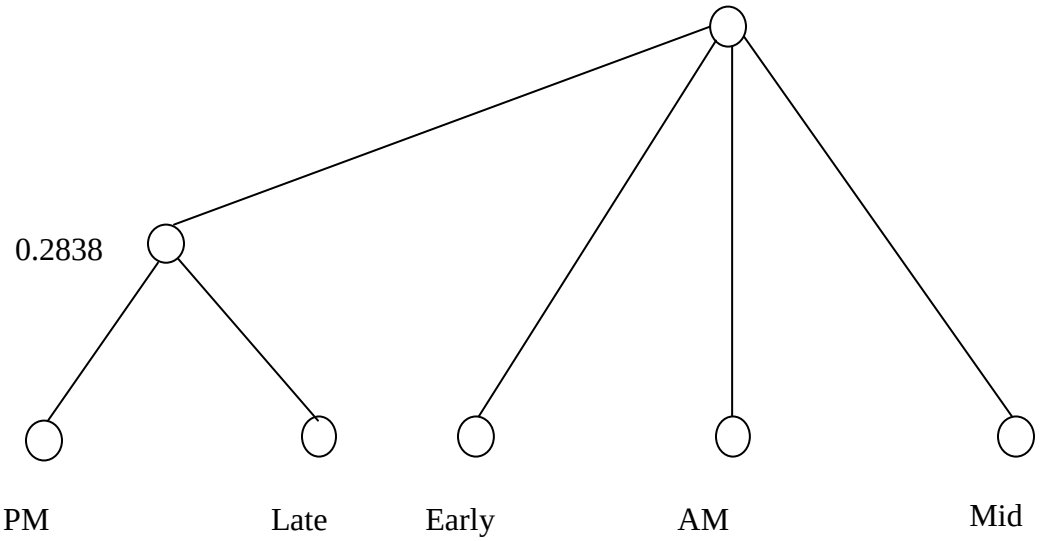


**Figure 3E: Tour Time of Day Nesting Structure: Transport and Handling Tours**

**Table 4A: EARLY Time Period Utilities by Employment Category**

| Attribute | Industrial | Wholesale | Retail / Fleet | Service | Transport & Handling |
|---|---|---|---|---|---|
| Residential Land Use | 1.1640 | - | - | - | - |
| Industrial Land Use | 1.1650 | - | 0.7020 | -0.5162 | -0.6363 |
| Employment Land Use | - | -1.2110 | - | -0.8024 | - |
| Employment >3,000 INDUSTRIAL | -0.6308 | - | - | - | - |
| Employment >3,000 RETAIL | - | - | 0.6183 | - | - |
| Employment >3,000 SERVICE | - | - | - | -0.4914 | - |
| % zonal employment INDUSTRIAL | 1.3800 | - | - | - | - |
| % zonal employment RETAIL | - | - | -6.749 | - | - |
| % zonal employment SERVICE | - | - | - | -0.8524 | - |
| % zonal employment T and H | - | - | - | - | 3.1450 |
| Composite Utility Tour Purpose/Vehicle Type | - | 0.43840 | - | - | 0.2223 |
| Constant | -1.5340 | -2.5440 | -1.8620 | -1.0150 | -1.9800 |

## Table 4B: AM Time Period Utilities by Employment Category

| Attribute | Industrial | Wholesale | Retail / Fleet | Service | Transport & Handling |
|---|---|---|---|---|---|
| Residential Land Use | 0.8059 | - | - | - | - |
| Industrial Land Use | 0.7884 | 1.3970 | 0.3770 | - | -0.5278 |
| Employment >3,000 INDUSTRIAL | -0.2712 | - | - | - | - |
| Employment >3,000 WHOLESALE | - | 0.3952 | - | - | - |
| Employment >3,000 SERVICE | - | - | - | 0.2697 | - |
| % zonal employment RETAIL | - | - | -0.3089 | - | - |
| % zonal employment SERVICE | - | - | - | -0.5860 | - |
| % zonal employment T and H | - | - | - | - | -2.2490 |
| Composite Utility Tour Purpose/Vehicle Type | 0.5767 | - | 0.8392 | 0.2407 | 0.2223 |
| Constant | -1.7960 | -1.5914 | -2.1093 | 0.1447 | -0.2727 |
| Constant Fleet (Additional) | | | -0.8719 | | |

## Table 4C: MIDDAY Time Period Utilities by Employment Category

| Attribute | Industrial | Wholesale | Retail / Fleet | Service | Transport & Handling |
|---|---|---|---|---|---|
| Composite Utility Tour Purpose/Vehicle Type | 0.5767 | 0.4384 | 0.8392 | 0.2407 | - |
| Constant | 0.5935 | 2.5163 | 1.1158 | 0.8186 | 0.9776 |
| Constant Fleet (Additional) | | | 0.4164 | | |

## Table 4D: PM Time Period Utilities by Employment Category

| Attribute | Industrial | Wholesale | Retail / Fleet | Service | Transport & Handling |
|---|---|---|---|---|---|
| Commercial Land Use | - | - | -0.9184 | - | - |
| Industrial Land Use | -0.3953 | 0.7744 | 0.9404 | -0.5919 | -1.6560 |
| Employment Land Use | - | - | - | 0.6292 | - |
| % zonal employment WHOLESALE | - | -3.7960 | - | - | - |
| % zonal employment RETAIL | - | - | 2.1640 | - | - |

| | | | | | |
|---|---|---|---|---|---|
| Retail Zone | - | 1.9720 | - | - | - |
| Composite Utility<br>Tour Purpose/Vehicle Type | 0.5767 | 0.4384 | 0.8392 | 0.2407 | 0.2223 |
| Constant | -2.7525 | -2.7253 | -0.8838 | -1.4396 | -3.8855 |
| Constant Fleet (Additional) | | | 0.4745 | | |

**Table 4E: LATE Time Period Utilities by Employment Category**

| Attribute | Industrial | Wholesale | Retail / Fleet | Service | Transport & Handling |
|---|---|---|---|---|---|
| Residential Land Use | 0.4634 | - | 0.9369 | - | - |
| Industrial Land Use | -0.5059 | - | -1.1860 | -0.3414 | - |
| Employment >3,000 WHOLESALE | - | -0.7958 | - | - | - |
| % zonal employment INDUSTRIAL | 1.1130 | - | - | - | - |
| % zonal employment RETAIL | - | - | 1.3810 | - | - |
| Composite Utility<br>Tour Purpose/Vehicle Type | 0.5767 | 0.4384 | - | - | 0.2223 |
| Constant | -4.4375 | -0.9261 | -1.3640 | -1.6129 | -4.9048 |
| Constant Fleet (Additional) | | | 1.1307 | | |

## 3.4 Vehicle Type and Tour Purpose Models

In this step, each tour for an individual zone is assigned both a purpose and a vehicle type. The selection probabilities are determined using nested logit models based on establishment category with utility functions that include zonal-level land use, establishment location and accessibility attributes.

Three choices exist for tour purpose:

- Goods – may make ‘goods’, ‘other’ and ‘return to establishment’ stops.
- Service – may make ‘service’, ‘other’ and ‘return to establishment’ stops.
- Other – may make ‘other’ and ‘return to establishment’ stops.

Four commercial vehicle types are used:

- Light vehicle FHWA classes 1-3, 5;
- Medium truck < 9.6 short tons – FHWA classes 6-7;
- Medium Truck > 9.6 short tons – FHWA classes 6-7;
- Heavy Truck – FHWA classes 8-13.

The generalized utility function for the combined tour purpose and vehicle choice is:

$U_{PV} = ASC_{PV} + \theta_{LU,P} + \theta_{LU,V} + \theta_{est,P} + \theta_{est,V} + ( \theta_{pop} \times ACC_{pop} ) + ( \theta_{emp} \times ACC_{emp} )$

where:

$U_{PV}$ = utility function for the combined tour purpose and vehicle choice

$ASC_{PV}$ = alternative specific constant for a given combination of tour purpose and vehicle choice

$\theta_{LU,P}$ = land use attribute coefficient for tour purpose

$\theta_{LU,V}$ = land use attribute coefficient for vehicle choice

$\theta_{est,P}$ = establishment type attribute coefficient for tour purpose

$\theta_{est,V}$ = establishment type attribute coefficient for vehicle choice

$\theta_{pop}$ = population accessibility coefficient

$\theta_{emp}$ = employment accessibility coefficient

$ACC_{pop}$ = population accessibility

$ACC_{emp}$ = employment accessibility

Nesting structures for the vehicle type / tour purpose models are given in Figures 4A to 4E for each employment type.

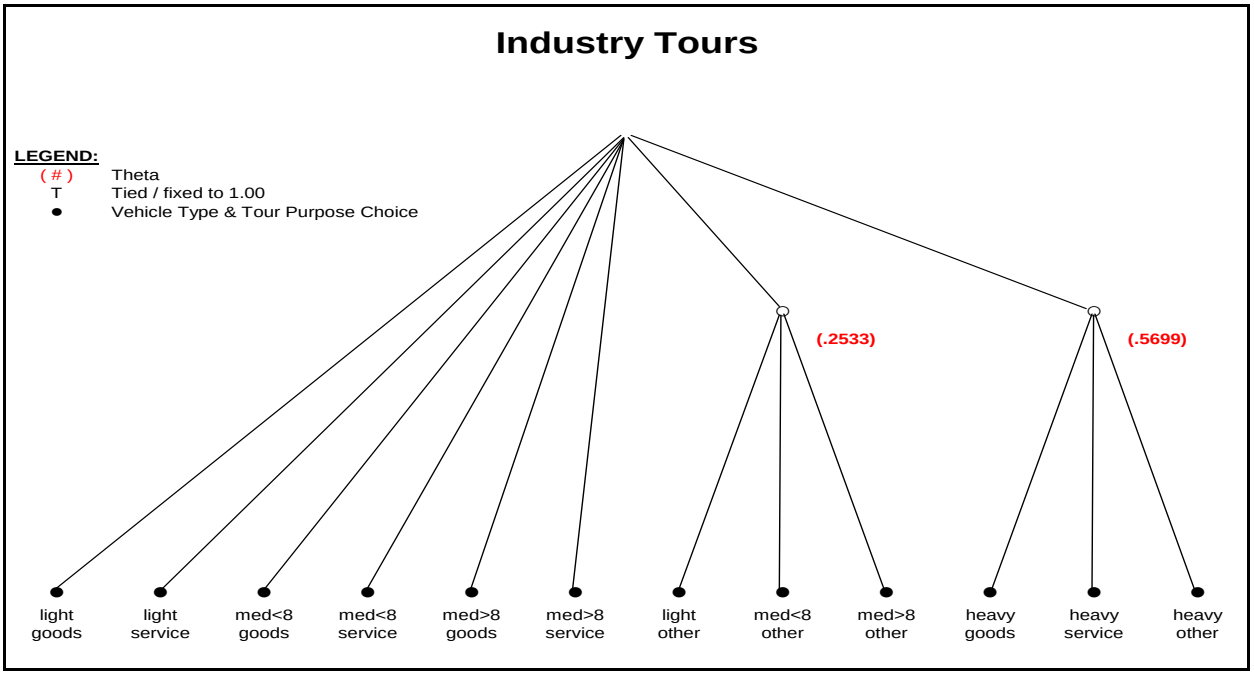


**Figure 4A: Tour Vehicle Type / Purpose Nesting Structure: Industry Tours**

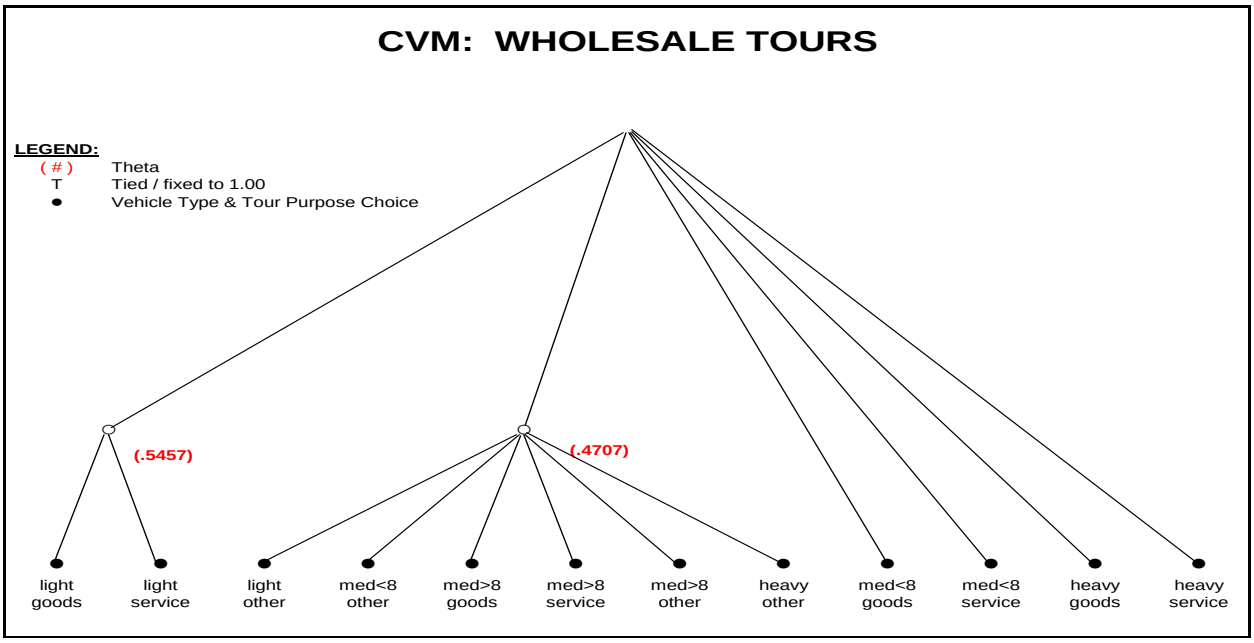


**Figure 4B: Tour Vehicle Type / Purpose Nesting Structure: Wholesale Tours**

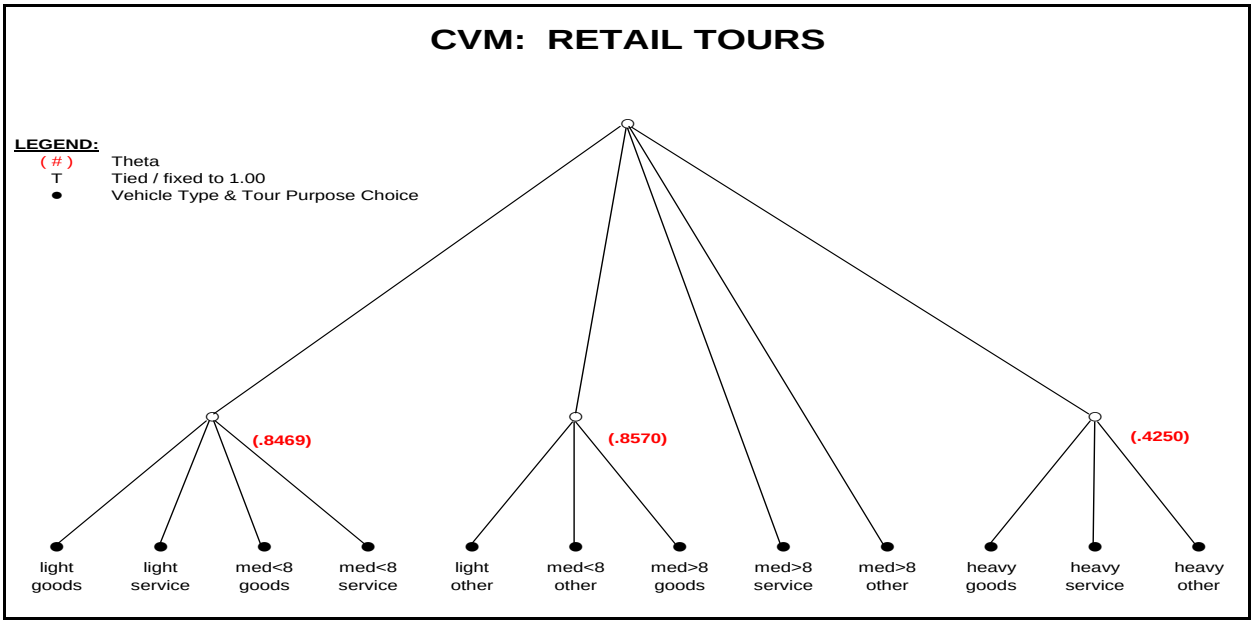


**Figure 4C: Tour Vehicle Type / Purpose Nesting Structure: Retail Tours**

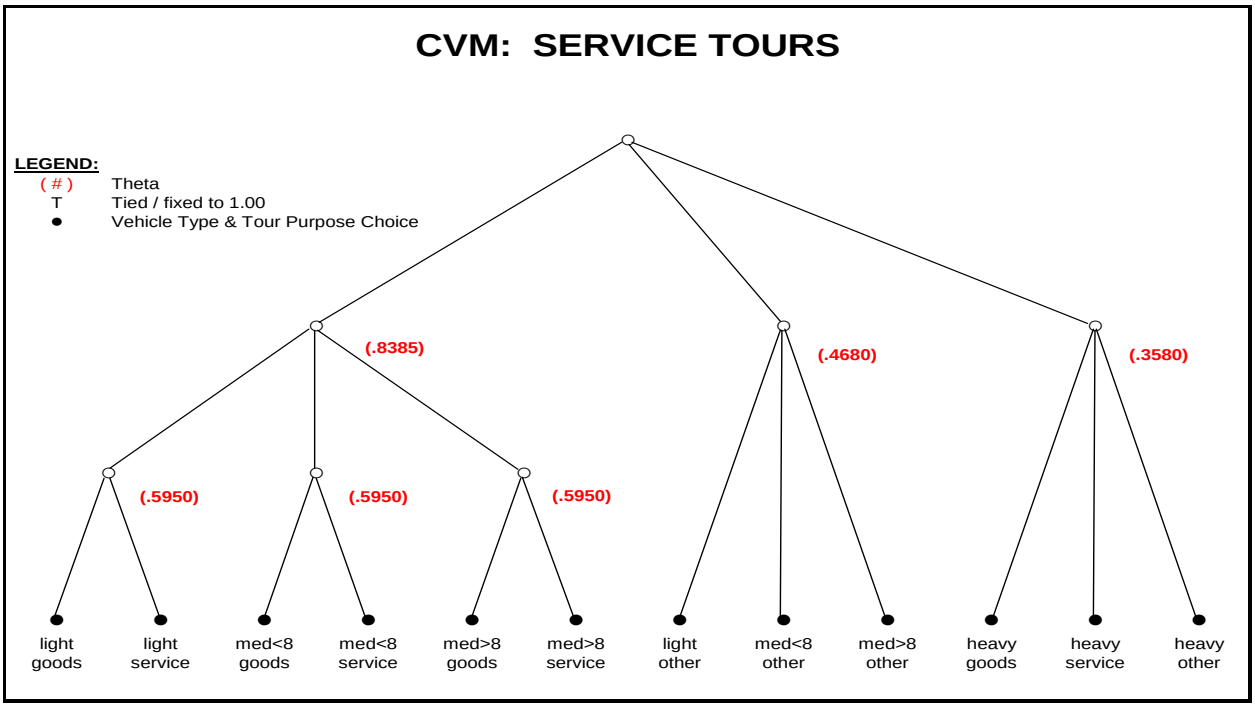


**Figure 4D: Tour Vehicle Type / Purpose Nesting Structure: Service / Fleet Tours**

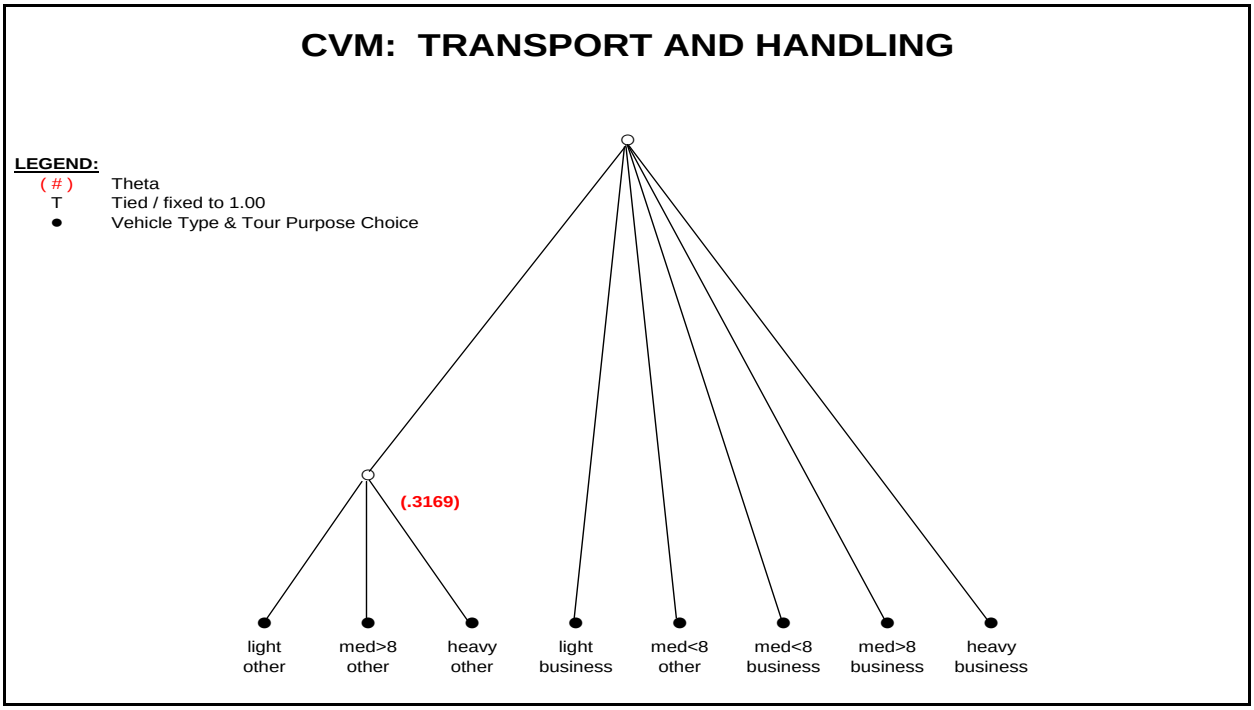


**Figure 4E: Tour Vehicle Type / Purpose Nesting Structure: Transport Tours**

Tour purpose and vehicle choice model coefficients are shown in Table 5A to 5E.

## Table 5A: Utilities for Tour Purpose and Vehicle Choice - INDUSTRY Employment Category

| Parameter | Light Goods | Light Service | Light Other | Medium <9.6ton Goods | Medium <9.6ton Service | Medium <9.6ton Other | Medium >9.6ton Goods | Medium >9.6ton Service | Medium >9.6ton Other | Heavy Goods | Heavy Service | Heavy Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Accessibility to Total Employment ($x10^{-6}$) | 6.603 | 6.603 | 6.603 | 6.603 | 6.603 | 6.603 | 6.603 | 6.603 | 6.603 | 6.603 | 6.603 | 6.603 |
| Accessibility to Total Population ($x10^{-6}$) | 6.603 | 6.603 | 6.603 | 6.603 | 6.603 | 6.603 | 6.603 | 6.603 | 6.603 | 6.603 | 6.603 | 6.603 |
| Industrial Land Use (Tour Purpose) | 0.5910 | - | - | 0.5910 | - | - | 0.5910 | - | - | 0.5910 | - | - |
| Industrial Land Use (Vehicle Type) | - | - | - | 0.8489 | 0.8489 | 0.8489 | - | - | - | 0.7822 | 0.7822 | 0.7822 |
| Employment Land Use (Tour Purpose) | - | -1.9100 | -4.8680 | - | -1.9100 | -4.8680 | - | -1.9100 | -4.8680 | - | -1.9100 | -4.8680 |
| Employment Land Use (Vehicle Type) | - | - | - | - | - | - | -1.5780 | -1.5780 | -1.5780 | 2.5170 | 2.5170 | 2.5170 |
| Commercial Land Use (Tour Purpose) | - | 0.2850 | - | - | 0.2850 | - | - | 0.2850 | - | - | 0.2850 | - |
| Commercial Land Use (Vehicle Type) | - | - | - | 1.3280 | 1.3280 | 1.3280 | - | - | - | 3.8230 | 3.8230 | 3.8230 |
| Residential Land Use (Tour Purpose) | - | 0.5624 | 1.0900 | - | 0.5624 | 1.0900 | - | 0.5624 | 1.0900 | - | 0.5624 | 1.0900 |
| Residential Land Use (Vehicle Type) | - | - | - | -1.4430 | -1.4430 | -1.4430 | -0.7010 | -0.7010 | -0.7010 | -1.3120 | -1.3120 | -1.3120 |
| % Zonal Employment Industrial (Tour Purpose) | 1.0120 | - | - | 1.0120 | - | - | 1.0120 | - | - | 1.0120 | - | - |
| % Zonal Employment Industrial (Vehicle Type) | - | - | - | - | - | - | -0.9040 | -0.9040 | -0.9040 | 3.8420 | 3.8420 | 3.8420 |
| % Zonal Employment Wholesale (Vehicle Type) | - | - | - | - | - | - | - | - | - | - | - | - |
| Alternative Specific Constant (Tour Purpose) | 0.0000 | 1.2432 | -2.1178 | 0.0000 | 1.2432 | -2.1178 | 0.0000 | 1.2432 | -2.1178 | 0.0000 | 1.2432 | -2.1178 |
| Alternative Specific Constant (Vehicle Type) | 0.0000 | 0.0000 | 0.0000 | -2.4640 | -2.4640 | -2.4640 | -0.5749 | -0.5749 | -0.5749 | -1.5427 | -1.5427 | -1.5427 |

## Table 5B: Utilities for Tour Purpose and Vehicle Choice - WHOLESALE Employment Category

| Parameter | Light Goods | Light Service | Light Other | Medium <9.6ton Goods | Medium <9.6ton Service | Medium <9.6ton Other | Medium >9.6ton Goods | Medium >9.6ton Service | Medium >9.6ton Other | Heavy Goods | Heavy Service | Heavy Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Accessibility to Total Employment ($x10^{-6}$) | 3.664 | 3.664 | 3.664 | - | - | - | - | - | - | 3.664 | 3.664 | 3.664 |
| Accessibility to Total Population ($x10^{-6}$) | 3.664 | 3.664 | 3.664 | - | - | - | - | - | - | 3.664 | 3.664 | 3.664 |
| Industrial Land Use (Tour Purpose) | - | -2.1170 | - | - | -2.1170 | - | - | -2.1170 | - | -2.1170 | - | - |
| Industrial Land Use (Vehicle Type) | - | - | - | - | - | - | - | - | - | -0.7206 | -0.7206 | -0.7206 |
| Employment Land Use (Tour Purpose) | - | -2.5570 | - | - | -2.5570 | - | - | -2.5570 | - | - | -2.5570 | - |
| Employment Land Use (Vehicle Type) | - | - | - | - | - | - | - | - | - | -1.5730 | -1.5730 | -1.5730 |
| Commercial Land Use (Tour Purpose) | - | -2.6740 | - | - | -2.6740 | - | - | -2.6740 | - | - | -2.6740 | - |
| Commercial Land Use (Vehicle Type) | - | - | - | -1.0170 | -1.0170 | -1.0170 | - | - | - | - | - | - |
| Residential Land Use (Tour Purpose) | - | - | - | - | - | - | - | - | - | - | - | - |
| Residential Land Use (Vehicle Type) | - | - | - | -0.9528 | -0.9528 | -0.9528 | - | - | - | 1.0790 | 1.0790 | 1.0790 |
| % Zonal Employment Industrial (Tour Purpose) | - | - | - | - | - | - | - | - | - | - | - | - |
| % Zonal Employment Industrial (Vehicle Type) | - | - | - | - | - | - | - | - | - | - | -1.7930 | -1.7930 |
| % Zonal Employment Wholesale (Vehicle Type) | - | - | - | 2.9910 | 2.9910 | 2.9910 | 8.5330 | 8.5330 | 8.5330 | 4.4480 | 4.4480 | 4.4480 |
| Alternative Specific Constant (Tour Purpose) | 0.0000 | 0.0958 | -3.4693 | 0.0000 | 0.0958 | -3.4693 | 0.0000 | 0.0958 | -3.4693 | 0.0000 | 0.0958 | -3.4693 |
| Alternative Specific Constant (Vehicle Type) | 0.0000 | 0.0000 | 0.0000 | -1.3747 | -1.3747 | -1.3747 | -1.2175 | -1.2175 | -1.2175 | -0.4522 | -0.4522 | -0.4522 |

## Table 5C: Utilities for Tour Purpose and Vehicle Choice - RETAIL Employment Category

| Parameter | Light Goods | Light Service | Light Other | Medium <9.6ton Goods | Medium <9.6ton Service | Medium <9.6ton Other | Medium >9.6ton Goods | Medium >9.6ton Service | Medium >9.6ton Other | Heavy Goods | Heavy Service | Heavy Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Accessibility to Total Employment ($x10^{-6}$) | 7.191 | 7.191 | 7.191 | 7.191 | 7.191 | 7.191 | 7.191 | 7.191 | 7.191 | 7.191 | 7.191 | 7.191 |
| Accessibility to Total Population ($x10^{-6}$) | 7.191 | 7.191 | 7.191 | 7.191 | 7.191 | 7.191 | 7.191 | 7.191 | 7.191 | 7.191 | 7.191 | 7.191 |
| Industrial Land Use (Tour Purpose) | - | - | - | - | - | - | - | - | - | - | - | - |
| Industrial Land Use (Vehicle Type) | - | - | - | 0.6027 | 0.6027 | 0.6027 | - | - | - | - | - | - |
| Employment Land Use (Tour Purpose) | - | -0.7483 | -0.5303 | - | -0.7483 | -0.5303 | - | -0.7483 | -0.5303 | - | -0.7483 | -0.5303 |
| Employment Land Use (Vehicle Type) | - | - | - | - | - | - | 0.4739 | 0.4739 | 0.4739 | - | - | - |
| Commercial Land Use (Tour Purpose) | - | -0.8507 | - | - | -0.8507 | - | - | -0.8507 | - | - | -0.8507 | - |
| Commercial Land Use (Vehicle Type) | - | - | - | -0.2942 | -0.2942 | -0.2942 | - | - | - | - | - | - |
| Residential Land Use (Tour Purpose) | - | -0.3099 | 0.9274 | - | -0.3099 | 0.9274 | - | -0.3099 | 0.9274 | - | -0.3099 | 0.9274 |
| Residential Land Use (Vehicle Type) | - | - | - | -1.2920 | -1.2920 | -1.2920 | -0.4324 | 00.4324 | -0.4324 | - | - | - |
| % Zonal Employment Industrial (Tour Purpose) | 0.8801 | - | - | 0.8801 | - | - | 0.8801 | - | - | 0.8801 | - | - |
| % Zonal Employment Industrial (Vehicle Type) | - | - | - | - | - | - | 3.0460 | 3.0460 | 3.0460 | 16.830 | 16.830 | -16.830 |
| % Zonal Employment Wholesale (Vehicle Type) | - | - | - | - | - | - | - | - | - | - | - | - |
| Alternative Specific Constant (Tour Purpose) | 0.0000 | -0.3072 | -3.1011 | 0.0000 | -0.3072 | -3.1011 | 0.0000 | -0.3072 | -3.1011 | 0.0000 | -0.3072 | -3.1011 |
| Alternative Specific Constant (Vehicle Type) | 0.0000 | 0.0000 | 0.0000 | -2.3854 | -2.3854 | -2.3854 | -2.2121 | -2.2121 | -2.2121 | -9.6302 | -9.6302 | -9.6302 |

## Table 5D: Utilities for Tour Purpose and Vehicle Choice – SERVICE / FLEET Employment Category

| Parameter | Light Goods | Light Service | Light Other | Medium <9.6ton Goods | Medium <9.6ton Service | Medium <9.6ton Other | Medium >9.6ton Goods | Medium >9.6ton Service | Medium >9.6ton Other | Heavy Goods | Heavy Service | Heavy Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Accessibility to Total Employment ($x10^{-6}$) | 40.99 | 40.99 | 40.99 | 40.99 | 40.99 | 40.99 | 40.99 | 40.99 | 40.99 | 40.99 | 40.99 | 40.99 |
| Accessibility to Total Population ($x10^{-6}$) | 40.99 | 40.99 | 40.99 | 40.99 | 40.99 | 40.99 | 40.99 | 40.99 | 40.99 | 40.99 | 40.99 | 40.99 |
| Industrial Land Use (Tour Purpose) | 1.8730 | - | - | 1.8730 | - | - | 1.8730 | - | - | 1.8730 | - | - |
| Industrial Land Use (Vehicle Type) | - | - | - | 0.9352 | 0.9352 | 0.9352 | - | - | - | -4.9180 | -4.9180 | -4.9180 |
| Employment Land Use (Tour Purpose) | - | -0.4268 | - | - | -0.4268 | - | - | -0.4268 | - | - | -0.4268 | - |
| Employment Land Use (Vehicle Type) | - | - | - | - | - | - | -2.5360 | -2.5360 | -2.5360 | -7.7330 | 7.7330 | -7.7330 |
| Commercial Land Use (Tour Purpose) | - | - | - | - | - | - | - | - | - | - | - | - |
| Commercial Land Use (Vehicle Type) | - | - | - | -1.1200 | -1.1200 | -1.1200 | - | - | - | -7.0770 | -7.0770 | -7.0770 |
| Residential Land Use (Tour Purpose) | - | - | - | - | - | - | - | - | - | - | - | - |
| Residential Land Use (Vehicle Type) | - | - | - | -2.6570 | -2.6570 | -2.6570 | -3.2710 | -3.2710 | -3.2710 | -6.8420 | -6.8420 | -6.8420 |
| % Zonal Employment Industrial (Tour Purpose) | 0.5355 | - | - | 0.5355 | - | - | 0.5355 | - | - | 0.5355 | - | - |
| % Zonal Employment Industrial (Vehicle Type) | - | - | - | - | - | - | - | - | - | - | - | - |
| % Zonal Employment Wholesale (Vehicle Type) | - | - | - | - | - | - | - | - | - | - | - | - |
| Alternative Specific Constant (Tour Purpose) - SERVICE | 0.0000 | 2.6633 | -1.7230 | 0.0000 | 2.6633 | -1.7230 | 0.0000 | 2.6633 | -1.7230 | 0.0000 | 2.6633 | -1.7230 |
| Alternative Specific Constant (Vehicle Type) - SERVICE | 0.0000 | 0.0000 | 0.0000 | -4.7268 | -4.7268 | -4.7268 | -1.9909 | -1.9909 | -1.9909 | 1.4527 | 1.4527 | 1.4527 |
| Alternative Specific Constant (Tour Purpose) - FLEET | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Alternative Specific Constant (Vehicle Type) - FLEET | 0.0000 | 0.0000 | 0.0000 | -2.7029 | -2.7029 | -2.7029 | 3.0244 | 3.0244 | 3.0244 | 5.8072 | 5.8072 | 5.8072 |

## Table 5E: Utilities for Tour Purpose and Vehicle Choice – TRANSPORT AND HANDLING Employment Category

| Parameter | Light Business | Light Other | Medium <9.6ton Business | Medium <9.6ton Other | Medium >9.6ton Business | Medium >9.6ton Other | Heavy Business | Heavy Other |
|---|---|---|---|---|---|---|---|---|
| Accessibility to Total Employment ($x10^{-6}$) | 12.55 | 12.55 | 12.55 | 12.55 | 12.55 | 12.55 | 12.55 | 12.55 |
| Accessibility to Total Population ($x10^{-6}$) | 12.55 | 12.55 | 12.55 | 12.55 | 12.55 | 12.55 | 12.55 | 12.55 |
| Industrial Land Use (Tour Purpose) | - | - | - | - | - | - | - | - |
| Industrial Land Use (Vehicle Type) | - | - | 0.4906 | 0.4906 | - | - | 0.7601 | 0.7601 |
| Employment Land Use (Tour Purpose) | - | - | - | - | - | - | - | - |
| Employment Land Use (Vehicle Type) | - | - | - | - | - | - | 1.1150 | 1.1150 |
| Commercial Land Use (Tour Purpose) | - | - | - | - | - | - | - | - |
| Commercial Land Use (Vehicle Type) | - | - | - | - | - | - | - | - |
| Residential Land Use (Tour Purpose) | - | - | - | - | - | - | - | - |
| Residential Land Use (Vehicle Type) | - | - | - | - | -1.6300 | -1.6300 | - | - |
| % Zonal Employment Industrial (Tour Purpose) | - | - | - | - | - | - | - | - |
| % Zonal Employment Industrial (Vehicle Type) | - | - | - | - | -1.1370 | -1.1370 | 0.7476 | 0.7476 |
| % Zonal Employment Wholesale (Vehicle Type) | - | - | - | - | - | - | - | - |
| Alternative Specific Constant (Tour Purpose) | 0.0000 | -7.7135 | 0.0000 | -7.7135 | 0.0000 | -7.7135 | 0.0000 | -7.7135 |
| Alternative Specific Constant (Vehicle Type) | 0.0000 | 0.0000 | -0.6474 | -0.6474 | 1.6233 | 1.6233 | 1.3459 | 1.3459 |

## 4. Tour-Based microsimulation

The list of tours per zone is fed into the micro-simulation process, where each tour is assigned a tour start time, next stop purpose, next stop location and next stop duration. The micro-simulation process is executed using JAVA applications. The commercial vehicle model uses a 24-hour, continuous concept of time. Tours can cross from any time period to another, but are capped at 24 hours length.

### 4.1 Tour Start Time Models

For every tour, start times are established. Tour start times are determined using a Monte Carlo process, with sampling distributions based on a cumulative percentage distribution function, calculated by time period.

The general equation forms used for the tour start time are:

- Exponential: $y = ce^{(ax+b)} + d$
- Cubic: $y = a+bx+cx^2+dx^3$

**Table 6: Tour Start Time Functions by Time Period and Employment Category**

| Start time | Function Type | a | b | c | d |
|---|---|---|---|---|---|
| Early (12 AM – 7AM) | Exponential | -7.1040 | 4.8860 | -0.0472 | 6.4210 |
| AM (7AM – 9AM) | Cubic | -0.3088 | 4.3093 | -4.8436 | 2.7496 |
| MIDDAY (9AM – 4PM) | Cubic | -0.3229 | 4.5740 | 0.9784 | 1.5009 |
| PM (4PM – 6PM) | Cubic | -0.2106 | 2.6074 | -3.5143 | 2.9485 |
| Late (6PM – 12AM) | Cubic | -0.0044 | -0.587 | 6.6964 | -0.9137 |

These time period definitions are different from those used in the CSTDM09. However, the exact minute that the tour starts is obtained from these functions. This is used to allocate tour start time to the time periods used in the CSTDM09.

## 4.2 Next Stop Purpose Models

Once the tour start time has been assigned to a given tour, the micro-simulation begins the iterative process of 'growing' the tour by assigning sets of *next stop purpose*, *next stop location* and *next stop duration* until the *next stop purpose* returns to establishment.

The purpose for each subsequent stop is assigned from the following alternatives:

- Goods – pick up goods, drop off goods, or combination of both
- Service – perform service, pick up supplies needed to perform service
- Return to Establishment – return to the business establishment operating the vehicle
- Other – operations not included in the above; may include such things as fuel stops, banking, vehicle repairs, meals, etc.

The term 'business stop' is used to refer to stops made by Transport and Handling vehicles because they provide the service of moving goods.

The next stop purpose model assigns a purpose to the next stop made. This purpose determines whether the vehicle is returning to the establishment, performing a stop for a business purpose or a non-business purpose. With a tour purpose already decided, the range of next stop purposes is limited; service tours permit service and other stops; goods tours permit goods and other stops; transportation handling tours permit business and other stops, and other tours permit only other stops. In addition, after the first trip has been determined (i.e. for the second and every stop thereafter), the option to return to the establishment is provided, which determines tour length.

The Monte Carlo process is used to assign the next stop purpose with the selection probabilities determined using single-level logit models for 13 different segments based on combinations of industry category, vehicle type and tour purpose, consistent with differences in the influences on next stop choice behaviour, as follows:

- **S-S-L**: service tours by Services establishments using light vehicles;
- **S-S-MH**: service tours by Services establishments using medium or heavy vehicles;
- **G-S-LMH**: goods tours by Services establishments using any vehicle type;
- **S-R-LMH**: service tours by Retail establishments using any vehicle type;
- **G-R-LMH**: goods tours by Retail establishments using any vehicle type;
- **S-I-L**: service tours by Industrial establishments using light vehicles;
- **S-I-MH**: service tours by Industrial establishments using medium or heavy vehicles;
- **G-I-LMH**: goods tours by Industrial establishments using any vehicle type;
- **S-W-LMH**: service tours by Wholesale establishments using any vehicle type;
- **G-W-L**: goods tours by Wholesale establishments using light vehicles;
- **G-W-MH**: goods tours by Wholesale establishments using medium or heavy vehicles;
- **B-T-LMH**: business tours by Transport establishments using any vehicle type; and
- **O-X-LMH**: other tours by any establishments using any vehicle type.

For next stop purpose for Fleet Allocator tours the Service establishment models were used.

The generalized form of the utility functions used is:

$$U_{business} = ASC_{business} + \theta_{\text{business previous}} \times \ln(\text{number of previous business stops})$$

$$U_{other} = \theta_{\text{other previous}} \times \ln(\text{number of previous other stops}) + \theta_{\text{other total time}} \times \text{elapsed total time} + \theta_{\text{other emp acc}} \times \text{accessibility to employment}$$

and

$$U_{return} = ASC_{return} + \theta_{total\ previous} \times \ln(\text{number of previous stops}) + \theta_{total\ time} \times \text{elapsed total time} + \theta_{travel\ time} \times \text{elapsed travel time} + \theta_{return\ gen\ utility} \times \text{travel utility for return to establishment}$$

where:

- $ASC_{business}$ and $ASC_{return}$ are the alternative specific constants for the business stop purpose (actually goods or service stop purpose, depending on the segment) and the return to establishment stop purpose, respectively;
- 'number of previous business stops' is the number stops for business purposes made previously in the tour;
- 'number of previous other stops' is the number of stops for other purposes made previously in the tour;
- 'number of previous stops' is the number of stops for any purposes made previously in the tour;
- 'elapsed total time' is the total time that has been spent on the tour up to that point, including all times spent at stops and in travel between stops up to that point (minutes);
- 'elapsed travel time' is the total time that has been spent travelling on the tour up to that point, including all times spent in travel between stops but not including all times spent at stops up to that point (minutes);
- 'travel utility for return to establishment' is the travel utility associated with making the trip from the current location zone to the zone where the tour began for the vehicle type being used; and
- 'accessibility to employment' is the accessibility for the current location to all categories of employment in all zones for the vehicle type being used.

The estimation results for the above generalized utility function for each segment are shown in Tables 7A through 7D, with each table covering a different subset of the full set of 13 segments.

**Table 7A: Next Stop Purpose Utility Functions for Selected Segments**

| Parameter | S-S-L | S-S-MH | G-S-LMH | S-R-LMH | G-R-LMH |
|---|---|---|---|---|---|
| $ASC_{business}$ | 2.352 | 2.936 | 2.284 | 2.707 | 3.725 |
| $\theta_{business\ previous}$ | 0.4774 | 0.3514 | 1.133 | 0.6021 | 0.1141 |
| $\theta_{other\ previous}$ | 1.053 | 0.2715 | 1.336 | 0.9202 | 1.557 |
| $\theta_{other\ total\ time}$ | 0.1048 | 0.1046 | 0.2716 | 0.1532 | -0.1128 |
| $\theta_{other\ emp\ acc}$ | 0 | 0 | 0 | 0 | 0 |
| $\theta_{total\ previous}$ | -0.7774 | -1.045 | -0.5174 | -0.1112 | -1.519 |
| $\theta_{total\ time}$ | 0.3402 | 0.2539 | 0.3909 | 0.1837 | 0.2083 |
| $\theta_{travel\ time}$ $(\times 10^{-3})$ | 2.587 | 5.969 | 6.431 | -0.8995 | 8.930 |
| $\theta_{return\ gen\ utility}$ | 0.06057 | 0.03981 | 0.0006944 | 0.05538 | -0.03348 |
| $ASC_{return}$ Light | 2.425 | n/a | 3.038 | 3.042 | 4.693 |
| $ASC_{return}$ Medium | n/a | 2.826 | 3.878 | 1.832 | 3.484 |
| $ASC_{return}$ Heavy | n/a | 4.073 | 5.125 | 6.102 | 7.754 |

**Table 7B: Next Stop Purpose Utility Functions for Selected Segments**

| Parameter | S-I-L | S-I-MH | G-I-LMH | S-W-LMH | G-W-L |
|---|---|---|---|---|---|
| $ASC_{business}$ | 2.525 | 2.599 | 2.890 | 2.302 | 3.448 |
| $\theta_{business\ previous}$ | 1.075 | 0.06148 | 0.3996 | 0.9692 | 0.4821 |
| $\theta_{other\ previous}$ | 1.121 | 1.202 | 0.9585 | 1.159 | 1.412 |
| $\theta_{other\ total\ time}$ | 0.2234 | 0.1187 | 0.1103 | 0.1509 | -0.1719 |
| $\theta_{other\ emp\ acc}$ | 0 | 0 | 0 | 0 | 0 |
| $\theta_{total\ previous}$ | -0.9242 | -1.133 | -1.127 | -0.3461 | -0.4929 |
| $\theta_{total\ time}$ | 0.3525 | 0.3025 | 0.2748 | 0.3419 | 0.2715 |
| $\theta_{travel\ time}$ $(\times 10^{-3})$ | 3.123 | 9.960 | 4.555 | 2.754 | 4.501 |
| $\theta_{return\ gen\ utility}$ | 0.03253 | 0.1075 | 0.03335 | 0.09744 | 0.01402 |
| $ASC_{return}$ Light | 3.191 | n/a | 3.882 | 2.852 | 3.238 |
| $ASC_{return}$ Medium | n/a | 2.424 | 3.246 | 2.251 | n/a |
| $ASC_{return}$ Heavy | n/a | 3.944 | 4.767 | 3.853 | n/a |

## Table 7C: Stop Purpose Utility Functions for Selected Segments

| Parameter | G-W-MH | B-T-LMH Transport | B-T-LMH Fleet | O-X-LMH Service | O-X-LMH Retail |
|---|---|---|---|---|---|
| $ASC_{business}$ | 2.984 | 2.901 | 2.901 | - | - |
| $\theta_{business\ previous}$ | 0.3894 | 1.395 | 1.395 | - | - |
| $\theta_{other\ previous}$ | 1.316 | 2.174 | 2.174 | 0 | 0 |
| $\theta_{other\ total\ time}$ | 0.006591 | 0.2447 | 0.2447 | 0 | 0 |
| $\theta_{other\ emp\ acc}$ | 0 | 0 | 0 | $7.015\times10^{-7}$ | $7.015\times10^{-7}$ |
| $\theta_{total\ previous}$ | -0.4665 | 0.06366 | 0.06366 | -3.380 | -3.380 |
| $\theta_{total\ time}$ | 0.1746 | 0.2964 | 0.2964 | 0.7893 | 0.7893 |
| $\theta_{travel\ time}$ $(\times10^{-3})$ | 10.28 | 1.819 | 1.819 | 0 | 0 |
| $\theta_{return\ gen\ utility}$ | 0.02118 | 0.07048 | 0.07048 | 0.2696 | 0.2696 |
| $ASC_{return}$ Light | n/a | 3.139 | 2.352 | 4.283 | 4.428 |
| $ASC_{return}$ Medium | 2.292 | 2.797 | 2.352 | 5.122 | 3.218 |
| $ASC_{return}$ Heavy | 3.894 | 4.104 | 2.352 | 6.370 | 7.488 |

## Table 7D: Stop Purpose Utility Functions for Selected Segments

| Parameter | O-X-LMH Industry | O-X-LMH Wholesale | O-X-LMH Transport | O-X-LMH Fleet |
|---|---|---|---|---|
| $ASC_{business}$ | - | - | - | - |
| $\theta_{business\ previous}$ | - | - | - | - |
| $\theta_{other\ previous}$ | 0 | 0 | 0 | 0 |
| $\theta_{other\ total\ time}$ | 0 | 0 | 0 | 0 |
| $\theta_{other\ emp\ acc}$ | $7.015\times10^{-7}$ | $7.015\times10^{-7}$ | $7.015\times10^{-7}$ | $7.015\times10^{-7}$ |
| $\theta_{total\ previous}$ | -3.380 | -3.380 | -3.380 | -3.380 |
| $\theta_{total\ time}$ | 0.7893 | 0.7893 | 0.7893 | 0.7893 |
| $\theta_{travel\ time}$ $(\times10^{-3})$ | 0 | 0 | 0 | 0 |
| $\theta_{return\ gen\ utility}$ | 0.2696 | 0.2696 | 0.2696 | 0.2696 |
| $ASC_{return}$ Light | 4.315 | 4.120 | 4.274 | 3.332 |
| $ASC_{return}$ Medium | 3.679 | 3.520 | 3.932 | 3.332 |
| $ASC_{return}$ Heavy | 5.200 | 5.122 | 5.239 | 3.332 |

### 4.3 Next Stop Location Models

A logit choice model is used to determine which of the zones in the 50-mile catchment area for the establishment origin zone are next to be visited by the commercial vehicle. All of these zones are available for the vehicle's choice, although some of the zones are more attractive than others.

The next stop location model uses 12 segments as defined below in Figure 5:

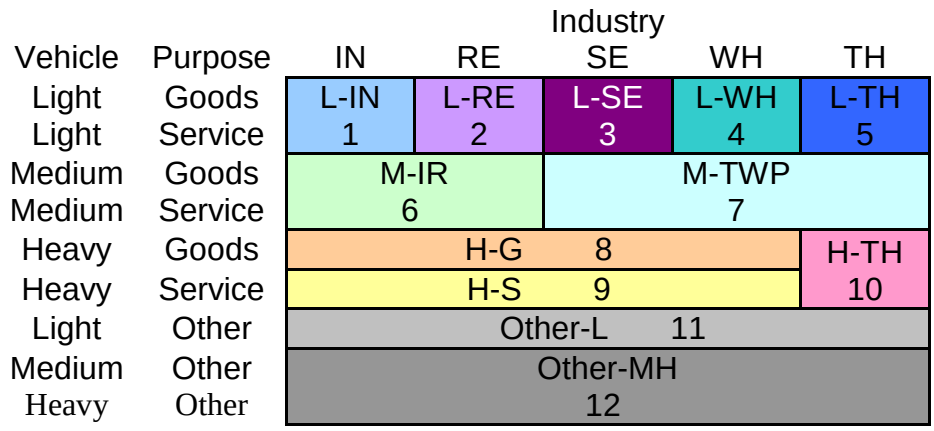


**Figure 5: Next Stop Location segments**

- 1 – L-IN – Light vehicles, industrial firms, goods and service trips
- 2 – L-RE – Light vehicles, retail firms, goods and service trips
- 3 – L-SE – Light vehicles, service firms, goods and service trips (also used for Fleet Allocator Tours)
- 4 – L-WH – Light vehicles, wholesale firms, goods and service trips
- 5 – L-TH – Light vehicles, transportation handling firms, goods and service trips
- 6 – M-IR – Medium vehicles, industrial and retail firms, goods and service trips

- 7 – M-TWP – Medium vehicles, transportation handling, wholesale and service firms, goods and service trips
- 8 – H-G – Heavy vehicles, all industries except transportation handling, goods trips
- 9 – H-S – Heavy vehicles, all industries except transportation handling, service trips
- 10 – H-TH – Heavy vehicles, transportation handling, goods and service (business) trips
- 11 – Other-L – Light vehicles, all industries, other trips
- 12 – Other-MH – Medium and heavy vehicles, all industries, other trips

These segments are divided based on trip purpose for this model, rather than tour purpose. (As an example, a light-retail-goods tour can generate an “other’ stop, and this other stop would use the light-other stop location model.)

The generalized utility function for each zone j as the next stop location is as follows:

$U_{zone\ j}$ = $\theta_{Acc\_E}$ × accessibility to employment for zone j
+ $\theta_{Acc\_P}$ × accessibility to population for zone j
+ $\theta_{Income}$ × average household income in zone j
+ $\theta_{ODCostAdd}$ × travel utility for trip from current zone to zone j, if not first trip
+ $\theta_{DECostAdd}$ × travel utility for trip from zone j to zone containing establishment, if not first trip
+ $\theta_{EmpDens}$ × employment density in zone j (jobs/$mi^2$)
+ $\theta_{PopDens}$ × population density in zone j (people/ $mi^2$)
+ $\theta_{ODCost}$ × travel utility for trip from current zone to zone j, applied on all trips

$+ \theta_{\text{size term}} \times \ln$ ( total employment in zone j

$+ \theta_{\text{PopTot}} \times$ total population in zone j

$+ \theta_{\text{EmpIn}} \times$ industrial employment in zone j

$+ \theta_{\text{EmpWh}} \times$ wholesale employment in zone j

$+ \theta_{\text{EmpRe}} \times$ retail employment in zone j

$+ \theta_{\text{EmpSe}} \times$ service employment in zone j

$+ \theta_{\text{EmpTh}} \times$ transportation employment in zone j

$+ \theta_{\text{LULoEmp}} \times$ total employment in zone j $\times$ binary flag zone j low density land use

$+ \theta_{\text{LUResEmp}} \times$ total employment in zone j $\times$ binary flag zone j residential land use

$+ \theta_{\text{LURCEmp}} \times$ total employment in zone j $\times$ binary flag zone j commercial land use

$+ \theta_{\text{LUInEmp}} \times$ total employment in zone j $\times$ binary flag zone j industrial land use

$+ \theta_{\text{LUEmpEmp}} \times$ total employment in zone j $\times$ binary flag zone j employment node

$+ \theta_{\text{Area}} \times$ total area of zone j ($mi^2$)

where:

- ‘average household income for zone j’ is set to the region-wide average household income, weighted across all households for zones j where there are no households;
- ‘accessibility to population for zone j’ is the accessibility for zone j to all categories of population in all zones for vehicle type being used;
- ’accessibility to employment for zone j’ is the accessibility for zone j to all categories of employment in all zones for vehicle type being used;
- ‘enclosed angle for zone j’ is the angle (in degrees) enclosed by (a) the straight line from the current zone to the zone containing the establishment and (b) the straight line from the current zone to zone j.
- The enclosed angle measures the angle formed by the intersection of the lines connecting the establishment to the current location and from the current location to the possible destination alternative.

An example of this angle is shown in Figure 6. A value of 0° indicates that zone j is in the same direction as the zone containing the establishment and a value of 180° indicates that zone j is in the opposite direction from the zone containing the establishment. An enclosed angle of 0° would imply heading back directly towards the establishment; an enclosed angle of 180° would imply that the vehicle is heading directly away from the establishment; values range between these two extremes.

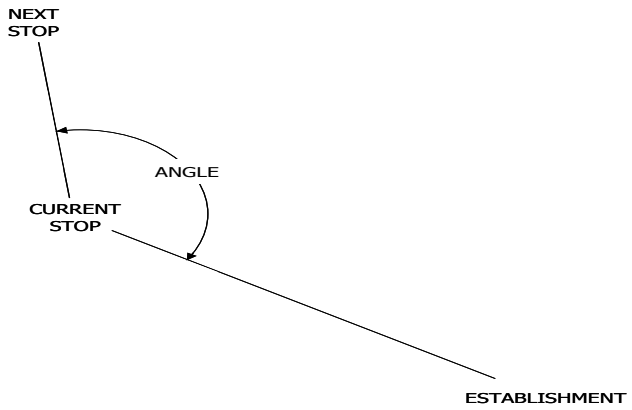


**Figure 6: Enclosed Angle**

Between zones, the off-peak generalised cost was used. There are three measures of generalised cost; OD, OD Additional and DE Additional. OD represents the travel cost for any trip from the origin to the destination under consideration. OD Additional represents the travel cost for trips from the origin to the destination, but is only applied to trips other than the initial departure from establishment. DE Additional represents the 'return to establishment' travel cost (from the considered destination back to the establishment), for all trips other than the initial departure. This permits a variable cost structure on tours; the original trip cost is usually lower than the cost for travel to additional stops, and the return to establishment cost is unnecessary for the first trip, when it correlates nearly 100% with the travel cost from the establishment to the destination under consideration.

Utilities for next stop location are shown in Tables 8A-8D.

## Table 8A: Next Stop Location Utility Functions for selected segments

| Parameter | L-IN | L-RE | L-SE | L-WH |
|---|---|---|---|---|
| $\theta_{Acc\_E}$ ($\times 10^{-5}$) | 3.257 | -3.91 | -7.301 | -3.511 |
| $\theta_{Acc\_P}$($\times 10^{-5}$) | -5.174 | -2.085 | -2.100 | -1.840 |
| $\theta_{Income}$($\times 10^{-6}$) | 3.413 | 0 | 8.606 | 3.474 |
| $\theta_{EncAng}$($\times 10^{-2}$) | -0.511 | 0 | -0.463 | 0.175 |
| $\theta_{ODCostAdd}$ | 0.3475 | 0.5512 | 0.9831 | 0.7845 |
| $\theta_{ODCostAdd}$ FLEET | n/a | n/a | 1.0665 | n/a |
| $\theta_{DECostAdd}$ | 0 | 0.4273 | 0 | 0.2387 |
| $\theta_{EmpDens}$($\times 10^{-6}$) | 0 | 0 | -4.626 | -7.967 |
| $\theta_{PopDens}$($\times 10^{-6}$) | 42.241 | 0 | 36.794 | 0 |
| $\theta_{ODCost}$ | 0.6482 | 0.9162 | 0.5977 | 0.7103 |
| $\theta_{ODCost}$ FLEET | n/a | n/a | 0.6484 | n/a |
| $\theta_{SizeTerm}$ | 0.745 | 0.625 | 0.809 | 0.766 |
| $\theta_{PopTot}$ | 0.886 | 0.800 | 3.290 | 0.338 |
| $\theta_{EmpIn}$ | 3.539 | -86 | 1.869 | -86 |
| $\theta_{EmpWh}$ | 31.817 | 14.101 | 56.079 | 15.221 |
| $\theta_{EmpRe}$ | 4.516 | 1.508 | 33.567 | 15.546 |
| $\theta_{EmpSe}$ | -86 | -86 | -86 | -86 |
| $\theta_{EmpTh}$ | -86 | 10.621 | -86 | -86 |
| $\theta_{LULoEmp}$ | -86 | -86 | -86 | -86 |
| $\theta_{LUResEmp}$ | -86 | -86 | 7.938 | -86 |
| $\theta_{LURCEmp}$ | -86 | 2.027 | -86 | -86 |
| $\theta_{LUInEmp}$ | -86 | 10.513 | 5.657 | 6.855 |
| $\theta_{LUEmpEmp}$ | -86 | -86 | 3.285 | -86 |
| $\theta_{Area}$ | 7.955 | 76.017 | 490.612 | 24.254 |

## Table 8B: Next Stop Location Utility Functions for selected segments

| Parameter | L-TH | M-IR | M-TWP | H-G |
|---|---|---|---|---|
| $\theta_{Acc\_E}$ ($\times 10^{-5}$) | 0 | -84.498 | -56.887 | 0 |
| $\theta_{Acc\_P}$($\times 10^{-5}$) | 0 | -1.451 | -1.663 | -3.136 |
| $\theta_{Income}$($\times 10^{-6}$) | 0 | -3.741 | 5.316 | -16.263 |
| $\theta_{EncAng}$($\times 10^{-2}$) | -0.157 | -0.326 | -0.429 | -0.677 |
| $\theta_{ODCostAdd}$ | 0.5117 | 0.3238 | 0.3084 | 0.0764 |
| $\theta_{ODCostAdd}$ FLEET | n/a | n/a | 0.6163 | 0.1638 |
| $\theta_{DECostAdd}$ | 0 | 0 | 0 | 0.1092 |
| $\theta_{DECostAdd}$ FLEET | n/a | n/a | 0 | 0.2344 |
| $\theta_{EmpDens}$($\times 10^{-6}$) | -11.094 | 0 | -30.275 | 15.089 |
| $\theta_{PopDens}$($\times 10^{-6}$) | 76.847 | 76.328 | 0 | 0 |
| $\theta_{ODCost}$ | 0.0630 | 0.1552 | 0.1342 | 0.2130 |
| $\theta_{ODCost}$ FLEET | n/a | n/a | 0.2682 | 0.4569 |
| $\theta_{SizeTerm}$ | 1 | 0.704 | 0.867 | 0.587 |
| $\theta_{PopTot}$ | 0.085 | 0.832 | -86 | -86 |
| $\theta_{EmpIn}$ | -86 | 6.161 | 21.084 | 0.967 |
| $\theta_{EmpWh}$ | 3.679 | 36.288 | 49.905 | -86 |
| $\theta_{EmpRe}$ | 0.438 | -86 | 16.579 | -86 |
| $\theta_{EmpSe}$ | -86 | -86 | -86 | -86 |
| $\theta_{EmpTh}$ | -86 | 8.154 | -86 | -86 |
| $\theta_{LULoEmp}$ | -86 | -86 | -86 | -86 |
| $\theta_{LUResEmp}$ | -86 | -86 | 5.786 | -86 |
| $\theta_{LURCEmp}$ | 0.222 | 1.491 | 2.641 | 1.491 |
| $\theta_{LUInEmp}$ | 1.946 | 1.910 | 6.579 | 1.622 |
| $\theta_{LUEmpEmp}$ | -86 | -86 | -86 | -86 |
| $\theta_{Area}$ | -86 | 177.739 | 205.764 | 80.760 |

## Table 8C: Next Stop Location Utility Functions for selected segments

| Parameter | H-S | H-TH | L-OT (SE/RE/IN/WH/FL) | L-OT (TH) |
|---|---|---|---|---|
| $\theta_{Acc\_E}$ ($\times 10^{-5}$) | 0 | 15.419 | -10.65 | -10.65 |
| $\theta_{Acc\_P}$($\times 10^{-5}$) | -2.717 | -2.092 | -2.008 | -2.008 |
| $\theta_{Income}$($\times 10^{-6}$) | 0 | -14.221 | 0 | 0 |
| $\theta_{EncAng}$($\times 10^{-2}$) | -0.583 | -0.567 | -0.420 | -0.420 |
| $\theta_{ODCostAdd}$ | 0.1872 | 0.0380 | -0.1143 | -0.0758 |
| $\theta_{ODCostAdd}$ FLEET | 0.4015 | n/a | -0.1129 | n/a |
| $\theta_{DECostAdd}$ | 0 | 0 | 0.4579 | 0.3036 |
| $\theta_{DECostAdd}$ FLEET | 0 | n/a | 0.4925 | n/a |
| $\theta_{EmpDens}$($\times 10^{-6}$) | -28.146 | -132.287 | -26.624 | -26.624 |
| $\theta_{PopDens}$($\times 10^{-6}$) | 99.926 | -2113.891 | 0 | 0 |
| $\theta_{ODCost}$ | 0.2042 | 0.0616 | 1.2150 | 0.8056 |
| $\theta_{ODCost}$ FLEET | 0.4380 | n/a | 1.3067 | n/a |
| $\theta_{SizeTerm}$ | 0.618 | 0.700 | 1 | 1 |
| $\theta_{PopTot}$ | 0.050 | 0.477 | 0.672 | 0.672 |
| $\theta_{EmpIn}$ | 5.190 | 3.733 | 1.830 | 1.830 |
| $\theta_{EmpWh}$ | -86 | 19.561 | 19.289 | 19.289 |
| $\theta_{EmpRe}$ | 6.107 | -86 | 32.820 | 32.820 |
| $\theta_{EmpSe}$ | -86 | -86 | -86 | -86 |
| $\theta_{EmpTh}$ | -86 | -86 | -86 | -86 |
| $\theta_{LULoEmp}$ | -86 | -86 | -86 | -86 |
| $\theta_{LUResEmp}$ | -86 | 7.305 | 2.258 | 2.258 |
| $\theta_{LURCEmp}$ | -86 | -86 | -86 | -86 |
| $\theta_{LUInEmp}$ | -86 | 0.879 | -86 | -86 |
| $\theta_{LUEmpEmp}$ | -86 | -86 | -86 | -86 |
| $\theta_{Area}$ | 502.696 | 51.476 | 221.496 | 221.496 |

## Table 8D: Next Stop Location Utility Functions for selected segments

| Parameter | MH-OT |
|---|---|
| $\theta_{Acc\_E}$ ($\times 10^{-5}$) | 0 |
| $\theta_{Acc\_P}$($\times 10^{-5}$) | -5.158 |
| $\theta_{Income}$($\times 10^{-6}$) | -16.299 |
| $\theta_{EncAng}$($\times 10^{-2}$) | -0.628 |
| $\theta_{ODCostAdd}$ MEDIUM | 0 |
| $\theta_{ODCostAdd}$ HEAVY | 0 |
| $\theta_{ODCostAdd}$ FLEET | 0 |
| $\theta_{DECostAdd}$ MEDIUM | 0.0280 |
| $\theta_{DECostAdd}$ HEAVY | 0.0323 |
| $\theta_{DECostAdd}$ FLEET | 0.0693 |
| $\theta_{EmpDens}$($\times 10^{-6}$) | -22.932 |
| $\theta_{PopDens}$($\times 10^{-6}$) | -310.561 |
| $\theta_{ODCost}$ MEDIUM | 0.2645 |
| $\theta_{ODCost}$ HEAVY | 0.3046 |
| $\theta_{ODCost}$ FLEET | 0.6535 |
| $\theta_{SizeTerm}$ | 0.652 |
| $\theta_{PopTot}$ | -86 |
| $\theta_{EmpIn}$ | -86 |
| $\theta_{EmpWh}$ | 100.994 |
| $\theta_{EmpRe}$ | -86 |
| $\theta_{EmpSe}$ | -86 |
| $\theta_{EmpTh}$ | -86 |
| $\theta_{LULoEmp}$ | -86 |
| $\theta_{LUResEmp}$ | 8.202 |
| $\theta_{LURCEmp}$ | 11.427 |
| $\theta_{LUInEmp}$ | 7.291 |
| $\theta_{LUEmpEmp}$ | -86 |
| $\theta_{Area}$ | 216.729 |

## 4.4 Stop Duration Models

The duration of stops is of interest to the commercial vehicle model for two main reasons. Firstly, by delaying vehicles at stops, their trips are spread throughout the day and cross time periods realistically. Secondly, the total elapsed time for a vehicle since leaving its' establishment is important for the return-to-establishment decision in the next stop purpose model.

The Monte Carlo process is used to assign the next stop location.

The power function, with the following form was used for all stop duration model segments:

$$T = \mathbf{a}x^{\mathbf{b}} + cx^{\mathbf{d}} + \mathbf{e}x + \mathbf{f}$$

Where:

- T is the time duration of the stop (in hours)
- a, b, c, d, e and f are calibrated constants for the power function
- x is a flat random input between 0 and 1.

19 separate models are applied for the 13 segments used for next stop location (for 6 segments the stop duration for medium vehicles is split between the two weight classes for that vehicle type). The stop segments are:

- **S-S-L**: service tours by Services establishments using light vehicles;
- **S-S-I**: service tours by Services establishments using medium vehicles <9.6 tons;
- **S-S-MH**: service tours by Services establishments using medium >9.6 tons or heavy vehicles;
- **G-S-LIMH**: goods tours by Services establishments using any vehicle type;
- **S-R-LIMH**: service tours by Retail establishments using any vehicle type;

- **G-R-LI**: goods tours by Retail establishments using light or medium <9.6 tons vehicles;
- **G-R-MH**: goods tours by Retail establishments using medium >9.6 tons or heavy vehicles;
- **S-I-L**: service tours by Industrial establishments using light vehicles;
- **S-I-I**: service tours by Industrial establishments using medium <9.6 tons vehicles;
- **S-I-MH**: service tours by Industrial establishments using medium >9.6 tons or heavy vehicles;
- **G-I-LI:** goods tours by Industrial establishments using light or medium <9.6 tons vehicles;
- **G-I-MH**: goods tours by Industrial establishments using medium >9.6 tons or heavy vehicles;
- **S-W-LIMH**: service tours by Wholesale establishments using any vehicle type;
- **G-W-L**: goods tours by Wholesale establishments using light vehicles;
- **G-W-I**: goods tours by Wholesale establishments using medium <9.6 tons vehicles;
- **G-W-MH**: goods tours by Wholesale establishments using medium >9.6 tons or heavy vehicles;
- **B-T-LI:** business tours by Transport establishments using light or medium <9.6 tons vehicles;
- **B-T-MH**: business tours by Transport establishments using medium >9.6 tons or heavy vehicles; and
- **O-X-LIMH**: other tours by any establishments using any vehicle type.

For next stop duration for Fleet Allocator tours the Retail establishment models were used.

The model coefficients for each segment are given in Table 9.

## Table 9: Stop Duration Models

| Stop Segment | Function Type | Parameters | | | | | |
|---|---|---|---|---|---|---|---|
| | | a | b | c | d | e | f |
| S-S-L | power: y = ax^b + cx^d + ex + f | 11.66667 | 38 | 3.416667 | 5.5 | 1.166667 | 0 |
| S-S-I | power: y = ax^b + cx^d + ex + f | 6.483333 | 58 | 0.35 | 5 | 1.583333 | 0 |
| S-S-MH | power: y = ax^b + cx^d + ex + f | 6.9 | 48 | 0.133333 | 3.7 | 0.883333 | 0 |
| G-S-LIMH | power: y = ax^b + cx^d + ex + f | 10.66667 | 210 | 1.25 | 15 | 0.333333 | 0 |
| S-R-LIMH | power: y = ax^b + cx^d + ex + f | 11 | 26 | 1.133333 | 6 | 0.866667 | 0 |
| G-R-LI | power: y = ax^b + cx^d + ex + f | 12.83333 | 210 | 1.25 | 15 | 0.166667 | 0 |
| G-R-MH | power: y = ax^b + cx^d + ex + f | 15.16667 | 250 | 0.666667 | 25 | 0.666667 | 0 |
| S-I-L | power: y = ax^b + cx^d + ex + f | 13.83333 | 12.75 | 1.166667 | 2 | 0.616667 | 0 |
| S-I-I | power: y = ax^b + cx^d + ex + f | 10.25 | 13 | 0.416667 | 10.5 | 0.283333 | 0 |
| S-I-MH | power: y = ax^b + cx^d + ex + f | 13.5 | 20 | 0.3 | 45 | 1.083333 | 0 |
| G-I-LI | power: y = ax^b + cx^d + ex + f | 9.833333 | 180 | 1.416667 | 20 | 0.416667 | 0 |
| G-I-MH | power: y = ax^b + cx^d + ex + f | 10.91667 | 225 | 1.083333 | 15 | 0.75 | 0 |
| S-W-LIMH | power: y = ax^b + cx^d + ex + f | 10.36667 | 12.5 | 0.216667 | 5 | 0.416667 | 0 |
| G-W-L | power: y = ax^b + cx^d + ex + f | 13.68333 | 230 | 0.833333 | 15 | 0.283333 | 0 |
| G-W-I | power: y = ax^b + cx^d + ex + f | 7.25 | 230 | 0.916667 | 15 | 0.333333 | 0 |
| G-W-MH | power: y = ax^b + cx^d + ex + f | 14.58333 | 225 | 1 | 15 | 0.666667 | 0 |
| B-T-LI | power: y = ax^b + cx^d + ex + f | 10.91667 | 170 | 2.25 | 15 | 0.333333 | 0 |
| B-T-MH | power: y = ax^b + cx^d + ex + f | 13.16667 | 180 | 2.25 | 5 | 0.583333 | 0 |
| O-X-LIMH | power: y = ax^b + cx^d + ex + f | 10.86667 | 85 | 1.833333 | 5 | 0.3 | 0 |

To implement these models, a random number is generated and used to determine the stop length in hours from the appropriate curve. The overall model process flow then returns to the next stop purpose model, and the next stop on the tour is generated.

# 5. Model Calibration

The SDCVM model for the year 2000 run for California was calibrated for each industry type, to fit within a range of observed values from survey data for the Edmonton and Calgary urban regions in Alberta, Canada. Specific “observed” data for California is not readily available, so the calibration was based on a reasonable match to the observed Alberta data, for generation rates and trips per tour.

The models were specifically calibrated for the following:

- Daily Commercial Vehicle Tours / Employee;
- # trips / tour;
- Trip Length.

Tables 10 through 12 summarize calibration results.

**Table 10: Year 2000 Model Calibration for Daily Tours / Employee by Industry Type**

| Industry | Target Tours / Employee | Model Tours / Employee | Ratio Model / Target |
|---|---|---|---|
| Service | 0.04819 | 0.04848 | 1.01 |
| Retail | 0.06417 | 0.06348 | 1.00 |
| Industry | 0.11231 | 0.11161 | 0.99 |
| Wholesale | 0.15536 | 0.15394 | 0.99 |
| Transport and Handling | 0.23007 | 0.22848 | 0.99 |
| Fleet | 0.02032 | 0.02083 | 1.02 |

Table 10 shows that the overall modeled daily tour generation rates, by industry type, match the target values.

**Table 11: Year 2000 Model Calibration for Trips / Tour by Tour Type**

| Industry Type | Tour Purpose | Vehicle Type | Target Trips/Tour | Model Trips/Tour | Ratio Model/Target |
|---|---|---|---|---|---|
| Service | Service | Light | 3.68 | 3.81 | 1.04 |
| Service | Service | Medium, Heavy | 4.89 | 4.91 | 1.00 |
| Service | Goods | All | 3.56 | 3.79 | 1.07 |
| Retail | Service | All | 4.03 | 4.19 | 1.04 |
| Retail | Goods | All | 5.11 | 5.13 | 1.00 |
| Industry | Service | Light | 3.70 | 3.85 | 1.04 |
| Industry | Service | Medium, Heavy | 4.60 | 4.87 | 1.06 |
| Industry | Goods | All | 3.99 | 4.07 | 1.02 |
| Wholesale | Service | All | 4.53 | 4.49 | 0.99 |
| Wholesale | Goods | Light | 5.35 | 5.37 | 1.00 |
| Wholesale | Goods | Medium, Heavy | 4.55 | 4.70 | 1.03 |
| Transport and Handling | Business | All | 6.31 | 6.40 | 1.01 |
| Fleet | All | All | 7.18 | 7.33 | 1.02 |
| All | Other | All | 2.82 | 2.89 | 1.02 |

Table 11 shows that the model overall daily trips/ tour rates, by tour type, match the target values within a range of model / target ratio of 0.99 to 1.07.

**Table 12: Year 2000 Model Calibration for Trip Length by Industry / Vehicle Type**

| Industry Type | Vehicle Type | Target Trip Length (Miles) | Model Trip Length (Miles) | Ratio Model/Target |
|---|---|---|---|---|
| Service | Light | 7.7 | 8.3 | 1.07 |
| Service | Medium (I) | 7.6 | 14.3 | 1.88 |
| Service | Medium (M) | 9.8 | 14.1 | 1.45 |
| Service | Heavy | 12.4 | 16.8 | 1.35 |
| Retail | Light | 6.9 | 5.5 | 0.79 |
| Retail | Medium (I) | 6.7 | 9.7 | 1.44 |
| Retail | Medium (M) | 8.0 | 10.4 | 1.30 |
| Retail | Heavy | 9.5 | 15.1 | 1.59 |
| Industry | Light | 5.5 | 8.0 | 1.45 |
| Industry | Medium (I) | 7.2 | 10.7 | 1.49 |
| Industry | Medium (M) | 8.6 | 11.6 | 1.35 |
| Industry | Heavy | 8.8 | 11.5 | 1.32 |
| Wholesale | Light | 7.3 | 5.8 | 0.80 |
| Wholesale | Medium (I) | 6.7 | 12.2 | 1.82 |
| Wholesale | Medium (M) | 9.4 | 12.3 | 1.31 |
| Wholesale | Heavy | 10.7 | 12.7 | 1.19 |
| Transport and Handling | Light | 6.3 | 9.6 | 1.52 |
| Transport and Handling | Medium (I) | 7.6 | 11.3 | 1.47 |
| Transport and Handling | Medium (M) | 7.6 | 11.8 | 1.55 |
| Transport and Handling | Heavy | 7.9 | 16.7 | 2.12 |
| Fleet | Light | 5.7 | 6.2 | 1.08 |
| Fleet | Medium (I) | 5.9 | 7.7 | 1.31 |
| Fleet | Medium (H) | 5.9 | 7.8 | 1.32 |
| Fleet | Heavy | 8.5 | 7.4 | 1.13 |

Table 12 shows model trip lengths in a range of 0.74 to 1.23 of the targets. This is considered acceptable, given the uncertainty of the actual trip lengths for California. Observed trip lengths in California for journey to work commuting flows are twice those observed for the Edmonton region (13.8 miles to 6.8 miles), and so trip length targets for the SDCVM were set at twice the observed Edmonton data.

During model validation, 10% of the LDCVM trips forecast to occur in the AM period are moved to Midday; and 20% of the PM period trips to Off-peak, to match observed time period flows.

## 6. Implementation in CSTDM09

The SDCVM is implemented in the CSTDM09 using the CUBE software interface. The SDCVM model itself contains two specially-written computer programs:

- A program written in python script to calculate the TAZ-level tour generation component of the model;
- A program written in java script to implement the tour micro-simulation component of the model.

The first program reads in the following input data:

- A TAZ demographic data input file;
- TAZ to TAZ Skim files from CUBE giving times and costs by time period by commercial vehicle type.

This first program calculates the number of daily tours generated in each TAZ for each industry by tour purpose, vehicle type and time of day.

This output data is then passed to the second program which reads in the following data:

- TAZ numbers of tours by industry, tour purpose, vehicle type and time of day;
- Model specification files for each industry type / time of day giving details of parameters and travel skim and demographic data input sources;
- A TAZ demographic data input file;
- TAZ to TAZ Skim files from CUBE giving times and costs by time period by commercial vehicle type.

This second program then micro-simulates each tour, and produces a trip list for every trip on every tour giving TAZ origin and destination, vehicle type, and time period of travel in the CSTDM09 time period definitions.

More details of the SDCVM program set-up and input / output files are given in the CSTDM09 User Guide.