California Statewide Travel Demand Model, Version 2.0

Short and Long Distance Commercial Vehicle Models

final

report

prepared for

California Department of Transportation

prepared by

Cambridge Systematics, Inc.

and

HBA Specto, Inc.

May 2014

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1.0 Introduction

The original version of the California Statewide Travel Demand Model (CSTDM09) defined two separate models to be applied to forecast commercial truck travel generated by California business on a typical fall weekday.

The Short Distance Commercial Vehicle Model (SDCVM) applies to commercial truck trips made up to 50 miles from the home business establishment. The Long Distance Commercial Vehicle Model (LDCVM) forecasts truck movements greater than 50 miles. This distance classification was 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 intent for the CSTDM, Version 2.0, was to integrate the California Statewide Freight Forecasting Model (CSFFM) into the CSTDM structure. Significant efforts were spent on preparation for the CSFFM-CSTDM integration process, including developing compatible highway networks and expanding the CSFFM vehicle trip tables to match the CSTDM model system. However, the CSFFM was not completed with sufficient validation in time to be included in this version of the CSTDM. As such, the original versions of the SDCVM and LDCVM were retained for the CSTDM Version 2.0 model system. Please note that long distance out-of-state commercial vehicle travel is fully contained within the External Travel Model.

Previous LDCVM assumptions, which consisted of fixed trip tables, from CSTDM09 were retained for base and future year scenarios. This technical note summarizes the SDCVM and LDCVM base year trip tables included in CSTDM, Version 2.0.

2.0 Short Distance Commercial Vehicle Model Overview

The SDCVM model was developed by HBA Specto for CSTDM09 using data and analysis from the cities of Calgary and Edmonton, Alberta. 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- hour 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).

The SDCVM has not been updated for CSTDM Version 2.0, so an extensive description of this model is not provided here. Ultimately, this model may be updated with California data on short distance goods movement and service vehicles. Full documentation of the original SDVCM is provided in Appendix A in this documentation.

3.0 Short Distance Commercial Vehicle Model Trip Summaries

CSTDM Version 2.0 SDCVM trips are summarized for Year 2000 and Year 2010 conditions. Future year forecasts for SDCVM trips will be summarized in a companion CSTDM 2.0 travel forecasting report. Table 3.1 summarizes Year 2000 SDCVM trips by region, and Table 3.2 summarizes Year 2010 SDCVM trips by region. An additional table, Table 3.3, further summarizes and compares the 2000 and 2010 SDVCM truck trips.

Comparing the SDCVM truck trips between years 2000 and 2010, there is a noticeably increase in trips from Southern California, but a decrease in Northern California. Table 3.4 compares total population and employment for each region, and Table 3.5 shows the different in employment by industry. Both tables reveal an increase in total employment (a major factor in short distance commercial tour generation) for Southern California (assumed to be SCAG and SANDAG regions), as shown in Table 3.6, as well as changes in employment by industry. These tables show a considerable decrease in total employment for the San Francisco Bay Area and reductions in Industrial employment across other parts of Northern California. Given these differences, the resulting changes to total tours generated by SDCVM were reasonable.

Table 3.1 Year 2000 Short Distance Commercial Vehicle Trips By Region

Region	Far North	W. Sierra Nevada	SACOG/ TRPA	MTC	Central Coast	San Joaquin Valley	SCAG	SANDAG	Total
Far North	342,700	0	6,700	1,600	0	0	0	0	351,000
Western Sierra Nevada	0	56,600	1,700	0	0	3,100	0	0	61,400
SACOG/TRPA	6,700	1,700	534,500	9,000	0	6,800	0	0	558,700
MTC	1,600	0	8,900	2,195,000	13,200	9,800	0	0	2,228,500
Central Coast	0	0	0	13,200	438,600	700	4,400	0	456,900
San Joaquin Valley	0	3,100	6,900	9,800	600	1,018,900	2,500	0	1,041,800
SCAG	0	0	0	0	4,400	2,500	4,047,500	8,500	4,062,900
SANDAG	0	0	0	0	0	0	8,500	650,000	658,500
	351,000	61,400	558,700	2,228,600	456,800	1,041,800	4,062,900	658,500	9,419,700

TRPA includes California portion only.

Table 3.2 Year 2010 Short Distance Commercial Vehicle Trips By Region

Region	Far North	W. Sierra Nevada	SACOG/ TRPA	MTC	Central Coast	San Joaquin Valley	SCAG	SANDAG	Total California
Far North	300,100	0	5,200	1,400	0	0	0	0	306,700
Western Sierra Nevada	0	53,300	1,300	0	0	2,400	0	0	57,000
SACOG/TRPA	5,200	1,300	507,900	6,700	0	6,100	0	0	527,200
MTC	1,400	0	6,700	2,169,700	12,200	9,600	0	0	2,199,600
Central Coast	0	0	0	12,200	418,600	500	3,500	0	434,800
San Joaquin Valley	0	2,400	6,100	9,600	500	1,079,700	2,000	0	1,100,300
SCAG	0	0	0	0	3,500	2,000	4,436,000	10,600	4,452,100
SANDAG	0	0	0	0	0	0	10,600	709,700	720,300
Total California	306,700	57,000	527,200	2,199,600	434,800	1,100,300	4,452,100	720,300	9,798,000

Table 3.3 Years 2000 and 2010 SDCVM Truck Trip Trips

Origin Region	Year 2000 Truck Trips	Year 2000 Percent Intraregional	Year 2010 Truck Trips	Year 2010 Percent Intraregional	2000-2010 Percent Change in Trips
Far North	351,000	98%	306,700	98%	-13%
Western Sierra Nevada	61,400	92%	57,000	94%	-7%
SACOG	558,700	96%	527,200	96%	-6%
MTC	2,228,500	98%	2,199,600	99%	-1%
Central Coast	456,900	96%	434,800	96%	-5%
San Joaquin Valley	1,041,800	98%	1,100,300	98%	6%
SCAG	4,062,900	100%	4,452,100	100%	10%
SANDAG	658,500	99%	720,300	99%	9%
Statewide	9,419,700	99%	9,798,000	99%	4%

Table 3.4 Years 2000 and 2010 Population and Employment

Origin Region	Total Population			Total Employment		
	2000	2010	Percent Difference	2000	2010	Percent Difference
Far North	983,642	1,051,247	7%	398,881	400,994	1%
W. Sierra Nevada	179,418	191,217	7%	67,556	70,675	5%
SACOG	1,936,434	2,316,006	20%	929,563	981,739	6%
MTC	6,785,469	7,150,667	5%	3,821,805	3,475,792	-9%
Central Coast	1,357,191	1,426,201	5%	614,803	625,536	2%
SJV	3,303,837	3,971,602	20%	1,291,657	1,416,317	10%
SCAG	16,536,452	18,047,015	9%	7,747,566	7,852,662	1%
SANDAG	2,814,048	3,095,201	10%	1,427,796	1,519,101	6%
Statewide	33,896,491	37,249,156	10%	16,299,627	16,342,816	0%

Table 3.5 Difference in Civilian Employment by Industry between Years 2000 and 2010

Origin Region	Difference in Civilian Employment by Industry				
	Industrial	Retail	Service	Transport and Handling	Wholesale
Far North	-51,345	-1,098	54,286	-510	-400
W. Sierra Nevada	-9,035	-597	13,629	-467	-487
SACOG	-48,415	6,623	90,721	3,082	-806
MTC	3,343	-44,931	-250,517	-24,541	-27,594
Central Coast	-22,364	4,185	30,847	911	-3,383
SJV	-30,384	36,647	92,334	14,071	3,581
SCAG	51,271	36,530	14,581	21,237	-26,502
SANDAG	-12,516	5,425	94,299	5,446	474
Statewide	-119,445	42,784	140,180	19,229	-55,117

Table 3.6 Difference in Total Employment and Civilian Employment by Industry between Years 2000 and 2010

Origin Region	Difference in Total Employment		Difference in Civilian Employment by Industry				
			Industrial	Retail	Service	Transport and Handling	Wholesale
Northern California	-153,212	-3%	-158,200	829	31,300	-7,454	-29,089
Southern California	196,401	4%	38,755	41,955	108,880	26,683	-26,028

Southern California includes SCAG and SANDAG regions. Northern California includes the rest of the state.

4.0 Long Distance Commercial Vehicle Model Overview

The development of the LDCVM was built directly from the work conducted at ULTRANS for Caltrans to develop a computer-based model of the California spatial economic system using the PECAS modeling framework. A base Year 2000 PECAS model was being developed, and the output from this PECAS model was used to create an initial Year 2000 weekday long distance commercial vehicle Transportation Analysis zone (TAZ) to TAZ trip table.

Growth factors based on forecast changes in TAZ demographics were then applied to grow the base commercial truck trip table for future year scenarios. Future year growth factors were developed in 2012 by ULTRANS for the San Joaquin Valley Interregional Travel Model (SJVITM) project. Since future year forecasts were developed for long distance truck travel after publication of CSTDM09 documentation, the LDCVM garners significantly more analysis in this report than the SDCVM. Some additional notes on the LDCVM are as follows:

- The approach to generating future year LDCVM forecasts was not dependent upon the availability of future year PECAS model outputs. The derivation of the model used the Year 2000 PECAS model output as input, but application for future year scenarios was carried out using the resulting Year 2000 commercial vehicle trip table and scaling factors for each horizon year. This means that the travel model can immediately be applied to produce long distance truck trips for all future year scenarios.
- The PECAS model produced truck flows for all zone-to-zone pairs for all distance ranges. Only those for origin-destinations more than 50 miles were applied in the CSTDM09, and subsequently for CSTDM Version 2.0

Documentation of the CSTDM09 LDCVM is provided in Appendix B in this documentation.

5.0 Application of the Long Distance Commercial Vehicle Model

The long distance commercial vehicle trip tables obtained from factoring the California PECAS model for the Year 2000, for origin-destination pairs more than 50 miles apart, as was used directly in the Year 2000 CSTDM09.

For the Year 2008 CSTDM09 travel model scenario, the calibrated California PECAS model had been run with 2008 inputs derived from 2008 TAZ population and employment data inputs to give a year 2008 truck trip table.

For all future year travel model scenarios, the Year 2008 long distance truck tables were scaled using appropriate factors. The growth factor method had three basic steps:

1. Definition of overall statewide future growth factors for the commodity types used in the LDCVM;
2. Definition of county-level future growth rates for commodity production and consumption; and
3. Application of TAZ level origin and destination future growth factors to the 2008 LDCVM truck trips.

Each of these steps is described below.

5.1 Statewide Growth Factors by Commodity Type

The LDCVM focused on 11 commodities primarily generating truck-based goods movement, as listed below:

1. Agriculture Animals Output;
2. Agriculture Plants Output;
3. Agriculture Forestry and Fishing Output;
4. Mining and Extraction Output;
5. Manufacturing Food Output;
6. Manufacturing Textiles Output;
7. Manufacturing Wood Products Printing Furniture Misc Output;

8. Manufacturing Petro Paper Chemicals Plastic Rubber Glass Cement Output;
9. Manufacturing Metal Steel Machinery Output;
10. Fuels; and
11. Scrap.

The Freight Analysis Framework (FAF) from the U.S. Department of Transportation (DOT) provides forecasts of future commodity flows in California for years 2020 and 2035. FAF data was used to compute the total increase in the statewide total flows for each one of the PECAS' 11 commodity categories for 2020 and 2035 (based on 2008 base year) from FAF data. Forecasts for 2015 were obtained by interpolating the growth between 2008 and 2020 by 7/12; and for 2040 and 2050 by extrapolating the growth from 2020 to 2035. Table 5.1 shows the projected growth in California truck commodity flows (in million dollars); and Table 5.2 shows the percent change from 2008.

Table 5.1 California PECAS Commodity Growth 2008 to 2040 from FAF Data

	FAF3 California Truck Commodity Flows (in Million Dollars)					
PECAS Commodity	**2008**	**2015**	**2020**	**2035**	**2040**	**2050**
Agriculture Animals Output	48,226	56,100	61,725	79,089	84,871	96,453
Agriculture Plants Output	138,847	164,548	182,905	243,446	263,606	303,987
Agriculture Forestry and Fishing Output	6,373	7,190	7,773	9,636	10,257	11,499
Mining and Extraction Output	89,532	104,911	115,896	132,589	138,148	149,282
Manufacturing Food Output	30,729	33,823	36,034	46,131	49,493	56,228
Manufacturing Textiles Output	43,008	52,073	58,548	88,781	98,848	119,014
Manufacturing Wood Products Printing Furniture Misc Output	136,083	155,008	168,526	223,339	241,591	278,152
Manufacturing Petro Paper Chemicals Plastic Rubber Glass Cement Output	134,409	175,865	205,477	377,052	434,186	548,627
Manufacturing Metal Steel Machinery Output	293,415	380,218	442,219	727,686	822,747	1,013,153
Fuels	96,805	101,551	104,940	118,016	122,370	131,092
Scrap	119,170	154,243	179,295	282,521	316,895	385,747

Table 5.2 California PECAS Commodity Growth from 2008 from FAF Data

	FAF3 California Truck Commodity Flows– – Growth from 2008					
PECAS Commodity	**2008**	**2015**	**2020**	**2035**	**2040**	**2050**
Agriculture Animals Output	–	16.3%	28.0%	64.0%	76.0%	13.6%
Agriculture Plants Output	–	18.5%	31.7%	75.3%	89.9%	15.3%
Agriculture Forestry and Fishing Output	–	12.8%	22.0%	51.2%	61.0%	12.1%
Mining and Extraction Output	–	17.2%	29.4%	48.1%	54.3%	8.1%
Manufacturing Food Output	–	10.1%	17.3%	50.1%	61.1%	13.6%
Manufacturing Textiles Output	–	21.1%	36.1%	106.4%	129.8%	20.4%
Manufacturing Wood Products Printing Furniture Misc Output	–	13.9%	23.8%	64.1%	77.5%	15.1%
Manufacturing Petro Paper Chemicals Plastic Rubber Glass Cement Output	–	30.8%	52.9%	180.5%	223.0%	26.4%
Manufacturing Metal Steel Machinery Output	–	29.6%	50.7%	148.0%	180.4%	23.1%
Fuels	–	4.9%	8.4%	21.9%	26.4%	7.1%
Scrap	–	29.4%	50.5%	137.1%	165.9%	21.7%

5.2 County-Level Growth Rates by Commodity Type

The University of California (UC) Davis ULTRANS purchased economic data from the commercially available modeling system TREDIS. TREDIS is a transportation economic impact tool that pivots economic growth (from transportation investment) off of a baseline economic forecast. TREDIS also links commodity trade to economic drivers, and has a series of modules that calculate various impacts and benefits. One module is an economic adjustment (EA) module, which calculates wider economic development benefits, including impacts of business productivity, economic development, and multiplier effects from input-output analysis.

In particular, TREDIS data projected future dollar amounts of economic activity for each county in California, by commodity type, for both production and consumption.

Some differences were found between the future forecast economic quantities between the FAF3 data and the TREDIS data. The FAF3 data was seen as more consistent and reliable, but was only available at large area geography. The TREDIS data forecast county shares of economic activity for each commodity type for each time period were, therefore, combined with the overall absolute growth levels from the FAF3 data to obtain more detailed county-level growth rates for each commodity flow for each year for both production and consumption.

The TREDIS data from the UC Davis analysis was only available for this project for the years 2008, 2020, and 2035. It was, therefore, assumed that the county shares for each commodity projected for 2020 could be applied to the year 2015 growth; and the county commodity shares for 2035 could be applied to the 2040 and 2050 growth.

For example, for agriculture plants production for Fresno County for 2040:

- Overall 2040 statewide growth is 89.9 percent:
  - Fresno County share of statewide agriculture plants production in 2008 is 11.75 percent, from TREDIS data for 2008;
  - Fresno County share of statewide agriculture plants production in 2008 is 13.10 percent, from TREDIS data for 2040; and
  - 2008 to 2040 growth rate for agriculture plants production from Fresno County:

    = 1.899 x 13.10 / 11.75

    = 2.116

Growth rates were, thus, obtained for each county for each commodity used in the LDCVM for both production and consumption.

In a handful of cases, the original TREDIS data suggested large increases or decreases in specific commodities for an individual county, beyond what could reasonably be expected (e.g., Kern County share of fuel production up from 3.8 percent in 2008 to 13.2 percent in 2035. In these cases, a more reasonable growth was manually applied. These resultant growth rates are provided in Table 5.3.

Table 5.3 California PECAS Commodity Growth from 2008 from FAF Data by County

County	Animal	Plants	Forestry	Mining	Food	Textiles	Misc	Petro etc	Machinery	Fuel	Scrap
Alameda	1.06	1.04	0.54	1.12	1.22	1.17	1.34	1.25	1.25	1.58	1.21
Alpine	1.06	1.06	---	---	1.03	---	1.00	1.01	0.99	0.92	---
Amador	1.16	1.13	---	2.04	1.22	1.01	0.66	0.94	0.81	0.89	1.24
Butte	1.12	1.10	1.52	1.10	1.23	0.28	1.15	1.27	0.99	0.79	1.33
Calaveras	1.05	1.02	3.52	3.73	0.97	1.01	0.98	2.49	1.37	1.01	---
Colusa	1.17	1.14	---	1.52	1.60	1.01	1.26	0.87	1.39	1.29	1.99
Contra Costa	1.04	1.02	0.41	0.70	1.51	1.37	2.46	1.01	2.90	1.00	2.46
Del Norte	1.15	---	---	---	0.94	---	0.83	0.41	0.99	4.50	---
El Dorado	1.01	0.99	0.03	1.71	0.67	0.82	0.92	0.72	1.13	2.07	1.12
Fresno	1.33	1.30	0.81	3.18	1.35	0.81	1.13	1.24	0.94	1.95	1.14
Glenn	1.08	1.05	---	---	2.15	---	0.96	0.69	0.86	1.86	---
Humboldt	1.03	1.01	---	0.86	1.19	2.55	0.75	1.35	1.27	0.55	1.55
Imperial	1.32	1.29	2.91	0.23	1.53	0.29	0.89	0.37	2.16	1.00	1.41
Inyo	---	1.06	3.62	---	2.81	1.01	1.57	1.85	0.99	---	---
Kern	1.34	1.31	1.39	1.45	1.53	1.20	1.46	1.16	1.51	1.29	1.30
Kings	1.38	1.35	1.26	1.61	1.60	0.70	1.24	1.16	1.04	2.12	1.99
Lake	1.13	1.11	0.22	---	1.42	1.01	1.68	0.80	0.96	2.51	1.44
Lassen	1.07	1.04	---	7.23	1.03	1.01	0.45	1.28	0.99	5.15	---
Los Angeles	0.95	0.94	0.54	1.28	1.09	1.25	1.20	1.15	1.22	0.90	1.21
Madera	1.61	1.57	0.09	1.04	1.12	3.02	1.40	1.06	0.66	1.46	1.24
Marin	1.35	1.32	1.06	1.91	1.25	0.99	0.92	1.21	1.03	2.66	0.94
Mariposa	---	1.04	0.10	2.70	0.81	1.01	2.48	0.45	0.94	1.70	---
Mendocino	0.99	0.97	---	0.99	1.01	---	0.97	0.70	1.18	0.65	---
Merced	1.22	1.19	0.12	0.59	1.08	1.01	0.92	0.40	0.64	1.15	0.98
Modoc	1.00	0.98	---	---	1.03	---	1.00	0.74	0.99	7.48	---
Mono	1.00	1.01	---	0.60	0.62	0.97	1.12	1.01	3.11	3.26	1.29
Monterey	1.68	1.64	2.35	0.72	1.12	1.94	1.12	1.49	2.29	1.62	1.41
Napa	1.27	1.24	0.95	2.05	1.27	0.61	1.07	0.96	1.00	1.69	1.04
Nevada	1.09	1.07	0.01	0.61	1.46	---	1.32	1.06	2.01	0.67	3.02
Orange	1.09	1.07	0.48	0.76	1.01	0.93	1.23	1.17	0.99	0.83	1.03
Placer	1.16	1.13	0.89	0.70	1.22	1.04	1.02	0.90	1.12	0.85	1.11
Plumas	0.74	0.82	0.94	0.93	0.62	1.02	0.85	0.79	0.80	0.71	0.83
Riverside	1.23	1.20	1.87	0.73	0.97	1.40	1.16	1.24	1.11	1.02	1.21
Sacramento	1.10	1.08	1.59	1.52	1.26	0.67	0.91	1.26	1.25	1.18	1.24
San Benito	1.12	1.09	0.48	0.42	0.70	---	1.08	1.09	1.45	1.20	1.28
San Bernardino	0.83	0.82	1.17	0.78	0.93	1.44	0.90	0.97	0.88	0.79	1.02

County	Animal	Plants	Forestry	Mining	Food	Textiles	Misc	Petro etc	Machinery	Fuel	Scrap
San Diego	0.98	0.98	2.09	0.74	0.98	1.12	1.34	1.22	1.05	2.84	1.15
San Francisco	1.12	1.17	0.06	6.82	0.90	0.91	1.00	1.32	1.47	3.90	1.05
San Joaquin	1.33	1.30	0.78	1.29	1.38	0.67	1.01	0.99	1.00	1.00	1.16
San Luis Obispo	1.10	1.08	0.44	0.71	0.96	1.66	1.12	1.38	1.40	0.98	1.26
San Mateo	0.88	0.87	1.14	1.11	0.89	1.36	1.05	1.38	0.99	1.77	1.04
Santa Barbara	1.18	1.15	1.69	1.68	0.89	0.66	1.06	1.27	1.69	1.03	1.53
Santa Clara	1.29	1.26	1.84	0.72	1.12	1.04	1.30	1.11	1.39	1.00	1.14
Santa Cruz	0.78	0.76	1.66	0.56	1.21	0.97	1.08	1.22	0.98	3.85	0.89
Shasta	1.05	1.03	---	1.35	2.29	0.47	0.70	0.70	0.88	1.60	1.24
Sierra	---	0.52	---	---	0.93	1.02	0.99	1.01	0.98	0.91	---
Siskiyou	1.09	1.07	---	1.02	0.72	0.71	1.10	0.41	0.88	4.93	---
Solano	1.16	1.14	2.14	1.18	0.99	1.01	1.31	1.37	1.01	0.73	1.22
Sonoma	1.06	1.04	1.61	0.46	1.05	1.91	1.30	1.19	1.33	0.67	1.20
Stanislaus	1.20	1.17	3.13	0.92	1.56	1.47	1.04	1.36	1.14	0.71	1.37
Sutter	1.10	1.07	1.42	3.33	0.83	4.54	1.59	1.34	1.19	4.34	1.59
Tehama	1.09	1.06	---	5.69	4.29	0.82	0.96	0.82	0.61	2.80	1.03
Trinity	1.00	0.98	---	---	1.03	---	1.08	0.88	0.85	1.56	---
Tulare	1.45	1.41	4.31	0.65	1.35	1.34	1.43	1.45	1.40	1.04	1.48
Tuolumne	0.95	0.91	0.41	1.46	0.86	1.26	1.05	0.61	0.96	1.40	---
Ventura	1.13	1.10	0.31	1.68	0.97	3.28	1.02	1.36	0.94	1.50	1.00
Yolo	1.44	1.40	0.56	0.98	1.64	0.98	0.85	0.92	1.12	1.88	1.18
Yuba	0.99	0.97	1.52	1.56	1.45	0.57	0.86	0.62	2.05	0.81	1.66

It should be noted that, for many county/commodity combinations, the number of long distance daily commercial vehicle movements is small, so that the application of the above growth rates produces only small changes in the forecast vehicle flows.

5.3 Application of County Growth Rates to 2008 LDCVM TAZ-TAZ Flows

The county-level growth rates for each commodity were applied to each trip record in the 2008 LDCVM output list. A simplifying assumption was that the county-level growth records could be uniformly applied to every trip record from or to that county. This approach was made for ease of method application, recognizing that this LDCVM application is an interim model.

For each future year, each 2008 LDCVM trip record has two growth factors:

1. A trip origin growth factor, based on the commodity-specific production growth factor for the county of the trip origin; and
2. A trip destination growth factor, based on the commodity-specific consumption growth factor for the county of the trip destination.

A Fratar trip distribution process was applied using the CUBE software program for trip distribution to develop individual trip record scaling factors that respected the county-level origin and destination growth requirements.

For consistency of CSTDM model application, the entire 2008 LDCVM model trip list output was scaled up using the process described above, for each future year. Table 5.3 shows the commercial vehicle trips input to the CSTDM Version 2.0. For each run, a CUBE script extracts the long distance trips (greater than 50 miles) from the future year LDCVM trip list file. Those trips less than 50 miles would presumably be captured with the SDCVM; including those trips in the LDCVM would result in overestimation of trips.

Table 5.4 Total CSTDM Version 2.0 Long Distance Commercial Daily Truck Trips

PECAS Commodity	2000	2008/2010	2015	2020	2035	2040	2050
Agriculture Animals Output	3,218	2,899	3,206	3,526	4,556	4,905	5,604
Agriculture Forestry and Fishing Output	716	784	872	952	1,331	1,429	1,626
Agriculture Plants Output	9,276	10,039	11,194	12,344	16,199	17,467	20,006
Manufacturing Metal Steel Machinery Output	11,063	10,778	12,567	13,881	18,416	19,875	22,789
Manufacturing Petro Paper Chemicals Plastic Rubber Glass Cement Output	40,044	42,163	48,450	53,413	69,109	74,504	85,304

Manufacturing Textiles Output	604	646	734	798	1,024	1,095	1,239
Manufacturing Wood Products Printing Furniture Misc Output	18,546	21,430	23,339	25,770	31,791	34,295	39,301
Mining and Extraction Output	10,763	13,587	16,165	17,476	22,294	23,765	26,700
Fuels	19,991	22,283	28,598	31,375	58,968	63,547	72,717
Scrap	24,367	26,849	33,720	36,326	38,664	41,000	45,673
Other	8,851	9,987	11,708	12,936	17,177	18,540	21,279
Total	**147,439**	**161,445**	**190,553**	**208,796**	**279,529**	**300,423**	**342,237**

6.0 CSTDM Version 2.0 LDCVM Trip Summaries

CSTDM Version 2.0 LDCVM trips are summarized for Year 2000 and Year 2010 conditions. Future year forecasts for LDCVM trips will be summarized in a companion CSTDM 2.0 travel forecasting report. Table 6.1 summarizes Year 2000 LDCVM trips by region, and Table 6.2 summarizes Year 2010 LDCVM trips by region. An additional table, Table 6.3, further summarizes and compares the 2000 and 2010 LDVCM truck trips. The resultant LDCVM trip tables intend to be a placeholder until integration with the CSFFM can better address and validate long-distance truck trips.

Table 6.1 Year 2000 Long Distance Commercial Vehicle Trips By Region

Region	Far North	W. Sierra Nevada	SACOG/ TRPA	MTC	Central Coast	San Joaquin Valley	SCAG	SANDAG	Total
Far North	300	0	300	800	100	200	200	0	1,900
Western Sierra Nevada	0	0	100	300	100	200	100	0	800
SACOG/TRPA	400	0	100	2,500	200	900	600	100	4,800
MTC	600	0	1,600	2,600	1,000	2,200	1,800	200	10,000
Central Coast	0	0	100	800	200	500	1,100	100	2,800
San Joaquin Valley	200	0	800	3,200	1,000	2,200	4,400	400	12,200
SCAG	100	0	300	1,600	1,100	2,400	9,000	4,300	18,800
SANDAG	0	0	0	200	100	300	5,400	100	6,100
	1,600	0	3,300	12,000	3,800	8,900	22,600	5,200	57,400

TRPA includes California portion only.

Table 6.2 Year 2010 Long Distance Commercial Vehicle Trips By Region

Region	Far North	W. Sierra Nevada	SACOG/ TRPA	MTC	Central Coast	San Joaquin Valley	SCAG	SANDAG	Total California
Far North	400	0	400	900	100	300	200	0	2,300
Western Sierra Nevada	0	0	100	400	100	300	200	0	1,100
SACOG/TRPA	500	0	100	2,600	300	1,000	700	100	5,300
MTC	700	100	1,800	2,600	1,200	2,400	2,100	200	11,100
Central Coast	0	0	100	800	300	700	1,300	100	3,300
San Joaquin Valley	200	0	900	3,300	1,200	2,800	5,200	500	14,100
SCAG	100	0	300	1,400	1,200	2,900	10,000	4,500	20,400
SANDAG	0	0	0	200	200	300	6,400	0	7,100
Total California	1,900	100	3,700	12,200	4,600	10,700	26,100	5,400	64,700

Table 6.3 Years 2000 and 2010 LDCVM Truck Trip Trips

Origin Region	Year 2000 Truck Trips	Year 2000 Percent Intraregional	Year 2010 Truck Trips	Year 2010 Percent Intraregional	2000-2010 Percent Change in Trips
Far North	1,900	16%	2,300	17%	21%
Western Sierra Nevada	800	0%	1,100	0%	38%
SACOG	4,800	2%	5,300	2%	10%
MTC	10,000	26%	11,100	23%	11%
Central Coast	2,800	7%	3,300	9%	18%
San Joaquin Valley	12,200	18%	14,100	20%	16%
SCAG	18,800	48%	20,400	49%	9%
SANDAG	6,100	2%	7,100	0%	16%
Statewide	57,400	25%	64,700	25%	13%

A. CSTDM09 SDCVM Documentation

CSTDM09 – California Statewide Travel Demand Model

Model Development

Short Distance Commercial Vehicle Model

Final System Documentation: Technical Note

ULTRANS
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UC Davis
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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.

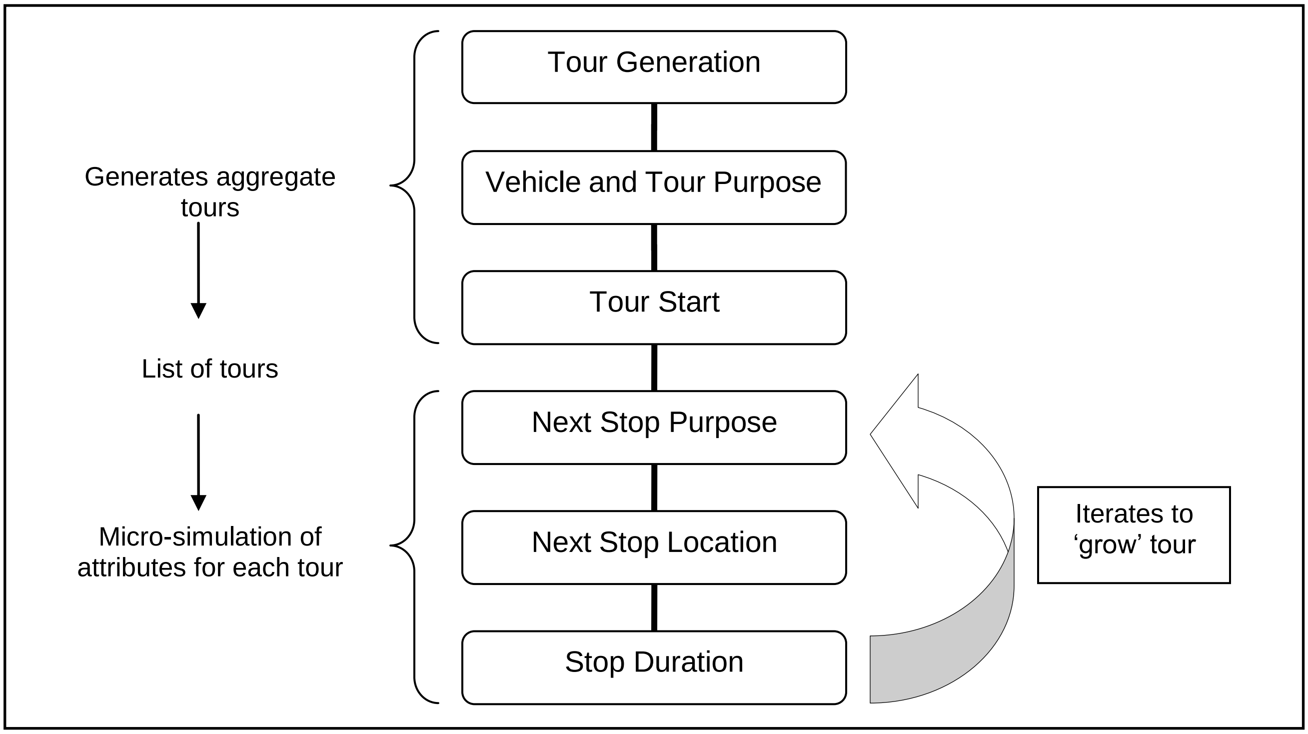

Figure 1: Tour-Based Model Structure

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:

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

where:

Accessibility_i = the accessibility for a given zone ***i*** to a particular factor

Opportunity_j = the quantity of the factor in zone ***j***

λ = 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.

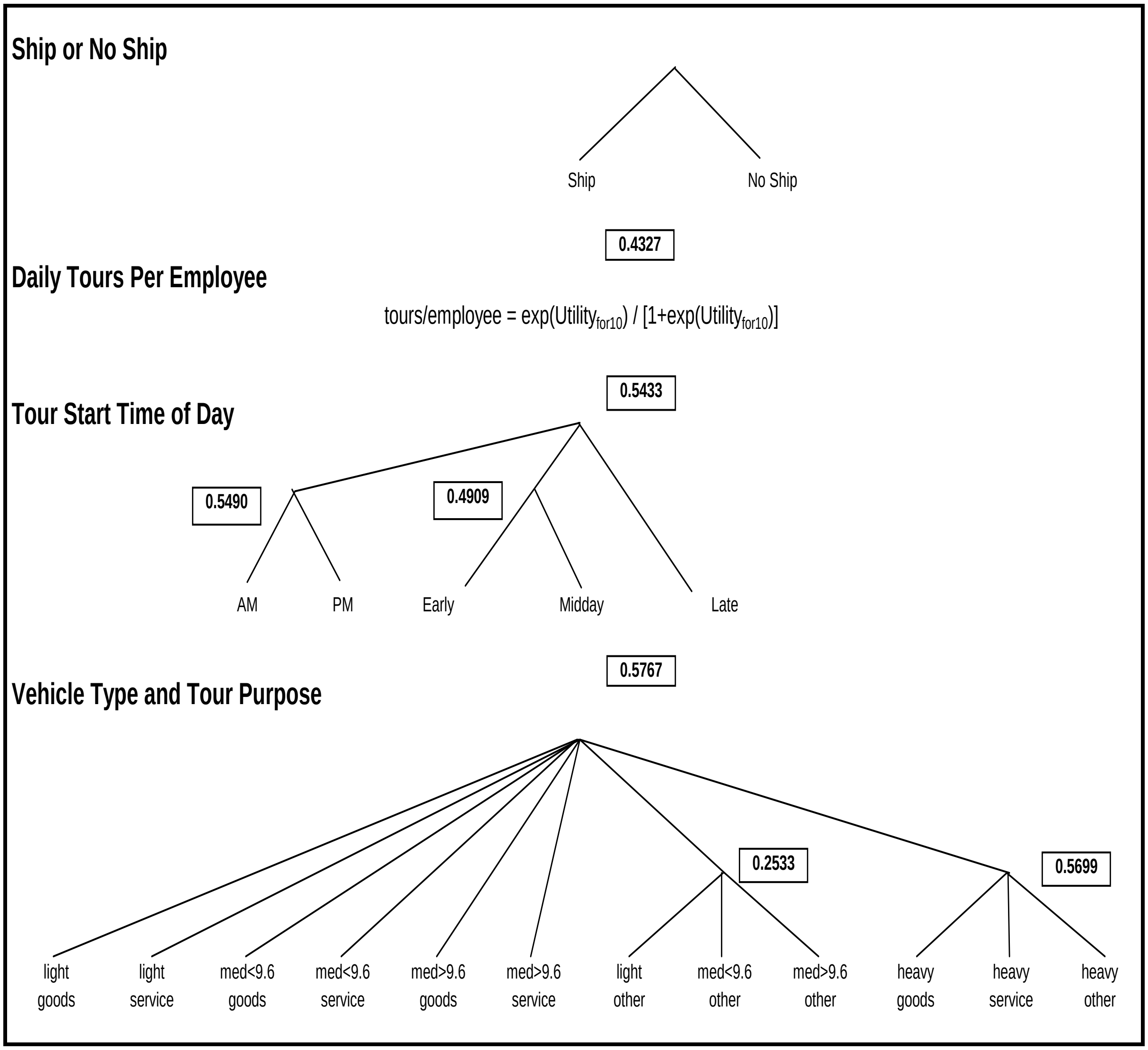

Figure 2: Tour Generation Model Structure Example: Industry Tours

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:

$$\text{Probability of Ship}_i = (\exp(\text{Utility Ship}_i)) / (\exp(\text{Utility Ship}_i) + \exp(\text{Utility No Ship}_i))$$

$$\text{Utility Ship}_i = \Sigma(\text{Attribute of zone}_i \times \text{Attribute Coefficient}) + \text{Ship Constant}$$

$$\text{Utility No Ship}_i = 0$$

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.

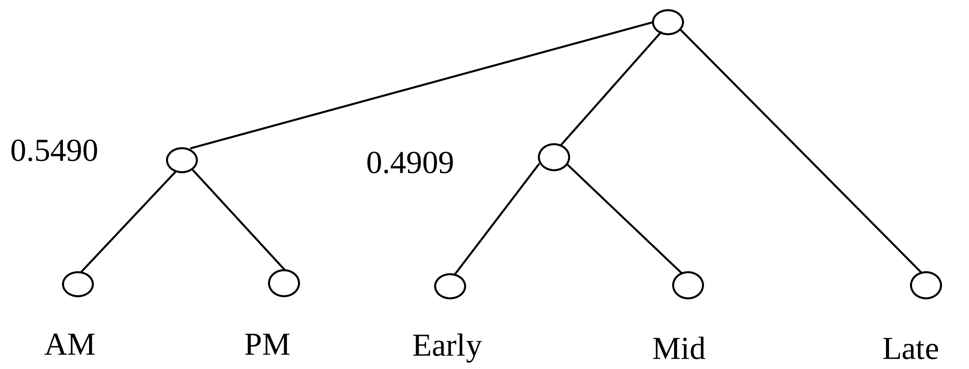

Figure 3A: Tour Time of Day Nesting Structure: Industry Tours

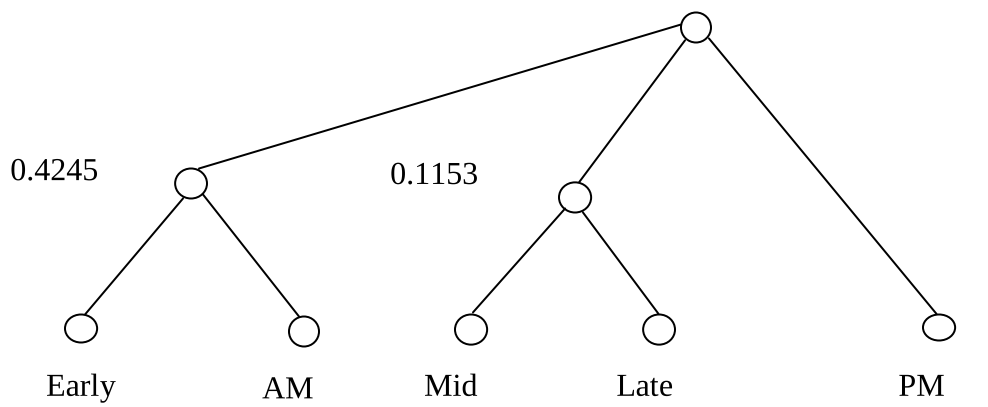

Figure 3B: Tour Time of Day Nesting Structure: Wholesale Tours

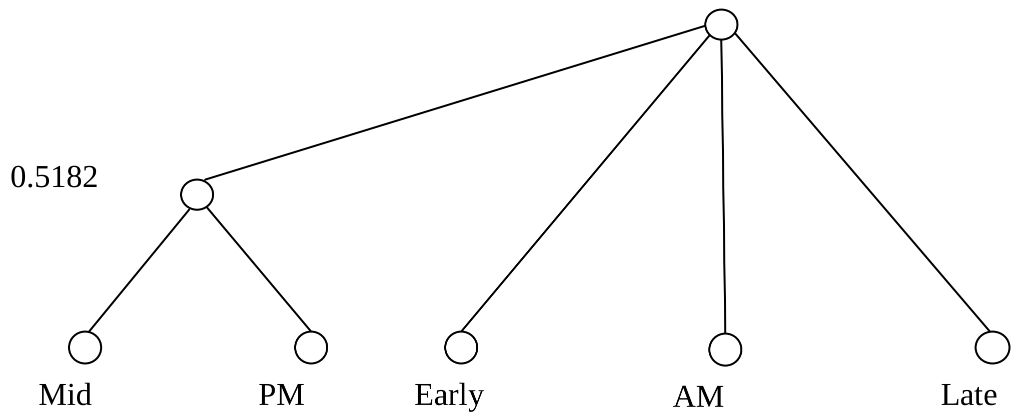

Figure 3C: Tour Time of Day Nesting Structure: Retail / Fleet Tours

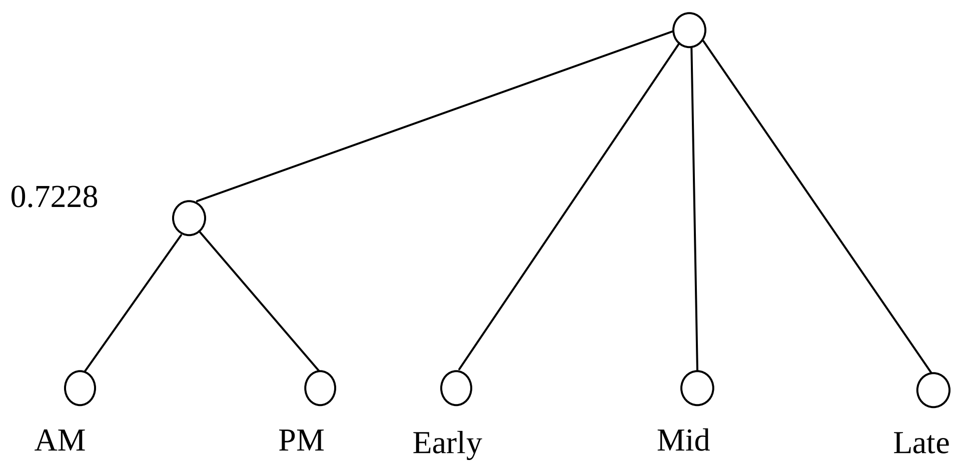

Figure 3D: Tour Time of Day Nesting Structure: Service Tours

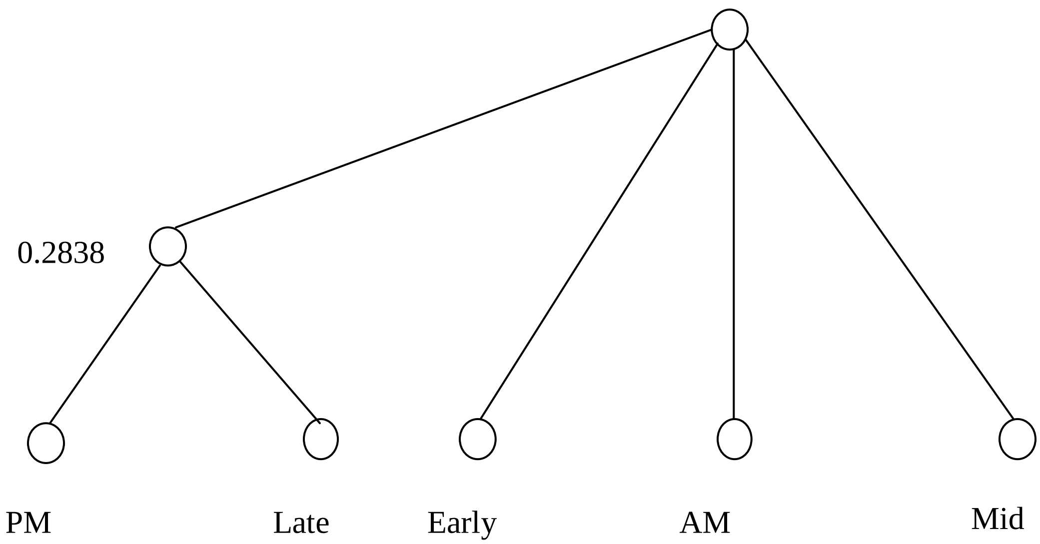

Figure 3E: Tour Time of Day Nesting Structure: Transport and Handling Tours

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 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 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

θ_{pop} = population accessibility coefficient

θ_{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.

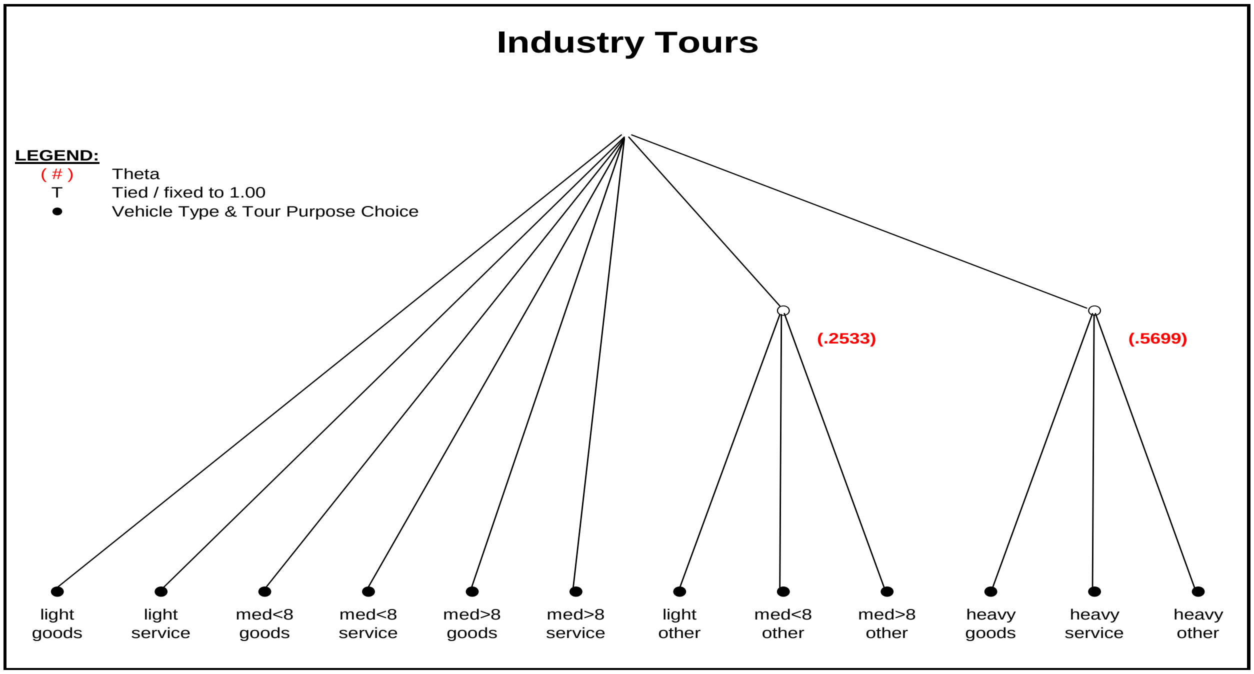

Figure 4A: Tour Vehicle Type / Purpose Nesting Structure: Industry Tours

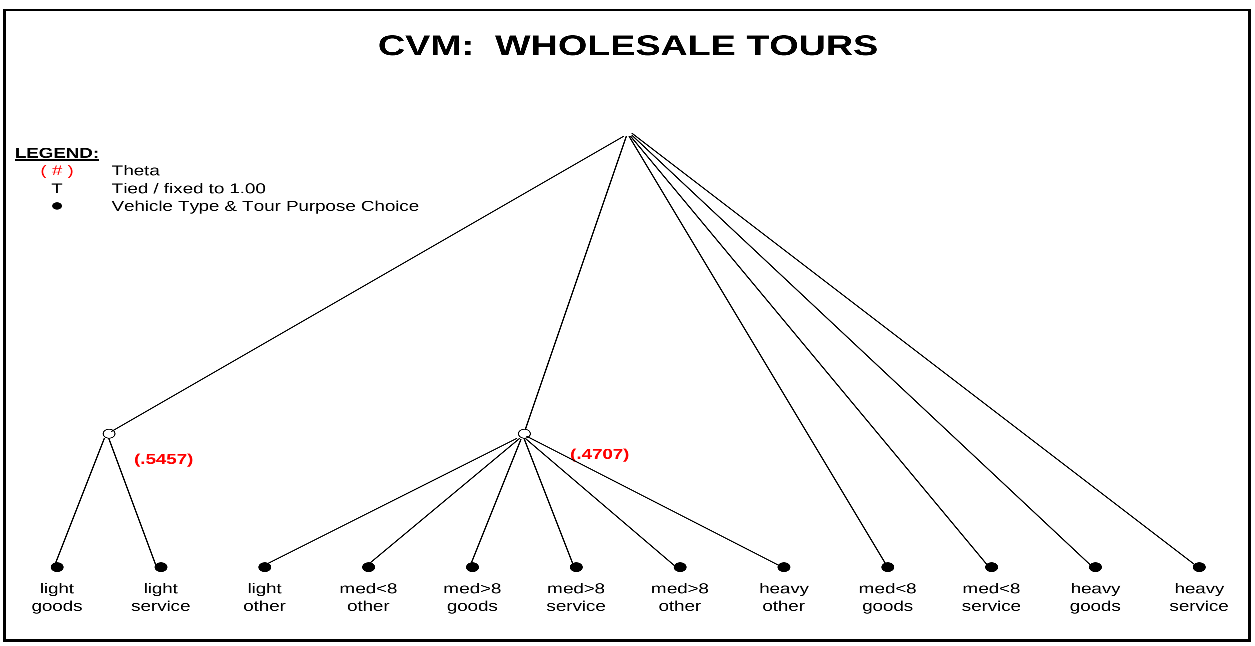

Figure 4B: Tour Vehicle Type / Purpose Nesting Structure: Wholesale Tours

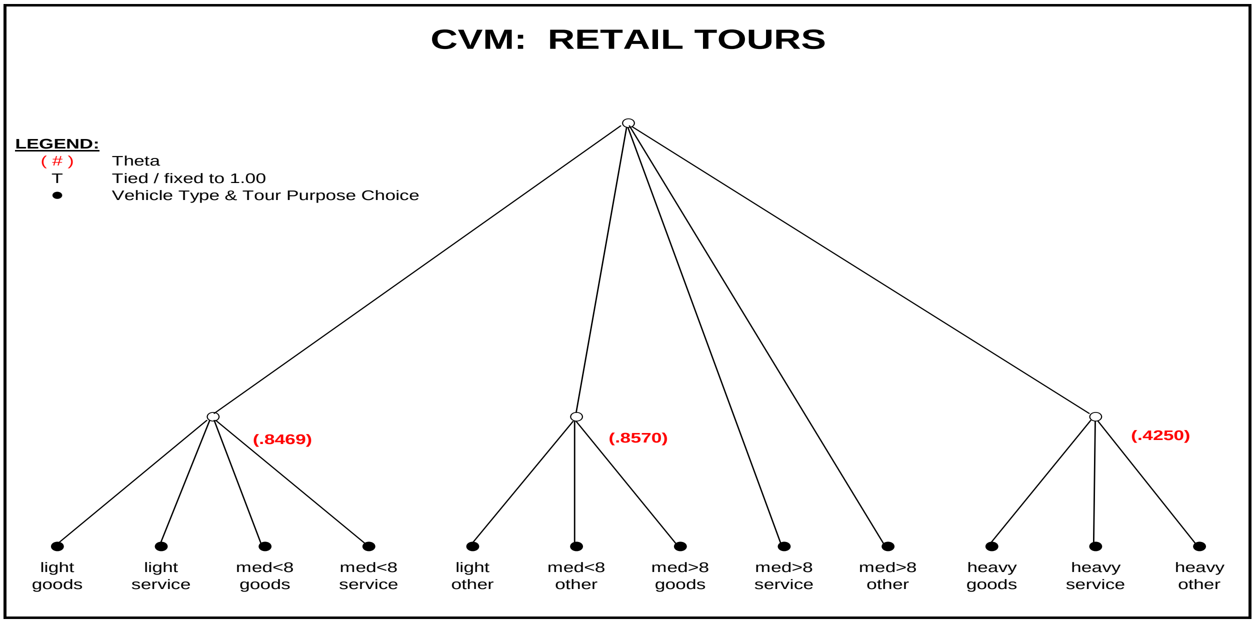

Figure 4C: Tour Vehicle Type / Purpose Nesting Structure: Retail Tours

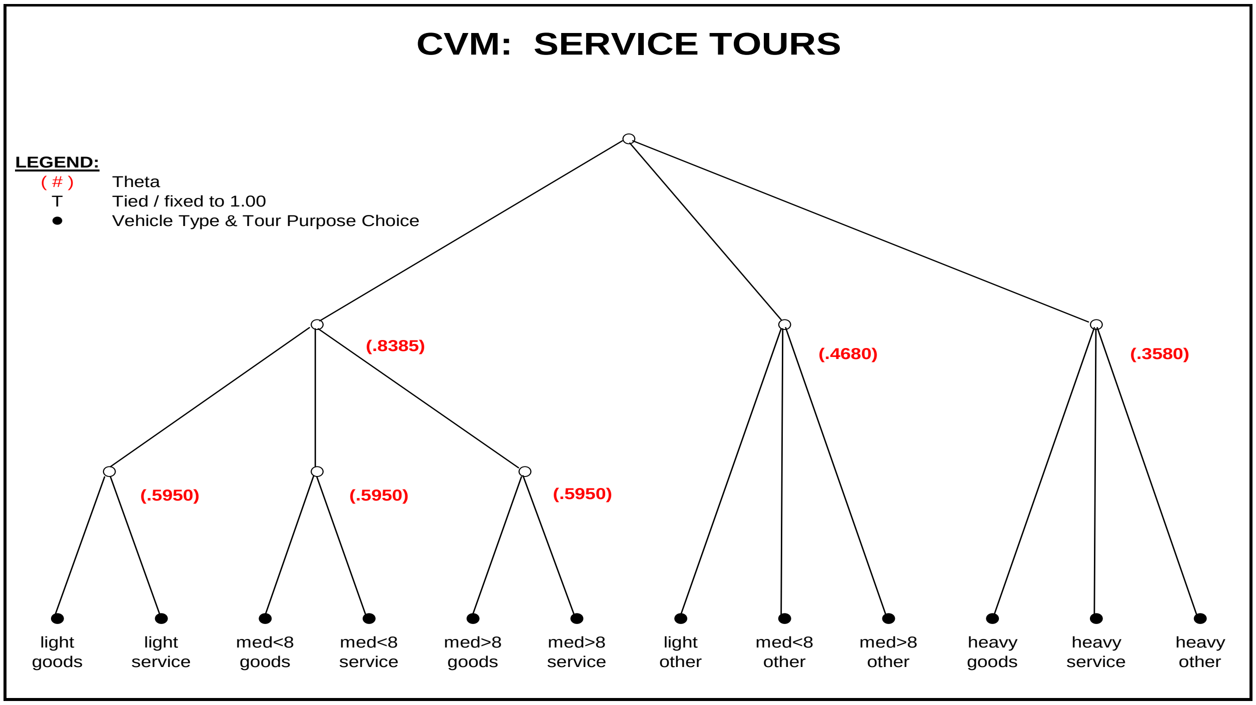

Figure 4D: Tour Vehicle Type / Purpose Nesting Structure: Service / Fleet Tours

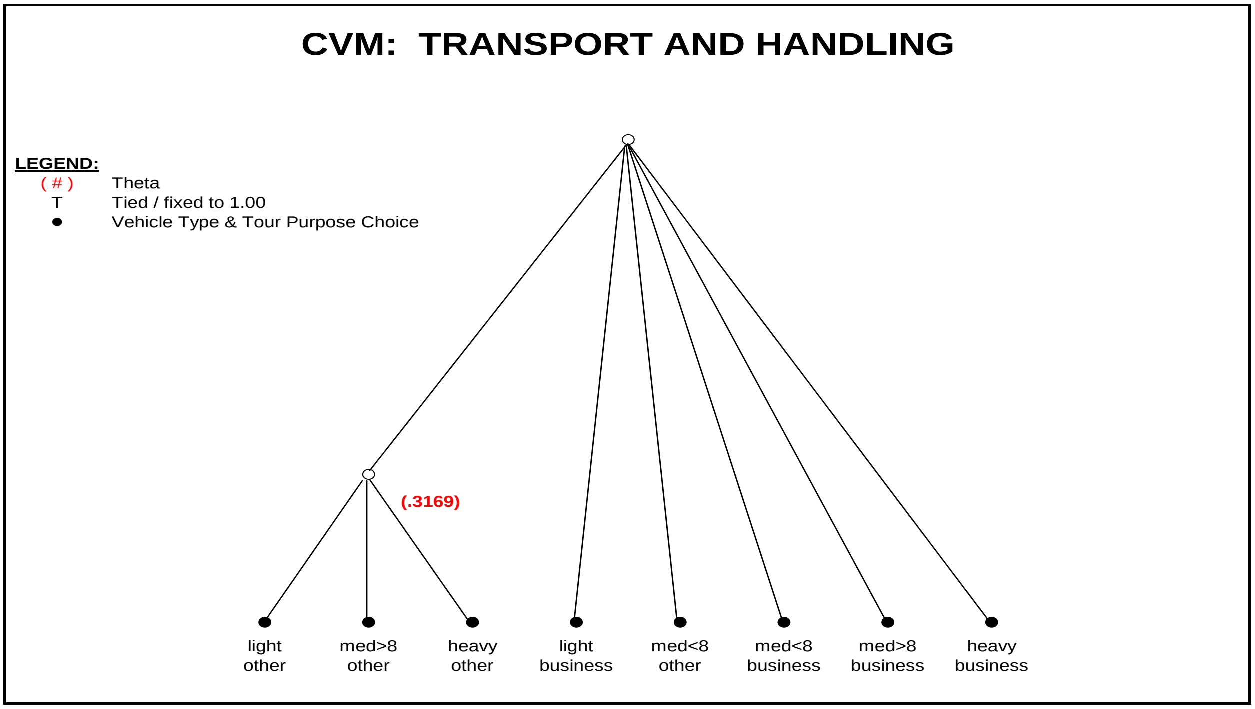

Figure 4E: Tour Vehicle Type / Purpose Nesting Structure: Transport Tours

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:

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

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

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	7.015×10^{-7}	7.015×10^{-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
$\theta_{other\ emp\ acc}$	7.015×10^{-7}	7.015×10^{-7}	7.015×10^{-7}	7.015×10^{-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:

<table>
<tr><th></th><th></th><th colspan="5">Industry</th></tr>
<tr><th>Vehicle</th><th>Purpose</th><th>IN</th><th>RE</th><th>SE</th><th>WH</th><th>TH</th></tr>
<tr><td>Light</td><td>Goods</td><td rowspan="2">L-IN
1</td><td rowspan="2">L-RE
2</td><td rowspan="2">L-SE
3</td><td rowspan="2">L-WH
4</td><td rowspan="2">L-TH
5</td></tr>
<tr><td>Light</td><td>Service</td></tr>
<tr><td>Medium</td><td>Goods</td><td colspan="2" rowspan="2">M-IR
6</td><td colspan="3" rowspan="2">M-TWP
7</td></tr>
<tr><td>Medium</td><td>Service</td></tr>
<tr><td>Heavy</td><td>Goods</td><td colspan="4">H-G 8</td><td rowspan="2">H-TH
10</td></tr>
<tr><td>Heavy</td><td>Service</td><td colspan="4">H-S 9</td></tr>
<tr><td>Light</td><td>Other</td><td colspan="5">Other-L 11</td></tr>
<tr><td>Medium</td><td>Other</td><td colspan="5" rowspan="2">Other-MH
12</td></tr>
<tr><td>Heavy</td><td>Other</td></tr>
</table>

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:

$U_{zone\ j}$ = θ_{Acc_E} × accessibility to employment for zone j

+ θ_{Acc_P} × accessibility to population for zone j

+ θ_{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)

+ θ_{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.

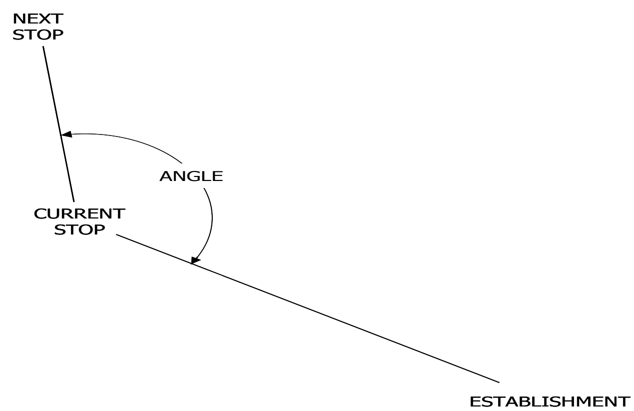

Figure 6: Enclosed Angle

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
θ_{Acc_E} ($\times 10^{-5}$)	3.257	-3.91	-7.301	-3.511
θ_{Acc_P}($\times 10^{-5}$)	-5.174	-2.085	-2.100	-1.840
θ_{Income}($\times 10^{-6}$)	3.413	0	8.606	3.474
θ_{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
θ_{ODCost}	0.6482	0.9162	0.5977	0.7103
θ_{ODCost} FLEET	n/a	n/a	0.6484	n/a
$\theta_{SizeTerm}$	0.745	0.625	0.809	0.766
θ_{PopTot}	0.886	0.800	3.290	0.338
θ_{EmpIn}	3.539	-86	1.869	-86
θ_{EmpWh}	31.817	14.101	56.079	15.221
θ_{EmpRe}	4.516	1.508	33.567	15.546
θ_{EmpSe}	-86	-86	-86	-86
θ_{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
θ_{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
θ_{Acc_E} ($\times 10^{-5}$)	0	-84.498	-56.887	0
θ_{Acc_P}($\times 10^{-5}$)	0	-1.451	-1.663	-3.136
θ_{Income}($\times 10^{-6}$)	0	-3.741	5.316	-16.263
θ_{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
θ_{ODCost}	0.0630	0.1552	0.1342	0.2130
θ_{ODCost} FLEET	n/a	n/a	0.2682	0.4569
$\theta_{SizeTerm}$	1	0.704	0.867	0.587
θ_{PopTot}	0.085	0.832	-86	-86
θ_{EmpIn}	-86	6.161	21.084	0.967
θ_{EmpWh}	3.679	36.288	49.905	-86
θ_{EmpRe}	0.438	-86	16.579	-86
θ_{EmpSe}	-86	-86	-86	-86
θ_{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
θ_{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)
θ_{Acc_E} ($\times 10^{-5}$)	0	15.419	-10.65	-10.65
θ_{Acc_P}($\times 10^{-5}$)	-2.717	-2.092	-2.008	-2.008
θ_{Income}($\times 10^{-6}$)	0	-14.221	0	0
θ_{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
θ_{ODCost}	0.2042	0.0616	1.2150	0.8056
θ_{ODCost} FLEET	0.4380	n/a	1.3067	n/a
$\theta_{SizeTerm}$	0.618	0.700	1	1
θ_{PopTot}	0.050	0.477	0.672	0.672
θ_{EmpIn}	5.190	3.733	1.830	1.830
θ_{EmpWh}	-86	19.561	19.289	19.289
θ_{EmpRe}	6.107	-86	32.820	32.820
θ_{EmpSe}	-86	-86	-86	-86
θ_{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
θ_{Area}	502.696	51.476	221.496	221.496

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

Parameter	MH-OT
θ_{Acc_E} ($\times 10^{-5}$)	0
θ_{Acc_P}($\times 10^{-5}$)	-5.158
θ_{Income}($\times 10^{-6}$)	-16.299
θ_{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
θ_{ODCost} MEDIUM	0.2645
θ_{ODCost} HEAVY	0.3046
θ_{ODCost} FLEET	0.6535
$\theta_{SizeTerm}$	0.652
θ_{PopTot}	-86
θ_{EmpIn}	-86
θ_{EmpWh}	100.994
θ_{EmpRe}	-86
θ_{EmpSe}	-86
θ_{EmpTh}	-86
$\theta_{LULoEmp}$	-86
$\theta_{LUResEmp}$	8.202
$\theta_{LURCEmp}$	11.427
$\theta_{LUInEmp}$	7.291
$\theta_{LUEmpEmp}$	-86
θ_{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.

B. CSTDM09 LDCVM Documentation

CSTDM09 – California Statewide Travel Demand Model

Model Development

Long Distance Commercial Vehicle Model

Final System Documentation: Technical Note

ULTRANS
Institute of Transportation Studies,
UC Davis
Davis, CA

HBA Specto Incorporated
Calgary, Alberta

May 2011

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Tables:

Figures:

1. Introduction

California Statewide Travel Demand Model (CSTDM09) has defined two separate 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 distance classification 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.

This technical note describes the Long Distance Commercial Vehicle Model (SDCVM) component of the CSTDM09. Section 2 gives an overview of the model. Section 3 details the factors used to convert CALSIM (PECAS) model output to truck flows by weekday time period. Section 4 gives details of the calibration of the model to observed Freight Analysis Framework (FAF) data for 2002. Section 5 describes how the model is applied in the overall CSTDM09 context.

2. Long Distance Commercial Vehicle Model Overview

The development of the LDCVM builds directly off the work being done at ULTRANS for the California Department of Transportation (Caltrans), to develop a computer-based model of the California spatial economic system using the CALSIM (PECAS) modeling framework. A base year 2000 PECAS model is being developed – the same base year being used for the state-wide travel model. Output from this PECAS model is being used to create an initial year 2000 weekday long distance commercial vehicle TAZ to TAZ trip table. Growth factors based on forecast changes in TAZ demographics are then applied to this base commercial vehicle trip table for future year scenarios.

It is important to note that:

- this approach is not dependent upon the availability of future year PECAS model outputs. The derivation of the model uses the base year 2000 PECAS model output as input, but application for future year scenarios is carried out using the resulting year 2000 commercial vehicle trip table and scaling factors. This means that the travel model can immediately be applied to future year scenarios.
- The PECAS model produces truck flows for all zone to zone pairs, for all distance ranges. Only those for origin-destinations > 50 miles are applied in the CSTDM09.

In the longer term it is expected that future year PECAS model run output will be available directly to inform and enhance the estimation of long distance commercial vehicle flows.

A full description of the PECAS model is given in the documentation of the California PECAS project. A brief overview is given below.

PECAS is a generalized approach for simulating spatial economic systems. It is designed to provide a simulation of the land use component of land use transport interactive modeling systems.

PECAS stands for Production, Exchange, and Consumption Allocation System. Overall, it uses an aggregate, equilibrium structure with separate flows of exchanges (including goods, services, labor and space) going from production to consumption based on variable technical coefficients and market clearing with exchange prices.

It provides an integrated representation of spatially distinct markets for the full range of exchanges, with the transport system and the development of space represented in more detail with specific treatments.

PECAS includes two basic modules that are linked together with travel models and aggregate economic forecasts to provide a representation of the complete spatial economic system.

Activity Allocation module (AA module): It represents how activities locate within the space provided by developers and how these activities interact with each other at a given point in time. Flows of exchanges from production to exchange zones and from exchange zones to consumption are allocated using nested logit models according to exchange prices and transport generalized costs (expressed as transport utilities with negative signs). These flows are converted to transport demands that are loaded to transport networks in order to determine congested travel utilities. Exchange prices determined for space inform the calculation of changes in space thereby simulating developer actions.

Space Development module (SD module): It represents the actions of developers in the provision of different types of developed space where activities can locate, including the new development, demolition and re-development that occurs from one point in time to the next. This developed space is typically floor space of various types. Developer actions are represented at the level of individual land parcels or grid cells using a micro-simulation treatment.

This linked system works through time in a series of discrete, fixed steps from one point in time to the next, with the AA module running at each point in time and the SD module considering the period from each point in time to the next. The system is run for each year being simulated, with the travel utilities and changes in space for one year influencing the flows of exchanges in the next year, as shown in Figure 1.

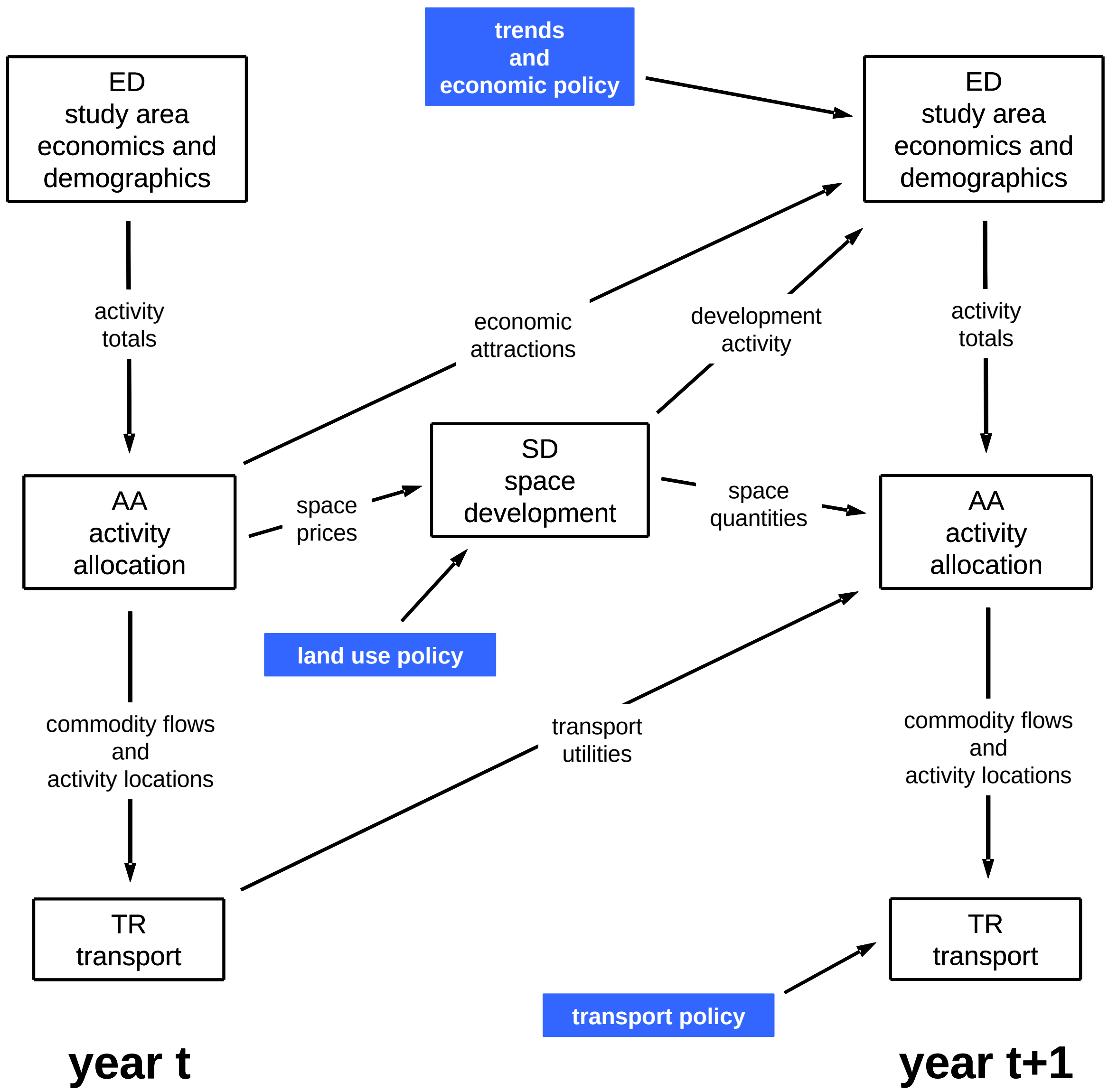

Figure 1: PECAS Modules and Information Flows Simulating Temporal Dynamics

The LDCVM application directly uses only the base year t (year 2000) output.

3. Conversion of Year 2000 PECAS Commodity Flows to Weekday Truck Flows

The California PECAS AA module is an aggregate representation applied at a "land use zone" (LUZ) level of geography. There are 524 LUZs in the California model. The 5,191 travel model TAZ system nests within these LUZs.

Activities are located in LUZs. Activities produce commodities and then transport and sell these commodities; they also consume commodities after buying them and transporting them. There are different types of activities, including industrial sectors, government and households. The California PECAS model defines 59 output commodities (excluding labor and space categories) e.g. manufacturing textiles output. Activity quantities are usually measured in annual dollars.

The AA module allocates the study-area wide quantity of each activity among the LUZs as part of its allocation process. Commodities flow at specific rates from where they are produced to where they are exchanged (from seller to buyer), and then from where they are exchanged to where they are consumed. The movement of these flows of commodities from where they are produced to where they are consumed is the economic basis for travel and transport in the modeling system. The travel conditions – the distances, costs, times and associated disutilities by mode – for the movement of these commodities influence the interactions among activities and the attractiveness of locations for activities.

The AA module allocates the flows of commodities from production location LUZ to exchange location LUZ and from exchange location LUZ to consumption location LUZ, and finds the corresponding set of prices at the exchange location LUZ that clears all markets, as part of its allocation process. These LUZ to LUZ flows are also disaggregated into TAZ to TAZ level flows for use in the travel models.

Not all the producing activities in the California PECAS model generate significant goods movements, and resulting commercial vehicle movements for use in the travel model. Table 1 gives the 11 coomodities primarily generating goods movement:

Table 1: California PECAS Model Producing Activities for Goods Movement

PECAS Commodity
Agriculture Animals Output
Agriculture Plants Output
Agriculture Forestry and Fishing Output
Mining and Extraction Output
Manufacturing Food Output
Manufacturing Textiles Output
Manufacturing Wood Products Printing Furniture Misc Output
Manufacturing Petro Paper Chemicals Plastic Rubber Glass Cement Output
Manufacturing Metal Steel Machinery Output
Fuels
Scrap

The PECAS model outputs TAZ to TAZ level commodity flows for each of the above activities, in units of annual $ flows.

Freight Analysis Framework (FAF) data for 2002 is a primary source of factors to convert PECAS annual $ flows to truck flows. FAF is built and maintained by the Federal Highway Administration (FHWA). FAF consists of a set of models that are based primarily on survey data and statistical approaches to estimate freight flows at a significant level of detail.

The 2002 FAF consists of three four-dimensional matrices (for tons, ton miles, and value) in which the four dimensions are origin, destination, commodity, and mode.

Commodities are defined at the 2-digit SCTG (Standard Classification of Transported Goods) level. Modes are defined as in the 2002 Commodity Flow Survey. 11 separate modes are defined, including “truck”.

From the FAF2 data it is possible to derive appropriate California factors for annual truck tons generated per million $ of annual commodity flow. Table 2 gives these factors for the PECAS production activities. The following approaches were used to obtain these factors:

- IMPLAN year 2000 Annual “Make $” data for California, broken down into 528 categories, was used to provide weightings to convert FAF2 data for SCTG commodity categories to PECAS categories;
- The use of a truck ton rate per million $ of total commodity flow explicitly takes into account the truck mode share for each commodity flow.

Table 2: Truck Tons Per Million $ of Commodity Flow for California PECAS

PECAS Commodity	**Truck Tons per Million $**
Agriculture Animals Output	923
Agriculture Plants Output	2,253
Agriculture Forestry and Fishing Output	2,889
Mining and Extraction Output	32,294
Manufacturing Food Output	1,226
Manufacturing Textiles Output	73
Manufacturing Wood Products Printing Furniture Misc Output	585
Manufacturing Petro Paper Chemicals Plastic Rubber Glass Cement Output	2,424
Manufacturing Metal Steel Machinery Output	192
Fuels	1,987
Scrap	10.301

Some differences exist between the annual dollar make quantities for each commodity reported in IMPLAN and used in the PECAS model, with the annual dollar quantities reported in the FAF data. Table 3 gives the conversion factors required to adjust truck flows derived from PECAS annual dollar commodity flow quantities with commodity flows reported in the FAF data.

Table 3: Adjustment Factors : PECAS Commodities $ to FAF $

PECAS Commodity	Adjustment Factor
Agriculture Animals Output	2.581
Agriculture Plants Output	2.590
Agriculture Forestry and Fishing Output	0.248
Mining and Extraction Output	0.370
Manufacturing Food Output	1.055
Manufacturing Textiles Output	0.856
Manufacturing Wood Products Printing Furniture Misc Output	1.261
Manufacturing Petro Paper Chemicals Plastic Rubber Glass Cement Output	0.781
Manufacturing Metal Steel Machinery Output	0.873
Fuels	1.019
Scrap	0.463

Washington State data from the Cross-Cascades Corridor Freight O/D Study can be used to derive average truck loads in tons, for each PECAS Commodity type, given in Table 4. (The original data was defined in STCC (Standard Transportation Commodity Codes) commodity categories. IMPLAN data was used to apply appropriate weights to convert the STCC data to PECAS commodity categories).

Table 4: Average Truck Loads in Tons for California PECAS Commodities

PECAS Commodity	Tons per Truck
Agriculture Animals Output	13.59
Agriculture Plants Output	21.05
Agriculture Forestry and Fishing Output	19.84
Mining and Extraction Output	14.65
Manufacturing Food Output	14.97
Manufacturing Textiles Output	9.94
Manufacturing Wood Products Printing Furniture Misc Output	15.48
Manufacturing Petro Paper Chemicals Plastic Rubber Glass Cement Output	15.26
Manufacturing Metal Steel Machinery Output	15.38
Fuels	21.40
Scrap	15.60

The Highway Capacity Manual suggests that annual truck flows can be converted to typical weekday by using a factor of 300 weekdays per year. This factor is used in a number of other freight modeling projects including the 2002 study “Freight Impacts on Ohio’s Roadway System” and the 2005 New Jersey “Northerly Crossings Corridor Congestion Mitigation Study”. A factor of 300 is therefore used in the CSTDM09 to convert annual truck flows to weekday truck flows.

The truck ton per million $ of commodity flow rates given in Table 2 are combined with the adjustment factors in table 3, and the average truck load rates in Table 4, and the 300 weekday to annual truck flow factor, to give typical weekday truck flows per million $ of annual commodity flows, as given in Table 5.

Table 5: Weekday Truck Flows per Million $ Flow for PECAS Commodities

PECAS Commodity	Weekday Trucks per Million $
Agriculture Animals Output	0.5842739
Agriculture Plants Output	0.9240546
Agriculture Forestry and Fishing Output	0.1201988
Mining and Extraction Output	2.7188427
Manufacturing Food Output	0.2880447
Manufacturing Textiles Output	0.0211093
Manufacturing Wood Products Printing Furniture Misc Output	0.1587953
Manufacturing Petro Paper Chemicals Plastic Rubber Glass Cement Output	0.4133390
Manufacturing Metal Steel Machinery Output	0.0364065
Fuels	0.3153964
Scrap	1.0185988

The daily truck flow matrices, obtained from the PECAS model output & applying the factors from Table 5, are assigned to time periods based on analysis of time of day distribution of observed truck flows at key inter-regional locations in California. Data from all the screen-line sites in California for heavy truck movements by time of day were averaged to give these time period distributions. Table 6 gives long distance truck volume time of day factors.

Table 6: Time of Day Factors for Weekday Long Distance Truck Flows

Time Period	Proportion of Weekday
Off Peak (3AM to 6AM plus 7PM to 3AM)	0.306
AM Peak (6AM to 10AM)	0.199
Midday (10AM to 3PM)	0.302
PM Peak (3PM to 7PM)	0.193

4. Calibration to Observed FAF Flows

Freight Analysis Framework (FAF) data for 2002 is the primary source of calibration targets for the long distance commercial vehicle model. The 2002 FAF consists of three four-dimensional matrices (for tons, ton miles, and value) in which the four dimensions are origin, destination, commodity, and mode.

Origins and destinations consist of 114 regions as defined and used in the 2002 Commodity Flow Survey (CFS). California is divided into 5 regions (Los Angeles (including the Inland Empire of Riverside and San Bernardino counties); San Francisco; San Diego; Sacramento; Rest), as shown below - plus 17 international gateways (see Figure 2).

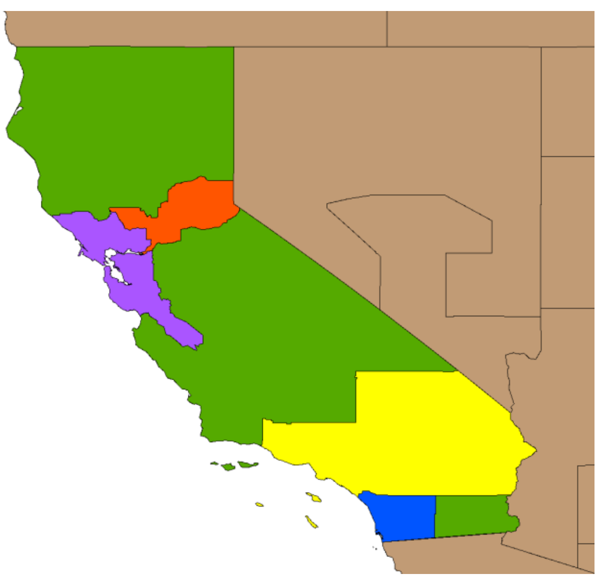

Figure 2: Commodity Flow Survey Districts

Table 7 gives 2002 FAF data for "internal California" annual truck tons flows by commodity type between the 5 FAF California regions (including intra-region flows).

Table 7: 2002 Annual Truck-Ton Commodity Flows between California Regions

		Destination					
Commodity	**STCG**	**CA Los A**	**CA rem**	**CA Sacra**	**CA San D**	**CA San J**	**Total**
Alcoholic beverages	8	4,633,860	1,846,220	836,590	492,270	1,660,590	**9,469,530**
Animal feed	4	8,743,550	14,604,870	4,877,610	3,407,730	4,213,870	**35,847,630**
Articles-base metal	35	6,486,010	1,281,100	1,175,270	1,016,230	2,937,670	**12,896,280**
Base metals	32	4,767,550	1,159,290	1,048,810	827,150	1,774,690	**9,577,490**
Basic chemicals	20	3,919,920	4,648,260	600,520	128,810	1,051,990	**10,349,500**
Building stone	10	378,120	86,790	57,310	69,580	231,910	**823,710**
Cereal grains	2	9,398,480	5,472,770	917,750	1,610,340	4,108,830	**21,508,170**
Chemical prods.	23	1,916,710	2,131,070	796,230	228,140	870,830	**5,942,980**
Coal	15	33,660	6,730	4,820	5,640	18,610	**69,460**
Coal-n.e.c.	19	19,782,850	8,213,800	4,529,770	6,287,690	9,664,570	**48,478,680**
Crude petroleum	16	439,920	67,900	230	340	312,730	**821,120**
Electronics	35	2,800,620	265,860	172,840	37,590	515,350	**3,792,260**
Fertilizers	22	5,767,280	5,227,340	2,126,820	346,540	2,362,250	**15,830,230**
Fuel oils	18	6,179,940	2,634,650	1,426,560	1,788,510	2,952,530	**14,982,190**
Furniture	39	1,783,130	675,340	295,620	211,300	575,020	**3,540,410**
Gasoline	17	28,527,740	12,698,330	6,171,290	8,835,880	13,292,940	**69,526,180**
Gravel	12	50,103,020	66,089,880	26,538,180	17,804,430	30,245,390	**190,780,900**
Live animals/fish	1	4,413,150	1,631,880	338,170	698,610	1,713,320	**8,795,130**
Logs	25	159,410	9,492,570	1,609,940	34,450	3,892,760	**15,189,130**
Machinery	34	6,399,960	1,130,240	1,128,320	1,281,840	3,893,690	**13,834,050**
Meat/seafood	5	1,891,740	2,529,490	885,560	269,980	915,940	**6,492,710**
Metallic ores	14	60,680	9,490	10,020	10,810	37,650	**128,650**
Milled grain prods.	6	3,827,420	1,576,820	673,850	333,300	1,317,000	**7,728,390**
Misc. mfg. prods.	40	2,987,230	988,460	449,920	164,140	856,670	**5,446,420**
Mixed freight	42	13,281,390	4,846,500	2,113,500	1,754,660	3,698,940	**25,694,990**
Motorized vehicles	36	4,862,040	664,880	319,140	348,700	958,710	**7,153,470**
Natural sands	11	11,410,030	13,427,640	5,591,850	3,573,950	6,302,790	**40,306,260**
Newsprint/paper	27	1,031,680	1,220,060	567,370	231,160	239,910	**3,290,180**
Nonmetal min. prods.	31	63,007,080	14,886,570	13,063,910	15,349,920	23,881,750	**130,189,230**
Nonmetallic minerals	13	2,074,480	1,708,220	389,710	430,810	1,244,200	**5,847,420**
Other ag prods.	3	10,342,760	9,885,480	3,101,610	2,414,550	4,848,240	**30,592,640**
Other foodstuffs	7	16,498,460	6,465,300	2,932,910	1,288,670	5,962,330	**33,147,670**
Paper articles	28	2,097,180	1,342,260	654,520	309,020	848,920	**5,251,900**
Pharmaceuticals	21	195,800	127,400	16,130	17,840	81,290	**438,460**
Plastics/rubber	24	1,186,870	1,167,130	492,120	18,770	455,910	**3,320,800**
Precision instruments	38	785,390	99,310	39,650	36,360	141,500	**1,102,210**
Printed prods.	29	1,889,270	721,350	345,290	242,610	913,060	**4,111,580**
Textiles/leather	30	908,560	335,630	204,140	59,390	406,410	**1,914,130**
Tobacco prods.	9	82,360	19,900	8,130	5,890	21,190	**137,470**
Transport equip.	37	1,060,550	164,560	173,150	186,352	651,632	**2,236,244**
Unknown	43	17,735,060	2,852,900	2,658,420	2,900,660	10,449,040	**36,596,080**
Waste/scrap	41	55,709,820	22,666,280	6,111,340	8,300,870	19,028,070	**111,816,380**
Wood prods.	26	6,859,330	3,617,180	1,880,970	591,340	3,050,210	**15,999,030**
		386,420,060	**230,687,700**	**97,335,860**	**83,952,822**	**172,600,902**	**970,997,344**

Note: The PECAS model does not deal with the following FAF STCG commodities:

- Gravel (12)
- Coal (15)
- Mixed Freight (42)
- Unknown (43)

The average tons per truck factors in Table 3 can be used, along with the 300 weekdays per year factor, to convert FAF annual truck ton flows to truck flows per day, by commodity. These flows can be grouped into PECAS commodity categories, for comparison with the PECAS output. Table 8 compares FAF observed daily truck flows with PECAS model flows.

Table 8: Comparison FAF Daily Truck Flows with PECAS Year 2000 Truck Flows

PECAS Commodity	FAF Observed Daily Flow	PECAS Year 2000 Daily Flow	% Difference (PECAS-FAF) / FAF
Agriculture Animals Output	3,200	3,220	0.6%
Agriculture Plants Output	9,040	9,270	2.5%
Agriculture Forestry and Fishing Output	700	710	1.4%
Mining and Extraction Output	10,730	10,760	0.3%
Manufacturing Food Output	18,380	18,520	0.8%
Manufacturing Textiles Output	620	600	-3.2%
Manufacturing Wood Products Printing Furniture Misc Output	8,900	8,830	-0.8%
Manufacturing Petro Paper Chemicals Plastic Rubber Glass Cement Output	39,250	40,010	1.9%
Manufacturing Metal Steel Machinery Output	10,950	11,040	0.8%

Fuels	19,920	19,980	0.3%
Scrap	23,890	24,360	2.0%
ALL COMMODITIES	**145,580**	**147,300**	**1.2%**

Note: The daily truck totals in Table 8 include trips for all trip lengths (both <50 miles and >50 miles).

The 2002 Commodity Flow Survey (undertaken through a partnership between the U.S. Census Bureau, U.S. Department of Commerce, and the Bureau of Transportation Statistics) gives data on the distance travelled by each commodity type, for shipments originating in California, by distance bands. This data has been used to obtain average “observed” trip lengths for the PECAS commodity categories, considering shipments made up to 750 miles in length. In turn, The California PECAS AA model buying and selling dispersion parameters have been adjusted, so that the PECAS model output gives average truck trip lengths by commodity that match these “observed” trip lengths.

Table 9 summarizes the modeled and observed trip lengths.

Table 9: Comparison 2000 CFS and PECAS Year 2000 average Trip Length

PECAS Commodity	2002 CFS Average Trip Length (Miles)	PECAS 2000 Average Trip Length (Miles)
Agriculture Animals Output	109	109
Agriculture Plants Output	100	100
Agriculture Forestry and Fishing Output	96	96
Mining and Extraction Output	26	26
Manufacturing Food Output	113	113
Manufacturing Textiles Output	207	207
Manufacturing Wood Products Printing Furniture Misc Output	141	141
Manufacturing Petro Paper Chemicals Plastic Rubber Glass Cement Output	84	84
Manufacturing Metal Steel Machinery Output	141	141
Fuels	50	50
Scrap	20	20

5. Application of the Long Distance Commercial Vehicle Model in CSTDM09

The long distance commercial vehicle trip tables obtained from factoring the California PECAS model for the year 2000, for Origin-Destination pairs >50 miles apart, are used directly in the year 2000 California travel model scenario.

For the year 2008 travel model scenario, the calibrated California PECAS AA model has been run with 2008 inputs derived from 2008 TAZ population and employment data inputs, to give a year 2008 truck trip table.

For all future year travel model scenarios, the year 2008 long distance truck tables are scaled using appropriate factors. The origin scaling factors can be derived from the relative changes in the primary and manufacturing employment numbers for each TAZ, as these employment categories “generate” the great majority of the production activities.