SEMCOG E8Plus Travel Model Improvement and Update

technical

report

prepared for

Southeast Michigan Council of Governments

prepared by

Cambridge Systematics, Inc.

with

AECOM

Updated by

SEMCOG for the version of E8Plus

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date

February 14, 2019

Updated by

SEMCOG for the version of E8Plus

date

April 30, 2024

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1.0 Introduction

This report includes a description of the E7 model development process, and documents model processes and parameters employed by the resulting SEMCOG E7 travel model, as well as references to the additional updates made in SEMCOG E8Plus model.

1.1 The E7 Model Update

The SEMCOG E7 model update, completed by CS, expands on the previous E6 version of the model. The purpose of the E7 update included the primary objectives listed below.

- Update the model base year to 2015 and model forecast year to 2045.
- Replace Quarterly Census of Employment and Workers (QCEW) employment data which comes with redistribution restrictions with the more distributable Bureau of Economic Analysis Equivalent Job (BEA-EJ) employment data.
- Revise the model to better reflect current data, including current economic and employment conditions in Southeast Michigan.
- Make use of currently available data on travel behavior, including household travel surveys conducted in 2004/2005 and in 2015; an on-board transit survey conducted in 2010; and passively collected 2015 origin-destination and 2015 speed data.
- Make use of current 2015 traffic count data and transit boarding counts.
- Improve representation of travel to, from, and within the SEMCOG region, including travel across the border with Canada and between SEMCOG and the Toledo area.
- Update model processes and procedures to ensure reasonable and appropriate sensitivity to planning and policy variables.
- Thoroughly validate and test the model to verify that it will meet SEMCOG’s ongoing planning needs.

Development of the SEMCOG E7 model included an extensive review of all E6 model steps, with revisions and improvements made throughout the modeling process. Notable changes and improvements are listed below.

- Revisions to the variables used in trip generation based on an extensive review of available household survey data.
- Incorporation of a new disaggregate auto ownership model.
- Development of a new University model that better generates and distributes trips by students to and from the region’s universities.
- Re-estimation and calibration of the Destination Choice model using improved techniques and model formulations.

- Incorporation of an updated mode choice that is consistent with recommendations provided by the Federal Transit Administration in review of New Starts studies conducted using the E6 model.
- Development of an automated mode choice calibration routine, which was applied using up-to-date mode choice and transit assignment calibration targets.
- Improvements to the consistency between mode choice (conducted in production-attraction format) and transit assignment (conducted in origin-destination format).
- Revisions to trip time of day parameters to better reflect both household survey and vehicle count data.
- Improvements to modeling of external travel, making use of passively collected GPS data.
- Use of the most current version of the TransCAD software at the time of model completion (TransCAD 8).

In addition, the E7 model includes several new user convenience functions such as automated reporting of model results, a mapping dashboard function, and specific utilities to streamline model application tasks related to air quality and environmental justice analysis. The model also features an improved scenario management system.

1.2 What's New in the E8Plus Model

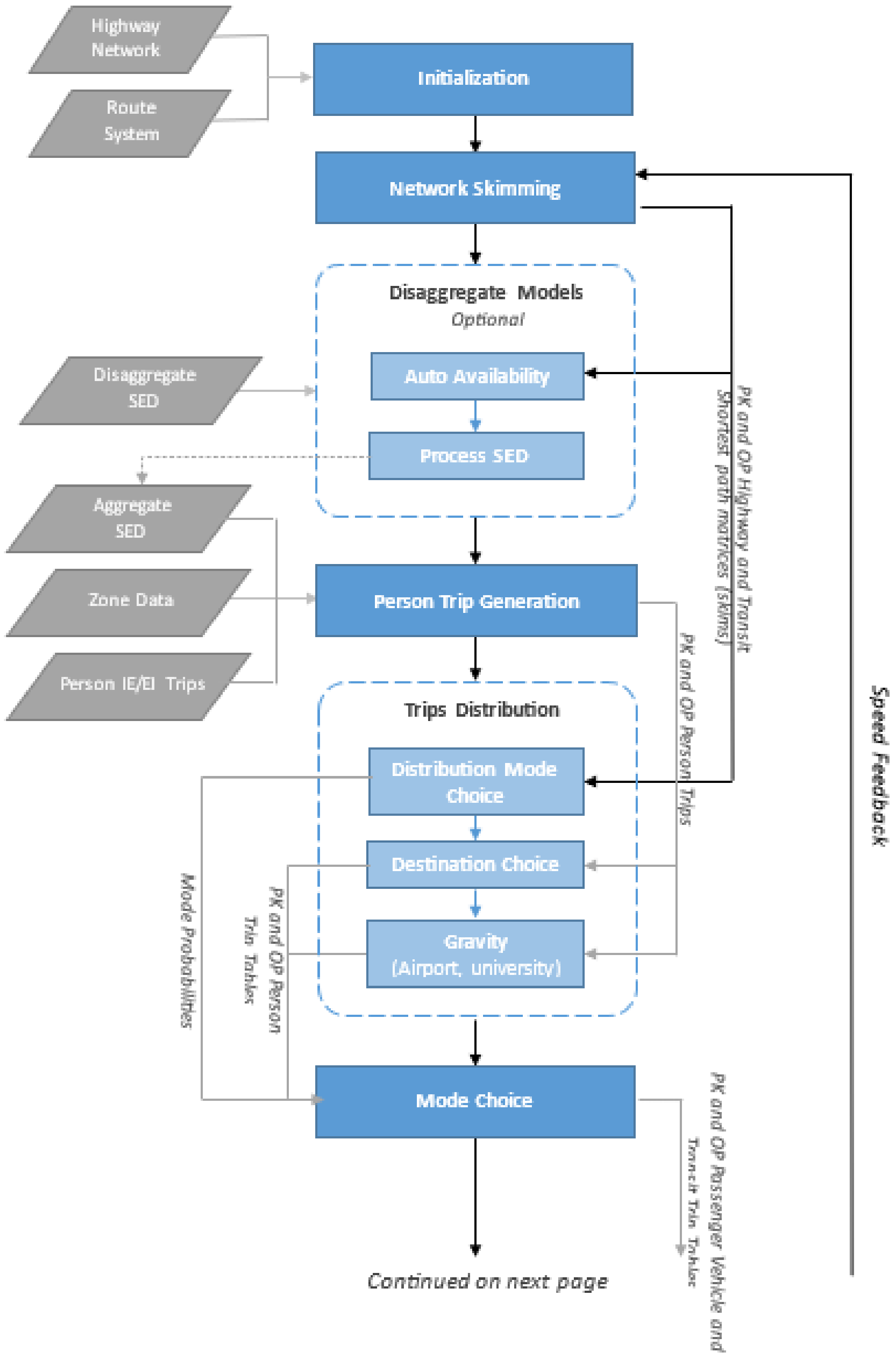
Since the E7 model updates, SEMCOG conducted two travel surveys: one is the 2017 Commercial Vehicle Survey (CVS) and another one is the 2019 On-Board Transit Survey (OBTS). The purpose of SEMCOG E8Plus model update is to integrate these two recent survey data into SEMCOG's regional travel demand model and update SEMCOG's commercial vehicle model (CVM) to meet SEMCOG's planning needs. The following are the major changes in the E8Plus model compared to the E7 model.

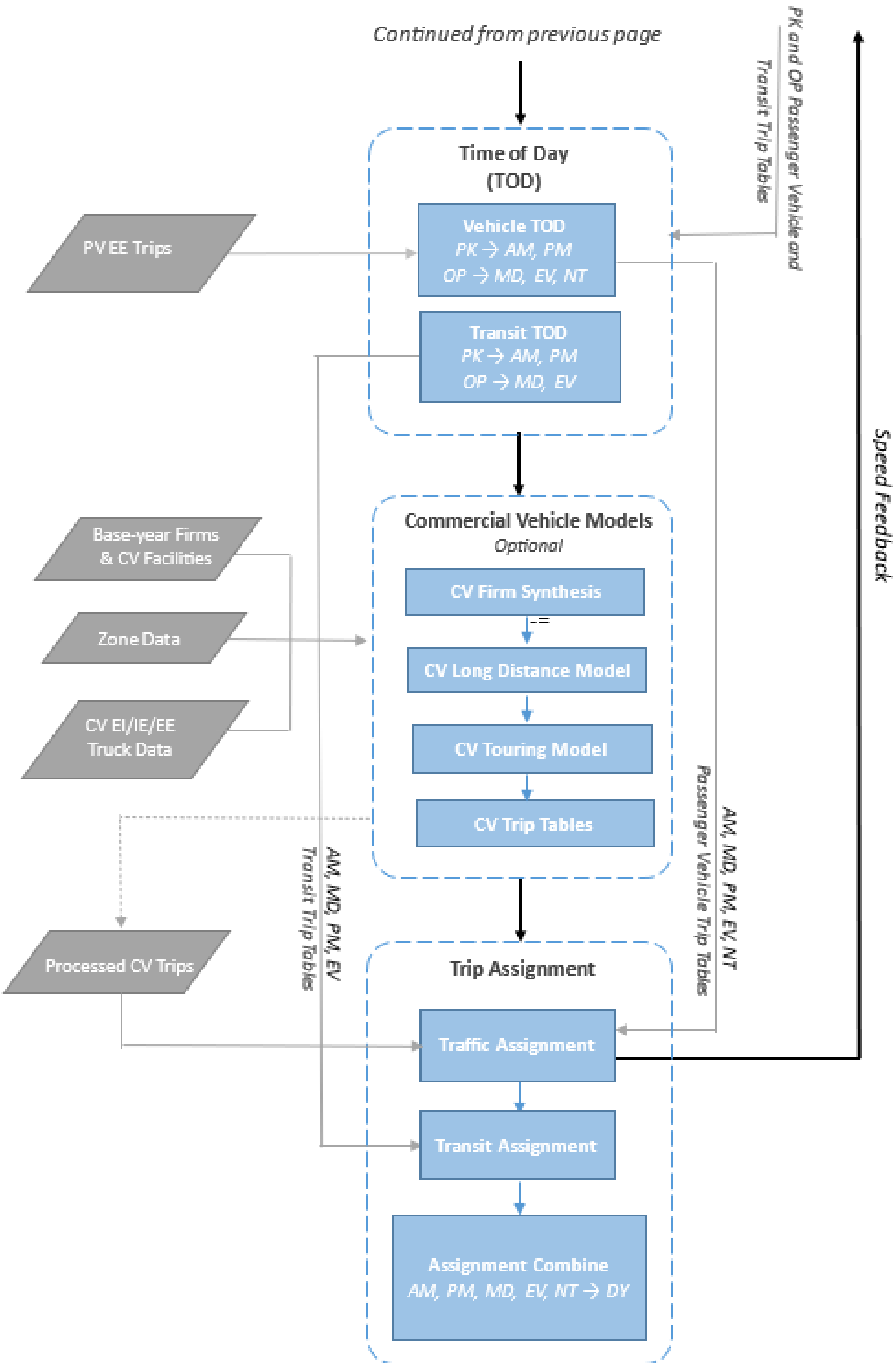
- Make use of the currently available 2019 OBTS data to recalibrate the E7 transit mode choice model and improve the transit ridership by transit provider. This work, described in Appendix L – "Transit Model Update using the 2019 OBTS", was a combined effort between CS and SEMCOG.
- Implement a tour-based commercial vehicle model to estimate commercial vehicle travel demand using the 2017 CVS and observed truck data in the region. The high-level description of model components is in Chapter 7 of this report. The modeling detail is in a separate documentation – "SEMCOG Commercial Vehicle Model Report", developed by RSG. The regional model including this newly developed CVM is referred to as the E8 model.

1.3 Model Process Flowchart

The overall model process is demonstrated in the Flowchart shown in **Figure 1.1**. This flowchart shows each model step along with selected sub-steps, identifies primary network and socioeconomic input data, and indicates the flow of intermediate data between steps.

Figure 1.1 Model Flowchart




Continued from previous page
Time of Day
(TOD)
Vehicle TOD
PK → AM, PM
OP → MD, EV, NT
Transit TOD
PK → AM, PM
OP → MD, EV
PV EE Trips
PK and OP Passenger Vehicle and
Transit Trip Tables
Speed Feedback
Commercial Vehicle Models
Optional
CV Firm Synthesis
CV Long Distance Model
CV Touring Model
CV Trip Tables
Base-year Firms
& CV Facilities
Zone Data
CV EI/IE/EE
Truck Data
Processed CV Trips
AM, MD, PM, EV
Transit Trip Tables
AM, MD, PM, EV, NT
Passenger Vehicle Trip Tables
Trip Assignment
Traffic Assignment
Transit Assignment
Assignment Combine
AM, PM, MD, EV, NT → DY

2.0 Data Used in Model Development

This chapter describes the household and transit survey data used for estimating the E7 model parameters along with the input zonal socioeconomic, highway and transit network data, and cost data used for the 2015 base year model calibration/validation. Finally, this chapter describes the location-based services (LBS) data, and traffic counts, and transit boarding data used for model calibration/validation.

2.1 Household Survey Expansion

The SEMCOG E7 Model update includes updates to model parameters and calibration targets based on a re-expanded version of the 2004 SEMCOG household travel survey combined with applicable data from the 2005 MI Travel Counts household travel survey[1],which was the most current survey available at the time model development commenced. The E7 model has a validation base year of 2015, but has been estimated and calibrated using the 2004/2005 combined household survey expanded to reflect 2010 conditions. To support this model update, the 2004/2005 combined household survey has been expanded using the procedures described in this section.

2.1.1 Data Preparation

The first step of the survey expansion procedure was to prepare the household survey data for expansion and to develop control totals for the survey expansion process.

Survey Expansion Geography

SEMCOG's study region consists of seven counties in Southeast Michigan: Livingston, Macomb, Monroe, Oakland, St. Clair, Washtenaw, and Wayne County. Wayne County was split into two regions: East Wayne and Other Wayne to reflect the differences in the demographics and community characteristics of Detroit and the remainder of Wayne County.

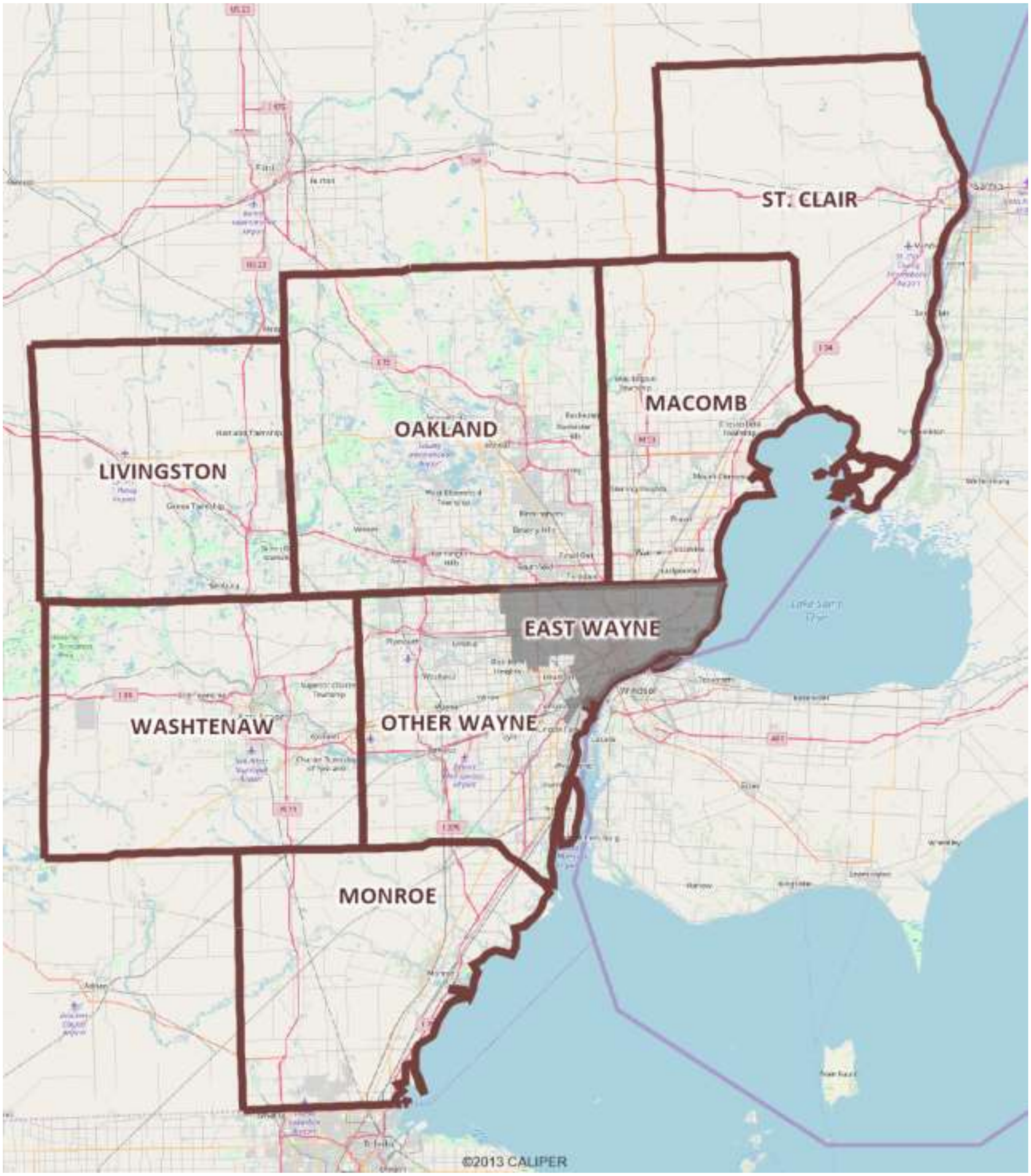
- The **East Wayne** summary area includes Detroit, the Grosse Pointe communities, Hamtramck, Harper Woods, and Highland Park. While Grosse Point is more similar to other parts of Wayne County than Detroit, it was necessary to include this area in the East Wayne summary area to be consistent with the Public Use Micro Sample (PUMS) data, which is only available at an aggregate level. The original expansion of the 2004/2005 survey used Detroit as a district instead of the East Wayne district described here.

- The **Other Wayne** summary area includes the remainder of Wayne County.

In total, eight geographic summary areas were used for the survey expansion process. The summary areas are shown in **Figure 2.1**. **Table 2.1** lists the number of usable household and person records from the household survey within each of the eight geographic summary areas.

[1] The combined surveys will hereinafter be referred to as the 2004/2005 combined household survey. The individual surveys will be referred to as 2004 SEMCOG survey or 2005 MI Travel Counts survey.

Figure 2.1 Geographic Summary Areas



Source: CS Analysis of Model Geography, TransCAD geography files, OpenStreetMap imagery.

Table 2.1 Number of Usable Household Survey Records

Geographic Summary Area	Household Records	Person Records
Livingston	440	1,079
Macomb	966	2,354
Monroe	348	861
Oakland	1,228	2,998
St. Clair	511	1,250
Washtenaw	613	1,425
East Wayne	901	2,266
Other Wayne	1,058	2,489
Total	**6,065**	**14,722**

Source: CS Analysis of SEMCOG Household Survey Data.

2.1.2 Control Variables

The survey expansion required sociodemographic control totals obtained from American Community Survey (ACS) data. The 5-year ACS database for the period from 2008 to 2012 was selected as the best representation of the 2010 expansion year. For Wayne County, county subdivision and Public Use Microdata Area (PUMA) level data were aggregated to develop separate control totals for the East Wayne and Other Wayne County geographies. For the remaining summary areas, county level ACS summary data and PUMS data were used.

Because the household survey was conducted in 2004/2005, income ranges are specified in 2005 dollars. The 2008 to 2012 ACS dataset reports households by income group using 2012 dollars, and the SEMCOG E7 model makes use of income quartiles defined in 2010 dollars. To account for these inconsistencies, income ranges from the household survey were adjusted using a 2005 to 2012 Consumer Price Index (CPI) factor of 1.1756. Similarly, the SEMCOG socioeconomic data quartile ranges were adjusted to reflect 2012 dollars using a CPI factor of 1.0529. A set of ACS income ranges was then selected for survey expansion that best matched the adjusted income quartiles. Survey records were then assigned to an income group using the survey income definitions adjusted to 2012 dollars.

Several household and person level variables known to influence travel behavior have been included as control totals in the expansion process. After review of the survey dataset and discussions between the consultant and SEMCOG staff, the household control variables listed in **Table 2.2**, and person control variables listed in **Table 2.3** were selected for use in survey expansion.

2.1.3 Preparation of Household Survey Dataset for Survey Expansion

The household travel survey had been previously analyzed to determine which records could be used in data analysis, reporting, and modeling. No additional checks were conducted to assess the quality of usable records. However, it was necessary to address missing information associated with some survey records.

Table 2.2 Household Level Control Variables

Variable	Values
Household Size	1, 2, 3, 4, 5, and 6+ persons
Number of Household Workers	0, 1, 2, and 3+ resident workers
Household Vehicles	0, 1, 2, and 3+ vehicles
Household Income[2]	Low (less than $30,000); Medium-Low ($30,000 to less than $60,000); Medium-High ($60,000 to less than $100,000); and High ($100,000 and over)
Household Lifecycle[3]	1. Households with children; 2. Households with adult students (but without children); 3. Households with adult non-student workers (but without children or adult students); and 4. Household with adult non-student non-workers (but without children or adult students or adult non-student workers)

Source: CS Analysis of ACS, PUMS, and household survey data.

Table 2.3 Person Level Control Variables

Variable	Values
Age	Under 15; 15 to 24; 25-34; 35 to 44; 45 to 54; 55 to 64; and 65 and over
Gender	Male or Female
Employment Status	Employed or unemployed
Student Status[4]	Preschool/Nursery/Kindergarten; K-12; University/College/Professional; and Not a student

Source: CS Analysis of ACS data and household survey data.

[2] Income ranges are shown in 2012 dollars for consistency with ACS data. Income ranges from the household survey have been adjusted upwards from 2005 to reflect 2012 dollars using the Consumer Price Index (CPI).

[3] The household lifecycle variable cannot be obtained directly from the ACS dataset. So, the Public Use Microdata Sample (PUMS) data were used to generate the household lifecycle variable. This variable was aggregated using the PUMS weights to produce household level targets. The PUMA level data were then assigned to the appropriate area geography used in the survey expansion procedures.

[4] The household survey includes kindergarten in the *K-12* category, while ACS includes kindergarten in the *Preschool/Nursery/Kindergarten* category. Review of the data indicates that this overlap is small.

A review of records for completeness across the dimensions of interest revealed missing variables for some sociodemographic variables. These are listed below, along with a description of actions taken to address the missing data.

- Gender (*4 person records had missing information*): The gender of the person was inferred by looking at the relationship between the person and other members of the household (e.g. husband of, wife of).
- Age (*9 person records had missing information*): Missing age information was inferred by assessing household relationships.
- Number of Vehicles in Household (*1 household record had missing information*): This variable was imputed by looking at other households with similar worker, household income, and location status.
- Student Status (*7 person records had missing information*): The student status was imputed using the age variable. Specifically, all children age 5 to 17 that had missing student status were assumed to be students.
- Household Income (*331 households records had missing information)*: A significant number of households did not report income information. It would have been possible to impute household income using variables such as number of workers, life cycle, or autos. Because these variables are already explicitly accounted for in the expansion process, household income was not imputed. Instead, the weight of these households remained unchanged when adjusting for household income during the expansion process.

2.1.4 Survey Expansion Methodology and Results

Iterative proportional fitting (IPF) or “raking” is a well-established and widely-used technique used to match survey responses against the general population, especially when multiple dimensions of information are taken into account during expansion. A two-step IPF process was applied to the household survey records in order to improve consistency between the expanded survey and sociodemographic control totals obtained from ACS. The re-expanded survey more accurately matches regional household and person-level control variables listed in **Table 2.2** and **Table 2.3**.

Survey expansion was conducted using a series of univariate distributions. An alternate approach would have included some bivariate distributions in the process, such as a combined household size and income group. However, margins of error in the ACS data increased rapidly with the addition of a second variable. Furthermore, many cells in a bivariate distribution contain very few survey records, with some combinations containing only a single record.

Household-Level IPF

The first phase of the two-phase IPF process adjusts expansion factors so that expanded survey records are consistent with household distributions in each of the eight geographic summary areas. The household control variables mentioned in the previous section were used as targets within each geographic summary area sequentially and iteratively as follows:

1. Household size;
2. Number of workers per household;

3. Number of vehicles per household;
4. Household income group; and
5. Household Lifecycle.

For each of these five steps listed above, the household survey data were first tabulated by the appropriate control variable category. Expansion factors were then adjusted based on the ratio of the ACS control total distributions to the initial tabulations. At the initial stage of the expansion, every household was assigned a weight of one, which served as the initial seed for survey expansion.

This process was repeated for up to 100 iterations, with the process stopping if the maximum difference between iterations dropped below 10^{-5}. Upon completion, the final expansion factors were reviewed to ensure the process had converged and that the expansion factors produced an expanded survey dataset representative of the ACS distributions across each of the five household control variables.

Person-Level IPF

The household expansion factors from the first phase of the two-phase IPF process were assigned to each household member to serve as an initial seed in the person-level IPF. Four person-level sociodemographic variables were used in the person-level IPF:

1. Age;
2. Gender;
3. Employment status; and
4. School enrollment.

The person level IPF procedure was conducted using a methodology similar to that described for the household variables. As with the household phase, up to 100 iterations of the factoring process were conducted, with a convergence setting of 10^{-5}. Again, the process was found to converge to the specified value within the 100 iterations.

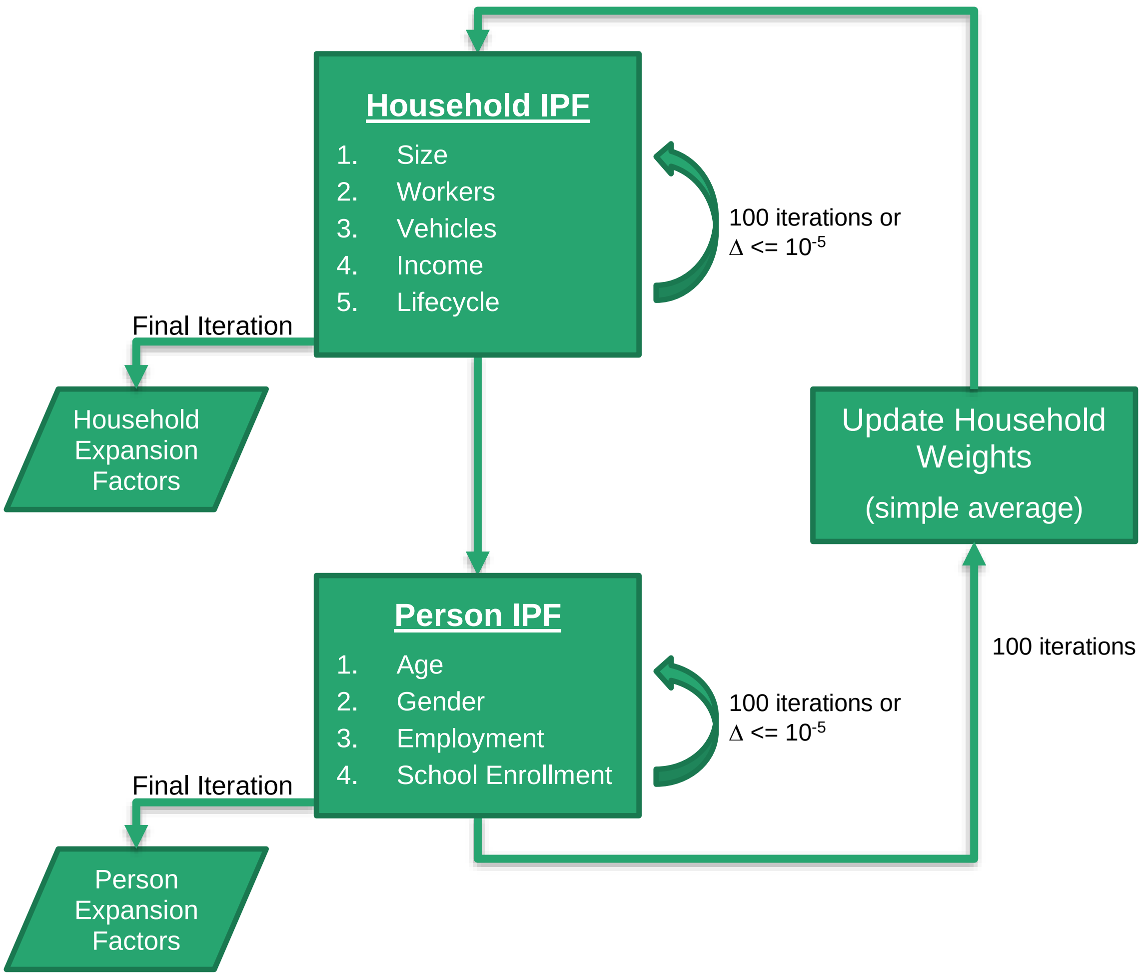
Household / Person Iterations

After the person-level IPF was completed, household expansion factors were recomputed as the simple average of the person-level expansion factors. These average household expansion factors then served as a seed for an additional household-level IPF procedure. Household and person level IPF procedures were conducted alternately as demonstrated in **Figure 2.2** for 100 iterations. Results were then reviewed to confirm that the process had successfully converged.

This process generated separate person and household level expansion factors. Household expansion factors resulted from the final household level IPF procedure, while person level expansion factors were obtained from the final person level IPF procedure. This approach was selected because use of household expansion factors at the person level resulted in a lower total population than would be expected, as demonstrated in **Table 2.4**. This characteristic was particularly notable in the East Wayne and Other Wayne geographic summary areas. Review of the data indicated that this was due to averaging of household sizes for the 6+ household size group, along with averaging individual person demographics for population segments that were under-represented in the survey dataset.

As a result, person records in the expanded household survey dataset have different expansion factors than the corresponding household. In survey analysis, household expansion factors will only be used when tabulating data at the household level. Tabulations of information such as total number of trips will be tabulated using person expansion factors. This approach will help reduce under-estimation of total trips during trip generation model estimation.

Figure 2.2 Combined Household and Person IPF Procedure



Source: CS.

Table 2.4 Estimated Persons Based on Household or Person Expansion Factors

Geographic Summary Area	Household Expansion	Person Expansion	% Difference
Livingston	178,080	180,526	-1.4%
Macomb	817,171	834,026	-2.0%
Monroe	146,607	150,387	-2.5%
Oakland	1,173,309	1,196,042	-1.9%
St. Clair	158,107	161,340	-2.0%
Washtenaw	316,436	325,700	-2.8%
East Wayne	711,800	801,629	-11.2%
Other Wayne	939,907	999,196	-5.9%
Total	4,441,418	4,648,846	-4.5%

Source: CS analysis of 2004/2005 combined household survey data with updated expansion factors.

2.1.5 Survey Expansion Results

The outcome of the household-level and person-level survey expansion is presented at a regional level in **Table 2.5** and **Table 2.6**. Detailed comparisons of household-level and person-level variables by geographic summary area are listed in **Appendix A** and **Appendix B**. The expansion process ensures that the survey data will match each independent household and person variable almost exactly. However, the expanded households by income match targets on a percentage basis rather than by total households due to the large number of records with missing income data. The re-expanded survey results in representation of the population across key market segments that are of great interest from a travel demand modeling perspective. This is expected due to use of both person and household characteristics in the expansion process.

Table 2.5 Regional Household Expansion Results

Variable	Value	ACS Control	Expanded Households
Household Size	1	540,697	540,697
	2	579,988	579,988
	3	280,663	280,663
	4	244,263	244,263
	5	106,025	106,025
	6+	60,858	60,858
Household Workers	0	559,651	559,651
	1	713,871	713,871
	2	444,952	444,952
	3+	94,020	94,020
Household Vehicles	0	158,845	158,845
	1	661,362	661,362
	2	681,800	681,800
	3+	310,487	310,487
Household Income Group	Low	530,552	474,866
	Medium-Low	480,448	426,593
	Medium-High	400,183	353,794
	High	401,311	353,889
	Unknown	n/a	203,353
Household Lifecycle	1	588,013	588,013
	2	171,258	171,258
	3	607,912	607,912
	4	445,311	445,311
Total Households		1,812,494	1,812,494

Source: CS Analysis of 2008-2012 ACS Data and 2004 Combined Household Survey Data.

Table 2.6 Regional Person Expansion Results

Variable	Value	ACS Control	Expanded Persons
Age	Under 15	904,870	904,869
	15 to 24	639,939	639,939
	25 to 34	561,332	561,332
	35 to 44	637,287	637,287
	45 to 54	716,942	716,942
	55 to 64	580,622	580,622
	65 +	607,853	607,854
Gender	Female	2,392,484	2,392,484
	Male	2,256,362	2,256,362
Employment Status	Employed	2,019,342	2,019,343
	Not Employed	2,629,504	2,629,503
School Enrollment	Preschool	132,737	132,737
	K-12	782,926	782,926
	University	382,535	382,535
	Not in School	3,350,647	3,350,647
Total Persons		4,648,846	4,648,846

Source: CS Analysis of 2008-2012 ACS Data and 2004 Combined Household Survey Data.

2.2 Transit Survey Data

The 2010 on-board transit survey provided information useful in refining transit network settings and in defining model calibration and validation targets. SEMCOG had previously expanded the survey to 2010 conditions at the route level, allowing direct application of the survey data for 2010. Further expansion to reflect 2015 transit ridership was required to support development of 2015 mode choice and transit assignment validation targets. Expansion to 2015 conditions was conducted at the route level and is detailed in **Appendix I**.

The on-board survey was processed to create TAZ to TAZ transit trip tables for the purpose of refining the transit network settings and transit assignment procedures. Use of these trip tables is further detailed in **Section 3.0**. Records from the on-board survey were also processed to generate mode choice calibration and validation targets for transit, which are detailed further in **Section 6.2**.

2.3 Zonal and Network Data

The E6 zone structure and base highway and transit networks served as starting points for the development of the E7 model. Changes made to the base structures for implementation of the E7 model are further detailed in this section.

2.3.1 Traffic Analysis Zone Data

The updated E7 model separates TAZ data into three separate components: TAZ geography; TAZ data such as parking cost, area type, and university information; and socioeconomic data. The TAZ data input structures have been modified to minimize information present in the TAZ geography file and to separate socioeconomic data from other TAZ data. Furthermore, the E7 model can use either aggregate or disaggregate input socioeconomic data. TAZ data inputs have been largely retained from the E6 model, with several key modifications to the previous file format related to universities and the newly implemented university special generators. A summary of adjustments made to the TAZ data file to support the university model is included in **Table 2.7**.

Table 2.9 lists the fields present in this file and indicates which fields are required to run the model. Numerous fields present in the E6 TAZ data table have been either removed entirely or relocated to the socioeconomic data input table.

Table 2.7 University Data Adjustments

Field	Changes
University_Name	This table contains the name of the university in a TAZ for all universities listed in **Table 4.16**. Zones that do not include a Tier 1 – 3 university are left blank.
University_Tier	This field identifies the tier of the university in a TAZ (1, 2, or 3), with university tiers further defined in **Section 4.6**.
Univ_Resident	This field replaces the field named "University_GQ" in the E6 TAZ dataset. It contains the number of university students living on campus in each zone, which is calculated as follows. • For each of the Tier 1 and 2 universities, this field has been calculated by allocating the total group quarter number in **Table 4.16** to each campus TAZ based on the methods further detailed in **Section 4.6**. • This field is 0 for all Tier 3 universities.
Univ_Enrollment	This field replaces the field named "University_Enrollment" in the E6 TAZ dataset. It represents the total number of enrolled students, regardless of on- or off-campus residency. It is calculated as follows. • For the Tier 1 and 2 universities spanning multiple zones, this field is calculated by allocating the total enrollment at each university as further detailed in **Section 4.6**. • For remaining universities, total enrollment at each university is used directly.

Source: CS.

Table 2.8 TAZ Layer Table Structure

Field	Required	Notes
ID	*	Unique TransCAD identifier, set to equal the TAZ number.
Area	*	TAZ area in square miles
TAZCE10_N		2010 Census TAZ ID (not required by model)
COUNTY	*	Numeric county identifier 1=Detroit 2=Other Wayne 3=Oakland 4=Macomb 5=Washtenaw 6=Monroe 7=St Clair
EXTERNAL	*	Set to 1 to indicate an external station, blank for all other zones.
DISTRICT		Useful for data summarization
SUPER_DIST_25		Useful for data summarization
Walk_Buf_AM_Qrtr		The model adds these fields to the layer if they are not present, and any data present in these fields are overwritten when running the model. After running the model, these fields contain information used by the destination and mode choice models to identify the share of each zone within the specified distance from transit stops.
Walk_Buf_MD_Qrtr		
Walk_Buf_AM_Half		
Walk_Buf_MD_Half		
Walk_Access Flag		
Walk_Qrtr_AM		
Walk_Qrtr_MD		
Walk_Half_AM		
Walk_Half_MD		

Source: CS.

Table 2.9 TAZ Data Table Structure

Field	Required	Notes
ID	*	Unique TransCAD identifier, set to equal the TAZ number.
County	*	Numeric county identifier
TAZCE10_N		2010 Census TAZ ID (not required by model)
WrkPrkCost	*	All day parking cost applied to commute trips
NonWrkPrk	*	Short-term parking cost applied to non-work trips
External	*	Set to 1 to indicate an external station, blank for all other zones.
AirportADT	*	Airport volume used by the airport special generator model.
AreaType	*	Area type designation 1=CBD 2=Urban Economic Activity Area 3=Urban 4=Suburban 5=Rural
University_Name	*	See detailed definitions in Table 2.7
University_Tier	*	
Univ_Enrollment	*	
Univ_Resident	*	
UMI	*	Indicates University of Michigan zone
CBD	*	Indicates a CBD zone
DET	*	Indicates a zone in the Detroit portion of Wayne County

Source: CS.

Socioeconomic data can be input to the model in one of two formats. The model can read disaggregate household data as described in **Table 2.10** along with disaggregate person data as described in **Table 2.11**. The household and person tables are generated by SEMCOG's UrbanSim forecasting process and facilitate running the disaggregate vehicle availability model described in **Section 4.7**. When running the model with disaggregate input data, the model aggregates data required for trip generation and subsequent model steps.

Alternately, socioeconomic data can be input to the model in aggregate format, which reduces model run time and reduces the amount of input data required to run the model. When using aggregate socioeconomic data, the auto ownership model is not run. The aggregate socioeconomic data table is generated by completing a model run using disaggregate data, and includes over 300 fields. The input aggregate socioeconomic data table includes all fields listed in **Table 2.9**, as well as household and employment data by zone. Employment data is summarized by the types required for the trip generation model, and household data is summarized into the various cross-classifications required for trip generation.

Table 2.10 Disaggregate Household Data Table Structure

Field	Required	Notes
hhid	*	Unique household ID, must match to the corresponding field in the person table
persons	*	Number of persons in the household
workers	*	Number of resident workers in the household
cars	*	Number of autos owned by household members
quartile	*	Household income quartile
children	*	Number of children in the household
zoneid	*	Household TAZ ID
build_id		Building ID
income	*	Household income in 2010 dollars
age_of_h3		Age of the head of household
race_h3		Race of the head of household 1=Non-Hispanic White 2=Non-Hispanic Black 3=Hispanic 4=Others

Source: SEMCOG, CS.

Table 2.11 Disaggregate Person Data Table Structure

Field	Required	Notes
personid		Unique person ID
hhid	*	Unique household ID, must match to the corresponding field in the household table
age	*	Person age
mem_id		Person member ID
gender		Person gender 1=Male 2=Female
race_id		Person race 1=Non-Hispanic White 2=Non-Hispanic Black 3=Hispanic 4=Others
relation		Relationship to head of household 00=Reference person 01=Husband/wife 02=Biological son or daughter 03=Adopted son or daughter 04=Stepson or stepdaughter 05=Brother or sister 06=Father or mother 07=Grandchild 08=Parent-in-law 09=Son-in-law or daughter-in-law 10=Other relative 11=Roomer or boarder 12=Housemate or roommate 13=Unmarried partner 14=Foster child 15=Other nonrelative

Source: SEMCOG, CS.

2.3.2 Highway Network

The E7 model update process did not include changes to the highway network maintained by SEMCOG. The input highway network must contain the fields indicated in **Table 2.12**, as required by the travel model. When run, the model adds a large number of additional fields to the highway network. If present, these additional fields will be overwritten with calculated values when the travel model is run.

Table 2.12 Highway Network Table Structure

Field	Required	Notes
ID	*	Unique ID maintained by TransCAD
Dir	*	Link direction 0= Two-way travel 1= A to B travel only -1= B to A travel only
Length	*	Length in miles maintained by TransCAD
AB_LANES	*	Number of directional lanes
BA_LANES	*	
CENT_LANE	*	Indicates presence of a center turn lane, increasing capacity by 10%.
MODE_ID	*	Identifies managed lanes, further described in **Table 10.2**.
NFC	*	Functional Class 1-7 obtained from the Michigan Geographic Framework (MGF) and above 7 added by SEMCOG: 1=Interstate Freeway 2=Other Freeway 3=Principal Arterial 4=Minor Arterial 5=Major Collector 6=Minor Collector 7=Local Road 8=Not used 9=Uncertified Road 81=Detroit People Mover 82=Rail (AADD Right of Way) 83=Rail (WALLY Right of Way) 96=Park and Ride Walk Access Link 90 = External Connector 99 = Centroid Connector
NFC_FLAG	*	Flag indicating type of facility with the functional class. The model uses this to define ramps and collector distributors. DIV=Wide-Median Divided Highway DV2=Second-Tier Divided Highway FCD=Freeway Collector-Distributor *(Model as collector-distributor)* GRV=Unpaved Road RFF=Fast Freeway to Freeway Ramp *(Model as ramp)* RFS=Slow Freeway to Freeway Ramp *(Model as ramp)* ROF=Freeway Off Ramp *(Model as ramp)* RON=Freeway On Ramp *(Model as ramp)* RSF=Surface-Street Ramp *(Model as ramp)*
AREA_TYPE	*	This field is automatically updated by the model based on area type values in the TAZ data table
COUNTY	*	Numeric county identifier 1=Detroit 2=Other Wayne

Field	Required	Notes
		3=Oakland 4=Macomb 5=Washtenaw 6=Monroe 7=St Clair 8=Livingston
FENAME		Feature name (e.g., street name)
FEYPE		Feature type (e.g., Rd, Ave)
PR		Physical Route (from the MGF database)
BMP		Link beginning milepost (from the MGF database)
EMP		Link ending milepost (from the MGF database)
TransitOnly	*	Set to 1 for mixed flow links that have an adjacent transit-only facility, causing RTCC BRT transit routes to move at freeflow instead of congested speed on these links.

Source: SEMCOG, CS.

2.3.3 Route Systems

As with the highway networks, the E6B route systems formed the basis for the E7 model. Route system attributes are defined in **Table 2.13**. When running the model, route systems are combined with information contained in the highway network to create transit networks. The coding and processing of the transit networks were extensively reviewed and tested using 2010 transit on-board survey data. This processing is detailed in **Section 3.0**.

Table 2.13 Route System Table Structure

Field	Required	Notes
Route_Name	*	Unique Route Name
Route_ID	*	Arbitrary unique route ID. Managed by TransCAD and may change when routes are edited.
MODE_ID	*	Route mode identifying operator and type of service, as defined in the MODE table (e.g., 11=AAATA Local, 16=DDOT Express).
AVE_FARE	*	Average fare on route
DWELL_TIME		Average dwell time on route (not used by the model, a global dwell time is used instead)
AM_HDWY	*	Headway by time of day
MD_HDWY	*	
PM_HDWY	*	
EV_HDWY	*	
NT_HDWY	*	
RT_AUTHOR	*	Route operator (e.g., DDOT, SMART), used for summarization
RT_NUMBER	*	Route number, used for summarization
RT NAME	*	Descriptive route name, used for summarization
RT_OTHER		Notes describing route details, such as pattern information
CENT_LANE	*	Indicates presence of a center turn lane, increasing capacity by 10%.
Direction	*	Identifies “Inbound” and “Outbound” SMART routes, or “None” for SMART routes that do not have City of Detroit boardin or alighting restrictions.
TotalLength		Total route length

Source: SEMCOG, CS.

2.4 Parking Data

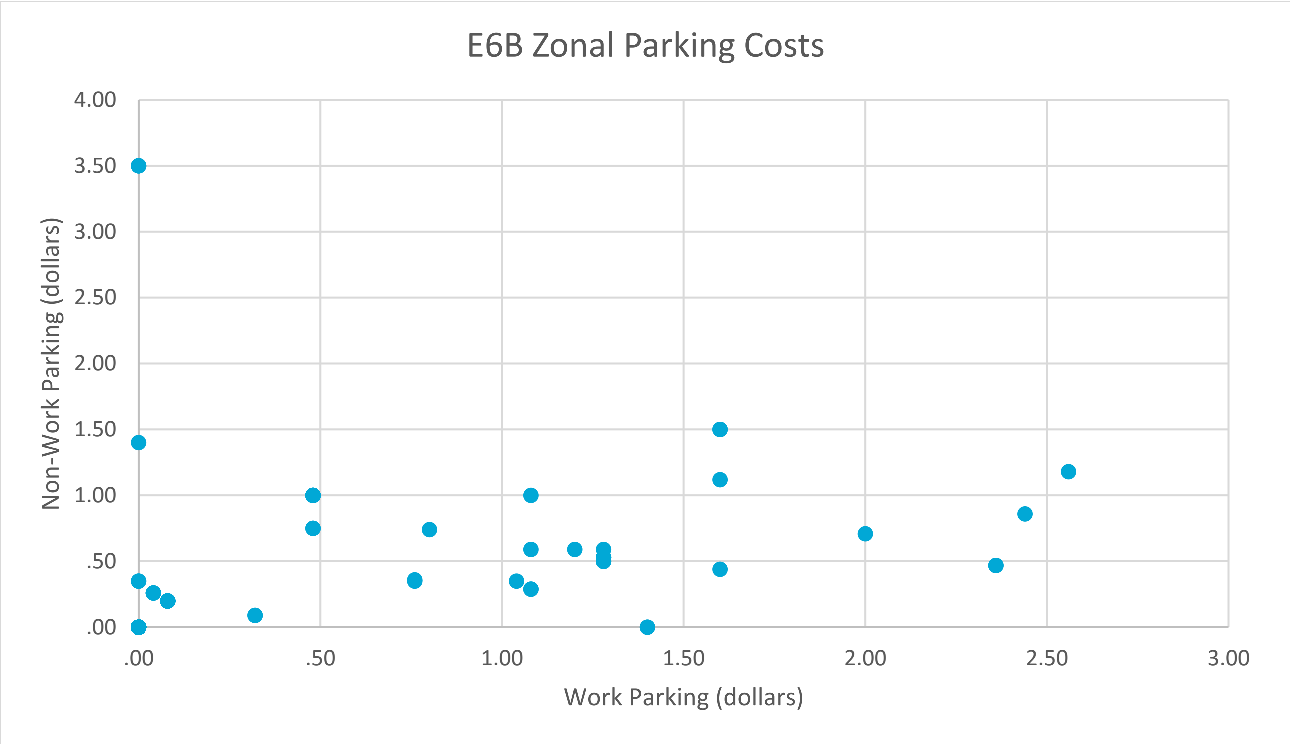
As part of the E7 model update, a review of opportunities to improve the accuracy of the parking cost dataset was conducted. Guidance on improving the accuracy of the parking cost data set were provided in a memorandum[5]. The following sections provide background on the procedures for the E7 model, which are consistent with the E6 model. The following summarizes findings regarding input parking cost data for the E6 and E7 models.

- Zonal-level data are input as total work parking (daily) costs and non-work (short term) parking costs;
- Work trips are for a longer duration, but may have access to free/subsidized employer parking and be able to buy ‘bulk-access’ such as monthly passes;

[5] “*Parking Costs: model needs, data needs, and forecasting*” from Marty Milkovits and Sean McAtee, February 9, 2017.

- The work parking costs are often higher than the non-work parking costs as shown in **Figure 2.3** and **Table 2.14** . This implies that the duration of work-activities overrides the savings from monthly passes and employer subsidies.
- **Figure 2.4** and **Figure 2.5** show zones with parking costs in the E6 and E7 models.

Figure 2.3 Non-work Zonal Parking Costs versus Work Parking Costs



Source: CS summary of SEMCOG E6 and E7 Model Parking Data.

Table 2.14 E6 and E7 Zonal Parking Cost Summary Statistics

	Work	Non-work
Minimum Non-zero Parking Cost (2010 Dollars)	$0.04	$0.09
Average Parking Cost (2010 Dollars)	$0.92	$0.71
Maximum Parking Cost (2010Dollars)	$2.56	$3.50

Source: CS summary of SEMCOG E6 and E7 Model Parking Data.

Figure 2.4 Zones with Parking Costs (Detroit and Airport)

Source: SEMCOG E6 and E7 models, OpenStreetMap imagery.

Figure 2.5 Zones with Parking Costs (Ann Arbor)

Source: SEMCOG E6 and E7 models, OpenStreetMap imagery.

2.5 Socioeconomic Data

Socioeconomic data is generated for the E7 model using an UrbanSim model and process developed and maintained by SEMCOG. The E7 model update changed the source of existing employment data from the Quarterly Census of Employment and Wages (QCEW) dataset used by the E6 and earlier models to the Bureau of Economic Analysis Equivalent Job (BEA-EJ) dataset. The BEA-EJ dataset has fewer data distribution restrictions, allowing SEMCOG to distribute the socioeconomic data required to run the E7 model to outside parties. The BEA-EJ dataset includes wage and salary principal jobs, self-employed jobs, and secondary jobs. The previous QCEW dataset only included wage and salary principal jobs. A summary of 2015 data by county is provided in Table 2.15.

Table 2.15 2015 Socioeconomic Data Summary

County	Population in Households	Households	Employees
Detroit	642,846	257,362	336,820
Other Wayne	1,092,451	433,561	590,971
Oakland	1,226,753	500,466	959,918
Macomb	855,889	339,687	421,451
Washtenaw	334,042	137,542	256,648
Monroe	147,124	58,493	58,460
St Clair	158,288	64,273	64,234
Livingston	185,661	70,620	85,721

Source: SEMCOG.

2.6 GPS and Location Based Data (Streetlight Data)

Two types of passively collected data were used to supplement household travel survey data available for the E7 model update. This passively collected data was particularly useful in gaining a better understanding of travel to, from, and through the SEMCOG region. It also provided district to district travel times useful for calibration of network speeds and a district-based trip table that was useful in trip distribution calibration.

Both GPS-based and LBS-based passively collected data were obtained from StreetLight Data in the form of a district to district trip table. The trip table was limited to weekdays (Tuesday through Thursday) in 2015. Data were formatted into an approximately 300 by 300 district table, with the 300 districts representing aggregations of model TAZs plus districts representing external stations.

An initial analysis of non-commercial trips relied on GPS data, largely obtained from in-dash GPS systems in passenger vehicles. The GPS-based analysis showed inconsistency with observed data, population and employment patterns, and the calibrated E6 model. Further investigation showed that this dataset under-represented trips made in lower income areas, while over-representing trips in higher income areas. Concerns with GPS data sample bias led to exploration of an alternate Location Based Services (LBS) dataset based on mobile device applications.

GPS and LBS data were compared to 2004/2005 household survey data at the county level in order to evaluate them for suitability for use in model development. As shown in **Table 2.16**, the number of trips by the eight geographic areas obtained from the LBS dataset is considerably more consistent with household survey than a similar dataset obtained from the GPS dataset.

Table 2.16 Comparison of GPS and LBS Data to Household Survey Data

County	Household Survey Trip-Ends	GPS Trip-Ends	LBS Trip-Ends	GPS Percent Error	LBS Percent Error
Detroit	1,027,270	890,154	1,158,252	-13%	13%
Other Wayne	2,591,225	2,076,307	2,502,881	-20%	-3%
Oakland	3,126,514	4,698,506	3,041,464	50%	-3%
Macomb	1,989,751	1,360,267	1,990,048	-32%	0%
Washtenaw	789,276	1,002,777	799,972	27%	1%
Monroe	247,943	105,168	280,328	-58%	13%
St. Clair	334,476	107,874	300,678	-68%	-10%
Livingston	373,206	238,606	406,038	-36%	9%
Total	**10,479,660**	**10,479,660**	**10,479,660**	**n/a**	**n/a**

Source: CS analysis of re-expanded 2004/2005 household travel survey data, GPS-based StreetLight Data, and LBS-based StreetLight Data.

Note: GPS and LBS total trip-ends were scaled to the 2004/2005 household survey total to facilitate comparison of the distribution of trip-ends by county.

2.7 Traffic Counts

The E7 model updated used traffic count data gathered and summarized by SEMCOG from multiple sources. SEMCOG provided traffic count data in a database format that was linked directly to the highway network. For 2015, this included traffic counts for over 4,734 locations, with over 4,612 of these including detail by time of day. Vehicle classification count data was available for 387 locations. Traffic count locations were spaced throughout the region and included good freeway, arterial, and collector coverage. Traffic counts were available for all high- and medium-volume external station locations, and provided nearly complete screenline coverage.

Table 2.17 Number of Traffic Counts by County and Facility Type

County	Freeway	Principal Arterial	Minor Arterial	Collector / Local	Ramp / Collector-Distributor	Total
Detroit	26	112	103	98	290	629
Other Wayne	25	158	86	95	270	634
Oakland	39	331	389	208	259	1,226
Macomb	20	300	219	57	106	702
Washtenaw	20	67	147	172	91	497
Monroe	14	16	58	102	65	255
St Clair	16	42	54	87	41	240
Livingston	14	28	123	356	30	551
Total	**174**	**1,054**	**1,179**	**1,175**	**1,152**	**4,734**

Source: CS analysis of SEMCOG count database.

2.8 Transit Boarding Data

The E7 model used boarding data provided by area transit agencies to support expansion of the 2010 on-board survey data, to develop mode choice calibration targets, and to validate transit assignment. Each agency provided 2015 transit boarding data by route, including estimates of the average number of transfers made per complete linked trip.

3.0 Transit Networks

This chapter describes adjustments made to transit network and pathbuilding settings. Transit network settings from the E6 model have been updated to better represent observed transit paths and to be compatible with TransCAD 8, with the resulting settings detailed in **Appendix C**. The transit network settings were reviewed and updated to validate the model with the 2010 On-Board survey. As part of this effort the Park and Ride (PNR) procedure was updated to enable PNR egress as well as access, which is necessary to facilitate assignment of park and ride trips in Origin-Destination format. Trip tables developed from the on-board survey were assigned to the model and assignment results were compared to the survey for overall transfer rates and route-group level boardings. The resulting networks are used to generate transit skims required to support destination and mode choice, and to assign transit trips resulting from mode choice. Transit networks represent transit service offered by the following seven providers in the region:

- Ann Arbor Area Transportation Authority (AATA);
- Blue Water Area Transit (BWAT);
- Detroit Department of Transportation (DDOT);
- Detroit People Mover (DPM);
- Lake Erie Transportation Commission (LETC);
- Suburban Mobility Authority for Regional Transportation (SMART); and
- University of Michigan Transit (UMI).

3.1 Survey Trip Table Assignments

In order to validate the model, the linked trips from the 2010 on-board survey were used to generate peak (AM and PM) and off-peak (mid-day and evening) trip tables in production and attraction format. These observed trip tables were then assigned to the transit networks and the results were compared to the route and service level boardings from the survey. **Table 3.1** shows the surveyed linked trips, boardings (unlinked trips), and transfer rates. **Table 3.2** and **Table 3.3** show the results of assigning the linked trips from the survey and before and after implementing updates to the transit network. The tables show the trips by transit mode, access mode, and time of day.

3.1.1 Path Parameter Adjustments

In addition to implementing PNR Egress, the remaining transit network settings were reviewed to ensure the model was properly assigning transit trips. This review found a significant number of trips that were unassigned, suggesting problems with maximums included in the pathfinder settings. The E6 Max Trip Cost Parameter was set to 20 dollars, while the default limit is 999. This appeared to be preventing the pathfinder from generating transit paths for longer trips and those involving transfers. Updating this parameter to the default value of 999 decreased the unassigned percent of trips from 9.5 percent to 2.6 percent. This change also affected the average transfer rate, which was further explored through use of prediction success tables as described below. A review of the highest-cost trips resulting from mode choice showed that removing the limitation on maximum trip cost did not result in unreasonable transit trips in the model results.

3.1.2 Prediction Success Tables

Prediction success tables serve as a measure of similarity between observed paths and modeled paths. They compare the number of transfers reported by survey participants to the number of transfers in the path generated by TransCAD. **Table 3.4** shows the original prediction success table with unadjusted transit network settings for AM Walk to Bus survey trips. **Table 3.5** shows the updated prediction success table after adjusting the Max Trip Cost from the original value of 20 to the default of 999. The adjustment reduced the percent of trips without a path from 17 percent to 4 percent with the percentage of trips that matched the surveyed number of transfers to the minimum skim number improving from 59 percent to 67 percent.

Table 3.1 Surveyed Average Weekday Linked Trips and Boardings

	2010 Survey Linked Trips			Survey Boardings			Survey Transfer Rate		
Path / Time of Day	PK	OP	Total	PK	OP	Total	PK	OP	Total
People Mover-Walk Access	1,029	1,402	2,430	1,128	1,603	2,731	1.10	1.14	1.12
All Bus-Walk Access	78,726	73,138	151,864	108,763	99,679	208,442	1.38	1.36	1.37
People Mover-Drive Access	403	824	1,227	417	862	1,280	1.04	1.05	1.04
All Bus-Drive Access	6,029	2,925	8,954	6,483	3,204	9,687	1.08	1.10	1.08
Total	86,187	78,289	164,475	116,791	105,349	222,140	1.36	1.35	1.35

Source: AECOM.

Table 3.2 Results of Assignment of Survey Trip Tables Before and After Transit Network Updates

	2010 Survey Linked Trips			Unassigned Trips			Intrazonal Trips			Survey Assignment Boardings			Transfer Rate		
Path / Time of Day	**PK**	**OP**	**Total**	**PK**	**OP**	**Total**	**PK**	**OP**	**Total**	**PK**	**OP**	**Total**	**PK**	**OP**	**Total**
Assignment Results Prior to Network Updates															
People Mover-Walk Access	1,029	1,402	2,430	304	557	861	0	8	8	725	837	1,561	1.00	1.00	1.00
All Bus-Walk Access	78,726	73,138	151,864	6,519	7,980	14,499	711	1,004	1,715	104,463	86,794	191,257	1.46	1.35	1.41
People Mover-Drive Access	403	824	1,227	42	54	96	7	0	7	354	776	1,130	1.00	1.01	1.01
All Bus-Drive Access	6,029	2,925	8,954	385	272	657	28	12	41	6,027	2,982	9,009	1.07	1.13	1.09
Total	**86,187**	**78,289**	**164,475**	**7,250**	**8,863**	**16,113**	**746**	**1,025**	**1,771**	**111,569**	**91,389**	**202,958**	**1.43**	**1.34**	**1.38**
Assignment Results After Network Updates															
People Mover-Walk Access	1,029	1,402	2,430	304	557	861	0	8	8	725	837	1,561	1.00	1.00	1.00
All Bus-Walk Access	78,726	73,138	151,864	1,432	1,806	3,238	711	1,004	1,715	115,842	101,416	217,259	1.51	1.44	1.48
People Mover-Drive Access	403	824	1,227	31	48	79	7	0	7	365	776	1,142	1.00	1.00	1.00
All Bus-Drive Access	6,029	2,925	8,954	25	117	142	28	12	41	6,171	3,053	9,223	1.03	1.09	1.05
Total	**86,187**	**78,289**	**164,475**	**1,792**	**2,528**	**4,320**	**746**	**1,025**	**1,771**	**123,103**	**106,082**	**229,185**	**1.47**	**1.42**	**1.45**

Source: AECOM.

Table 3.3 Surveyed and Modeled Boardings by Mode Before and After Transit Network Updates

Mode	2010 Surveyed Unlinked Trips (Boardings)			Prior to Transit Network Updates Boardings from 2010 Surveyed Trip Table Assignment			After Transit Network Updates Boardings from 2010 Surveyed Trip Table Assignment		
	PK	OP	Total	PK	OP	Total	PK	OP	Total
People Mover	1,545	2,466	4,011	1,078	1,613	2,691	1,090	1,613	2,703
All Bus	115,246	102,883	218,129	110,490	89,776	200,267	122,013	104,469	226,482
Total	116,791	105,349	222,140	111,569	91,389	202,958	123,103	106,082	229,185
Percent Differences									
People Mover	–	–	–	-30%	-35%	-33%	-42%	-53%	-49%
All Bus	–	–	–	-4%	-13%	-8%	6%	2%	4%
Total	–	–	–	-4%	-13%	-9%	6%	1%	3%

Source: AECOM.

Table 3.4 Initial Prediction Success Table of Peak Walk to Bus Survey Trips

Reported Boardings	Modeled Boardings (Match or Minimum Transfer Path in Skims)					
	No Path	**1**	**2**	**3**	**4**	**Total**
1	849	6,348	842	19	0	8,058
2	1,311	1,857	3,633	42	0	6,843
3	614	662	552	115	0	1,943
4	80	149	100	2	0	331
Total	2,854	9,016	5,127	178	0	17,175
No path	17%					
model>observed	5%					
model=observed	59%					
model<observed	19%					

Source: AECOM.

Table 3.5 Updated Prediction Success Table of Peak Walk to Bus Survey Assignment

Reported Boardings	Modeled Boardings (Match or Minimum Transfer Path in Skims)					
	No Path	**1**	**2**	**3**	**4**	**Total**
1	307	6,560	1,121	68	2	8,058
2	237	1,878	4,599	128	1	6,843
3	90	732	712	405	4	1,943
4	21	162	123	20	5	331
Total	655	9,332	6,555	621	12	17,175
No path	4%					
model>observed	8%					
model=observed	67%					
model<observed	21%					

Source: AECOM.

3.2 DDOT vs. SMART Competition

When assigning surveyed trip tables to the TransCAD transit networks, it was apparent that the model over assigned trips to SMART routes while under assigning to DDOT routes. This appeared to be caused by longer DDOT headways on some routes mixed with longer runtimes causing trips to prefer SMART routes. In order to address this discrepancy, the following headway coding rules were applied to DDOT routes:

- If Original Headway<=15 minutes then New Headway = Original Headway

- If Original Headway<=30 and >15 minutes then New Headway = 15 + (Original Headway – 15)/2
- If Original Headway>30 minutes then New Headway = 22.5 + (Original Headway – 30)/4

The revised headways helped to reduce perceived wait times for DDOT routes with longer headways, thereby increasing assigned boardings on DDOT routes. **Table 3.6** shows the service level modeled vs observed ridership with the original DDOT headways. **Table 3.7** shows the service level modeled vs observed ridership using the adjusted DDOT headways.

In addition to the headway adjustments described above, the transit networks were updated to represent fare policy SMART rules disallowing trips to be conducted entirely within the City of Detroit. Fare policies were adjusted to reflect a discounted transfer charge between SMART and DDOT routes. The prohibition on trips within Detroit was accomplished by prohibiting boardings on inbound SMART routes and prohibiting alightings on outbound SMART routes.

Table 3.6 Service Level Average Weekday Ridership - Original DDOT Headways

	On-Board Survey			Model Assigned Survey Trips			Model Assigned Trips - On-Board Survey		
Service	**PK**	**OP**	**Daily**	**PK**	**OP**	**Daily**	**PK**	**OP**	**Daily**
AAATA	10,634	11,376	22,010	11,353	11,915	23,267	718	539	1,257
BWAT	804	1,821	2,625	683	1,180	1,862	-121	-641	-763
DDOT	70,811	53,703	124,514	69,011	54,727	123,738	-1,800	1,024	-776
DPM	1,545	2,466	4,011	1,518	2,152	3,670	-27	-314	-341
LET	212	665	877	119	296	415	-93	-369	-462
SMART	15,673	18,203	33,876	20,900	18,010	38,910	5,227	-193	5,034
UMI	17,111	17,116	34,227	20,061	17,243	37,304	2,950	128	3,077
Total	**116,791**	**105,349**	**222,140**	**123,644**	**105,522**	**229,167**	**6,853**	**174**	**7,027**

Source: AECOM.

Table 3.7 Service Level Average Weekday Ridership - Adjusted DDOT Headways

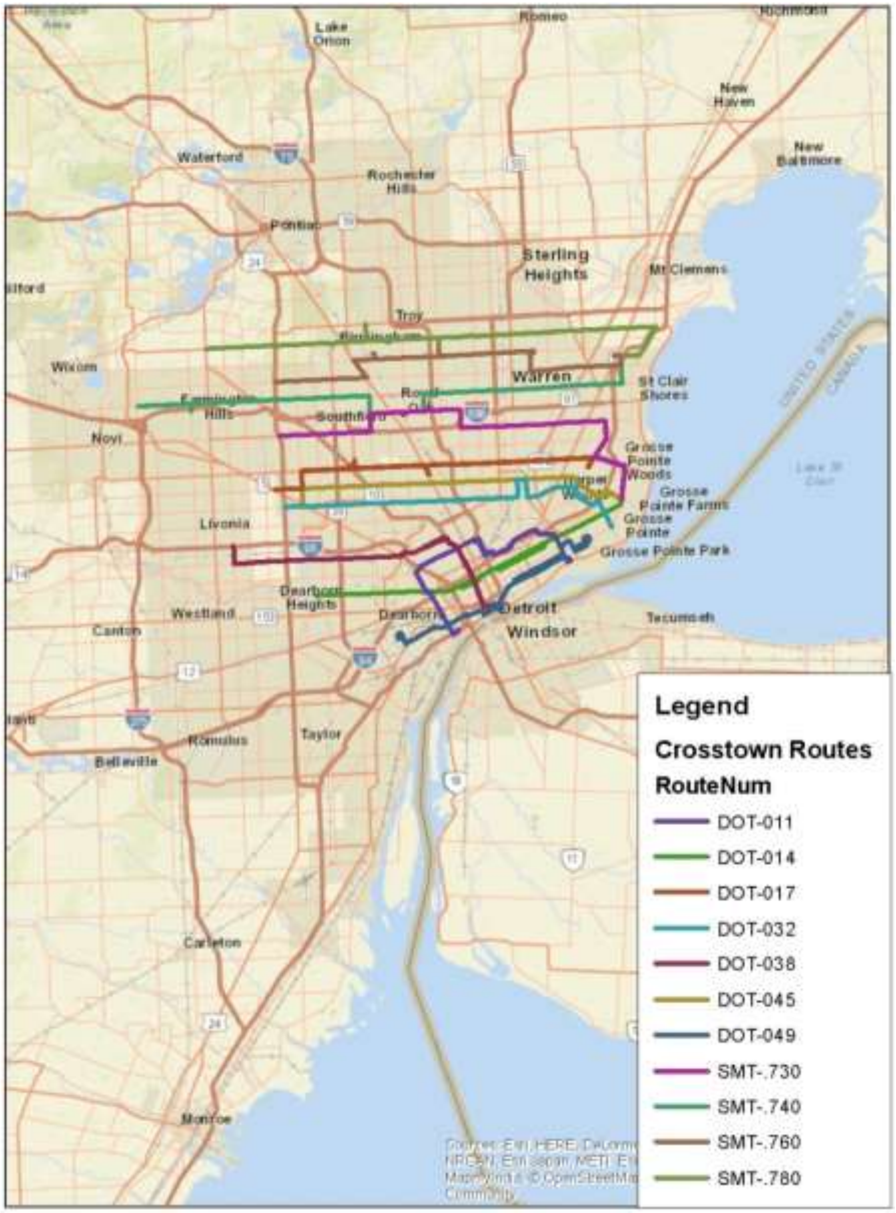
	On-Board Survey			Model Assigned Survey Trips			Model Assigned Trips - On-Board Survey		
Service	**PK**	**OP**	**Daily**	**PK**	**OP**	**Daily**	**PK**	**OP**	**Daily**
AAATA	10,634	11,376	22,010	11,342	11,989	23,330	707	613	1,320
BWAT	804	1,821	2,625	683	1,180	1,862	-121	-641	-763
DDOT	70,811	53,703	124,514	70,004	56,417	126,421	-807	2,714	1,907
DPM	1,545	2,466	4,011	1,521	1,948	3,469	-24	-518	-542
LET	212	665	877	119	296	415	-93	-369	-462
SMART	15,673	18,203	33,876	19,369	17,083	36,452	3,696	-1,120	2,576
UMI	17,111	17,116	34,227	20,066	17,169	37,235	2,954	54	3,008
Total	**116,791**	**105,349**	**222,140**	**123,103**	**106,082**	**229,185**	**6,312**	**733**	**7,045**

Source: AECOM.

3.3 Regional Assignment Summaries

Once the service level transit ridership looked reasonable, DDOT and SMART routes were grouped based on geographic location and general alignment into seven groups to make sure ridership on routes serving various areas also looked reasonable. These groups are: Crosstown, East North-South, East, North-South, Southwest, West North-South, and West. **Table 3.8** through **Table 3.14** show the DDOT vs SMART ridership by regional route groupings with the maps showing the groupings (**Figure 3.1** through **Figure 3.7**).

Figure 3.1 Crosstown DDOT and SMART Route Grouping



Source: CS Analysis of Model Geography, TransCAD geography files.

Table 3.8 Model Assigned Survey Trips – DDOT vs SMART - Crosstown

		On-Board Survey			Model Assigned Survey Trips			Model Assigned Survey Trips - On-Board Survey		
Service	**Provider**	**PK**	**OP**	**Daily**	**PK**	**OP**	**Daily**	**PK**	**OP**	**Daily**
Crosstown	Total	17,984	14,561	32,545	20,806	18,055	38,861	2,822	3,494	6,316
	DDOT	16,641	12,697	29,338	19,677	16,145	35,821	3,035	3,448	6,483
	SMART	1,343	1,864	3,207	1,130	1,910	3,039	-214	46	-168

Source: AECOM summaries.

Figure 3.2 East North-South DDOT and SMART Route Grouping

Source: CS Analysis of Model Geography, TransCAD geography files.

Table 3.9 Model Assigned Survey Trips – DDOT vs SMART – East North-South

		On-Board Survey			Model Assigned Survey Trips			Model Assigned Survey Trips - On-Board Survey		
Service	**Provider**	**PK**	**OP**	**Daily**	**PK**	**OP**	**Daily**	**PK**	**OP**	**Daily**
East North-South	Total	7,137	5,354	12,491	7,387	6,545	13,931	250	1,191	1,440
	DDOT	5,462	3,394	8,856	5,627	4,769	10,395	164	1,375	1,539
	SMART	1,675	1,960	3,635	1,760	1,776	3,536	85	-184	-99

Source: AECOM summaries.

Figure 3.3 East DDOT and SMART Route Grouping

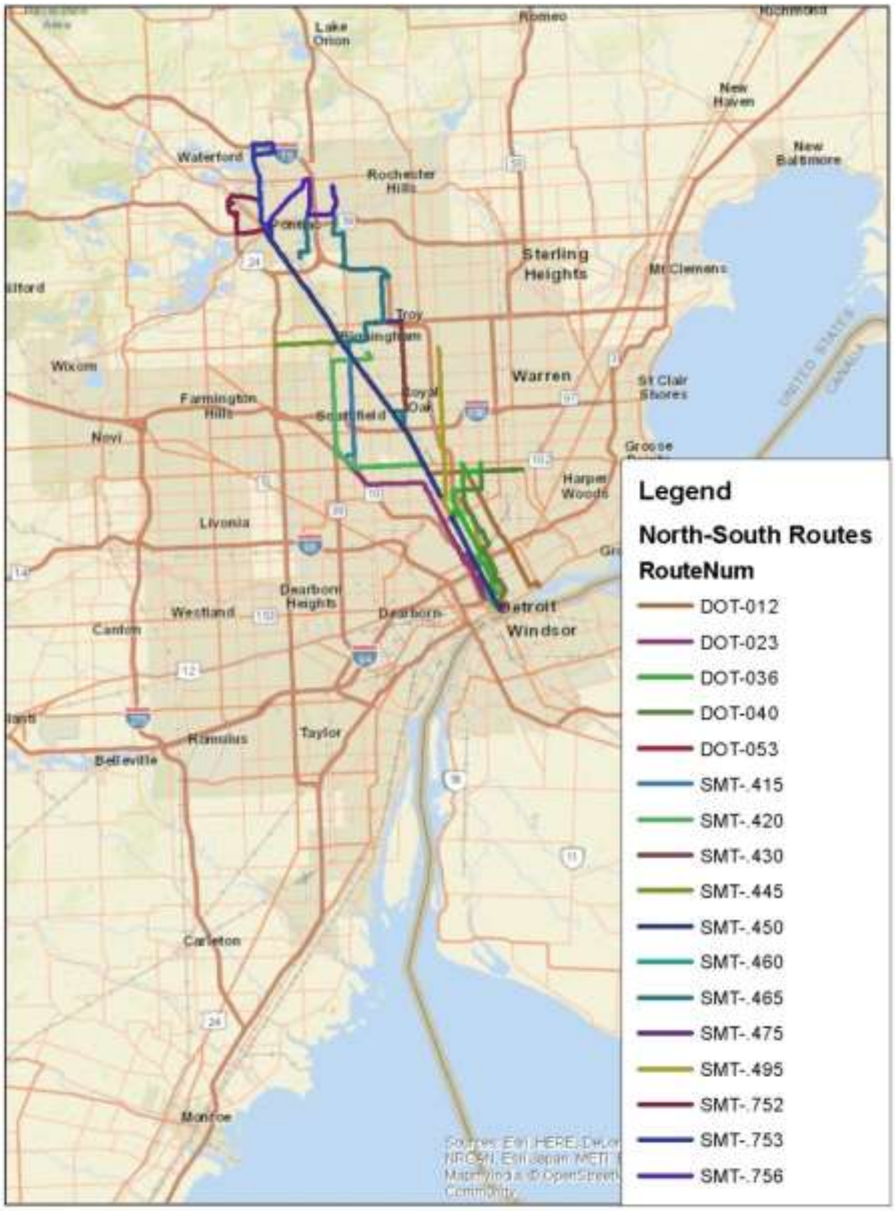
Source: CS Analysis of Model Geography, TransCAD geography files.

Table 3.10 Model Assigned Survey Trips – DDOT vs SMART - East

		On-Board Survey			Model Assigned Survey Trips			Model Assigned Survey Trips - On-Board Survey		
Service	Provider	PK	OP	Daily	PK	OP	Daily	PK	OP	Daily
East	Total	13,308	12,235	25,543	12,616	10,360	22,976	-692	-1,875	-2,567
	DDOT	9,490	7,458	16,948	7,773	6,042	13,815	-1,718	-1,416	-3,133
	SMART	3,818	4,777	8,595	4,844	4,318	9,162	1,026	-459	567

Source: AECOM summaries.

Figure 3.4 North-South DDOT and SMART Route Grouping



Source: CS Analysis of Model Geography, TransCAD geography files.

Table 3.11 Model Assigned Survey Trips – DDOT vs SMART - North-South

		On-Board Survey			Model Assigned Survey Trips			Model Assigned Survey Trips - On-Board Survey		
Service	**Provider**	**PK**	**OP**	**Daily**	**PK**	**OP**	**Daily**	**PK**	**OP**	**Daily**
North-South	Total	12,805	12,993	25,798	11,968	11,431	23,399	-837	-1,562	-2,399
	DDOT	9,297	8,147	17,444	7,385	7,059	14,444	-1,912	-1,088	-3,000
	SMART	3,508	4,846	8,354	4,583	4,372	8,955	1,075	-474	601

Source: AECOM summaries.

Figure 3.5 Southwest DDOT and SMART Route Grouping

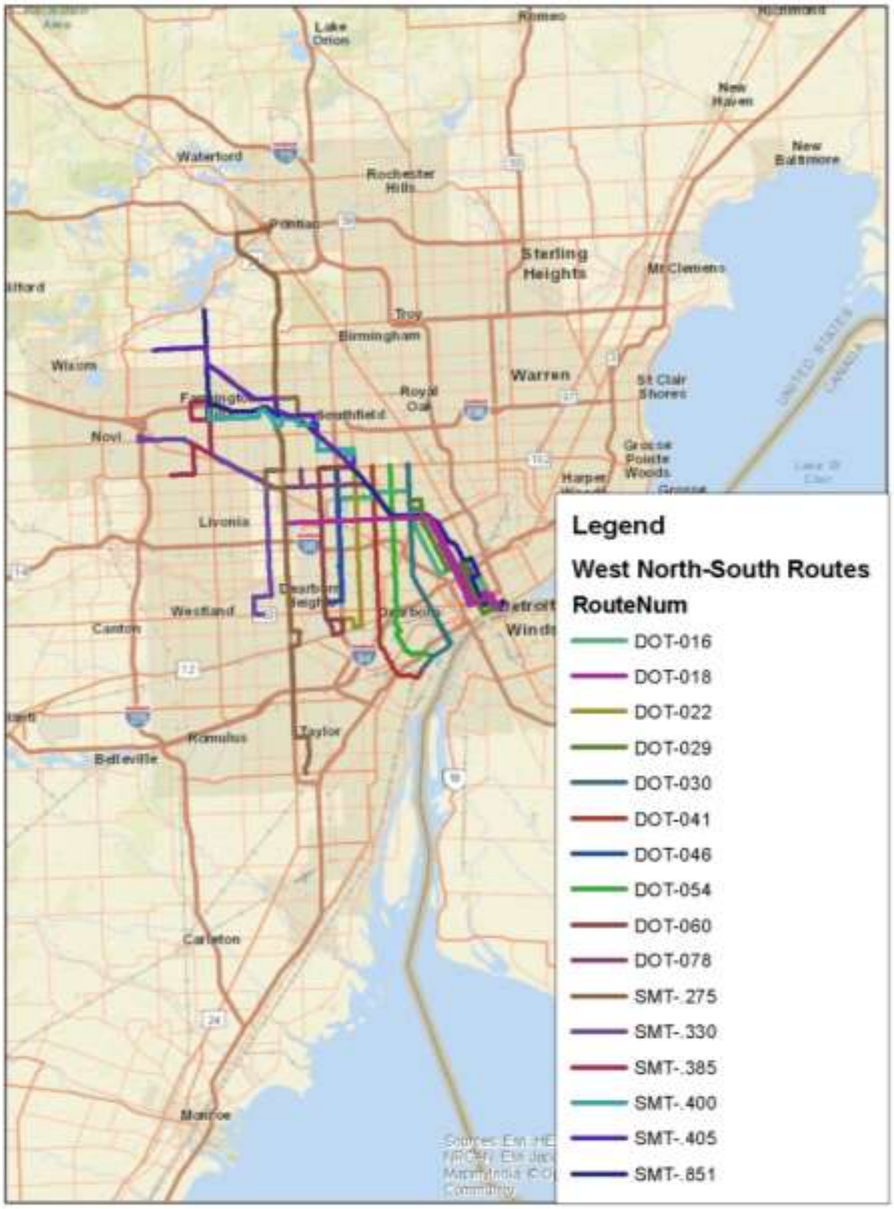
Source: CS Analysis of Model Geography, TransCAD geography files.

Table 3.12 Model Assigned Survey Trips – DDOT vs SMART - Southwest

		On-Board Survey			Model Assigned Survey Trips			Model Assigned Survey Trips - On-Board Survey		
Service	**Provider**	**PK**	**OP**	**Daily**	**PK**	**OP**	**Daily**	**PK**	**OP**	**Daily**
Southwest	Total	579	721	1,300	667	560	1,227	88	-161	-73
	DDOT	0	0	0	0	0	0	0	0	0
	SMART	579	721	1,300	667	560	1,227	88	-161	-73

Source: AECOM summaries.

Figure 3.6 West North-South DDOT and SMART Route Grouping



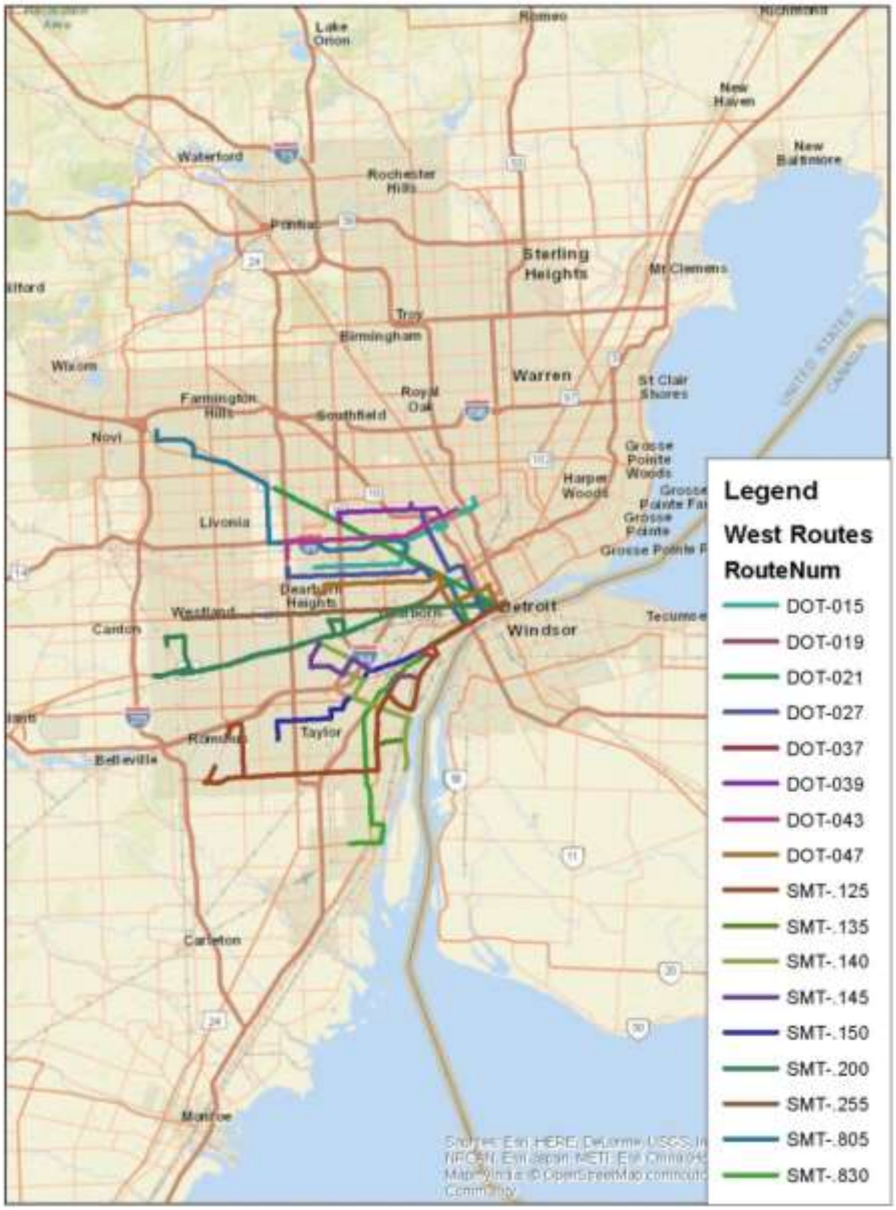
Source: CS Analysis of Model Geography, TransCAD geography files.

Table 3.13 Model Assigned Survey Trips – DDOT vs SMART - West North-South

		On-Board Survey			Model Assigned Survey Trips			Model Assigned Survey Trips - On-Board Survey		
Service	**Provider**	**PK**	**OP**	**Daily**	**PK**	**OP**	**Daily**	**PK**	**OP**	**Daily**
West North-South	Total	19,874	14,256	34,130	22,192	14,764	36,956	2,319	508	2,826
	DDOT	18,548	12,759	31,307	20,088	13,309	33,397	1,540	550	2,090
	SMART	1,325	1,498	2,823	2,104	1,455	3,560	779	-42	737

Source: AECOM summaries.

Figure 3.7 West DDOT and SMART Route Grouping



Source: CS Analysis of Model Geography, TransCAD geography files.

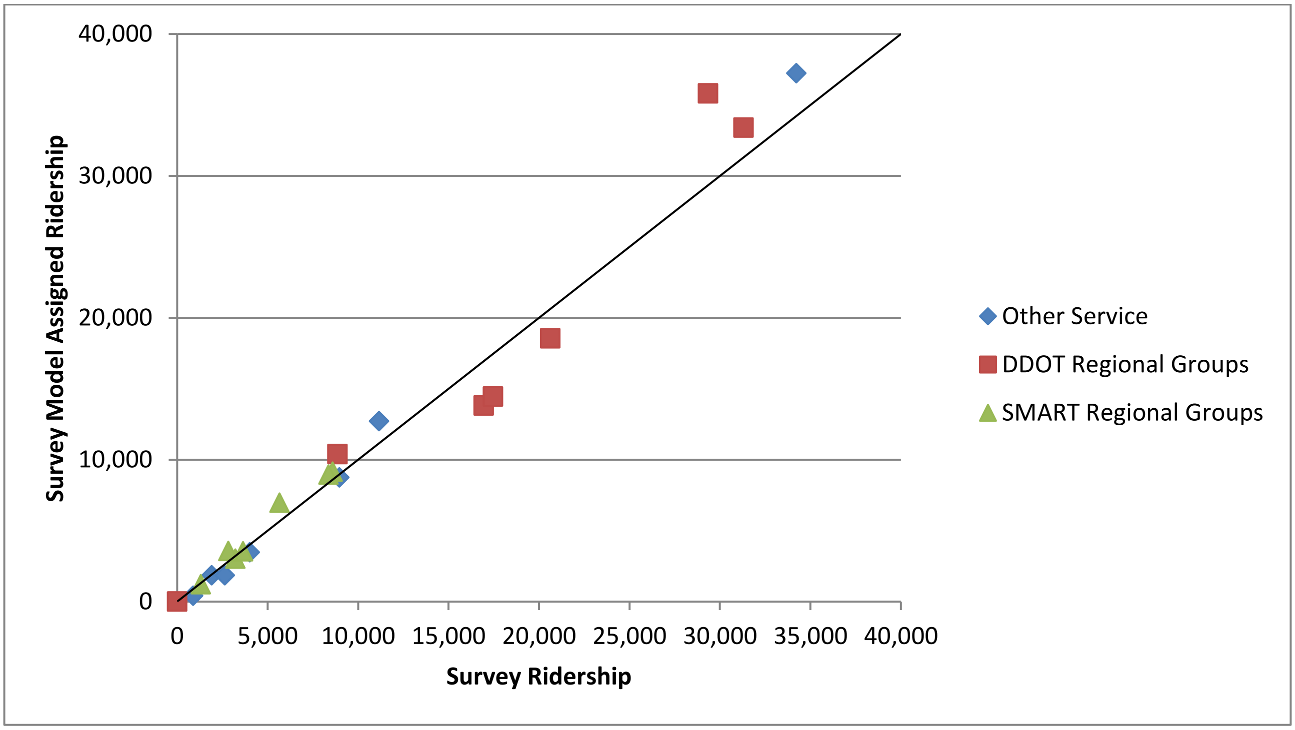
Table 3.14 Model Assigned Survey Trips – DDOT vs SMART - West

		On-Board Survey			Model Assigned Survey Trips			Model Assigned Survey Trips - On-Board Survey		
Service	**Provider**	**PK**	**OP**	**Daily**	**PK**	**OP**	**Daily**	**PK**	**OP**	**Daily**
West	Total	14,537	11,744	26,281	13,736	11,785	25,522	-801	41	-759
	DDOT	11,373	9,248	20,621	9,455	9,094	18,549	-1,917	-155	-2,072
	SMART	3,164	2,496	5,660	4,281	2,692	6,973	1,117	196	1,313

Source: AECOM summaries.

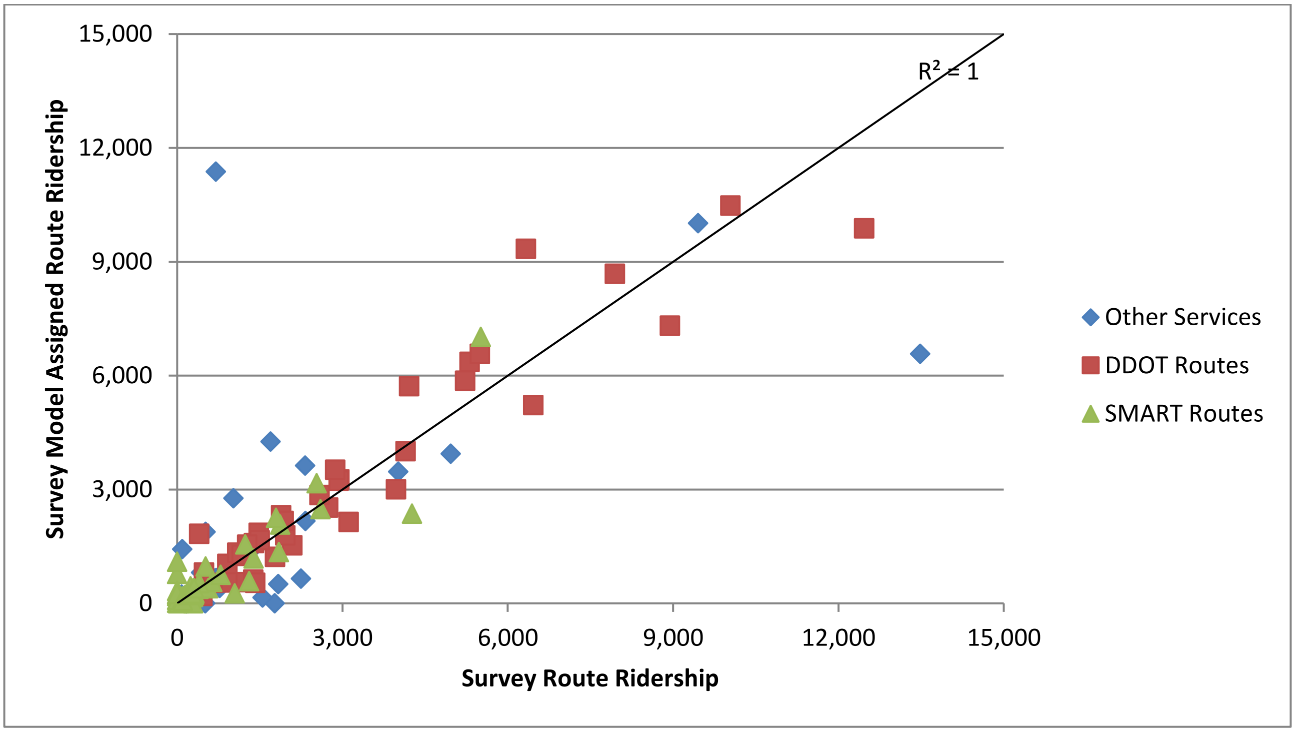
Figure 3.8 and **Figure 3.9** show graphically the modeled vs observed ridership from the survey trips. **Figure 3.8** shows the service level ridership with each service representing one marker and the DDOT and SMART routes broken into regional groups from the above maps. **Figure 3.9** shows the individual route level comparison of modeled compared to observed ridership. While there are some notable outliers at the individual route level, these outliers are offset within each service level.

Figure 3.8 Survey vs Modeled Survey Average Weekday Ridership - Service Level



Source: AECOM.
Note: Other service includes AATA, BWAT, LETC, UMI, and DPM.

Figure 3.9 Survey vs Modeled Survey Average Weekday Ridership - Route Level



Source: AECOM.

Note: Other service includes AATA, BWAT, LETC, UMI, and DPM.

3.4 Transit Speed Functions

The E7 model retains transit speed functions from the E6 model. All transit lines in mixed flow traffic travel at the congested link speed, but also experience added dwell time of 0.32 seconds at each stop. This dwell time accounts for the time required to slow down, load and unload passengers, and accelerate back to the prevailing speed. On transit links such as people mover and rail facilities, transit vehicles are modeled to travel at the freeflow speed coded on these links, again experience added dwell time at stops. To simplify coding of BRT on transit-only links adjacent to existing roadway links, the RTCC BRT mode experiences the freeflow speed on such links. This is accomplished by setting the TransitOnly variable on the highway layer to a value of 1 on such links. Note that the 2015 base year network does not include RTCC BRT transit, nor does it include any links with TransitOnly set to 1.

4.0 Trip Generation

This chapter presents the Trip Generation model update for internal trips. The primary driver behind the model update is the utilization of Bureau of Economic Analysis Equivalent Job (BEA-EJ) data for zonal employment data. The model update also takes advantage of the improved 2004/2005 combined household survey expansion, described in Section 2 as well as a new 2015 household survey that became available during model validation. The trip generation model update includes two new modeling approaches for home-based university trips and household vehicle availability. This chapter includes the following topics:

- Derivation of trip purpose and trip production/attraction end;
- Estimation of trip production rates by purpose;
- Estimation of trip attraction rates by purpose;
- Estimated worker-income disaggregation rates for household income and employment segment;
- Updated home-based university trip generation approach;
- Vehicle availability model estimation results; and
- Assessment of commercial vehicle model trip rates with new employment data.

The trip generation parameters documented in this chapter are final parameters after all model calibration. The parameters originally estimated from the survey data are shown in **Appendix D** and **Appendix E**.

4.1 Data Preparation

This section describes the preparation of the model estimation data set from the available 2004/2005 household survey data.

4.1.1 Data Sources

The SEMCOG E7 trip generation model update utilizes household and trip information from the 2004/2005 combined household travel survey dataset, including the updated expansion factors described in Section 2. The new expansion process consisted of a households and persons process and produced slightly different expansion factors by household and person. The person factors were used to estimate trip generation rates to capture trip making from large households and under-represented persons. This approach was selected because use of household expansion factors at the person level resulted in a lower total population than would be expected. This characteristic was particularly notable in the East Wayne and Other Wayne geographic summary areas. Review of the data indicated that this was due to averaging of household sizes for the 6+ household size group, along with averaging individual person demographics for population segments that were under-represented in the survey dataset. Comparisons of the trips by geographic area origin and destination as well as trip purpose are shown in **Appendix F**.

The trip attraction and commercial vehicle generation analysis use the revised socioeconomic data (SED) from SEMCOG that is based on the Bureau of Economic Analysis Equivalent Job (BEA-EJ) data set.

The E6 model included procedures based on the 2000 Census data to match home-based work (HBW) productions and attractions by household income. The 2010 Census no longer collected the detailed information. For the E7 model update, the American Community Survey (ACS) was used to develop a set of household to worker income and employment category to worker income factors.

4.1.2 Trip Purposes

The SEMCOG E7 model has retained the trip purpose definitions present in the E6 version of the travel model. These trip purposes include:

- Home-Based Work (HBW): Trips between the traveler's home and workplace location for the purpose of working;
- Home-Based School (HBSc): Trips between the travelers home and K-12 school location to attend school;
- Home-Based University (HBU): Trips between the traveler's home and college or university location to attend school or visit the university;
- Home-Based Shop (HBSh): Trips between the traveler's home and another location for the purpose of shopping (note that social/recreational trips such as trips to restaurants are not included in the HBSh trip purpose);
- Home-Based Other (HBO): Trips between the traveler's home and any other location not defined above;
- Non-Home-Based Work (NHBW): Trips between the traveler's workplace and another non-home location; and
- Non-Home-Based Other (NHBO): Trips between two locations that are neither the traveler's home nor workplace.

The trip purpose and direction for each record in the household survey dataset was defined based on a series of sequential steps, described below.

1. The reported activity at each trip end was identified and classified as described in **Table 4.1**.
2. Trip end activities were reclassified in the following cases:
    a. Activity was set to "Home" in all cases where the free answer origin or destination field was set to "HOME".[6]
    b. Home-Based University Trips that were not associated with a college or university zone were re-classified as Home-Based Work trips.

[6] The anonymized survey dataset does not contain this field. SEMCOG provided a list of trips with the origin or destination identified as home.

c. School activities by persons over 19 years old with a vocational/technical school or college location type are re-categorized as university.

d. University activities by persons under 18 with a non-university location type are re-categorized as school.

Table 4.1 Activity Categories Used to Define Trip Purpose

Survey Activity ID	Survey Description	Trip Purpose Category
3	Work	Work
5	Attend School	School
6	Attend College	University
9	Everyday Shopping	Shop
10	Major Shopping	Shop
4	Attend Childcare	Other
7	Eat Out	Other
8	Personal Business	Other
11	Religious/Community	Other
12	Social	Other
13	Recreation - Participate	Other
14	Recreation - Watch	Other
15	Accompany Another Person	Other
16	Pick-Up/Drop-Off Passenger	Other
17	Turn Around	Other

Source: CS Analysis of 2004/2005 household survey.

3. A purpose was assigned to each trip based on the combination of trip end activities as follows:

   a. Trips with at least one end at home were classified as home-based trips, with the non-home end defining the specific home based trip purpose.

   b. Non-Home Based trips with one trip end at the workplace were further classified as NHBW trips.

   c. Non-Home Based trips with neither trip end at the workplace were classified as NHBO trips.

4. Production and Attraction travel analysis zones (TAZs) were identified for each trip purpose.

   a. For Home-based trips, the production end is the home end and the attraction end is the non-home end.

   b. For NHBW trips, the production end is the work end and the attraction end is the non-work end.

   c. For NHBO trips, the production end is the origin end and the attraction end is the destination end.

5. Trip records where TRIPNUM=0 were removed from the trip dataset because this designation indicated that a trip was not made.

6. External trips, or trips with at least one trip end outside of the region, were removed from the trip dataset. The SEMCOG model has a separate procedure for external trips. As such, the main trip generation procedure only includes trips that begin and end within the region. External trips were identified using the same process developed for the E6 model update. The following external trips were removed:

   a. Trips with either an origin or destination TAZ of 9999, indicating an external TAZ.

   b. In-state trips that were missing TAZ information were flagged then examined to determine whether they should be included or not. More specifically, several in-state trip records with missing zip code (indicated by 99998 or 99999) were not used because their origin or destination cities were out of the area. This determination was made by finding the location of the city of record in Google Maps. Out-of-area cities include Oshawa, Maumee, Near Saginaw (sic), Alcona County, Coldwater, Alpine, Brutus, Mackinaw City and Petersburg.

The final Internal-to-Internal trip dataset contains a total of 53,712 unweighted observations and 16,543,996 weighted trips using the person-level expansion factors. **Table 4.2** shows the number of observations and weighted trips by purpose in the final dataset.

Particular attention was paid to definition of the HBSc trips during the survey analysis and expansion process. HBSc trips are identified as trips made between home and school by a student enrolled in a K-12 school, regardless of mode (e.g., school bus, walk, drive, or driven by parent). Trips made between home and a school to pick up or drop off a student are classified as HBO trips.

Table 4.2 Number of Observed and Expanded Internal Trips in Final Data Set

Trip By Purpose	Expanded Daily Internal-Internal Trips	Percent	Observed Internal-Internal Trip Records	Percent
Home Based Work	2,488,836	15%	8,200	15%
Home Based Other	6,074,825	37%	19,697	37%
Home Based Shop	1,718,236	10%	5,334	10%
Home Based School	1,235,208	7%	4,088	8%
Home Based University	242,315	1%	415	1%
Non-Home Based Work	1,358,531	8%	4,968	9%
Non-Home Based Other	3,426,047	21%	11,010	20%
Total	16,543,996		53,712	

Source: CS analysis of 2004/2005 household survey.

4.1.3 Area Type

The E7 model included updated area type definitions based on a re-evaluation performed by SEMCOG staff and further refined during the model update process. For purposes of trip generation analysis, area type was computed using a strict rule-based approach. As model development progressed, SEMCOG staff performed a manual smoothing process based on review of TAZ data, aerial photography, and local knowledge.

The rule-based area type density ranges are shown in **Table 4.3**. The rules were tested both at the TAZ and at a district level. For Wayne and Washtenaw Counties, the district-based rules produced more reasonable result and were applied for the E7 model. The TAZ-based rules provided more reasonable results and were applied for the remaining counties in the SEMCOG region. The Central Business District (CBD) area type was defined as shown in **Figure 4.1** based on knowledge of the central Detroit and Ann Arbor areas. Furthermore, within the City of Detroit, all zones were assigned an area type of urban, urban activity area, or CBD; suburban and rural area types were not used.

Table 4.3 Area Type Definitions

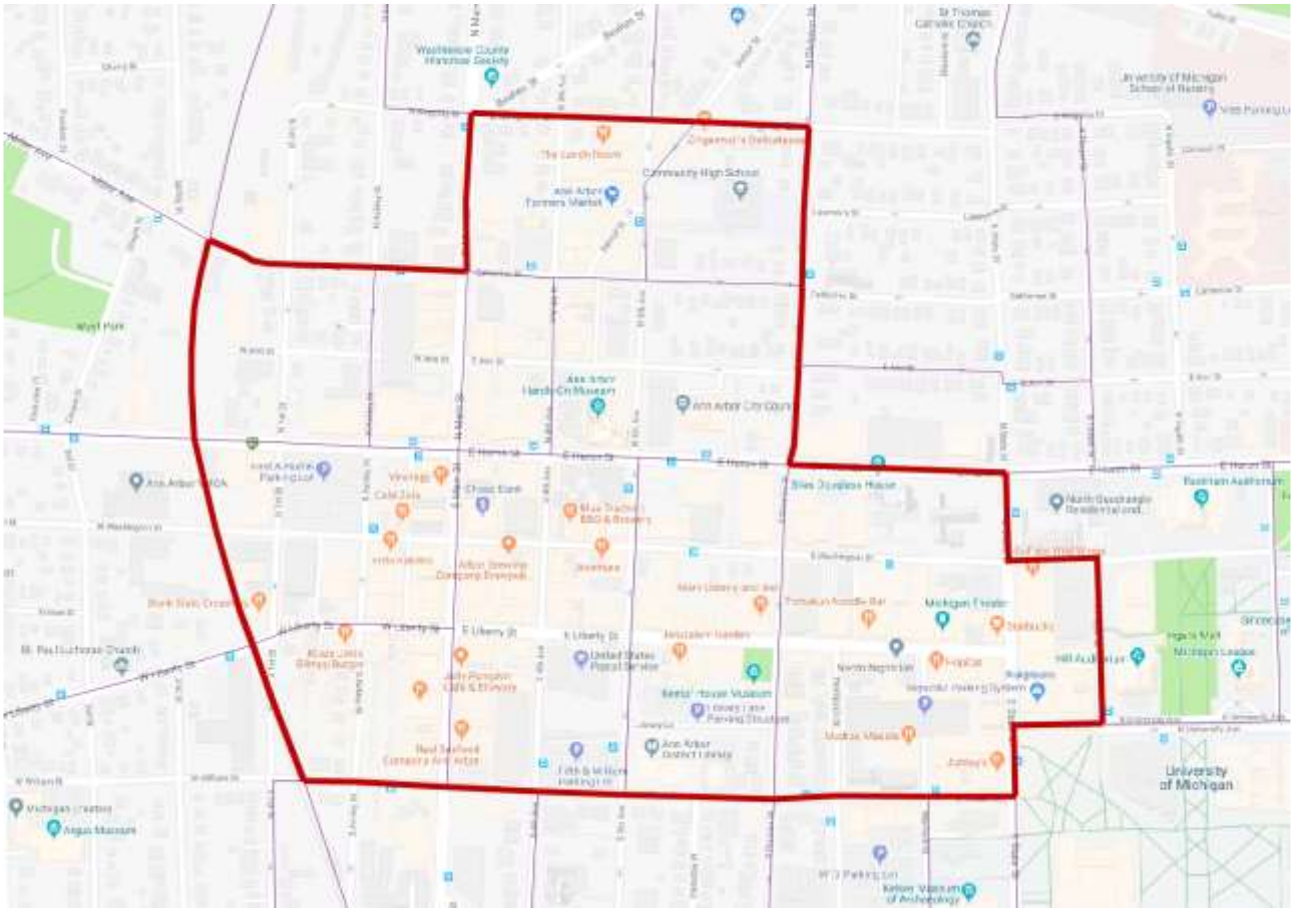
	District Based Rules		TAZ Based Rules	
Area Type	Minimum Density (inclusive)	Maximum Density	Minimum Density (inclusive)	Maximum Density
1 – CBD	Defined Manually		Defined Manually	
2 – Urban Economic Activity Area	5,000	∞	5,500	∞
3 – Urban	2,500	5,000	2,500	5,500
4 – Suburban	750	2,500	500	2,500
5 – Rural	0	750	0	500

Source: Area type analysis performed by SEMCOG staff.
Note: Density is calculated as the total population and employment per square mile.

Figure 4.1 Detroit CBD Area Type Definition

Source: SEMCOG staff.

Figure 4.2 Ann Arbor CBD Area Type Definition



Source: SEMCOG staff.

4.2 Production Rates

Trip production rates define the number of trips generated or "produced" by each household. In the case of home-based trips, both the number of trips generated and trip end locations are defined by the trip production rates. For non-home-based trips, the total number of trips generated are defined by household-based production rates. This allows the model to balance total non-home-based trips to households rather than employment. By definition, the production end of non-home-based trips are not located at the households where they are generated. Therefore, production trip-ends are allocated to zones based on a separate set of production allocation rates. Production allocation rates are estimated in a similar manner as attraction rates and are presented in **Section 4.3**.

For each trip purpose, the 2004/2005 combined household travel survey data were used to evaluate several potential cross-classification schemes. Individual variables were first reviewed to determine the most appropriate variables for each trip purpose. Prepared effects plots (included in **Appendix D**) were reviewed to further evaluate variable pairs that appeared to be relevant. The effects plots demonstrated the impact of one variable while controlling for the effects of another. The selected cross classification schemes represent the most statistically significant variable pair for each trip purpose. The following variable pairs were evaluated for significance:

- Household size by number of autos;
- Household size by income;
- Household size by number of children;
- Household workers by income;
- Household workers by number of autos;

An effects plot was also prepared for each trip purpose to evaluate the significance of area type while controlling for the two selected cross classification variables. In all cases, the resulting plots demonstrated that area type was not a significant contributor to trip production rates.

Review of the 2004/2005 combined household travel survey data for reasonable patterns combined with effects plots shown in **Appendix D** resulted in grouping of categories. Grouped categories (shown using a thicker orange table border) and resulting trip rates from the 2004/2005 data are shown in **Appendix D**. Subsequent to the analysis of the 2004/2005 data, 2015 household travel survey data became available. In order to make use of the 2004/2005 data analysis but, at the same time, use the most up-to-data travel survey data available, the 2015 travel survey data were aggregated by the same groups. The resulting cross-classified trip production rates based on the 2015 travel survey data are shown in **Table 4.4** through **Table 4.9**, with the overall rows and columns showing the effective trip rates given the household distributions.

The variable showing the strongest correlation to HBW trips per household is number of workers. Household income was found to be a better cross-classification variable than vehicles. Only a very small amount of work trips were generated by zero-worker households, as expected. Work trips from zero-worker households could be retirees doing volunteer work, for example. The lowest income households have a different trip rate than the other incomes, which are constrained to be the same. Households with an income less than $30,000 may consist of more part-time than full-time workers so the average daily work trips would be fewer, particularly for 3+ worker households.

Table 4.4 Home Based Work (HBW) Trip Production Rates

Household Income	0 Worker	1 Worker	2 Worker	3+ Worker	Overall
0-30K	0.08	1.06	2.39	2.94	**0.64**
30k-60k	0.08	1.29	2.39	3.96	**1.20**
60k-100k	0.08	1.29	2.39	3.96	**1.52**
100k+	0.08	1.29	2.39	3.96	**2.10**
Overall	**0.08**	**1.25**	**2.39**	**3.90**	1.49

Source: CS analysis of 2015 household survey data.

Of all the household attributes, the number of school age children should have the strongest correlation to home based school (HBSc) trip rates and the correlation should be positive. Household vehicles and income were not found to have significant and/or reasonable correlations to the HBSc trips per household. **Table 4.5** shows the HBSc trip rates by number of school age children and household size, although the rates are grouped across all household size categories. It is expected that children would make a similar number of school trips, no matter the size of the household.

Table 4.5 Home Based School (HBSc) Trip Production Rates

Children	2 person	3 person	4 person	5+ person	Overall
1 Child	1.00	1.00	1.00	1.00	**1.00**
2 Children	-	2.31	2.31	2.31	**2.31**
3+ Children	-	-	3.36	3.36	**3.36**
Overall	**0.08**	**0.66**	**1.73**	**2.73**	**0.58**

Source: CS analysis of 2015 household survey data.

Note: Children are defined as household members 5 to 17 years old. The average rates in the "Overall" row include households with no children, which are assumed not to generate Home Based School trips.

Home based shop (HBSh) had a strong correlation to income as well as household size. This is reasonable because larger households are expected to have greater needs to make shopping trips, as well as more people available to make such trips (such as joint travel of children with parents). However, there is not a monotonic increase in home based shop trips with household size since it is also possible for one household member to perform shopping tasks for the entire household.

The E6 model used household vehicles instead of income as the cross-classification variable for HBSh. The analysis based on the 2004/2005 data, shown in **Appendix D**, found that income showed a more consistent trend and that only the highest vehicle category (3+) had a significant difference in HBSh trip rates when household size was controlled. Analysis of the 2015 household survey data summarized to the same groups determined using the 2004/2005 combined household data confirmed that income had a strong impact on home based shop trips. However, the relationships were quite different. Specifically, home based shop trips had a tendency to decrease with increasing income as higher income households started substituting travel for other trip purposes such as home based other and non-home based other for home based shopping trips. The tendency to decrease home based shopping trips with increasing incomes might also reflect the ability for higher income households to stock up on goods and a growing propensity to substitute internet shopping for visits to actual brick and mortar stores. Based on these findings, the home based shop rates by the detailed household size and income categories were reanalyzed and regrouped as shown in **Table 4.6** to reflect the updated household size and income related trends.

Table 4.6 Home Based Shop (HBSh) Trip Production Rates

Household Income	1 person	2 person	3 person	4 person	5+ person	Overall
0-30K	0.74	1.07	1.48	1.48	2.03	**1.02**
30k-60k	0.61	1.07	1.07	1.07	2.03	**0.94**
60k-100k	0.39	0.98	0.98	0.98	0.98	**0.78**
100k+	0.39	0.73	0.73	0.73	0.98	**0.71**
Overall	**0.58**	**0.91**	**0.94**	**0.91**	**1.31**	**0.84**

Source: CS analysis of 2015 household survey data.

Home based other (HBO) trip productions are well correlated to household size. Unlike shopping trips, HBO includes trip purposes that cannot necessarily be served by a single member of the household, e.g. one person cannot go out to eat for the entire family. Therefore, each additional person increases the household HBO trip production rate. Income also affects HBO trip productions. However, as with home based shop trips, analysis of the 2015 data showed different trends with increasing income by household size than were shown by the 2004/2005 combined household survey data. For one, two, and three person households, home based other trip rates tended to decrease with increasing income possibly due to increasing levels of trip chaining producing more non-home based travel. For four or more person households, home based other trip rates for the highest income group were significantly higher than those for the lowest three income groups.

Table 4.7 Home Based Other (HBO) Trip Production Rates

Household Income	1 person	2 person	3 person	4 person	5+ person	Overall
0-30K	1.69	2.90	4.67	5.33	8.26	**2.88**
30k-60k	1.60	2.90	4.67	5.33	8.26	**3.17**
60k-100k	1.50	2.90	3.70	5.33	8.26	**3.07**
100k+	1.29	2.38	3.70	6.35	9.01	**4.09**
Overall	**1.56**	**2.68**	**4.00**	**5.93**	**8.69**	**3.44**

Source: CS analysis of 2015 household survey data.

NHBW productions are most strongly correlated to the number of workers in the household. Household income and vehicles were both tested and household vehicles were found to have a more reasonable correlation to NHBW productions. Workers from households with vehicles are more likely to use a vehicle to get to work and thus are more mobile throughout the day. Households with vehicles are also more likely to practice trip-chaining, making intermediate stops between home and work. These chained trips are represented as a combination of individual trips such as NHBW and HBO trips.

Table 4.8 Non-Home Based Work (NHBW) Trip Production Rates

Household Vehicles	0 Worker	1 Worker	2 Worker	3+ Worker	Overall
0 Vehicles	0.02	0.54	1.47	2.15	**0.26**
1 Vehicle	0.04	0.97	1.47	2.15	**0.70**
2 Vehicles	0.04	0.97	1.60	2.15	**1.18**
3 Vehicles	0.19	0.97	1.60	2.15	**1.48**
Overall	**0.05**	**0.94**	**1.59**	**2.15**	**0.99**

Source: CS analysis of 2015 household survey data.

The NHBO production rates are similar to the NHBW with household size as the base classification variable instead of household workers. The production rates do not show the distinction between zero vehicle households and households with vehicles, except for one person households. The primary determinant of non-home based other trip rates is the household size.

Table 4.9 Non-Home Based Other (NHBO) Trip Production Rates

Household Income	1 person	2 person	3 person	4 person	5+ person	Overall
0 Vehicles	0.92	1.79	1.92	2.73	3.91	**1.38**
1 Vehicle	1.38	1.79	1.92	2.73	3.91	**1.67**
2 Vehicles	1.38	1.79	1.92	2.73	3.91	**2.16**
3 Vehicles	1.38	1.79	1.92	2.73	3.91	**2.30**
Overall	**1.29**	**1.79**	**1.92**	**2.73**	**3.91**	**1.95**

Source: CS analysis of 2015 household survey data.

4.2.1 Trip Production Rate Adjustment Factors for Final Model

During the model validation, it was determined that trip rates had to be increased to reproduce observed vehicle-miles of travel (VMT) in the SEMCOG region for 2015. These types of trip rate adjustments are common in model validations due to underreporting of trips in travel surveys. GPS surveys have shown that regular daily trips such as HBW trips are more reliably reported than occasional trips such as HBO and NHB trips. Therefore, the trip rate adjustments vary in magnitude by trip purpose. In addition to adjusting trip rates, some adjustments were made to the destination choice model parameters and mode choice model parameters to ensure that average trip lengths and mode shares matched observed targets. The adjustment factors for each trip purpose were, thus, developed in an iterative fashion and reviewed with SEMCOG staff. The trip rate adjustment factors by purpose were factored are shown in **Table 4.10**. Trip rates for all strata for each purpose were factored. For example, trip rates for each of the 16 income group by number of workers in the household strata in the home based work model were factored by 1.07.

Table 4.10 Final Trip Production Rate Factors for Validated E7 Model

Trip By Purpose	Trip Rate Adjustment Factor
Home Based Work	1.07
Home Based School	1.07
Home Based Shop	1.12
Home Based Other	1.12
Non-Home Based Work	1.17
Non-Home Based Other	1.17

Source: CS analysis from overall E7 model validation.

4.3 Attraction Rates

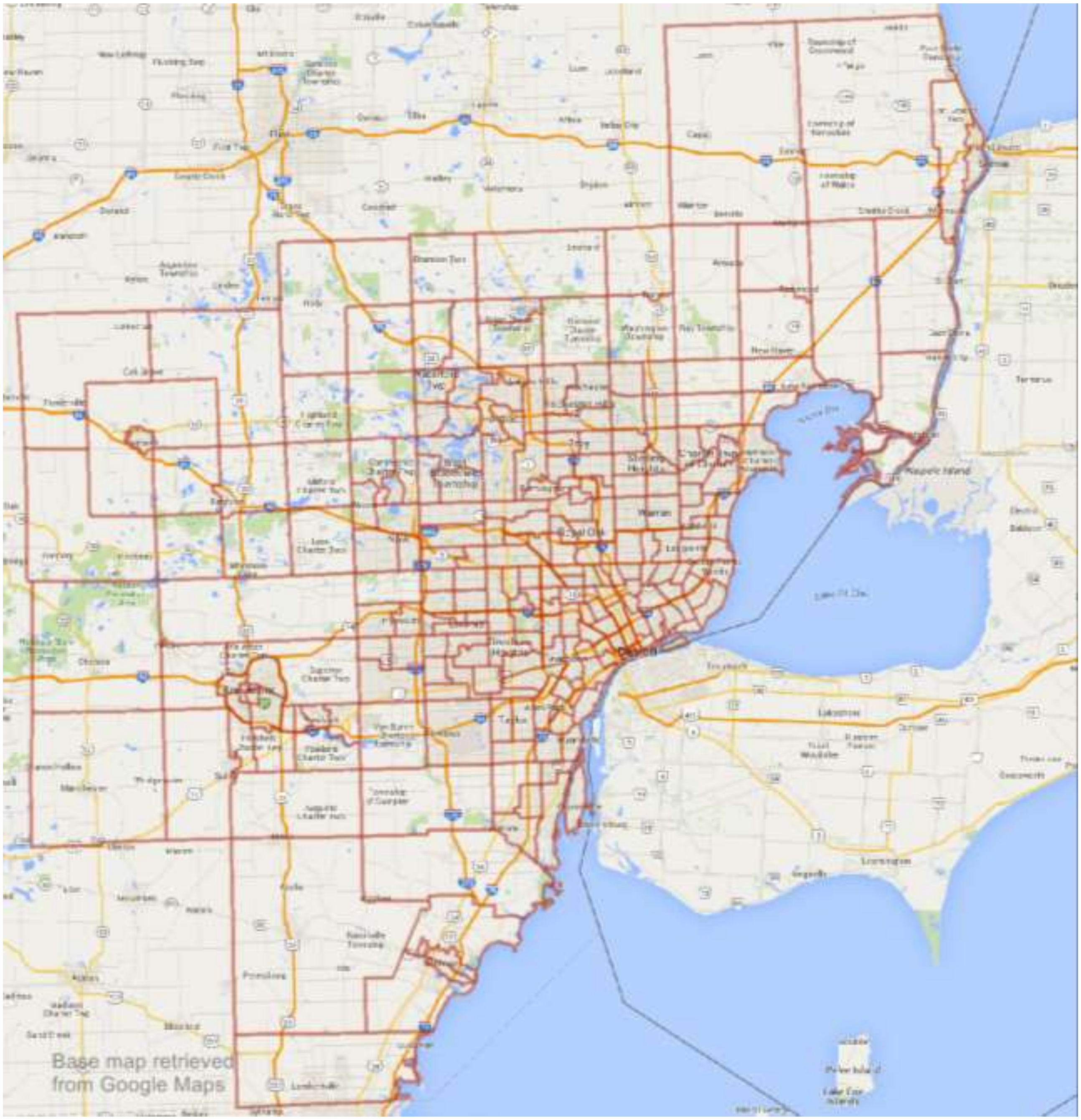
Trip attraction rates define the number of trips generated or “attracted” to locations outside of the home. For home-based trips, trip attractions represent the non-home end of each trip. For non-home based trips, trip attraction and production allocation rates define the locations where trip-ends occur, but the trip production rates define the total number of non-home based trips generated. Because the SEMCOG E7 model features a destination choice trip distribution model, trip attractions serve as a size variable input into the destination choice model rather than a distinct number of trip attractions.

The trip attraction model update uses the revised socioeconomic data (SED) from SEMCOG that is based on the Bureau of Economic Analysis Equivalent Job (BEA-EJ) data set. That dataset varies from the dataset used in the E6 model[7] in two important ways. First, the BEA-EJ dataset includes employment such as self-employment which was not covered by unemployment insurance programs, while the previous dataset does not. Second, the BEA-EJ dataset uses slightly different employment categories than the dataset used to support E6 SED development. However, the processed SED for the E7 model uses the same overall (aggregate) categories as the E6 model. As a result, trip attraction rates differed slightly from the rates estimated for the E6 model update.

The SED and correlations to trip attractions were analyzed at the district level. Analyzing data and estimating rates at the district level generally provides a better statistical fit than at the TAZ level due to the sparse nature of household survey data, along with geocoding issues that are very common at the attraction end. The TAZ level process also suffers from data expansion issues, even with relatively large household surveys. For example, suppose that neighboring TAZs both had 25 retail employees, a retail trip was captured being made to one of the TAZs in the travel survey, and finally, that the expansion factor for the surveyed trip was 250. One of the TAZs would have a home based shop trip attraction rate of 0 and the neighbor would have a trip attraction rate of 10. If the attraction model consisted of only one independent variable (e.g. retail employment), the overall average would not be affected. However, if there were two or more separate independent variables, such as home based other being attracted to say service employment, public administration employment, and households, the variation among zones might make it difficult to identify important variables in a regression-based model estimation due to the variation in TAZ level trip rates. For these reasons, a set of 251 districts, shown in **Figure 4.3**, was defined in the SEMCOG TAZ dataset and for use in attraction rate estimation. SEMCOG created these districts by combining zones that encompassed similar neighborhoods or types of activities. These districts were also used to define districts data purchased from StreetLight Data.

[7] The E6 model employment dataset is based on the Quarterly Census Employment and Wages (QCEW).

Figure 4.3 Districts Used in Regression Analysis



Source: CS Analysis of SEMCOG Zonal Data file and TransCAD geography files.

The SED categories that were found to be significant terms in the E6 model attraction rates were expected to continue to be significant with the BEA-EJ dataset. For each trip purpose, the correlation between trip attractions and each socioeconomic variable was first examined through the use of scatter plots (included in **Appendix E**). The SED categories examined included:

- Retail employment;
- Service employment, consisting of:

  - Information; financial activities; professional science & technical services; management of companies and enterprises; administrative support and waste services; health care and social assistance; leisure and hospitality; and other services;

- Public Administration;
- Education employment;
- Total employment;
- School enrollment; and
- Households.

The scatter plot analysis provided guidance in selection of significant variables for inclusion in a regression model for each individual trip purpose. A series of regression analyses for each trip purpose was then performed, beginning with the E6 model definitions but making modifications where exploratory analysis and statistical measures showed shortcomings.

To explore the possibility of an area type influence on trip attraction rates, regression analyses for the entire region and again for the subsets of districts with an area type of urban, urban economic activity area, or CBD were performed. While some variation between the regional and urban estimation results was noticeable, differences were generally small and did not justify segmentation of attraction rates by area type group.

For NHBW trips, a separate set of production allocation rates for the production end of such trips (the traveler's regular workplace) was estimated in addition to the attraction end of these trips. For NHBO trips, there was not a discernible distinction between the trip production (origin) and attraction (destination). Therefore, the NHBO trip rates function as both the trip attraction and production allocation rates. In model application, the NHBW and NHBO trip production totals are retained, but trip production locations are re-allocated based on production allocation rates.

Attraction and production allocation rates for all resulting models are shown along with regression statistics and a comparison of regression results by area type in **Appendix E**. As noted in **Section 4.2.1**, trip production rates were increased for the final model validation. **Table 4.11** shows the final trip attraction and production allocation rates after factoring to ensure that totals matched the validated trip totals by purpose. Factors applied to attraction rates are identical to those applied to production rates, defined in **Table 4.10**.

4.4 Trip Rate Reasonableness Checks

To evaluate the reasonableness of the trip rates presented above, Table 4.12 compares the overall trip rates after model validation to guidelines in the FHWA Model Validation and Reasonableness Checking Manual. As noted previously, raw trip rates resulting from household surveys are typically low and require increases in order to account for issues such as underreporting of travel by survey respondents and trips made by visitors to the region. After the adjustments to trip rates for the model validation, the resulting implied household trip rates for the SEMCOG region are very close to those noted in the manual.

Table 4.11 Trip Attraction and Production Allocation Rates

Trip Purpose	Employment					K-12 School Enrollment	Total Households
	Retail	Service	Public Admini-stration	Education	Total		
HBW	-	-	-	-	1.04	-	-
HBSc	-	-	-	-	-	1.77	-
HBSh	7.01	-	-	-	-	-	-
HBO	5.33	0.42	1.76	3.88	-	-	2.41
NHBW Attraction	2.32	0.49	0.83	1.14	-	-	0.18
NHBW Production Allocation	-	-	-	-	0.75	-	-
NHBO	7.74	-	0.51	2.17	-	-	0.98

Source: CS analysis of 2004/2005 household survey.

Table 4.12 Trip Rate Reasonableness Evaluation

	SEMCOG E7 Final Adjusted Trip Rates per Household	Reasonableness Manual Rates per Household	Percent Difference
HBW Trip Productions	1.59	1.54	3%
Total Home-Based Trip Productions	7.62	7.38	3%
Total Trip Productions	11.08	10.65	4%

Source: CS Analysis of 2004/2005 household survey data; FHWA Model Validation and Reasonableness Checking Manual, Second Edition, pp. 5-6, 5-10.

4.5 Employment and Worker Incomes

In preparation for trip distribution, it is necessary to assign an income group to home based work productions and attractions. Although the trip generation model is segmented by household income, the income of individual travelers is more important in trip distribution. Households in a particular income group may be made up of workers with varying income levels. For example, two high income parents and one low income teenager may comprise a high income household. The SEMCOG E6 model derived the worker-income relationship from the 2000 Census data, but this information is not available in the 2010 Census data. The SEMCOG E7 model obviates this step by converting from household income to worker earnings and employment by sector to employee earnings, as shown in **Figure 4.4**.

To develop the conversion factors, we used data from the ACS detailing worker earnings by household income (CTPP Table A103204) and employment earnings by sector (CTPP Table A202205). In application, HBW trip productions by worker income are assigned based on household income using the distribution shown in **Table 4.13**. The trip generation model applies this process directly to cross classification model results. For HBW attractions, employee income group is assigned based on a more detailed set of employment sectors present in the SEMCOG socioeconomic dataset. Employee income group by sector is listed in **Table 4.14**. The Census employment sectors are mapped to the BEA-EJ aggregate categories used in E7 as shown in **Table 4.15**.

Figure 4.4 Employment and Worker Income Process

Source: CS.

Table 4.13 Worker Income by Household Income

	Worker Income			
Household Income	< $30K	$30K-60K	$60K-100K	>$100K
< $30K	100%	-	-	-
$30K-60K	56%	44%	-	-
$60K-100K	35%	36%	29%	-
>$100K	23%	23%	29%	25%

Source: Census Transportation Planning Products Table A103204.

Table 4.14 Worker Income by Employment Sector

	Worker Income			
Employment Sector	< $30K	$30K-60K	$60K-100K	>$100K
Agriculture, forestry, fishing and hunting, and mining	59%	27%	12%	2%
Construction	37%	37%	20%	6%
Manufacturing	22%	30%	32%	16%
Wholesale trade	30%	36%	21%	13%
Retail trade	65%	23%	8%	4%
Transportation and warehousing, and utilities	30%	41%	23%	6%
Information	33%	33%	25%	9%
Finance, insurance, real estate and rental and leasing	33%	36%	19%	12%
Professional, scientific, management, administrative, and waste management services	36%	29%	21%	14%
Educational, health and social services	44%	32%	18%	6%
Arts, entertainment, recreation, accommodation and food services	80%	15%	4%	1%
Other services (except public administration)	62%	26%	9%	3%
Public administration	18%	38%	34%	9%
Armed forces	25%	45%	25%	6%

Source: Census Transportation Planning Products Table A202205.

Table 4.15 E7 Employment to ACS Employment Categories

E7 Employment Categories	ACS Employment Sector
Retail employment	Retail trade
Service employment	
Information	Information
Financial activities	Finance, insurance, real estate and rental and leasing
Professional science & technical services	Professional, scientific, management, administrative, and waste management services
Management of companies and enterprises	
Administrative support and waste services	
Health care and social assistance	Educational, health and social services
Leisure and hospitality	Arts, entertainment, recreation, accommodation and food services
Other services	Other services (except public administration)
Public Administration	Public Administration
Education employment	Educational, health and social services

Source: CS.

4.6 Home-Based University Trip Generation

The SEMCOG region is home to a number of colleges and universities. For the purpose of E7 model development, only universities with reported 2014 enrollment of at least 2,000 students have been considered. Trips to and from smaller universities are included in the non-university trip purposes and are addressed by the cross classification and regression models described previously. There are 29 college and university campuses in the SEMCOG region reporting enrollment of at least 2,000 students in 2014. These colleges and universities, listed in **Table 4.16**, have been separated into three tiers for further travel model analysis:

1. Tier 1: Large traditional university with enrollment of at least 20,000 students, significant on-campus housing, four-year undergraduate programs, and research and graduate programs;
2. Tier 2: Universities similar to Tier 1, but with smaller on-campus housing presence, higher share of non-traditional students, and a more regional focus; and
3. Tier 3: Institutions with enrollment of less than 20,000 students, including a combination of smaller public and private universities, as well as community colleges.

Based on a review of large universities in the region, only the University of Michigan was classified as a Tier 1 university for travel modeling purposes. This university has unique characteristics that suggest travel patterns significantly different from other universities in the region. Unique characteristics include a large share of students living on campus, a large multi-part campus connected by a university run transit system, and a student body consisting primarily of traditional undergraduate, graduate, and medical students.

Table 4.16 Colleges and Universities with at least 2,000 enrolled students

Tier	Name	City	2014/2015 Enrollment	2015 Group Quarters	2015 Off-Campus enrollment
1	University of Michigan (U of M) - Ann Arbor	Ann Arbor	43,625	10,342	33,283
2	Eastern Michigan University (EMU)	Ypsilanti	22,401	2,900	19,501
2	Oakland University	Auburn Hills	20,519	2,691	17,828
2	Wayne State University	Detroit	27,578	2,863	24,715
3	Lawrence Technical University	Southfield	4,015		
3	University of Detroit - Mercy	Detroit	4,945		
3	University of Michigan - Dearborn	Dearborn	13,790		
3	Henry Ford Community College	Dearborn	8,923		
3	WCCCD - Eastern	Detroit	4,136		
3	WCCCD - Downtown	Detroit	3,983		
3	WCCCD - Northwestern	Detroit	4,295		
3	WCCCD - Downriver	Taylor	2,459		
3	WCCCD - Western	Belleville	1,438		
3	Marygrove College	Detroit	1,774		
3	Schoolcraft College	Livonia	11,542		
3	Madonna University	Livonia	3,947		
3	OCC - Royal Oak	Royal Oak	5,146		
3	OCC - Southfield	Southfield	2,551		
3	OCC- Orchard Ridge	Orchard Ridge	6,098		
3	OCC - Highland Lakes	Highland Lakes	3,893		
3	OCC - Auburn Hills	Auburn Hills	6,344		
3	Walsh College	Troy	2,753		
3	Macomb Community College - South Campus	Warren	11,458		
3	Macomb Community College - Central Campus	Clinton Township	11,456		
3	Washtenaw Community College	Ann Arbor	12,295		
3	Monroe County Community College	Monroe	3,482		
3	St. Clair County Community College	Port Huron	4,127		

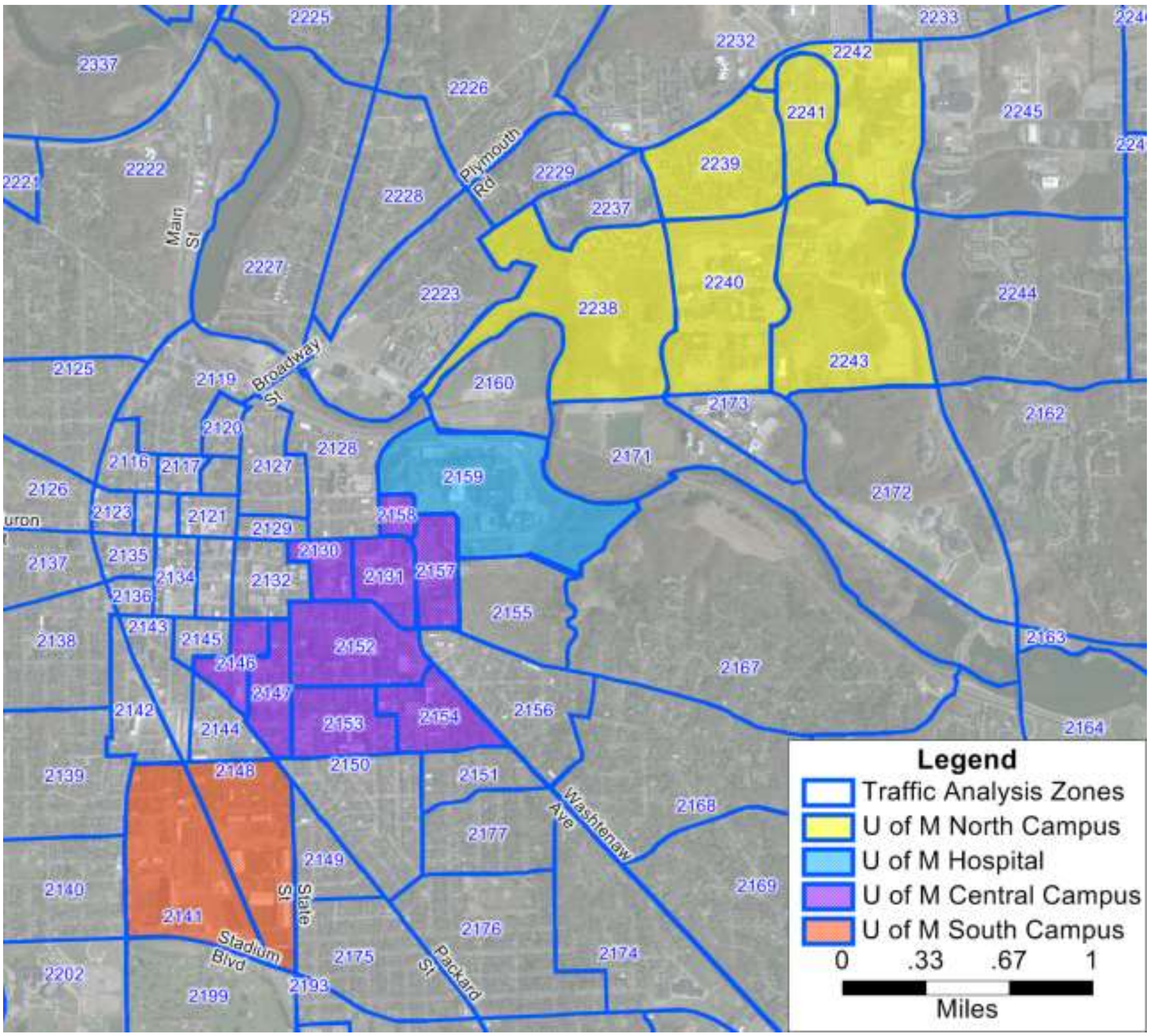
Source: Fall 2014 Data retrieved from http://nces.ed.gov/collegenavigator/, group quarters totals from the 2015 SEMCOG socioeconomic dataset and information provided by universities. WCCCD, OCC, and Macomb Community College totals were allocated to individual campuses based on E6 model distributions.

4.6.1 Tier 1 and 2 University Definitions

Most of the Tier 1 and 2 universities are well represented by a distinct set of TAZs, meaning that campus activities are consolidated within a set of zones and that these zones do not have significant non-university activities. While these universities may include some university buildings nearby their campuses in other zones, the majority of activity is located within a distinct set of traffic analysis zones. Because this outside activity is minimal, the E7 model assumes that all significant university activity occurs within the main campus zones. As shown in **Figure 4.5** through **Figure 4.8,** these universities range in size from 1 to 18 zones.

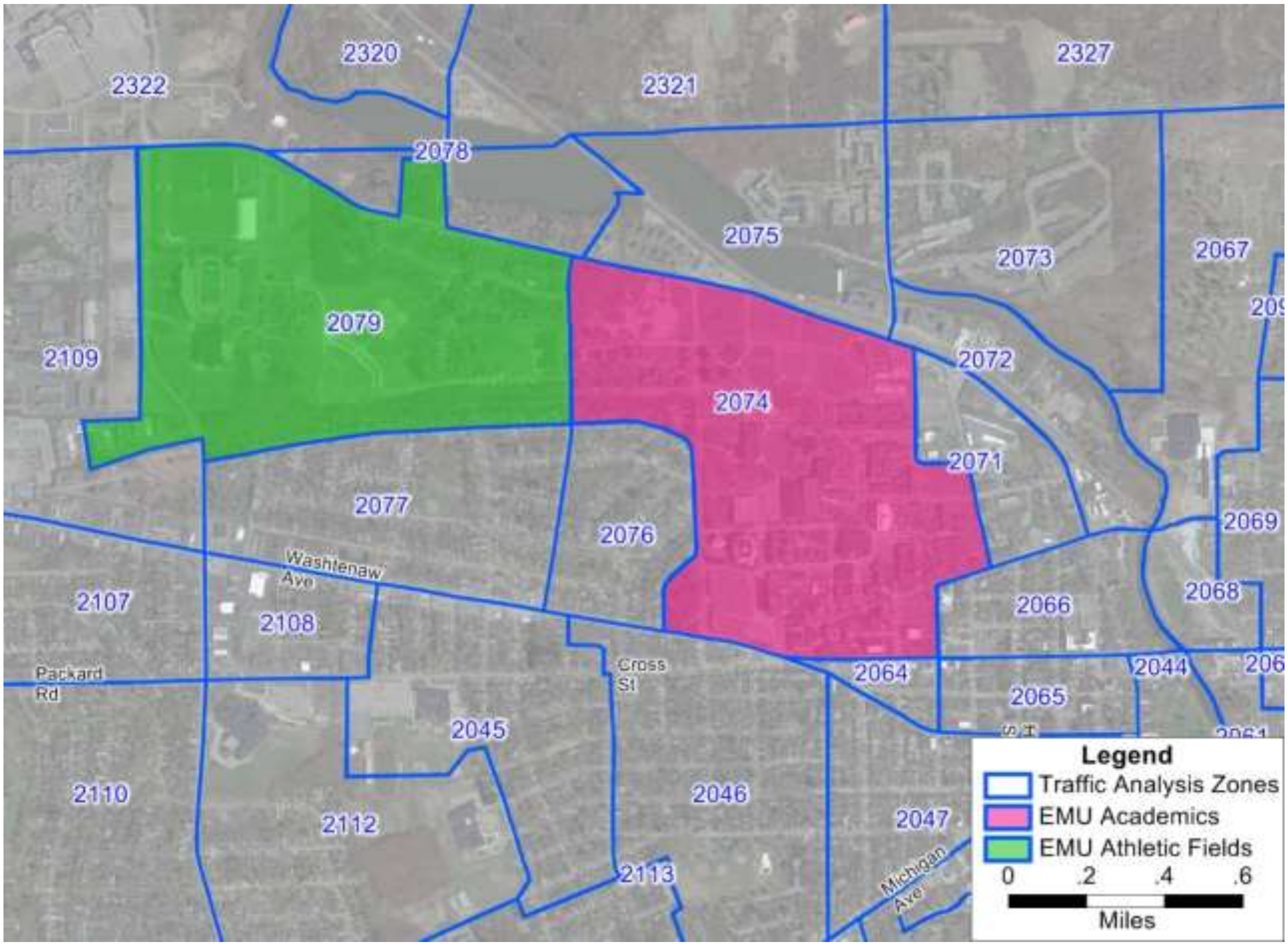
In addition to education and research activities, the U of M campus includes a university hospital. This hospital provides health services to the general public and acts more like a typical large hospital than a university zone. Therefore, the U of M Hospital was not included in analysis of university trips. Trips to this facility are addressed by the general trip attraction model.

Figure 4.5 University of Michigan Definition



Source: CS Analysis of SEMCOG Zonal Data file and TransCAD geography files.

Figure 4.6 Eastern Michigan University Definition

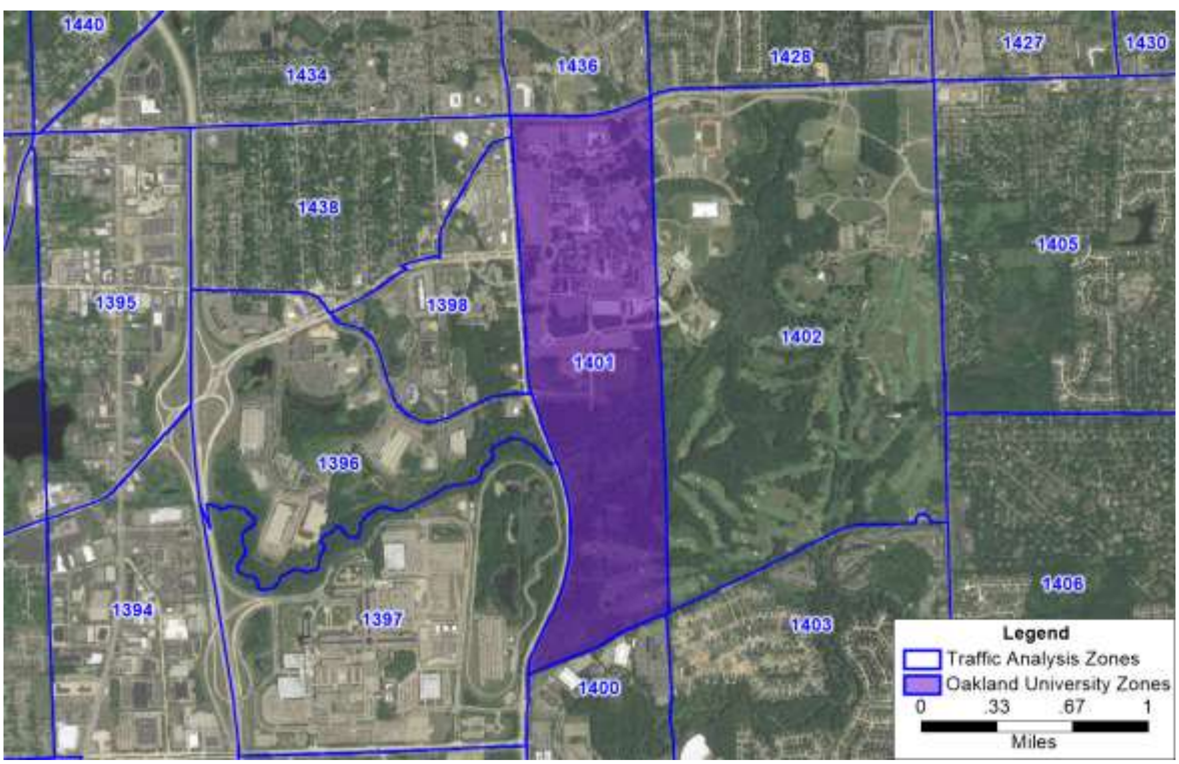


Source: CS Analysis of SEMCOG Zonal Data file and TransCAD geography files.

Figure 4.7 Wayne State University Definition

Source: CS Analysis of SEMCOG Zonal Data file and TransCAD geography files.

Figure 4.8 Oakland University Definition



Source: CS Analysis of SEMCOG Zonal Data file and TransCAD geography files.

4.6.2 University Trip Purposes

Because universities do not fall into the normal trip patterns used by the regional model, some special considerations are given to trip purposes at universities. In particular, the HBU trip purpose is defined as a trip by a university student or visitor between home and any location on the university campus. For Tier 3 universities, HBU attractions are modeled at the university, while all other trips to and from Tier 3 universities are represented by the trip rates applied to the region as a whole.

For Tier 1 and 2 universities, trip ends at the university are explicitly modeled based on university faculty and staff, students living on campus, and students and visitors living off campus. Trips are modeled for Tier 1 and 2 universities as follows:

- **HBW, HBSh, and HBO Productions:** These production trip ends can occur only for students living on campus. On-campus students can make home-based trips with an attraction at any non-university zone in the region.
- **HBW Attractions and NHBW Productions:** These trip ends can occur only for University faculty and staff. University trip-ends are matched to non-university trip-ends resulting from the general trip generation model.
- **NHBW Attractions and all NHBO Trips:** These trip ends can only occur for students living off campus, as well as university visitors who live off campus but do not attend the university.
- **HBSh and HBO Attractions:** These trip ends cannot occur at the University. All home-based trips to the University by students and visitors are considered HBU trips and all home-based trips to the University by faculty and staff are considered HBW trips.
- **HBU Productions:** Trips within Tier 2 universities are not modeled, so HBU productions cannot occur on campus. Intra-university trips are modeled in a separate process for the University of Michigan.
- **HBU Attractions:** HBU attractions can occur only for students living off campus, as well as university visitors who live off campus but do not attend the university.

4.6.3 University Trip Rates

The 2004/2005 household survey included a small number of HBU trip observations, broken down by university tier as shown in **Table 4.17**. For Tier 1 and 2 universities, the Washtenaw Area Transportation Study (WATS) Travel Demand Model[8] provides a more complete dataset on which to base a university trip model. This model utilizes trip rates borrowed from a pair of university special generator surveys[9] and has been validated at a local level for both U of M and EMU. The WATS model does not include a special trip

[8] WATS Travel Demand Model Improvements, Technical Memorandum #9 – Trip Generation.

[9] 1999 Colorado State University Special Generator Study, City of Fort Collins, CO; 2004 University of Northern Colorado Special Generator study, North Front Range MPO.

purpose for Tier 3 universities, so trip rates for these universities are based on analysis of the household survey.

Table 4.17 HBU Trip Observations from the Household Survey

University Tier	Unexpanded Trips	Expanded Trips
Tier 1	67	48,396
Tier 2	138	98,651
Tier 3	210	95,269
All Universities	415	242,316

Source: CS analysis of 2004/2005 household travel survey using person expansion factors.

Tier 1 and 2 University Trip Rates

Tier 1 and 2 universities generate HBU attractions based on off-campus student enrollment, as well as home-based trip productions based on on-campus students. Table 4.18 lists trip rates borrowed from the WATS travel model and applied in the SEMCOG E7 model. At these universities, university trip-ends associated with university workers (HBW attractions and NHBW productions) are retained from the general trip production and attraction models. Conversely, trip purposes that are not modeled at universities are set to zero. The remaining trip purposes, which are associated with university students, are generated using the trip rates shown in **Table 4.18**.

Table 4.18 Tier 1 and 2 University Related Trip Rates

Trip Purpose	Production Rate	Production Unit	Attraction Rate	Attraction Unit
HBW	0.22	On Campus Students	Use general model	n/a
HBSc	Set to zero	n/a	Set to zero	n/a
HBU	Set to zero	n/a	3.8	Off Campus Students
HBSh	0.20	On Campus Students	Set to zero	n/a
HBO	0.50	On Campus Students	Set to zero	n/a
NHBW	Use general model	n/a	0.19	Off Campus Student
NHBO	0.25	Off Campus Student	0.25	Off Campus Student

Source: WATS Travel Demand Model.

Tier 3 University Related Trip Rates

Tier 3 schools tend to have a large population of non-traditional and part time students, as well as a less geographically concentrated student base. For these reasons, trip rates are expected to be lower than at Tier 1 and 2 universities. An analysis of 2004/2005 household survey data does indicate that Tier 3 university trips occur at a lower rate per off-campus student. Due to the lack of an alternate source, HBU attraction rates for Tier 3 HBU trips are based directly on the expanded household survey results. Results of the HBU trip rates, shown in **Table 4.19**, are added to results of the regional trip generation model.

Table 4.19 Tier 3 HBU Attraction Rates

Expanded Trips	Enrollment	Trip Rate (Per student)
95,296	144,548	0.659

Source: CS analysis of household travel survey using person expansion factors; university enrollment data.

U of M Zone Allocation

The University of Michigan in Ann Arbor is made up of 3 distinct campuses and 17 different zones (excluding the hospital). It is necessary to allocate the productions and attractions generated at U of M to each of these zones based on placement of facilities such as classroom buildings, dorms, and research facilities. WATS has worked with the university to identify such facilities and apportion trip activity among the different campuses as shown in **Table 4.20**, and among the different zones within each campus as shown in **Table 4.21**. The SEMCOG E7 adopts this same allocation of university trip-ends within the University of Michigan.

Table 4.20 U of M Campus-Level Trip Allocation

Campus	Home-Based Productions	Staff / Faculty Attractions	Student/Visitor Attractions
North Campus	30%	24%	27%
Central Campus	65%	60%	68%
South Campus	5%	16%	5%
Total	100%	100%	100%

Source: WATS Regional Travel Model.

Table 4.21 U of M TAZ-Level Trip Allocation

Campus	TAZ ID	Home-Based Productions	Staff / Faculty Attractions	Student/Visitor Attractions
North Campus	2237	5%	0%	0%
	2238	15%	0%	0%
	2239	50%	0%	0%
	2240	0%	75%	75%
	2241	10%	0%	0%
	2242	5%	5%	5%
	2243	0%	15%	15%
	2244	15%	0%	0%
	2245	0%	5%	5%
Central Campus	2130	0%	3%	5%
	2131	0%	25%	25%
	2146	0%	2%	0%
	2147	45%	5%	5%
	2152	0%	30%	30%
	2153	30%	25%	25%
	2154	0%	2%	0%
	2157	25%	3%	5%
	2158	0%	5%	5%
South Campus	2141	0%	80%	80%
	2148	100%	100%	100%

Source: WATS Regional Travel Model.

Tier 2 University Trip Allocation

The Tier 2 universities each consist of only one or two zones. Trip-end allocations for each TAZ at Tier 2 universities are shown in **Table 4.22**. For EMU, trip-end allocations were obtained directly from the WATS model. EMU zone 2079 only includes athletic facilities, so all daily trip generation is assumed to occur at the main campus zone. Allocations for Wayne State University are based on a review of dorms, academic facilities (e.g., libraries, department, and classroom buildings), and administrative buildings.

Table 4.22 Tier 2 Trip Allocation

University	TAZ ID	Home-Based Productions	Staff / Faculty Attractions	Student/Visitor Attractions
Eastern Michigan University	2074	100%	100%	100%
	2079	-	-	-
Oakland University	1401	100%	100%	100%
Wayne State University	175	100%	70%	80%
	176	-	30%	20%

Source: WATS Regional Travel Model and CS Review of Wayne State Campus buildings.

HBU Trip Productions

The HBU trip purpose is controlled by university enrollment rather than regional or household population totals. HBU trip productions are also heavily influenced by proximity to a university, particularly for the Tier 1 and Tier 2 schools. To reflect these conditions, the model does not explicitly model HBU production rates. Instead, HBU productions are balanced to attractions and allocated based on a combination of household totals and proximity to the university. HBU trip production allocation models are documented in **Section 5.4**.

Intra-Campus Trips

The U of M campus is quite large, stretching approximately 4.5 miles from the northeast to southwest corner. Due to this large size, it is not appropriate to exclude trips within this university from the travel model. Many intra-university trips at U of M are made using motorized modes, requiring them to be modeled in order to adequately understand traffic and transit volumes in the vicinity. Furthermore, a considerable share of U of M transit system trips occur between different university zones.

The SEMCOG E7 model generates intra-campus trips for U of M based on the trip rates shown in Table 4.23. Intra-campus trips are then allocated to individual TAZs using the same shares applied to trips to and from campus. HBU productions are allocated based on the home-based production shares, while other intra-campus trips are allocated based on the student/visitor attraction shares.

Table 4.23 U of M Intra-Campus Trip Generation

Trip Purpose	Trip Rate	Unit
HBU Production / Attraction	3.8	On-Campus Students
NHBO Production / Attraction	3.0	Total Enrolled Students

Source: WATS Regional Travel Model.

The Tier 2 and 3 universities included in the SEMCOG model are represented by a maximum of two zones, and are sufficiently geographically compact that most intra-campus trips are made within a single zone or between two adjacent zones using non-motorized modes. It is therefore unnecessary to model intra-university trips for Tier 2 and 3 universities.

4.7 Vehicle Availability Estimation

SEMCOG's socioeconomic dataset includes information about household level vehicle availability produced using a land-use model embodied within UrbanSim. The land-use model does not have a behavioral vehicle availability model, but instead bases household vehicles on the sampled data with controls on other household attributes such as size and income.

An explicit choice-based vehicle availability model that considers accessibility gives greater control over the effect of household and area characteristics on the vehicles available in each household. The model described in this section is a household-based choice model applied using the disaggregate dataset of households generated by the land-use model currently maintained by SEMCOG coupled with accessibility information from the E7 model. The E7 model applies this model to simulate auto ownership for each household at the disaggregate level, and then aggregate the results into the cross-classified market segments required by the trip production model.

4.7.1 Alternatives and Variables

The choice alternatives are the same four auto-ownership segments contained in the E6 model, including zero, one, two, and three or more vehicle categories. The following variables were tested in development of the vehicle availability model:

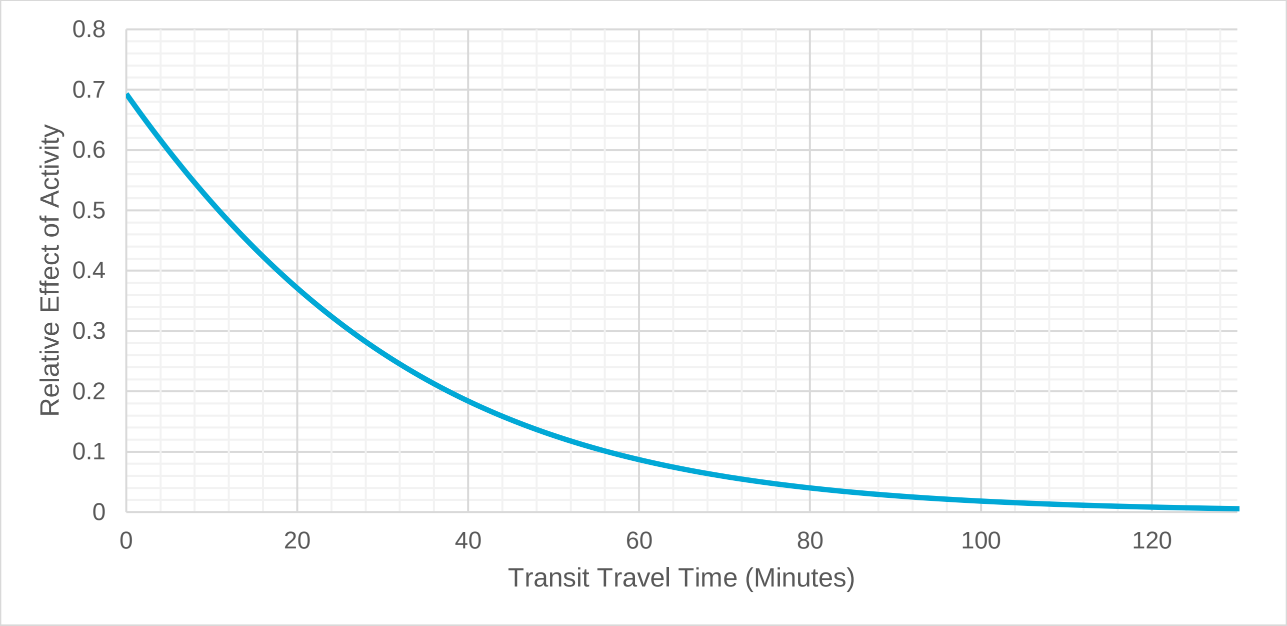
- Household Workers
- Household Drivers (age 16+)
- Household Income
- Household Workers by Income Level
- Household Drivers by Income Level
- Households with at least one senior (person 65 or older)
- Household that consists entirely of seniors (persons 65 or older)
- Household that consists entirely of older seniors (persons 75 or older)
- Transit Accessibility

Recently observed development patterns throughout the country have shown increases in the number of middle and high income households choosing to own fewer vehicles. Such households are often located in areas that feature dense mixed-use developments along with good accessibility to transit. Therefore, model formulations that included sensitivities to transit access were preferred to capture this trend in forecasts. The transit accessibility formulation applied in the auto availability model is shown below, where $AccFac_i$ is the accessibility factor for $zone\ i$, A_j represents the sum of households and employment in a $zone\ j$, T_{ij} represents the total transit travel time between $zones\ i$ and j, and α is a parameter set to 0.04.

$$AccFac_i = Ln\left(1 + \sum_{j=1}^{n} A_j \cdot e^{-\alpha T_{ij}}\right)$$

The resulting accessibility factor $AccFac_i$ for each $zone\ i$ represents the amount of regional activity within a reasonable distance on transit. As shown in **Figure 4.9**, the relative influence of household and employment based on distance from $zone\ i$ decreases as transit travel time increases.

Figure 4.9 Relative Influence of Accessible TAZs



Source: CS.

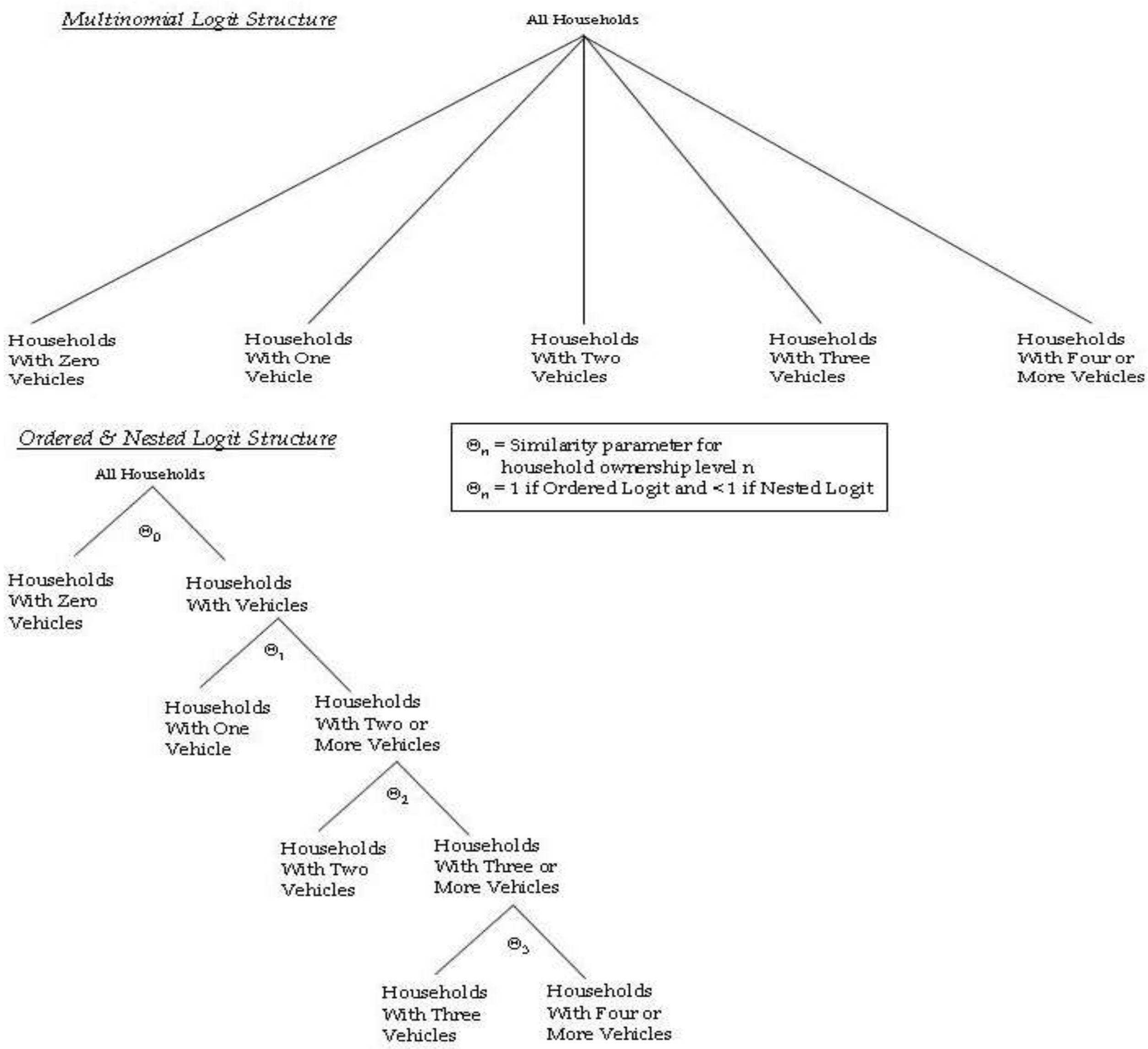
Another important trend in the SEMCOG region is the increasing share of households with seniors. Currently, more than 20 percent of households in the region are entirely composed of persons 65 or older. As will be discussed below, the only model formulation that resulted in a reasonable coefficient for households with older members was for households consisting entirely of seniors 75 or older. This might represent an age where people are more likely to voluntarily give up driving.

4.7.2 Model Formulations

Three possible discrete choice model formulations or structures for vehicle availability models are typically considered: 1) the multinomial logit (MNL) model, 2) the ordered response logit (ORL) model, and 3) the nested logit (NL) model. The structural differences among these discrete choice model formulations are depicted in **Figure 4.10**. The first structure shows the simpler multinomial model approach. The second structure implies a sequential choice by households, first determining whether to have any vehicles at all, and then how many to have. This structure requires an ordered model approach. The ORL structure also assumes that the similarity between the two choices available at each level of the choice structure (as reflected in the theta coefficient) is equal. The NL structure also assumes a sequential choice process, but does not assume that the choices at each level of the structure are considered equally. Instead, the theta coefficients of this model structure can vary to provide the best model fit to the available data.

Experience in vehicle availability modeling shows that the ORL model usually provides a slightly better statistical fit than the MNL model. The NL structure generally shows no advantage. All three model structures were tested in development of the SEMCOG model and the ORL structure gave a better fit than the MNL model. The ORL model also supported including terms for seniors in the household, household income, and transit accessibility. The nest coefficients from the NL structure were not reasonable, so that model structure was not used.

Figure 4.10 Choice Structures Considered for the Vehicle Availability Model



Source: CS.

4.7.3 Estimation Results

The ORL model requires a single utility equation that is consistent for all possible choices, with the SEMCOG E7 utility function defined as follows:

U = *0.537 * HH Workers*

*+ 1.211 * HH Drivers*
*- 0.889 * HH Drivers & Income < $30K*
*+ 0.303 * HH Drivers & Income $60K-$100K*
*+ 0.429 * HH Drivers & Income > $100K*
*- 0.324 * HH 75 or older*
*- 0.085 * Transit Accessibility*

In the utility specification, a variable with a positive coefficient implies that increasing the variable increases the expected number of vehicles that the household would own. Therefore, households with more workers and/or drivers will have more vehicles. Conversely, the negative coefficients estimated for senior households and transit accessibility imply that senior households and households with good transit accessibility are likely to own fewer autos.

The effect of each household driver varies by income. This is represented in the model by interacting the number of drivers (HH Drivers) with a dummy variable that is equal to one when true. The overall effect of each household driver is calculated by combining the income-specific coefficients with the base coefficient. For example, households in the lowest income category have the smallest increase in vehicles per driver although it is still a positive effect (1.211 − 0.889 = 0.322). Households in the upper income categories have the highest expected increase in vehicles per driver (1.211 + 0.429 = 1.640).

The ordered response logit utility works relative to a set of theta values that are specified for $n - 1$ alternatives (i.e., $4 - 1 = 3$ alternatives in this case), with the zero-vehicle alternative held as the base. The theta values are constrained to have the same order as the alternatives, such that an increase in utility makes the larger alternatives more likely. The relative differences between the thetas reflect the share of each alternative. **Table 4.24** shows the theta values and the relative difference between any two successive theta values. These relative differences are added to the utility equation for each alternative. Therefore, as the availability of vehicles goes up from 1 to 3 or more, the utility decreases as it becomes less likely that a household will own a higher number of vehicles. In model calibration, the theta values can be adjusted as necessary to fit the aggregate vehicle shares, similarly to how an alternative specific constant is adjusted in a standard logit model.

The full model results and statistics are shown in **Table 4.25**.

Table 4.24 Vehicle Availability Theta Values

Alternative	Variable	Coefficients	Relative Difference
1 Vehicle	Theta 1	-1.29	n/a
2 V**eh**icles	Theta 2	1.88	3.17
3+ V**eh**icles	Theta 3	4.93	3.05

Source: CS and SEMCOG analysis of household travel survey.

Table 4.25 Vehicle Availability Model Estimation Results

Variable	Coefficient	t-stat
Theta 1: One vehicle	-1.293	-8.09
Theta 2: Two vehicles	1.879	11.00
Theta 3: Three or more vehicles	4.930	20.08
Household workers	0.537	7.19
Household members 16 and older	1.211	12.57
Household members 16 and older & Household Income < $30K	-0.889	-8.95
Household members 16 and older & Household Income $60K – $100K	0.303	5.73
Household members 16 and older & Household Income > $100K	0.429	7.07
Household consists entirely of seniors (75+)	-0.324	-2.51
Transit Accessibility	-0.085	-9.92
Observations	6,065	
Log Likelihood at Zero	-8,408	
Log Likelihood with Constants Only	-7,667	
Log Likelihood at Convergence	-5,434	
Rho Squared with respect to Zero	0.354	
Rho Squared with respect to Constants Only	0.291	

Source: CS and SEMCOG analysis of household travel survey.

4.8 Trips To/From External Stations

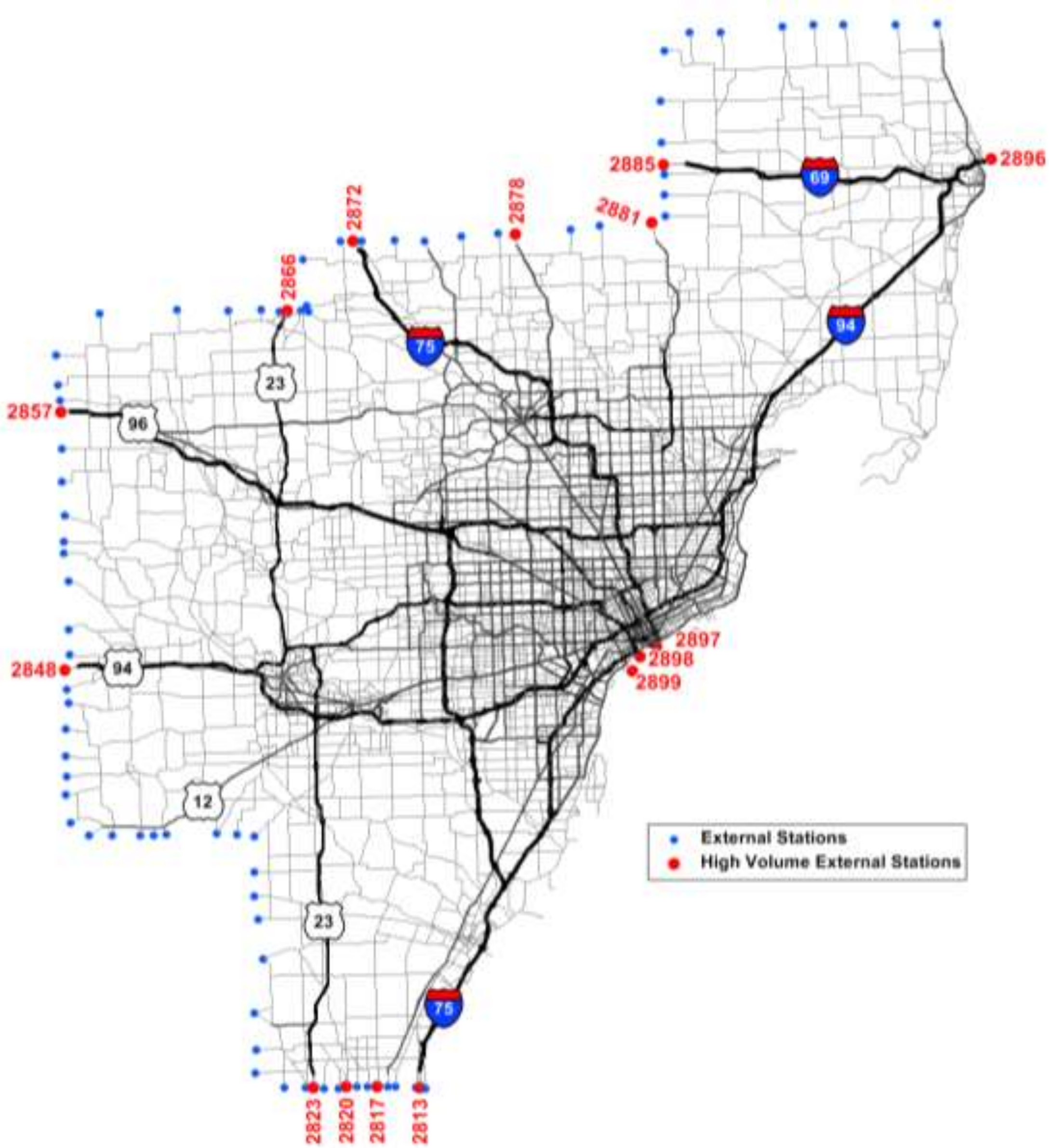
The external trip model is an integral part of the overall travel demand model and accounts for trips with at least one end outside of the region. These include internal to external (IE) trips, with a production end inside of the region, external to internal (EI) trips, with a production outside the region, and external to external (EE) trips that pass through the region. The external trip model is especially important for the SEMCOG region as it serves as a major gateway to Canada and is also located close to the city of Toledo, Ohio.

Five sources of data were used to develop the external trip model:

- Canadian border survey for Blue Water Bridge, Ambassador Bridge, and Detroit Windsor Tunnel external stations;
- The 2015 Michigan Statewide Household Travel Survey;
- The 2015 SEMCOG Household Travel Survey;
- StreetLight origin-destination data for the SEMCOG region; and
- External station traffic counts.

These sources of data were used in combination to understand external trip patterns and develop an external station model. The resulting model includes separate assumptions for personal vehicles and commercial vehicles. These external trips enter and leave the region at any of 88 external stations, shown in **Figure 4.11**. Because IE and EI trips are distributed along with person trips as part of the destination choice model, IE and EI vehicle trips have been factored by an average auto occupancy rate of 1.3, the average auto occupancy rate produced by the calibrated mode choice model.

Figure 4.11 SEMCOG Model External Stations



Source: CS and TransCAD geography files.

4.8.1 Total External Station Volumes

The first step in external model development was identification of traffic volumes at each external station. SEMCOG provided traffic counts for each of the external stations, with most locations segmented by vehicle class. Many of the count stations included counts by 13 FHWA vehicle classes while some included only three classes (passenger vehicles, single unit trucks, multiple-unit trucks). Most of the locations with only three classes were on freeways where MDOT count procedures precluded the collection of the 13 classes. At some locations, classification data was not available. For locations where vehicle classification data was unavailable, total volumes were split into three classes based on shares on nearby facilities with similar characteristics. The resulting volumes for high volume external stations are shown in **Table 4.26**. Values for all external stations are included in **Appendix G**.

Table 4.26 2015 Volumes at Major External Stations

Station ID	Station Name	Total Volume	Autos	Medium Trucks	Heavy Trucks
2813	I-75 S	64,315	38,511	2,122	23,682
2817	Lewis Ave	13,870	13,212	596	62
2820	Secor Rd	16,918	15,477	1,349	92
2823	US 23 S	58,191	43,687	1,789	12,715
2848	I-94 W	59,970	45,906	1,400	12,664
2857	I-96 W	57,551	50,341	1,590	5,620
2866	US-23 N	63,064	57,275	1,021	4,768
2872	I-75 N	50,454	46,992	1,069	2,392
2878	MI-24 N	18,423	16,743	1,375	305
2881	Earle Memorial Hwy	19,347	17,467	1,422	458
2885	I-69 W	14,169	10,076	294	3,800
2896	Blue Water Bridge	14,113	9,385	1,891	2,837
2897	Detroit Windsor Tunnel	12,314	12,227	28	59
2898	Ambassador Bridge	20,408	13,155	2,321	4,932
2899	Proposed Crossing	n/a	n/a	n/a	n/a

Source: CS analysis of SEMCOG count data.

4.8.2 Separation of IE/EI and EE Trips

The total number of vehicle trip-ends at each external station must be separated into total IE and EI trips, and EE trips. For external stations located along the Canadian border, the border survey was used to determine these shares as explained in more detail in the Canadian Border Survey section. For all other locations, StreetLight datasets were used for personal vehicles, medium trucks, and heavy trucks.

IE/EI and EE trip percentages were computed from an analysis of StreetLight GPS-based origin-destination data that included pass-through gates set up to capture external station activity. For selected high volume and state highway external stations, individual gates were set up to capture activity. Lower volume external stations were grouped together in order to obtain a large enough sample size. The share of through trips at each external station was calculated as the percent of trip-ends to and from each external station with a matching trip-end at another external station. These shares were applied to traffic count data to obtain total IE/EI and EE trip-ends at each external station. Through trip shares for each external station and group of external stations are shown in **Table 4.27**. Application of these factors to traffic counts for all external stations is shown in **Appendix G**.

Table 4.27 External-External Trip Shares at External Stations

Station ID	Station Name	Autos	Medium Trucks	Heavy Trucks
2812	Summit St	14%	19%	19%
2813	I-75 S	4%	26%	10%
2814 - 2822	(multiple)	4%	14%	27%
2823	US 23 S	18%	36%	42%
2824 - 2827	(multiple)	17%	23%	38%
2828	US 223 W	61%	61%	67%
2829 - 2835	(multiple)	17%	19%	39%
2836 - 2838	(multiple)	11%	28%	36%
2839 - 2847	(multiple)	9%	14%	39%
2848	I-94 W	3%	15%	9%
2849 - 2850	(multiple)	8%	7%	36%
2851	MI-52	13%	23%	25%
2852 - 2853	(multiple)	12%	10%	6%
2854	E MI-36	2%	14%	33%
2855 - 2856	(multiple)	7%	19%	10%
2857	I-96 W	5%	14%	21%
2858 - 2865	(multiple)	20%	13%	9%
2866	US-23 N	13%	16%	42%
2867 - 2871	(multiple)	43%	45%	52%
2872	I-75 N	45%	48%	51%
2873 - 2877	(multiple)	24%	9%	13%
2878	MI-24 N	4%	8%	13%
2879 - 2880	(multiple)	22%	27%	22%
2881	Earle Memorial Hwy	10%	12%	13%
2882 - 2884	(multiple)	19%	24%	32%
2885	I-69 W	29%	51%	34%
2886 – 2888	(multiple)	18%	25%	14%
2889 - 2894	(multiple)	21%	10%	22%
2895	Lakeshore Rd	5%	12%	34%
2896	Blue Water Bridge	40%	47%	31%
2897	Detroit Windsor Tunnel	14%	7%	19%
2898	Ambassador Bridge	23%	44%	34%
2899	Proposed Crossing	n/a	n/a	n/a

Source: CS analysis of StreetLight GPS Data.

The StreetLight data were also used to develop a base EE trip table. Once the number of through trips was calculated for each station, the EE trip tables were generated by applying an iterative proportional factoring (IPF) procedure to an initial through trip table generated from StreetLight data. This process was applied separately for autos, medium trucks, and heavy trucks.

StreetLight Data Reasonableness Checks

Initial attempts to generate through trip shares produced unintuitive results, especially for external stations near the Michigan/Ohio state line. In addition, issues related to income bias in the GPS dataset raised concerns about the reliability of the GPS-based StreetLight data for the purpose of separating IE and EI trips from EE trips.

To address concerns with EE trip shares for trucks, short convenience stops at truck stops were removed from the dataset and the through trip shares for trucks were recalculated.

As noted in Section 2.6, StreetLight Data provided a second dataset that makes use of location based services (LBS) data instead of GPS data. The LBS dataset had an increased sample size and a persistent device identifier, allowing for expansion based on approximate home locations. These characteristics reduced concerns about income bias. However, this data could not be processed using pass-through zones required to represent EE trips. This prevented the LBS dataset from being used directly in development of IE/EI shares and in creating a through trip seed matrix. Instead, the LBS data were processed using large external zones that approximate groups of external stations. The resulting dataset was useful in evaluating the reasonableness of GPS-based through trip patterns.

To evaluate the reasonableness of the GPS dataset in computing EE shares for autos, it was possible to use the LBS dataset to isolate trips between the area north of the SEMCOG region and the area to the south of the SEMCOG region. Such trips cannot be made without passing through the SEMCOG region. As shown in **Table 4.28**, the GPS data and LBS data produced similar results.

Table 4.28 Comparison of Data for IE/EI Trip Purpose Definition by Data Source

Dataset	IE/EI Trips	EE Trips	% EE Trips
GPS	77,965	941	1.2%
LBS	122,949	1,177	1.0%

Source: CS analysis of StreetLight GPS and LBS datasets.

IE and EI trips between SEMCOG and Canada

The 2015 Canadian border survey was used to develop the EE trip shares as well to estimate trip productions and attractions by trip purpose at the three border crossings. The 2015 border survey contained information on the trip origin, trip destination, trip origin purpose, and trip destination purpose, as well as an expansion factor based on traffic counts. As part of the analysis process, each record was assigned a trip purpose and the production end of the trip was identified. For the US trip end, a variable indicating whether it falls within the SEMCOG region was added to identify EE trips. The resulting trip shares by crossing, shown in **Table 4.29**, were used to develop EE trip shares discussed previously. In addition, the Canadian Border Survey was used to develop shares of IE and EI trips by purpose and direction as shown in **Table 4.30**.

Table 4.29 Canadian Border EE Trip Shares

Border Crossing	Origin	To SEMCOG	To Other Locations	Percent to/from SEMCOG	% Other
Ambassador Bridge	Canada	7,549	1,640	82%	18%
	USA	1,613	1,089	60%	40%
	Total	**9,162**	**2,729**	**77%**	**23%**
Detroit-Windsor Tunnel	Canada	6,785	747	90%	10%
	USA	3,434	966	78%	22%
	Total	**10,219**	**1,713**	**86%**	**14%**
Blue Water Bridge	Canada	4,233	1,962	68%	32%
	USA	1,532	1,959	44%	56%
	Total	**5,765**	**3,921**	**60%**	**40%**
Total		**25,146**	**8,363**	**75%**	**25%**

Source: CS Analysis of the Ministry of Transportation – Ontario (MTO) Cross-Border Survey.
Note: Through trip shares represent the total EE trips, including both passenger and commercial vehicles.

Table 4.30 Canadian Border Trip Productions and Attractions by Trip Purpose

Border Crossing	Trip Purpose	Productions (to SEMCOG)	Attractions (from SEMCOG)	Productions (Percent)	Attractions (Percent)	Purpose (Percent)
Blue Water Bridge	HBW	1,041	531	66%	34%	16%
	HBSH	1,872	70	96%	4%	20%
	HBO	2,597	2,456	51%	49%	52%
	NHBW	395	194	67%	33%	6%
	NHBO	290	238	55%	45%	5%
	Total	**6,195**	**3,491**	**64%**	**36%**	**100%**
Detroit-Windsor Tunnel	HBW	3,646	1,280	74%	26%	41%
	HBSH	831	93	90%	10%	8%
	HBO	2,533	2,561	50%	50%	43%
	NHBW	362	345	51%	49%	6%
	NHBO	159	122	57%	43%	2%
	Total	**7,532**	**4,400**	**63%**	**37%**	**100%**
Ambassador Bridge	HBW	5,549	641	90%	10%	52%
	HBSH	541	30	95%	5%	5%
	HBO	2,647	1,738	60%	40%	37%
	NHBW	307	104	75%	25%	3%
	NHBO	146	188	44%	56%	3%
	Total	**9,189**	**2,702**	**77%**	**23%**	**100%**

Source: CS Analysis of the Ministry of Transportation – Ontario (MTO) Cross-Border Survey.

IE and EI trips between SEMCOG and the rest of Michigan

The 2004 SEMCOG household travel survey was used to determine trip purposes of IE trips with productions in the SEMCOG region and attractions elsewhere Michigan (i.e. attractions at external stations).

The 2005 Michigan household survey was used to determine trip purposes of EI trips with productions in the state of Michigan but outside of the SEMCOG region, and IE trips attractions within the SEMCOG region (i.e. productions at external stations). Due to a common expansion methodology between the surveys, expanded Michigan travel survey trips were summarized together with the SEMCOG trips to produce the results shown in **Table 4.31**. Trip shares by purpose are assumed to be consistent for all external stations that are not located at a state or national border.

Table 4.31 IE and EI Trips and Purpose Shares for Michigan External Stations

Trip Purpose	Productions–EI (to SEMCOG)	Attractions–IE (from SEMCOG)	Productions (EI Percent)	Attractions (IE Percent)	Purpose (Percent)
HBW	103,821	42,289	71%	29%	34%
HBSH	12,664	6,683	65%	35%	5%
HBSC	12,328	6,432	66%	34%	4%
HBU	2,076	4,602	31%	69%	2%
HBO	82,334	66,229	55%	45%	35%
NHBW	26,271	10,681	71%	29%	9%
NHBO	34,313	18,977	64%	36%	12%
Total	**273,807**	**155,893**	**64%**	**36%**	**100%**

Source: CS Analysis of 2004 SEMCOG and 2005 MI Statewide Household Travel Surveys.

IE and EI Trips between SEMCOG and Ohio

IE trips produced in the SEMCOG region and attracted to destinations in Ohio were obtained from the 2004 SEMCOG household travel survey, using a procedure similar to that used to determine trip purpose shares for IE trips between SEMCOG and the rest of Michigan.

EI trips produced in Ohio and destined to the SEMCOG region were more difficult to obtain due to unavailability of an Ohio household survey. For home-based-work (HBW) trips, it was possible to use the Longitudinal Employment Household Dynamics (LEHD) dataset to inform the process. The LEHD dataset provides worker flows information that was used to compare the flow of home-based work trips from Ohio to the SEMCOG region and from the SEMCOG region to Ohio. The relative directional work flows were used to compute HBW EI trips by scaling the HBW IE trip totals computed using the SEMCOG household travel survey.

For the non-home-based-work (NHBW) purposes, the number of trips from Ohio to the SEMCOG region were calculated using a pivot analysis. This analysis included:

1. Factoring the NHBW SEMCOG to Ohio Trips by the ratio of Ohio HBW trips **to** SEMCOG by HBW trips **from** SEMCOG;

2. Apportioning the results based on the share of trip attractions by purpose from the SEMCOG household travel survey, relative to the HBW attraction share; and

3. Multiplying the results by the share of Michigan to Ohio trips that are HBW trips.

The resulting IE/EI trip productions and attractions between the SEMCOG region and Ohio by trip purpose are shown in **Table 4.32**.

Table 4.32 IE and EI Trips and Purpose Shares for Ohio External Stations

Trip Purpose	Productions–EI (to SEMCOG)	Attractions–IE (from SEMCOG)	Productions (EI Percent)	Attractions (IE Percent)	Purpose (Percent)
HBW	12,772	24,873	34%	66%	29%
HBSH	5,048	7,418	40%	60%	10%
HBSC	448	667	40%	60%	1%
HBU	7,850	1,868	81%	19%	8%
HBO	26,381	24,102	52%	48%	39%
NHBW	2,117	4,131	34%	66%	5%
NHBO	4,862	6,785	42%	58%	9%
Total	**59,479**	**69,845**	**46%**	**54%**	**100%**

Source: CS Analysis of the 2004 SEMCOG household travel survey and LEHD data.

4.8.3 Forecasts of Future EE, IE, and EI Trips

For future forecasts, auto, medium truck, and heavy truck crossings at external stations have been developed by SEMCOG. The information provided in **Table 4.27** was used to estimate the numbers of EE vehicle trips at each station. Those trips were subtracted from the total external station volumes to provide estimates of IE and EI vehicle trips at each station. The IE and EI vehicle trips by autos were factored by an average auto occupancy of 1.3 to estimate total IE and EI person trips. The shares of trips by purpose and by direction (IE or EI) provided in **Table** 4.30, **Table** 4.31, and **Table** 4.32 were then applied to estimate person trip productions (EI) and attractions (IE) at external stations. Medium and heavy truck trips at external stations were each assumed to split evenly between EI and IE. The estimates of person trip productions and attractions at external stations were used in conjunction with the internal-internal trips in subsequent model steps (i.e. external stations and person trips to and from the external stations were treated in the same manner as internal zones).

5.0 Destination Choice

The primary drivers behind the update to the trip distribution model were the use of Bureau of Economic Analysis Equivalent Job (BEA-EJ) data for zonal employment data, and some counter-intuitive sensitivities found with the E6 model distribution model results. The model update also took advantage of the improved 2004/2005 household survey expansion, described in **Section 2.1**. The trip distribution model update included a new modeling approach for home-based university trips.

5.1 Data Preparation

This section describes the data sources used for model estimation, trip purpose definitions from trip generation, trip mode choice structure and logsum calculations necessary for the destination choice model, trip attraction rates, and the preparation of the estimation dataset.

5.1.1 Data Sources

The inputs to the trip distribution model estimation process are the observed trips, socioeconomic data (destination zone density variables), modeled trip attractions, and network skim data (including interchange distances and mode choice model logsums). Application of the trip distribution model replaces observed trips used in model estimation with trip production results from the trip generation model (see **Section 4.0**).

Observed Trip Data

The SEMCOG E7 trip distribution model update was based on household and trip information from SEMCOG's official combined (MDOT and SEMCOG) survey dataset. This dataset contained data from the 2004/2005 SEMCOG household travel survey as well as data from an MDOT travel survey conducted during the same timeframe. The updated expansion factors, described in **Section 2.1**, were applied. The E7 model retained the trip purpose definitions present in the E6 model as documented in **Section 4.1.2**. Market segment information for trip makers (income group, vehicle ownership, and number of workers in each household) were also available from the survey.

Socioeconomic Data

Revised socioeconomic data (SED) were from the BEA-EJ data set. The data were used to calculate density variables in the alternative destination zones.

Network Skim Data

The network skim data inputs were from the AM peak period and midday period skims from the E6B_JG10 loaded networks. The AM period was chosen because destination choice is performed in production to attraction format, and the majority of peak period production to attraction trips occur in the AM period. Distance data from the shortest paths for the interchanges were used.

Mode Choice Logsums for Destination Choice

Since the destination choice model was estimated prior to the estimation of the E7 mode choice model, the E6 mode choice model was used to define the necessary input mode choice logsums. Logsums for HBW, HBO, and HBSh destination choice models were input for nine market segments based on the income and vehicle sufficiency markets shown in **Table 5.1**; no market segmentation was performed for the other trip purposes.

Table 5.1 Destination Choice Market Segmentation

<table>
<tr><th>Purpose</th><th>Income Markets</th><th>Vehicle Sufficiency Markets</th></tr>
<tr><td>Home Based Work</td><td rowspan="3">• Low
• Medium-Low
• Medium High & High</td><td rowspan="3">• 0-vehicle
• Vehicles < Workers
• Vehicles ≥ Workers</td></tr>
<tr><td>Home Based Other</td></tr>
<tr><td>Home Based Shop</td></tr>
<tr><td>Home Based School</td><td colspan="2">No Segmentation</td></tr>
<tr><td>Home Based University</td><td colspan="2">No Segmentation</td></tr>
<tr><td>Non-Home Based-Work</td><td colspan="2">No Segmentation</td></tr>
<tr><td>Non-Home Based-Other</td><td colspan="2">No Segmentation</td></tr>
</table>

Source: CS.

To calculate each mode choice logsum, the utility for each individual mode for an interchange is first computed using the mode choice model coefficients. If a mode is not available, the utility is set to a large negative value (e.g. -99)[10]. Next, the expected utilities of the lower nests are calculated by taking the log of the combined exponentiated utilities of each sub-mode within the nest and multiplying this value by the lower nest coefficient (θ_2) as shown in the following examples:

$$U_{sharedRide} = \theta_2 * \ln(\exp U_{sr2} + \exp U_{sr3})$$

$$U_{transit-walk} = \theta_2 * \ln\left(\exp U_{people\ mover} + \exp U_{all\ bus}\right)$$

The expected utility of the upper nests was calculated by taking the log of the combined exponentiated utilities of the lower nests and alternatives and multiplying this value by the upper nest coefficient (θ_1) as shown in the following examples:

$$U_{Auto} = \theta_1 * \ln\left(\exp U_{DriveAlone} + \exp U_{sharedRide} + \exp U_{auto-to-people\ mover}\right)$$

$$U_{Transit} = \theta_1 * \ln(\exp U_{transit-walk} + \exp U_{transit-PnR} + \exp U_{transit-KnR})$$

Finally, the mode choice logsum is calculated by taking the log of the combined exponentiated utilities of the upper level nests. Note that there is a nest coefficient for the root nest, but that it is constrained to 1.0.

$$Logsum = \ln(\exp U_{Auto} + \exp U_{Transit})$$

Note that the E6 mode choice model included only auto and transit as main modes. In application, the E7 mode choice model (see **Figure 6.1**) is used to create the logsums. While the E7 model includes non-motorized travel as a main mode, logsums for only the auto and transit modes are output for use in the destination choice model.

[10] Note that Streetcar, BRT, Urban Rail and Commuter Rail are all future modes and are thus not included in the logsum calculation for destination choice estimation.

Within the mode choice model, transit logsums are calculated by access-egress market for the following seven markets:

- Short walk access, short walk egress
- Short walk access, long walk egress
- Long walk access, short walk egress
- Long walk access, long walk egress
- Drive access, short walk egress
- Drive access, long walk egress
- No transit (i.e. drive access, drive egress)

Proportions of each interchange within the above access and egress markets are calculated based on the zonal data. For example, if 25 percent of an origin was within short access and 50 percent of a destination zone was within short egress, 12.5 percent of the interchange would be in the short walk access, short walk egress market. Drive access to transit is allowed from 100% of all zones.

Since destination choice is not modeled by access-egress market for each interchange, a weighted average of the exponentiated transit logsums for the seven access-egress markets is calculated used in the overall logsum for destination choice:

$$U_{Transit} = ln\left\{\sum\nolimits_{AE\ Mkt}[Share_{AE\ Mkt} \times exp(U_{AE\ Mkt})]\right\}$$

Attractions

While the model estimation was based on the 2004/2005 combined household survey data, the trip attractions by TAZ summarized from the survey data do not appropriately represent the attractiveness of the selected destinations in comparison to other, optional TAZ destinations. Thus, the zonal attractions used to represent the size (attractiveness) of each TAZ were determined using the trip attraction rates described in **Section 4.3**.

Estimation Dataset Assembly

The estimation dataset assembly began with the dataset prepared for the trip generation model development, as described in **Section 4.1**. The observed and expanded internal trips from the trip generation estimation (see **Table 4.2**) included trip observations for all modes. Next, the skim distances and mode choice logsums for every alternative (i.e. each TAZ in the region) were attached to survey data based on the trip production zone and household attributes. The skim distances and mode choice logsums were attached by trip purpose / market segment and time period (peak / off-peak). Some of the survey observations used in trip generation estimation did not have a known attraction zone and were removed from the estimation set. The set of observations with known trip ends is summarized in **Table 5.2**.

Table 5.2 Expanded Internal Trips with Known Trip Ends

Trip By Purpose	Expanded Daily Internal-Internal Trips	Expanded Daily Internal-Internal Trips with Usable Known Attraction TAZ	Percent Difference
Home Based Work	2,488,836	2,427,915	-2%
Home Based Other	6,074,825	5,945,710	-2%
Home Based Shop	1,718,236	1,694,705	-1%
Home Based School	1,235,208	1,219,192	-1%
Non-Home Based Work	1,358,531	1,341,443	-1%
Non-Home Based Other	3,426,047	3,335,107	-3%
Total	16,301,683	15,964,072	-2%

Source: CS analysis of 2004/2005 household survey.

The utility for each alternative in the destination choice model formulation consists of two main components: the alternative utility and the size function. The utilities are developed for all alternatives in the choice set for a production zone or, literally, all zones in the region. The alternative utility is defined by a sequence of terms that are linear in the parameters. The natural log of the size function term is added to the alternative utility to represent the attractiveness of a zone independent of the travel cost, distance, and time included in the alternative utility. Therefore, when the total utility is exponentiated, the size function effectively becomes a scaling parameter to the alternative probability. As demonstrated below, this implies that a zone with zero attractions and, thus, a zero size function will have zero utility, ensuring zero trips on the interchange[11]:

$$P(i) = \frac{\exp(\mathrm{V_i} + \ln(attractions_i))}{\sum_{j\epsilon N} \exp\,(V_j + \ln\,(attractions_j)} = \frac{attractions_i \times \exp\,(V_i)}{\sum_{j\epsilon N} \exp\,(V_j + \ln\,(attractions_j)} = 0\; where\; attractions_i = 0$$

As noted previously, the trip attractions estimated using the trip attraction rates documented in **Section 4.3** served as the size function in the destination choice model. For model estimation, observations from the survey that chose a zone with zero attractions (based on the trip attraction model) were not usable in model estimation and were removed from the dataset. The set of observations with non-zero attractions at the chosen zone is summarized by trip purpose in **Table 5.3**.

The largest change in expanded trips available for the destination choice model estimation was for home based school trips. Schools trips were particularly susceptible to a miscoding of the attraction trip end, resulting in a missing record in the estimation data set. For other trip purposes, similar miscoding could occur, but employment in adjacent zones was more likely. However, for schools trips, the likelihood of finding another school and concomitant school enrollment in an adjacent zone was less likely, therefore a small error in the geocoding would cause the trip to be unusable for destination choice estimation. However, there were still a substantial number of observations available for school trips so an intensive effort to correct these geocoding errors or issues in school records, for example private schools or home-schools, was deemed unnecessary.

The final trip distribution estimation set was dependent upon the market segment selected. For example, If the income segmentation from mode choice was used, records with unknown incomes needed to be

[11] Of course, ln(0) is undefined, so special implementation computer code is required to prevent errors in processing.

explicitly controlled for in the model or excluded. **Table 5.4** summarizes the expanded trips and observed trip records in the final estimation set.

Table 5.3 Expanded Internal Trips to Zones with Attractions

Trip By Purpose	Expanded Daily Internal-Internal Trips with Usable Known Attraction TAZ	Expanded Daily Internal-Internal Trips to Zones with Non-Zero Attractions	Percent Difference
Home Based Work	2,427,915	2,416,611	-0%
Home Based Other	5,945,710	5,944,653	-0%
Home Based Shop	1,694,705	1,644,097	-3%
Home Based School	1,219,192	978,733	-20%
Non-Home Based Work	1,341,443	1,339,772	-0%
Non-Home Based Other	3,335,107	3,327,376	-0%
Total	15,964,072	15,651,242	-2%

Source: CS analysis of 2004/2005 household survey.

Table 5.4 Final Internal Trip Distribution Estimation Set

Purpose	Income Group	Expanded Daily Internal-Internal Trips to Zones with Non-Zero Attractions	Observed Trip Records for Internal-Internal Trips to Zones with Non-Zero Attractions
Home Based Work	Low	232,393	336
	Other	1,886,096	6,786
	Unknown	298,122	830
Home Based Other	Low	1,093,889	1,610
	Other	4,224,399	15,624
	Unknown	626,364	1,830
Home Based Shop	Low	348,248	517
	Other	1,081,603	4,009
	Unknown	214,246	600
Home Based School	All	978,733	3,149
Non-Home Based Work	All	1,339,772	4,864
Non-Home Based Other	All	3,327,376	10,646
Total		15,651,242	50,801

Source: CS analysis of 2004/2005 household survey.

5.2 Model Formulation

5.2.1 Independent Variables

This section describes the independent variables tested as part of the destination choice model estimation and the acceptable sign and magnitude of each estimator.

Attractions

All destination choice model formulations were estimated with the mode choice logsum and attractions based on the appropriate trip and income market segment. The derivation of these variables is described in the previous section.

As described in the previous section, the natural log of the attractions were input to the exponentiated utility as the size function. The attractions coefficient was constrained to 1.0 in the estimation to have a consistent scale across estimation results and avoid unintended interactions between the attractions and other zonal terms in the utility, such as mixed-use density.

Logsums

The logsums represent travel time, cost, and the availability of different modes, including non-auto modes. Therefore, improvements in highway travel times or transit service could make the value of the mode choice logsum more positive. The logsum is calculated for each attraction alternative, that is, each possible destination zone, in the destination choice model.

The generally accepted range for logsum coefficients is between 0.2 and 1.0. Each model was initially estimated with a logsum coefficient constrained to 1.0. After testing other variables in the model, the logsum coefficient constraint was relaxed to test if a reasonable estimator (i.e. between 0.2 and 1.0) would result.

Piecewise linear distance

Non-linear distance formulations are common to capture the different sensitivity to a single unit (mile) change in distance between destinations that are close to the origin zone and those that are far away. For example, the utilities of two zones with the same attractions but a 1 mile different distance should be more similar if they are far away (say 99 and 100 miles) than if they are close (say 4 and 5 miles). A non-linear distance formulation is also convenient in calibration if the modeled trip length distribution does not reproduce the observed distribution. To represent this complex response, models have implemented distance with polynomial, natural log, and piecewise linear formulations.

The E6 model included a polynomial formulation that was partly responsible for an error that was introduced in calibration whereby the effective distance term became positive at longer distances. This led to unreasonable sensitivities in the model. It is difficult to recognize where a polynomial formulation generates a positive slope without calculating the distance term for a range of inputs.

The E7 model has been implemented with a piecewise linear formulation to protect against a positive slope being produced and to facilitate calibration. The check to ensure a negative slope was simply to verify that the net coefficient associated with each distance range (i.e. the sum of all coefficients for the distance range) had negative signs. If so, the distance component of the utility will be monotonically decreasing and would produce reasonable sensitivities.

The piecewise linear formulation estimated several linear terms with different starting offsets. The trip length distribution had the most variation for distances less than 20 miles so the models were first estimated with 5 mile distance increments under 20 miles and 10 mile increments over 20. There were few trip observations above 40 miles. The effective distance ranges for the model formulations are shown in **Table 5.5**.

Table 5.5 Effective Piecewise Linear Distance Ranges

Begin mile	End mile	Variable Used in Utility Formula
0 miles	4.99 miles	Distance in Miles
5 miles	9.99 miles	Max(Distance in miles – 5, 0)
10 miles	14.99 miles	Max(Distance in miles – 10, 0)
15 miles	19.99 miles	Max(Distance in miles – 15, 0)
20 miles	29.99 miles	Max(Distance in miles – 20, 0)
30 miles	39.99 miles	Max(Distance in miles – 30, 0)
40 miles	maximum	Max(Distance in miles – 40, 0)

Source: CS.

In application, the sum across the terms is applied to the distance variable by the distance range. For example, for any interchange distance, "D", the effective utility would be:

$$C_1 \times D + C_2 \times Max(D-5,0) + C_3 \times Max(D-10,0) + C_4 \times Max(D-15,0) + C_5 \times Max(D-20,0) + C_6 \times Max(D-30,0) + C_7 \times Max(D-40,0)$$

The resulting piecewise linear term must be monotonically decreasing. Furthermore, coefficients with large magnitudes or alternating sign indicate over-fitting of the model. The estimated parameters for the piecewise linear formulations were refined through the model calibration process based on these heuristics.

Walk-transit availability

The presence of a walk-transit path between the production zone and each destination alternative was determined and tested in the model as a 0/1 dummy variable. The coefficient for this term was expected to be positive to reflect the increased attractiveness of zones accessible by transit.

Intrazonal

The intrazonal variable was set equal to one when the attraction zone alternative was the same as the production zone and zero for all other alternatives. This variable was included in all model formulations.

Land-Use Density

The attraction size variable represented the effect of households and employment by type on the utility of a given destination zone. The land use and mixed-use density variables were included to represent the additional utility of a zone with both households and employment. The density variables were calculated for each attraction zone as follows:

emp_density = Total Employment in Zone / Zone Size (acres)
hh_density = Total Households in Zone / Zone Size (acres)
Mixed Use Density = (emp_density * hh_density) / (emp_density + hh_density)

The range of mixed-use density values for the 2010 socioeconomic dataset are shown in **Table 5.6**. Density variables must be monitored closely as future year datasets are developed because the maximum values can increase dramatically and skew model results. If future year datasets increase the maximum value by an order of magnitude, for example, a cap can be implemented to restrict the impact of this variable. A cap of 1.5 times the maximum base-year mixed-use density would dampen the model response to high-density future developments. The mixed-use density variable should have a positive coefficient.

Table 5.6 Mixed-Use Density Value Statistics

Statistic	Value
Minimum	0.0
Median	0.8046
Mean	1.1710
Maximum	15.9600

Source: CS Analysis of the SEMCOG 2010 SEMCOG Dataset.

5.2.2 Market Segmentation

As shown in **Table 5.1**, there are three vehicle availability market segments and three income market segments used for destination choice. The newly estimated vehicle availability model (see **Section 4.7**) estimates the number of vehicles per household between 0 and 3+. The number of vehicles is interacted with the number of workers to generate a three-level household vehicle availability market segmentation variable:

1. Zero-vehicle households
2. Households with at least one vehicle, but fewer vehicles than workers
3. Households with at least one vehicle and vehicles greater than or equal to workers

The zero-vehicle household segments are expected to make shorter trips (more sensitive to distance) and have a higher utility for transit-accessible and mixed-use zones. Conversely, households with vehicles are expected to make longer trips.

The use of three income market segments and three vehicle availability market segments results in destination choice models for nine unique market segments for the home based work, home based shop, and home based other trip purposes. The vehicle availability market segment can only be applied to home-based trips because the home-attributes are unknown for non-home based trips. The vehicle availability market segment was not tested for home-based school trips because many of the travelers are not drivers. The home-based university model (**Section 5.4**) uses a different model structure.

Destination choice is performed using both AM peak and midday skim and logsum data resulting in 18 different destination choice model applications for home based work, home based shop, and home based other trip purposes and two applications of destination choice for the other purposes.

5.2.3 Model Structure

The model is estimated as multinomial logit, with the destination choice set for each observation in the estimation file being all internal zones in the SEMCOG model. In model application, the model is applied for all zones including external station zones, with the exception that trips from external to external zones are prohibited. As described in **Section 4.8**, trips to and from external stations are stratified by trip purpose. Extra distances are added at external stations to account for travel beyond SEMCOG boundaries. This was done during model validation to match IE and EI trip patterns to observed data, and to improve the model's ability to match traffic counts near external stations. By adding extra distance at external stations, the destination choice model becomes less sensitive to distance, allowing IE/EI trips to travel further into the SEMCOG region.

5.3 Destination Choice Model Calibration Results

This section presents the final destination choice models and the resulting application terms by market segment and distance range after model calibration. Raw destination choice model estimation results are shown in **Appendix H**.

5.3.1 Model Calibration Approach

The model calibration step varied only distance-based parameters to ensure that the piecewise linear distance formula continued to be monotonically decreasing while matching observed trip length frequency distributions when the full E7 model was applied. Since the destination choice model is dependent upon modeled productions and attractions from the calibrated trip generation model as well as logsums from the calibrated mode choice model, the calibration approach was an iterative process.

5.3.2 Model Calibration Results – Trip Purposes with Vehicle Availability Segments

Table 5.7 shows the calibrated destination choice model coefficients for home based work, home based other, and home based shop trips. The calibrated distance variable terms are marginal terms applied in combination. Home-based other does not have distance-specific segmentation. Only the intrazonal and mixed-use density terms were calibrated for the different segments. Therefore, the distance utility components across all segments produce the same result for the home based other trip purpose. **Table 5.8**, **Table 5.9**, and **Table 5.10** show the resulting distance-based application terms for each vehicle availability market segment. The distance utility components are plotted in **Figure 5.1**, **Figure 5.2**, and **Figure 5.3**.

The destination choice models for the home based school, non-home based-work, and non-home based-other trip purposes are not segmented by market. Note that the non-home based-work and non-home based-other trip purposes cannot be segmented in application because there is no connection between a given non-home-based trip and the household that produced that trip. **Table 5.11** shows the calibrated destination choice model coefficients for the home based school, non-home based-work, and non-home based-other trip purposes and **Table 5.12** shows the resulting distance-based application terms. The distance utility components are plotted in **Figure 5.4**.

Table 5.7 Calibrated Models with Vehicle Availability Segments

Variable	Home-Based Work		Home-Based Other		Home-Based Shop	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
ZERO VEHICLES						
logsum	1.000	*	1.000	*	1.000	*
distance (miles)	-0.600	**	-1.000	**	-0.850	**
max(distance - 2.5, 0)	0.350	**	0.550	**	0.200	**
max(distance - 5, 0)	0.150	**	0.150	**	0.150	**
max(distance - 10, 0)	0.000	**	0.100	**	0.050	**
max(distance - 15, 0)	0.020	**	0.000	**	0.150	**
max(distance - 20, 0)	0.005	**	0.100	**	0.100	**
max(distance - 30, 0)	0.000	**	0.010	**	0.000	**
max(distance - 40, 0)	0.000	**	0.000	**	0.100	**
walk-transit	0.263	1.04	0.000	**	0.000	**
intrazonal	1.730	**	0.540	**	0.400	**
mixed use density						
ln(attractions)	1.000	*	1.000	*	1.000	*
VEHICLES > 0 AND VEHICLES < WORKERS						
distance (miles)	-0.580	**	-1.000	**	-0.828	**
walk-transit	0.000	**	0.000	**	0.000	**
intrazonal	1.280	**	0.280	**	0.250	**
mixed use density						
VEHICLES > 0 AND VEHICLES >= WORKERS						
distance (miles)	-0.560	**	-1.000	**	-0.754	**
intrazonal	0.290	**	0.170	**	0.050	**

Source: CS analysis of 2004/2005 combined household survey data.

* implies coefficient was constrained in model estimation.

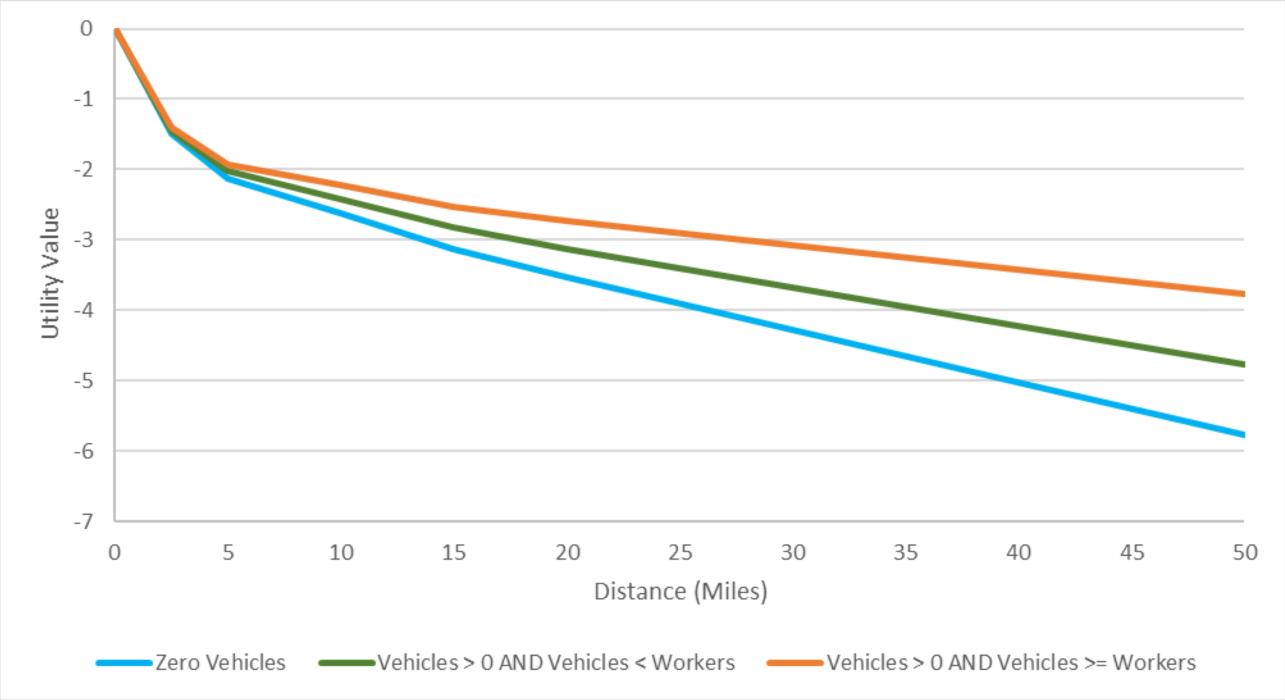
** implies coefficient was modified in the model calibration process.

Table 5.8 Home-Based Work Application Terms

Term	Zero Vehicles	Vehicles > 0 AND Vehicles < Workers	Vehicles > 0 AND Vehicles >= Workers
logsum	1.000	1.000	1.000
ln(attractions)	1.000	1.000	1.000
distance (0-2.5 miles)	-0.600	-0.580	-0.560
distance (2.5-5 miles)	-0.250	-0.230	-0.210
distance (5-10 miles)	-0.100	-0.080	-0.060
distance (10-15 miles)	-0.100	-0.080	-0.060
distance (15-20 miles)	-0.080	-0.060	-0.040
distance (20-30 miles)	-0.075	-0.055	-0.035
distance (30-40 miles)	-0.075	-0.055	-0.035
distance (40+ miles)	-0.075	-0.055	-0.035
walk-transit	0.263	0.000	0.000
intrazonal	1.730	1.280	0.290
mixed use density	0.000	0.000	0.000

Source: CS.

Figure 5.1 Home-Based Work Distance Utility Components



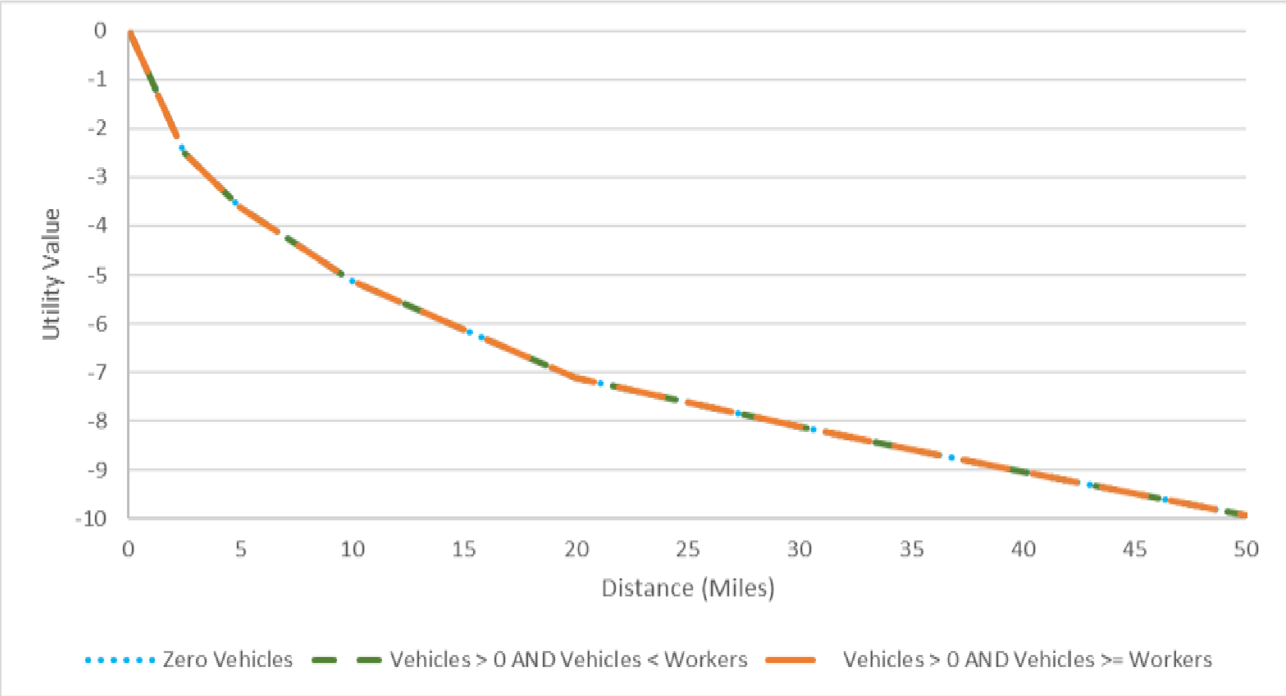
Source: CS.

Table 5.9 Home-Based Other Application Terms

Term	Zero Vehicles	Vehicles > 0 AND Vehicles < Workers	Vehicles > 0 AND Vehicles >= Workers
logsum	1.000	1.000	1.000
ln(attractions)	1.000	1.000	1.000
distance (0-2.5 miles)	-1.000	-1.000	-1.000
distance (2.5-5 miles)	-0.450	-0.450	-0.450
distance (5-10 miles)	-0.300	-0.300	-0.300
distance (10-15 miles)	-0.200	-0.200	-0.200
distance (15-20 miles)	-0.200	-0.200	-0.200
distance (20-30 miles)	-0.100	-0.100	-0.100
distance (30-40 miles)	-0.090	-0.090	-0.090
distance (40+ miles)	-0.090	-0.090	-0.090
walk-transit	0.000	0.000	0.000
intrazonal	0.540	0.280	0.170
mixed use density	0.000	0.000	0.000

Source: CS.

Figure 5.2 Home-Based Other Distance Utility Components



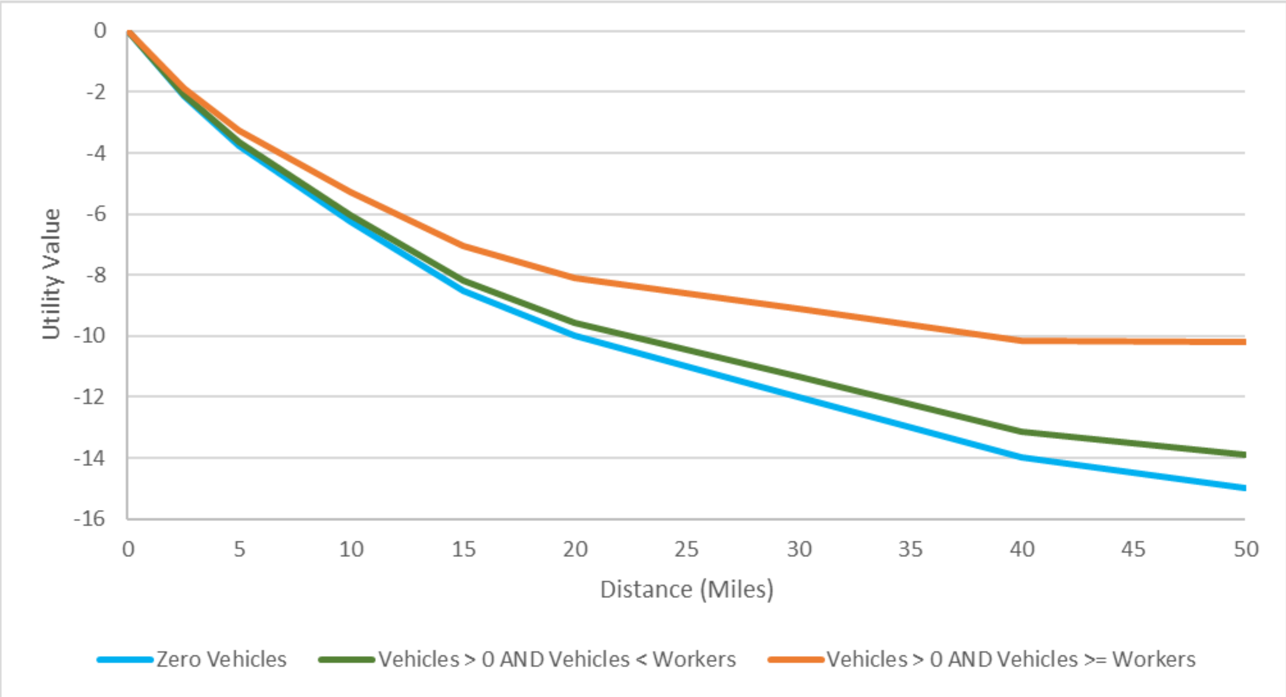
Source: CS.

Table 5.10 Home-Based Shop Application Terms

Term	Zero Vehicles	Vehicles > 0 AND Vehicles < Workers	Vehicles > 0 AND Vehicles >= Workers
logsum	1.000	1.000	1.000
ln(attractions)	1.000	1.000	1.000
distance (0-2.5 miles)	-0.850	-0.828	-0.754
distance (2.5-5 miles)	-0.650	-0.628	-0.554
distance (5-10 miles)	-0.500	-0.478	-0.404
distance (10-15 miles)	-0.450	-0.428	-0.354
distance (15-20 miles)	-0.300	-0.278	-0.204
distance (20-30 miles)	-0.200	-0.178	-0.104
distance (30-40 miles)	-0.200	-0.178	-0.104
distance (40+ miles)	-0.100	-0.078	-0.004
walk-transit	0.000	0.000	0.000
intrazonal	0.400	0.250	0.050
mixed use density	0.000	0.000	0.000

Source: CS.

Figure 5.3 Home-Based Shop Distance Utility Components



Source: CS.

Table 5.11 Calibrated Coefficients for Non-Segmented Models

	Home-Based School		Non-Home-Based Work		Non-Home-Based Other	
Variable	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
logsum	1.000	*	1.000	*	1.000	*
distance (miles)	-1.200	**	-0.450	**	-0.500	**
max(distance - 2.5, 0)	0.600	**	0.000	**	0.000	**
max(distance - 5, 0)	0.250	**	0.350	**	0.250	**
max(distance - 10, 0)	0.000	**	0.052	**	0.150	**
max(distance - 15, 0)	0.100	**	0.038	**	0.010	**
max(distance - 20, 0)	0.000	**	-0.020	**	0.040	**
max(distance - 30, 0)	0.010	**	0.000	**	0.000	**
max(distance - 40, 0)	0.000	**	0.000	**	0.000	**
walk-transit	0.000	**	0.000	**	0.000	**
intrazonal	0.146	**	0.300	**	0.800	**
mixed use density					0.005	0.79
ln(attractions)	1.000	*	1.000	*	1.000	*

Source: CS analysis of 2004/2005 combined household survey data.

* implies coefficient was constrained in model estimation.

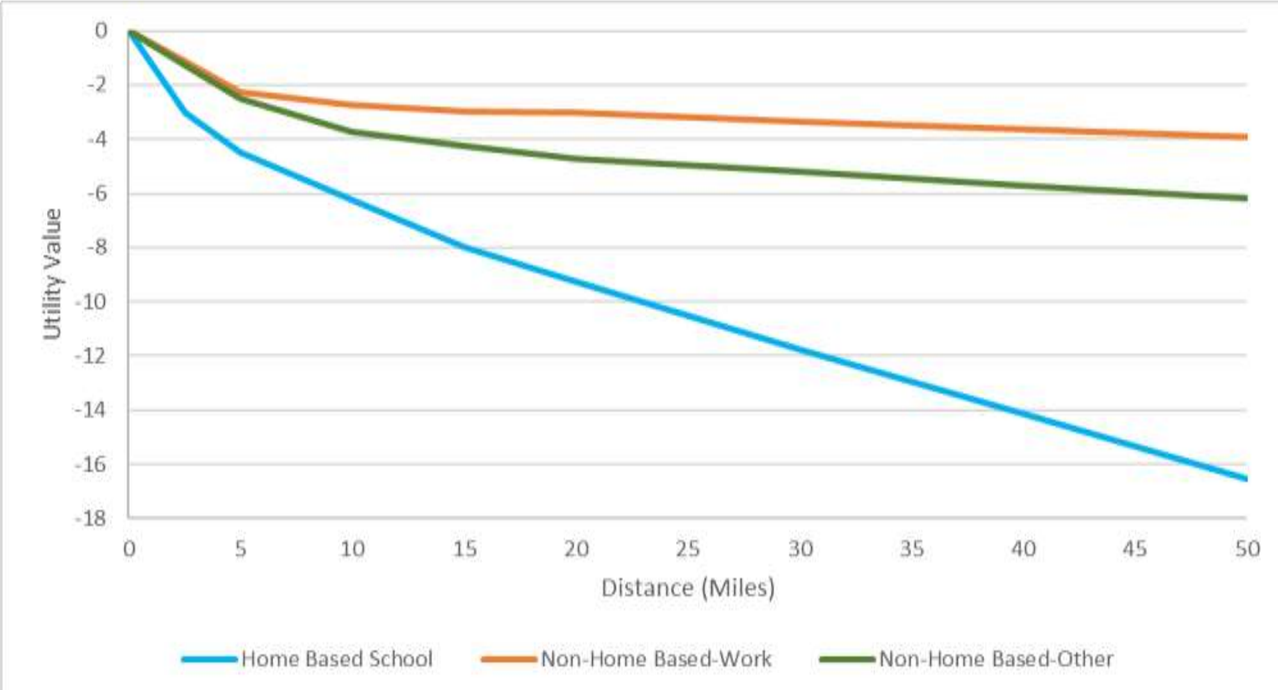
** implies coefficient was modified in the model calibration process.

Table 5.12 Non-Segmented Model Application Terms

Term	Zero Vehicles	Vehicles > 0 AND Vehicles < Workers	Vehicles > 0 AND Vehicles >= Workers
logsum	1.000	1.000	1.000
ln(attractions)	1.000	1.000	1.000
distance (0-2.5 miles)	-1.200	-0.450	-0.500
distance (2.5-5 miles)	-0.600	-0.450	-0.500
distance (5-10 miles)	-0.350	-0.100	-0.250
distance (10-15 miles)	-0.350	-0.048	-0.100
distance (15-20 miles)	-0.250	-0.010	-0.090
distance (20-30 miles)	-0.250	-0.030	-0.050
distance (30-40 miles)	-0.240	-0.030	-0.050
distance (40+ miles)	-0.240	-0.030	-0.050
walk-transit	0.000	0.000	0.000
intrazonal	0.146	0.300	0.800
mixed use density	0.000	0.000	0.005

Source: CS.

Figure 5.4 HBSchool and Non-Home-Based Distance Components



Source: CS.

5.4 Home Based University Distribution Model

The home based university trip distribution model reverses the normal trip distribution process. As noted in **Section 4.6.3**, home based university attractions are generated for students living off campus and other residents of the region visiting the campuses based on the type of university. The attractions at each university control the total numbers of home based university trips and the distribution process becomes one of identifying the home locations of the students living off campus. The trip distribution model is, in effect, a production allocation model. For the University of Michigan, intra-campus travel by students living in on campus housing is obtained from trip tables provided by the Washtenaw Area Transportation Study (WATS).

A gamma function based, singly constrained gravity model formulation is used for the home based university trip distribution process. The gamma function formulation is:

$$F_{ij} = \alpha \times imp_{ij}^{\beta} \times e^{\gamma \times imp_{ij}}$$

where: F_{ij} is the friction factor for interchange ij

α, β, γ are gamma function parameters

imp_{ij} is the impedance for interchange ij

e is the base of natural logarithms

For the E7 home based university distribution model, the impedance used is distance. The gamma function parameters were calibrated based on information regarding student residences for the various universities. The gamma functions are used to develop matrices of friction factors from each university to all other TAZs in the region. The gamma function parameters for the home based university trip distribution process are shown in **Table 5.13** and plots of the resulting friction factors are shown in **Figure 5.5**.

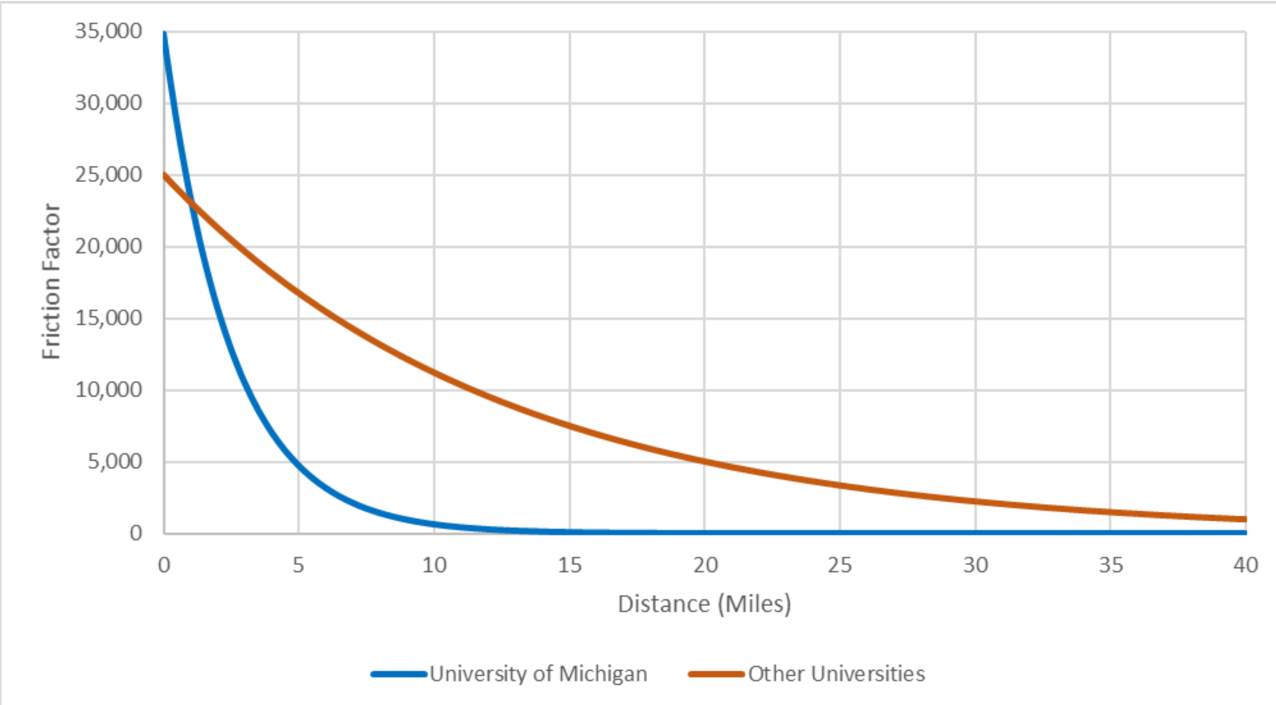
Table 5.13 Home Based University Gamma Function Parameters

University Type	Alpha	Beta	Gamma*
Type I (University of Michigan)	35000	0	-0.40
Type II & III (All other)	25000	0	-0.08

Source: CS.

* TransCAD internally negates the input Gamma parameter, so the values should be input as 0.40 and 0.08.

Figure 5.5 Home Based University Friction Factors



Source: CS.

5.5 Destination Choice Model Reasonableness Checks

As noted in **Section 4.2.1**, trip rates had to be increased to reproduce observed VMT in the SEMCOG region for 2015. Trip rate adjustments alone still left the modeled regional VMT short of the observed VMT so the destination choice models were adjusted during the model calibration to help match overall VMT in the region. Changes by purpose were made in an iterative manner in an effort to keep modeled average trip lengths reasonably close to the observed trip lengths while more closely matching the regional VMT. Note that the observed average trip lengths and durations were summarized from the 2015 household travel survey data.

Table 5.14 shows the resulting modeled versus surveyed average daily trip lengths and **Table 5.15** compares the average trip durations. The E7 model applies the destination choice model using both peak (AM) and off-peak (MD) networks and combines the results during the time-of-day modeling process. The data summarized in **Table 5.14** and **Table 5.15** show the composite, daily results. **Figure 5.6** through **Figure 5.12** show the modeled and observed composite daily trip length frequency distributions. As can be seen in the figures, the adjustments to the destination choice models did not cause the modeled trip length frequency distributions to vary substantially from the observed distributions. This is further corroborated by the high coincidence ratios of the distributions.

Table 5.14 Modeled versus Observed Daily Average Trip Lengths

Trip Purpose	Observed Average Trip Length (Miles)	Modeled Average Trip Length (Miles)	Difference (Miles)	Percent Difference	Coincidence Ratio
Home Based Work	12.6	13.1	0.5	4.1%	0.91
Home Based Other	5.4	5.6	0.2	3.6%	0.90
Home Based Shop	4.2	4.4	0.2	5.1%	0.87
Home Based School	3.5	3.7	0.2	4.9%	0.88
Home Based University	10.3	11.7	1.4	13.5%	0.71
Non-Home Based-Work	8.6	9.4	0.9	10.0%	0.88
Non-Home Based-Other	4.9	4.7	-0.3	-5.3%	0.94
Total	**6.5**	**6.8**	**0.2**	**3.6%**	**0.90**

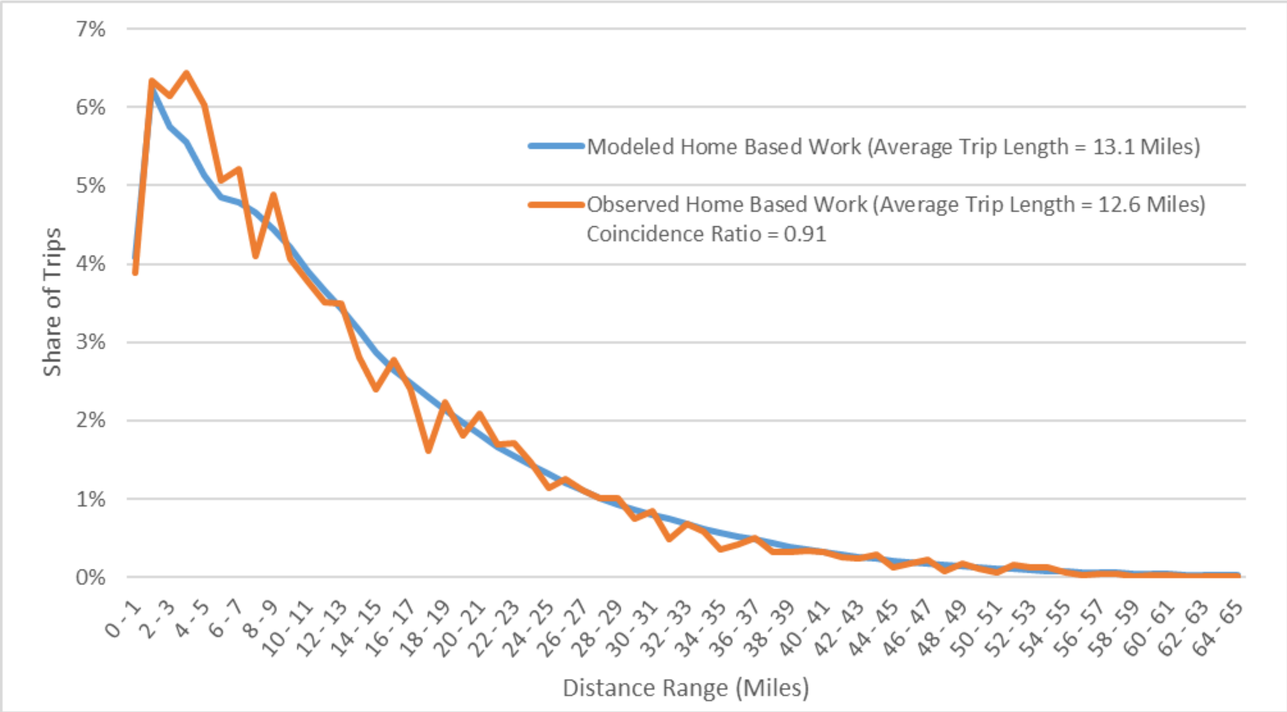
Source: CS; observed averages based on CS analysis of expanded 2015 household travel survey data.

Table 5.15 Modeled versus Observed Daily Average Trip Durations

Trip Purpose	Observed Average Trip Duration (Minutes)	Modeled Average Trip Duration (Minutes)	Difference (Minutes)	Percent Difference	Coincidence Ratio
Home Based Work	26.2	28.1	1.9	7.2%	0.86
Home Based Other	15.8	17.1	1.3	8.3%	0.88
Home Based Shop	13.7	15.2	1.5	11.0%	0.77
Home Based School	13.2	13.7	0.6	4.4%	0.85
Home Based University	23.6	29.0	5.4	22.8%	0.56
Non-Home Based-Work	19.3	22.4	3.1	15.9%	0.79
Non-Home Based-Other	14.6	15.4	0.8	5.2%	0.87
Total	**17.1**	18.7	1.5	8.9%	0.84

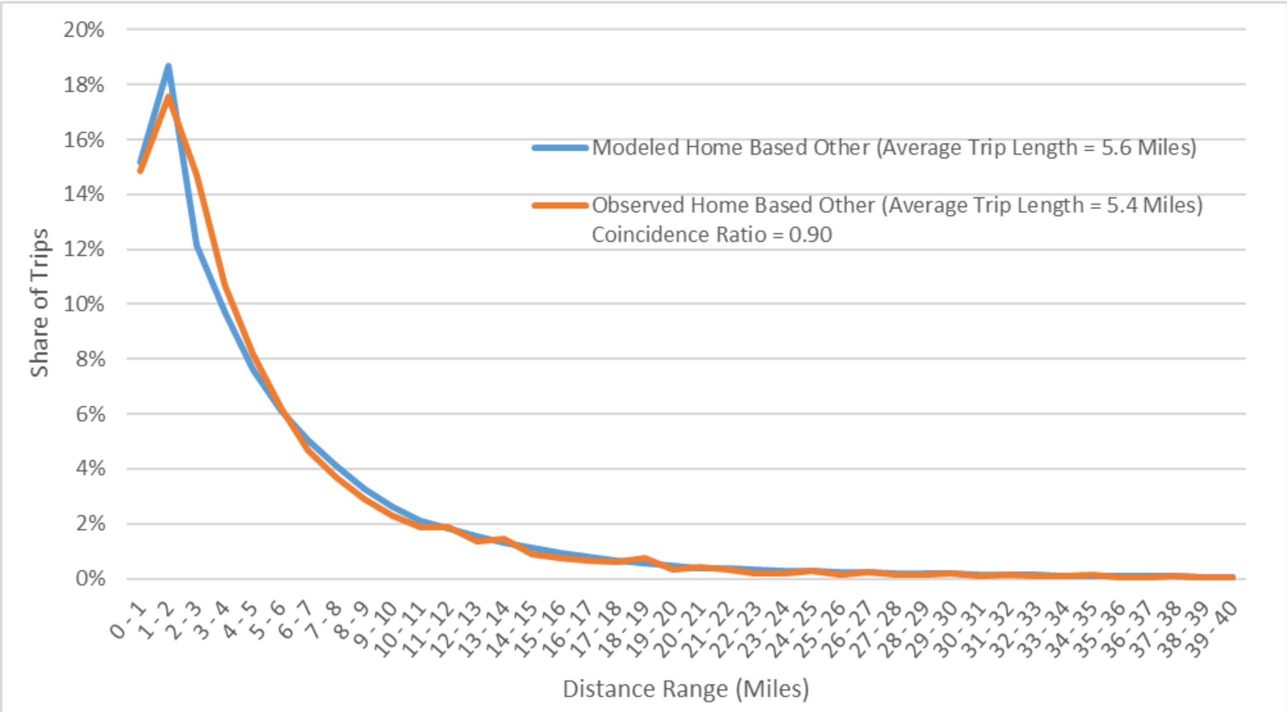
Source: CS; observed averages based on CS analysis of expanded 2015 household travel survey data.

Figure 5.6 Daily Home Based Work Trip Length Frequency Distributions



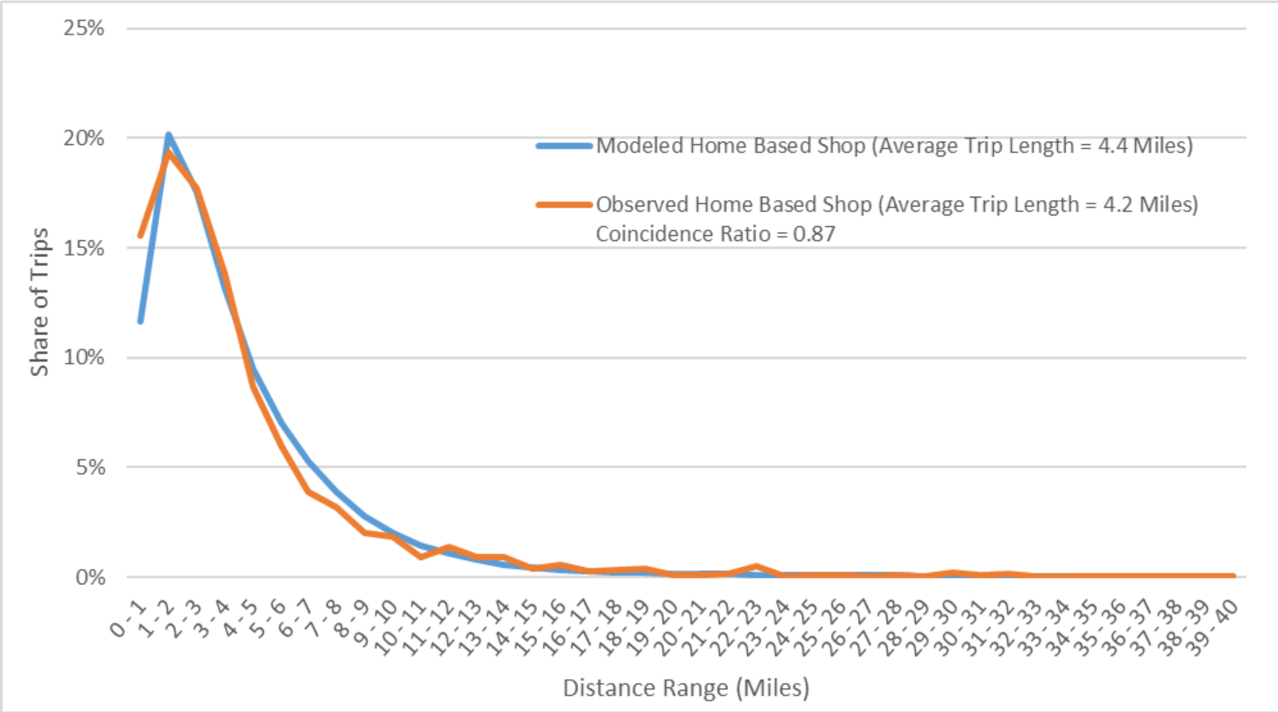
Source: CS; observed distribution based on CS analysis of expanded 2015 household travel survey data.

Figure 5.7 Daily Home Based Other Trip Length Frequency Distributions



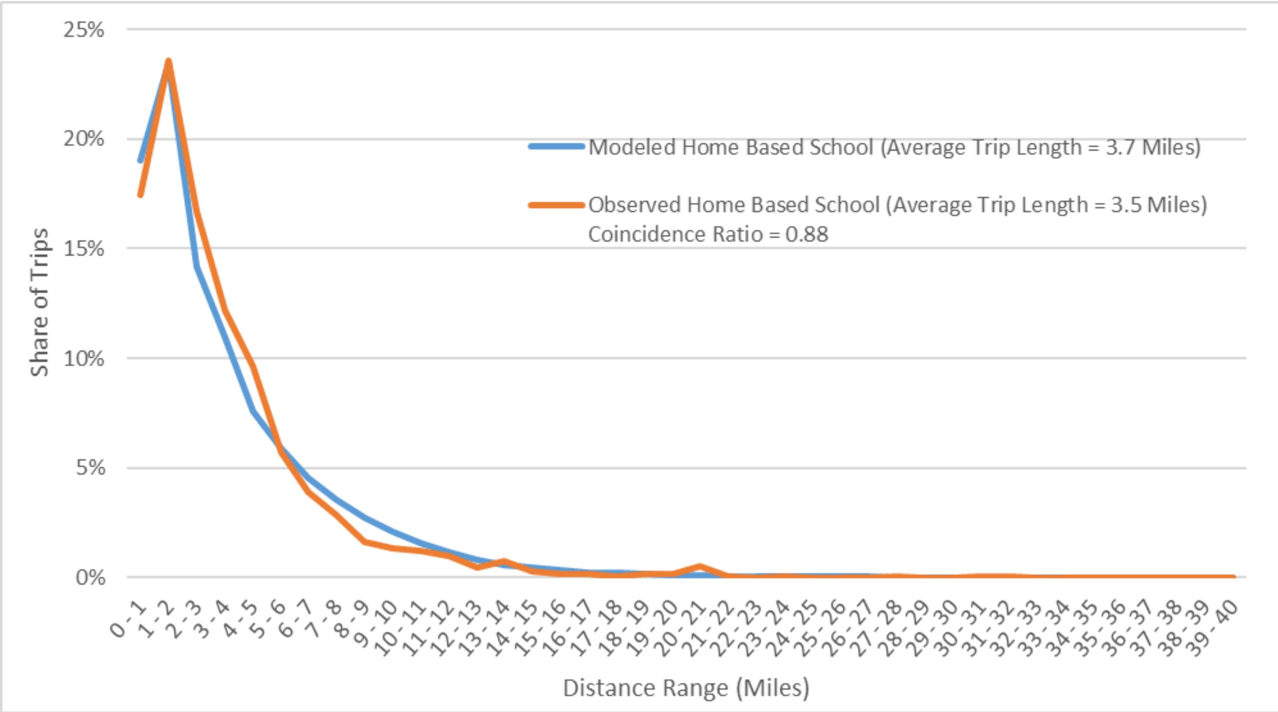
Source: CS; observed distribution based on CS analysis of expanded 2015 household travel survey data.

Figure 5.8 Daily Home Based Shop Trip Length Frequency Distributions



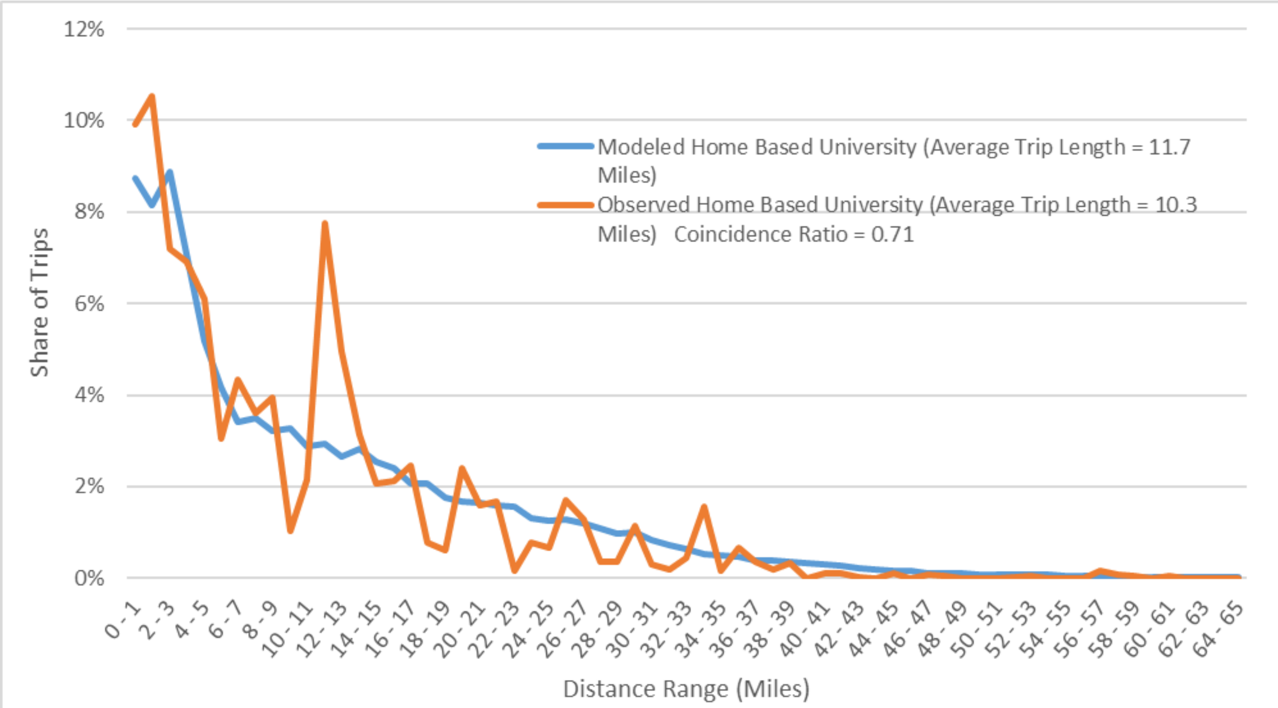
Source: CS; observed distribution based on CS analysis of expanded 2015 household travel survey data.

Figure 5.9 Daily Home Based School Trip Length Frequency Distributions



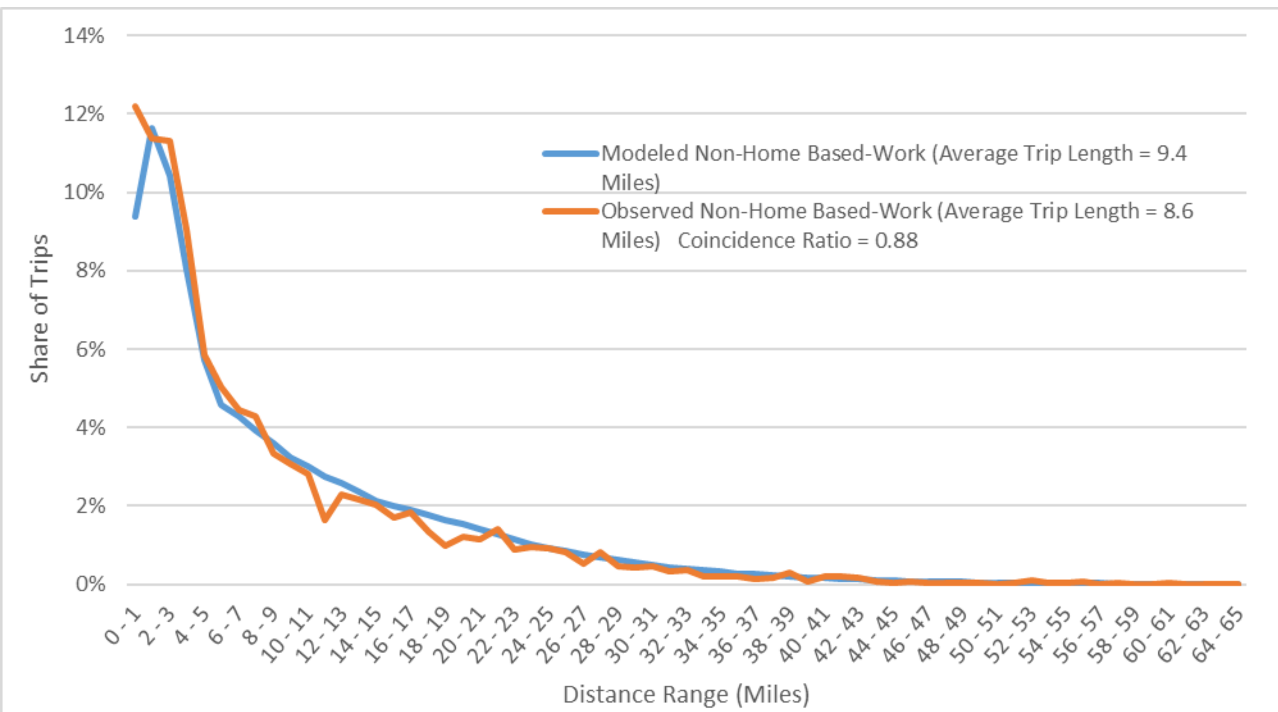
Source: CS; observed distribution based on CS analysis of expanded 2015 household travel survey data.

Figure 5.10 Daily Home Based University Trip Length Frequency Distributions



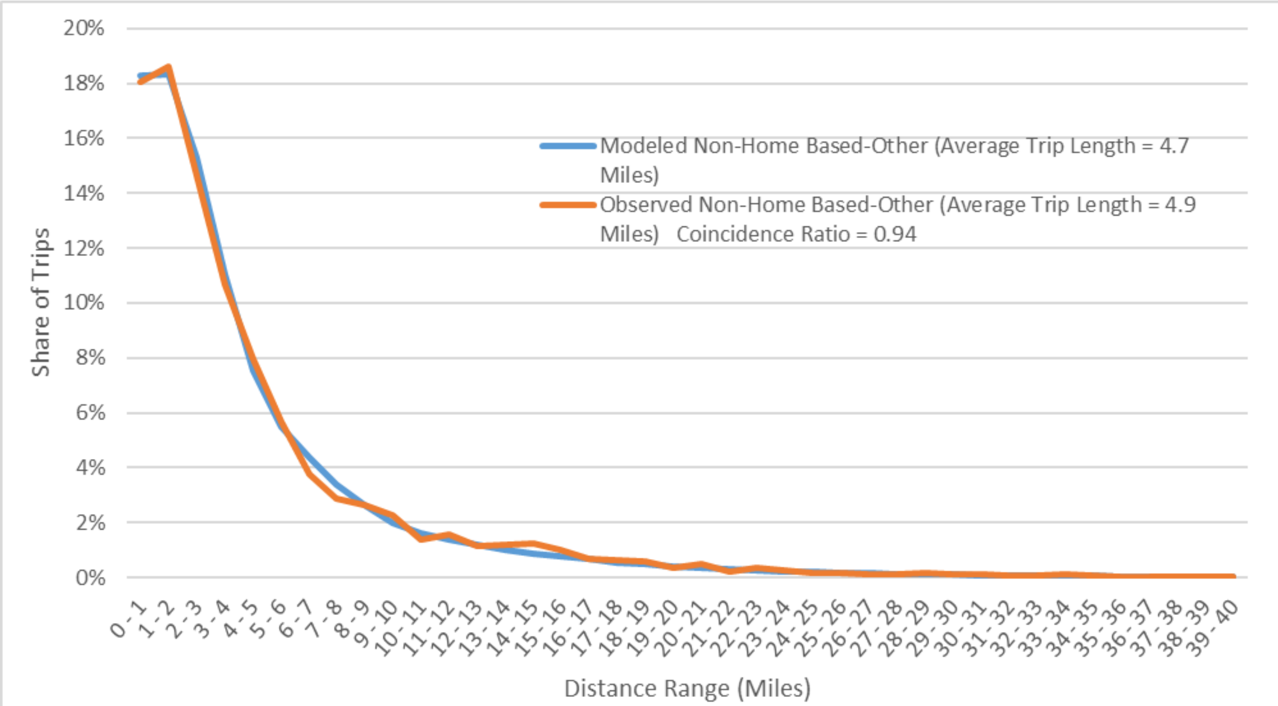
Source: CS; observed distribution based on CS analysis of expanded 2015 household travel survey data.

Figure 5.11 Daily Non-Home Based-Work Trip Length Frequency Distributions



Source: CS; observed distribution based on CS analysis of expanded 2015 household travel survey data.

Figure 5.12 Daily Non-Home Based-Other Trip Length Frequency Distributions



Source: CS; observed distribution based on CS analysis of expanded 2015 household travel survey data.

5.6 External-External Trip Distribution

Section 4.8.3 describes the generation of future EE auto, medium truck, and heavy truck trips at each external station. **Section 4.8.2** describes the development of base year EE trip tables. The base year trip tables will be factored through an IPF process to match the forecasts of EE vehicle trips at external stations. The resulting EE trip tables are added directly to the internal vehicle trip tables prior to traffic assignment.

5.7 Trip Distribution Application by Time of Day

The destination choice models were estimated based on daily trip information but using time of day specific logsum data. Based on this model estimation and calibration approach, the destination choice models can be applied for peak and off-peak period person trips by simply factoring the input daily person trips from the trip generation process by the proportions of those trips that occur in each period. The peak and off peak period time of day factors summarized from the expanded 2015 household survey are shown in **Table 5.16**. Based on the application of the factors, destination choice and mode choice will be performed by time of day. Results of those model components will be further stratified prior to traffic and transit assignment as documented in **Section 9.0**.

Table 5.16 Proportions of Trips by Time of Day Factors for Trip Distribution

Trip Purpose	Peak Period Proportion (AM and PM trips, modeled using the AM network)	Off-Peak Period Proportion (All other trips, modeled using the mid-day network)
Home Based Work	0.6069	0.3931
Home Based Other	0.4950	0.5050
Home Based Shop	0.3955	0.6045
Home Based School	0.8712	0.1288
Home Based University	0.3673	0.6327
Non-Home Based-Work	0.4586	0.5414
Non-Home Based-Other	0.4424	0.5576

Source:2015 household survey.

6.0 Mode Choice

6.1 Model Structure

The SEMCOG E6B mode choice model is a nested logit model with auto and transit as top level choices. The E7 model added non-motorized trips as a top level choice. The auto and transit sub-mode structure used for the E6B model has been maintained for the E7 model. Walk and bicycle were added as sub-modes under the non-motorized main mode. The resulting E7 mode choice model with sub-nests and choices is shown in **Figure 6.1**.

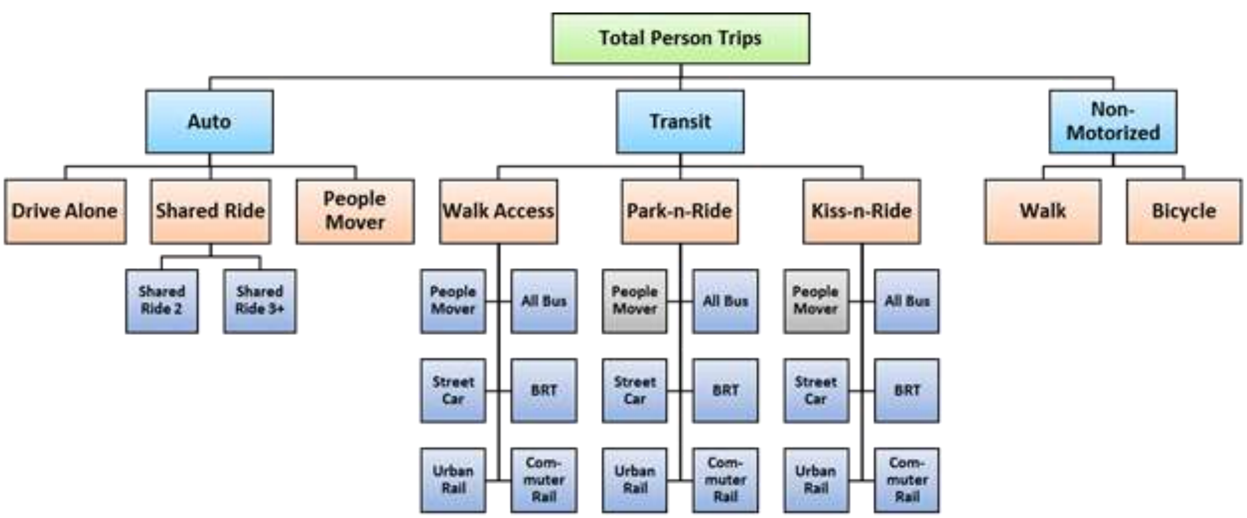
Transit pathbuilding, mode choice, and transit assignment are performed using the mode hierarchy defined in **Table 6.1**. For pathfinding and assignment, a weight of 5 times the weight of the primary mode in-vehicle time is applied to auxiliary modes. Auxiliary mode travel time does not receive a higher weight during mode choice.

Table 6.1 Mode Hierarchies

Primary Mode	Auxiliary Modes	Disabled Modes
People Mover	n/a	All others
All Bus	People Mover	Street Car, BRT, Urban Rail, Commuter Rail
Street Car	People Mover, All Bus	BRT, Urban Rail, Commuter Rail
BRT	People Mover, All Bus, Street Car	Urban Rail, Commuter Rail
Urban Rail	People Mover, All Bus, Street Car, BRT	Commuter Rail
Commuter Rail	People Mover, All Bus, Street Car, BRT, Urban Rail	n/a

Source: E7 model.

Figure 6.1 Mode Choice Structure



Source: E7 Model.

The People Mover mode appears in several different places in the E7 mode choice structure. The nuances of each People Mover choice option are as follows:

- Nested under auto: In this case, the People Mover is serving as a distributor mode for trips made by auto;
- Nested under transit, walk access: In this case, the People Mover is functioning as a transit mode in competition with other transit modes; and
- Nested under park-n-ride or kiss-n-ride: In these cases, the People Mover is functioning as part of a transit path where another transit mode is also used.

There are separate mode choice models for seven trip purposes and two time periods. In addition, some purposes are further segmented by three income categories (low, medium, and high) and three auto sufficiency groups (zero-vehicle households, households with at least one vehicle but fewer vehicles than workers, and households with at least one vehicle and vehicles greater than or equal to workers). In addition, mode choice is also performed for the seven walk access/egress submarkets based on short (less than 0.25 mi) and long (0.25-0.50 mi) walk distances to transit as shown in **Table 6.2**. Based on the various combinations of the aforementioned markets, the mode choice model is actually run 434 times as shown in **Table 6.3**.

Table 6.2 Transit Access / Egress Markets

Walk Access / Egress Distance Ranges		Egress Distance		
		Less than 0.25 miles	Greater than 2.5 miles & less than or equal to 0.5 miles	Greater than 0.5 miles
Access Distance	Less than 0.25 miles	(1) Short-Short	(2) Short-Long	(7) Transit Not Available
	Greater than 2.5 miles & less than or equal to 0.5 miles	(3) Long-Short	(4) Long-Long	
	Greater than 0.5 miles	(5) Drive Only-Short	(6) Drive Only-Long	

Source: CS.

Table 6.3 Mode Choice Model Market Segments

Purpose	Times of Day	Income Group Strata	Vehicle Ownership Groups	Transit Access/ Egress Markets	Total Model Applications
Home Based Work	2	3	3	7	126
Home Based Other	2	3	3	7	126
Home Based Shop	2	3	3	7	126
Home Based School	2	1	1	7	14
Home Based University	2	1	1	7	14
Non-Home Based-Work	2	1	1	7	14
Non-Home Based-Other	2	1	1	7	14
				Total Model Applications	**434**

Source: CS.

6.1.1 Mode Choice Conversion

The mode choice model has been updated to use TransCAD 8 syntax and structure as part of the conversion to the E7 model. The updated version uses the more current TransCAD nested logit engine that has been fully revamped to replace previous approach. This implementation makes the numerous applications more efficient. The mode choice model is actually run prior to destination choice to develop logsums for destination choice and output matrices of mode choice probabilities for each of the 434 market segments. Then, after destination choice and the production of purpose, income, and auto sufficiency specific trip tables, the actual mode specific trip tables are generated through simple matrix multiplications.

6.2 Calibration

All system parameters from the E6B model were maintained with the exception that the coefficients of cost were updated to account from the move from two income groups in the E6B model to three income groups in the E7 model. The cost coefficients by income group were specified so that the home based work, home based school, home based university, and non-home based-work implied values of time were one-third the average wage rate and the implied values of time for the other purposes were one-fourth the average wage rate. **Table 6.4** shows the E7 model mode choice model parameters.

Table 6.4 Mode Choice Model Parameters

Parameter	Parameter Units	Home Based Work	Home Based Other	Home Based Shop	Home Based School	Home Based University	Non-Home Based-Work	Non-Home Based-Other
Input Parameters								
Auto Cost Per Mile (2010$)	Cents	11	11	11	11	11	11	11
Shared Ride 2 Average Auto Occupancy	–	2	2	2	2	2	2	2
Shared Ride 3+ Average Auto Occupancy	–	4.3	3.66	3.55	3.64	4.3	3.48	3.74
Model Coefficients								
Cost - Low Income (2010$)	per Cent	-0.00706	-0.00377	-0.00377	-0.00283	-0.00706	-0.00565	-0.00754
Cost - Middle Income (2010$)	per Cent	-0.00230	-0.00123	-0.00123	-0.00092	-0.00230	-0.00184	-0.00245
Cost - Middle-High & High Income (2010$)	per Cent	-0.00094	-0.00050	-0.00050	-0.00037	-0.00094	-0.00075	-0.00100
In-Vehicle Travel Time[1]	per Minute	-0.025	-0.01	-0.01	-0.01	-0.025	-0.02	-0.02
Out-of-Vehicle Travel Time	per Minute	-0.0625	-0.025	-0.025	-0.025	-0.0625	-0.05	-0.05
Drive Access In-Vehicle Travel Time	per Minute	-0.0563	-0.0225	-0.0225	-0.0225	-0.0563	-0.045	-0.045
Drive Access Ratio[2]	–	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0
Nesting Coefficients								
Top Level	–	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Lower Level	–	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Derived Relationships								
Implied Values of Time								
Low Income	2010$/Hour	$2.12	$1.59	$1.59	$2.12	$2.12	$2.12	$1.59
Middle-Low Income	2010$/Hour	$6.53	$4.90	$4.90	$6.53	$6.53	$6.53	$4.90
Middle-High & High Income	2010$/Hour	$16.03	$12.02	$12.02	$16.04	$16.03	$16.02	$12.02
Out-of-Vehicle/In-Vehicle Travel Time	–	2.5	2.5	2.5	2.5	2.5	2.5	2.5

Source: E6B model with CS adjustments.

[1] In-Vehicle Travel Time coefficients may be set for separately by transit sub-mode: People Mover, Streetcar, BRT, Urban Rail, and Commuter Rail.

[2] The Drive Access Ratio is applied to the value of the drive access distance to transit divided by the total auto distance for the interchange in excess of 0.5: DAR = max[(Drive Access to Transit Distance/Auto Distance for Interchange) – 0.5,0]

6.2.1 Calibration Process

The mode choice model calibration process was fully automated within TransCAD. The calibration process iteratively adjusted mode choice model constants for each trip purpose so that modeled trips matched observed trips for various modes and sub-modes shown in **Figure 6.1** by time-of-day, income segment, auto sufficiency, and geography. The following formula was used to adjust the constants:

$$K_{Iter\ n} = K_{Iter\ n-1} + \ln\left(\frac{Target}{Result_{Iter\ n-1}}\right)$$

The development of targets for each calibration iteration was performed in a stepwise manner. Transit trip targets were specified as actual trips by transit mode and sub-mode since the targets were developed in such a way that, when assigned, the transit boardings by mode and operator closely matched observed transit boardings. The actual numbers of trips for the various auto and non-motorized mode targets were then calculated based on shares of the remaining person trips after the transit trips were removed.[12]

6.2.2 Auto and Non-Motorized Mode Calibration Targets

Calibration targets for auto and non-motorized modes were developed from the expanded 2015 household travel survey. Auto and non-motorized shares for the various sub-modes rather than actual numbers of trips were used to control the calibration process since the numbers of trips could change if trip generation rates were varied for any of the purposes. **Table 6.5** and **Table 6.6** show the peak and off-peak target shares, respectively, for the auto and non-motorized modes.

6.2.3 Transit Calibration Targets

The targets were prepared using the 2010 transit on-board survey and then scaled to 2015 conditions using available counts and service level data from transit operators and from the National Transit Database (see **Appendix I**).

Targets were developed by purpose for both peak and off-peak periods. Targets separated transit linked trips by mode of access and by use of People Mover in the transit path compared to using only bus. Due to limitations of the survey data, separate targets were developed by income group and by vehicle sufficiency rather than developing joint targets of income group by vehicle sufficiency. On-board survey records without income information for home based work, home based other, and home based shop trip purposes and records with insufficient vehicles availability information were removed from expansion process. The remaining qualified records were re-weighed at the route, time of day, and purpose level. **Table 6.7** shows the peak period transit trip calibration targets and **Table 6.8** shows the off-peak period calibration targets.

6.2.4 Other Calibration Adjustments

The mode choice model was calibrated to match the auto and transit targets discussed above. When the trips from the initial calibration effort were assigned, it was discovered that they did not adequately reproduce boardings by operator. To address this issue, production and attraction geographic constants were added to improve the assignment results.

[12] Note that drive to People Mover trips, nested under the auto mode, were also known and used as a specified target.

Table 6.5 2015 Peak Auto & Non-Motorized Mode Share Targets

Trip Purpose	Auto Sufficiency	Income Group	Drive Alone	Shared Ride 2	Shared Ride 3+	Walk	Bike
Home Based Work	–	Low	0.6487	0.2238	0.0737	0.0398	0.0140
	–	Medium-Low	0.7304	0.1921	0.0581	0.0160	0.0035
	–	Medium-High & High	0.7743	0.1765	0.0271	0.0124	0.0097
	0 Autos	–	0.1706	0.4167	0.0422	0.2631	0.1074
	Autos>0 & < Workers	–	0.6010	0.2569	0.0783	0.0383	0.0255
	Autos ≥ Workers	–	0.7768	0.1734	0.0328	0.0108	0.0062
Home Based Other	–	Low	0.2516	0.3058	0.2926	0.1322	0.0177
	–	Medium-Low	0.2962	0.2860	0.3164	0.0852	0.0162
	–	Medium-High & High	0.3046	0.3412	0.2906	0.0542	0.0095
	0 Autos	–	0.0986	0.2740	0.2191	0.3980	0.0244
	Autos>0 & < Workers	–	0.2421	0.2691	0.3333	0.1225	0.0244
	Autos ≥ Workers	–	0.3041	0.3303	0.2961	0.0585	0.0110
Home Based Shop	–	Low	0.3216	0.3068	0.1675	0.1809	0.0232
	–	Medium-Low	0.4827	0.2649	0.1882	0.0604	0.0037
	–	Medium-High & High	0.5286	0.3271	0.1138	0.0293	0.0012
	0 Autos	–	0.0490	0.3487	0.0554	0.5223	0.0247
	Autos>0 & < Workers	–	0.2945	0.3691	0.2284	0.0957	0.0123
	Autos ≥ Workers	–	0.5071	0.3006	0.1456	0.0402	0.0066
Home Based School	–	Total	0.0560	0.3365	0.4487	0.1409	0.018
Home Based University	–	Total	0.6190	0.1682	0.0517	0.1318	0.0292
Non-Home Based-Work	–	Total	0.7038	0.1945	0.0655	0.0311	0.0052
Non-Home Based-Other	–	Total	0.2866	0.3558	0.3020	0.0467	0.0089

Source: CS Summary of 2015 Household Travel Survey Data

Table 6.6 2015 Off-Peak Auto & Non-Motorized Mode Share Targets

Trip Purpose	Auto Sufficiency	Income Group	Drive Alone	Shared Ride 2	Shared Ride 3+	Walk	Bike
Home Based Work	–	Low	0.6157	0.2551	0.0707	0.0378	0.0206
	–	Medium-Low	0.7237	0.1884	0.0471	0.0187	0.0220
	–	Medium-High & High	0.7891	0.1606	0.0141	0.0155	0.0207
	0 Autos	–	0.1895	0.4787	0.0463	0.1387	0.1467
	Autos>0 & < Workers	–	0.5481	0.2736	0.0922	0.0446	0.0414
	Autos ≥ Workers	–	0.7913	0.1604	0.0214	0.0128	0.0141
Home Based Other	–	Low	0.3762	0.3269	0.1465	0.1382	0.0123
	–	Medium-Low	0.4453	0.3349	0.1567	0.0460	0.0172
	–	Medium-High & High	0.4632	0.3345	0.1590	0.0330	0.0103
	0 Autos	–	0.1308	0.3627	0.1190	0.3634	0.0270
	Autos>0 & < Workers	–	0.2954	0.3003	0.3104	0.0517	0.0270
	Autos ≥ Workers	–	0.4646	0.3324	0.1500	0.0431	0.0099
Home Based Shop	–	Low	0.4915	0.3372	0.1095	0.0453	0.0165
	–	Medium-Low	0.4515	0.3334	0.1795	0.0279	0.0077
	–	Medium-High & High	0.6118	0.3028	0.0676	0.0144	0.0035
	0 Autos	–	0.0517	0.3163	0.0922	0.4696	0.0338
	Autos>0 & < Workers	–	0.4917	0.3163	0.1242	0.1227	0.0146
	Autos ≥ Workers	–	0.5740	0.3142	0.0724	0.0342	0.0052
Home Based School	–	Total	0.1878	0.3712	0.2582	0.1714	0.0114
Home Based University	–	Total	0.5935	0.1860	0.0203	0.1754	0.0248
Non-Home Based-Work	–	Total	0.6366	0.2049	0.0843	0.0699	0.0044
Non-Home Based-Other	–	Total	0.4160	0.3941	0.1203	0.0611	0.0084

Source: CS Summary of 2015 Household Travel Survey Data

Table 6.7 2015 Peak Transit Targets (Linked Trips)

Trip Purpose	Auto Sufficiency	Income Group	Drive-People Mover	Walk-People Mover	Walk-Bus	Park & Ride-Bus	Kiss & Ride-Bus
Home Based Work	–	Low	8	68	11,509	382	1,259
	–	Medium-Low	98	132	4,941	1,764	438
	–	Medium-High & High	20	35	3,306	2,183	292
	0 Autos	–	0	100	10,020	89	664
	Autos>0 & < Workers	–	0	45	3,723	364	609
	Autos ≥ Workers	–	126	90	6,012	3,877	716
Home Based Other	–	Low	132	98	6,510	66	596
	–	Medium-Low	147	162	1,056	164	120
	–	Medium-High & High	36	0	380	76	146
	0 Autos	–	0	82	5,338	22	413
	Autos>0 & < Workers	–	0	54	500	58	222
	Autos ≥ Workers	–	315	125	2,108	226	227
Home Based Shop	–	Low	0	35	2,086	17	156
	–	Medium-Low	0	19	355	0	27
	–	Medium-High & High	0	0	77	4	12
	0 Autos	–	0	0	1,966	9	89
	Autos>0 & < Workers	–	0	0	252	4	17
	Autos ≥ Workers	–	0	54	300	7	89
Home Based School	–	Total	0	0	3,231	12	676
Home Based University	–	Total	0	31	11,975	782	655
Non-Home Based-Work	–	Total	73	757	2,117	516	251
Non-Home Based-Other	–	Total	76	206	7,266	248	436

Source: CS and AECOM Summary of 2010 Transit On-Board Survey Data and 2015 Observed Boardings.
Note: Targets are specified separately by income and auto ownership, so targets total to more than the overall sum of transit trips.

Table 6.8 2015 Off-Peak Transit Targets

Trip Purpose	Auto Sufficiency	Income Group	Drive-People Mover	Walk-People Mover	Walk-Bus	Park & Ride-Bus	Kiss & Ride-Bus
Home Based Work	–	Low	235	35	10,334	239	1,082
	–	Medium-Low	220	60	3,033	331	354
	–	Medium-High & High	124	158	1,993	435	171
	0 Autos	–	38	69	9,220	46	766
	Autos>0 & < Workers	–	161	132	2,697	151	445
	Autos ≥ Workers	–	379	52	3,443	808	396
Home Based Other	–	Low	111	218	8,333	127	685
	–	Medium-Low	180	167	1,663	52	114
	–	Medium-High & High	61	134	602	17	78
	0 Autos	–	72	187	7,335	62	460
	Autos>0 & < Workers	–	57	32	724	13	98
	Autos ≥ Workers	–	223	300	2,540	121	318
Home Based Shop	–	Low	0	18	2,777	24	300
	–	Medium-Low	0	18	702	0	55
	–	Medium-High & High	0	0	117	0	15
	0 Autos	–	0	18	2,558	23	285
	Autos>0 & < Workers	–	0	0	257	0	20
	Autos ≥ Workers	–	0	18	780	1	65
Home Based School	–	Total	0	0	1,667	89	284
Home Based University	–	Total	27	41	13,971	836	911
Non-Home Based-Work	–	Total	197	632	2,477	302	238
Non-Home Based-Other	–	Total	55	311	7,389	250	329

Source: CS and AECOM Summary of 2010 Transit On-Board Survey Data and 2015 Observed Boardings.

Note: Targets are specified separately by income and auto ownership, so targets total to more than the overall sum of transit trips.

6.2.5 Final Calibration Constants

The final model choice model calibration constants are summarized in **Appendix J**.

7.0 Commercial Vehicle Model

The E8Plus commercial vehicle (CV) model is tour-based and simulates the formation of commercial vehicle tours within the SEMCOG region, as well as commercial vehicle trips to, from, and through the region. These CV travel model components were implemented in 2021 using SEMCOG's 2017 commercial vehicle survey and other observed truck data. The commercial vehicle model considers light trucks, medium trucks, and heavy trucks. These three categories of commercial vehicles are grouped from the 13 FHWA vehicle classes, using the definitions listed below.

- Light Commercial Vehicle: Comprise a portion of FHWA vehicle class 3. Not explicitly validated in the E8Plus model update.
- Medium Commercial Vehicle: Validated based on vehicle classification counts for FHWA Vehicle classes 4 through 7.
- Heavy Commercial Vehicle: Validated based on vehicle classification counts for FHWA Vehicle classes 8 through 13.

The CV model includes three model components, each of them briefly described in the remailing sections of this chapter while the modeling details can be found in a separate commercial vehicle model report.

7.1 Firm Synthesis Model

The CV model's first component is the firm synthesis model. The firm synthesis model develops a list of business establishment locations and processes zonal land use data used to generate truck trip demand in later steps of the CV model. The firm synthesis model contains two steps, each one producing one of the two databases.

- TAZ Land Use. This step processes TAZ socioeconomic data into a database of employment and households for the scenario or forecast years.
- Enumerate Firms and Scale Employment. This step enumerates a list of synthetic firms, which is an input describing the base year set of business establishments in the model region by location (TAZ), industry (18 employment categories that are combinations of one or more 2 or 3-digit NAICS code) and firm size (number of employees), and scales it to match TAZ-level employment data by employment category for the scenario and forecast years.

7.2 Long-Distance Truck Model

The long-distance truck model estimates long-distance freight truck travel and its allocation to TAZs inside the SEMCOG region and external stations around the boundary of the SEMCOG model region. It also estimates cross region freight truck movements (external-to-external truck trips) that do not stop at businesses or other freight activity locations in the SEMCOG region.

The external-to-external trips in the long-distance model are based on the expanded ATRI GPS data. During the processing of the ATRI GPS dataset, stops at truck rest stops were removed. Therefore, some of the trips that are included in the long-distance truck model as external-to-external truck trips might in reality have had rest stops within the SEMCOG region.

The long-distance truck model does not cover truck travel between the SEMCOG region and the buffer region around the SEMCOG region, nor does it cover external-to-external travel from one part of the buffer to another part of the buffer that traverses the SEMCOG region. All trips generated by the long-distance truck model have at least one trip end outside of the CV model region, which means that the trip starts or ends beyond the buffer region.

The model components of the long-distance truck model take the following form:

- Internal to External and External to Internal - Internal Trip Ends: Internal trip generation equations estimated at the TAZ level using a function of land use variables, such as employment by industry, number and size of business establishments by industry, the size or capacity of high-intensity freight locations in the TAZ, and accessibility and proximity variables describing variables such as the distance to the interstate highway network.
- Internal to External and External to Internal - External Trip Ends: External trip generation equations estimated for each external station as a function of commodity flows between external regions of North America and the SEMCOG region.
- Trip Distribution: internal trip ends and external trip end for external to internal and internal to external long-distance movements are paired into trips based on a gravity model calibrated using the observed trip length frequencies from the expanded ATRI truck GPS data.
- External to External Trips: the observed patterns of external-to-external trips based on the expanded ATRI truck GPS data were used to develop a base year external-to-external truck trip table. This trip table is grown to the horizon year of interest based on commodity flow forecasts of growth the specific flows that lead to these through trips.
- External Trips by Time of Day: the daily trips (for internal to external, external to internal, and external to external trips) are allocated to vehicle types and time of day based on the observed time of day distribution of long-distance trips.

The output from the long-distance truck model is a list of long-distance trips to and from the SEMCOG region. Some of the origins and destinations of long-distance freight truck trips within the region are TAZs that include warehouse and distribution centers, or intermodal facilities, based on the high-intensity freight location database that is an input to the long-distance truck model. The long-distance truck model identifies the external stations where internal-to-external trips leave the region and external-to-internal trips enter the SEMCOG region.

Another output from the long-distance truck is an external-to-external truck trip list, which is combined with the internal-to-external trips and external-to-internal trips to produce a complete list of all truck trips to, from, and through the SEMCOG region that have at least one trip end outside of the SEMCOG region and beyond the buffer region.

7.3 Commercial Vehicle Touring Model

The Commercial Vehicle Touring Model (CVTM) develops the demand for stops by the remainder of the travel of light, medium, and heavy trucks which is for within-CV model region movements including trucks travelling for non-freight purposes. The within-region movements include providing services and local goods delivery to households and businesses.

Since the CV model region includes the buffer region around the SEMCOG region, from the perspective of just the SEMCOG region some trips developed by the CVTM might be external-to-internal, internal-to-external, external-to-external, or never enter the SEMCOG region at all, as well as internal-to-internal trips.

The CVTM then simulates the truck tours that serve the demand for truck stops. The CVTM groups truck stops into tours using a series of models that cluster, sequence, and time truck tours and stops based on truck travel behavior observed in the commercial vehicle survey and truck GPS data to create a range of realistic truck touring patterns.

Each step in the CVTM is described briefly here:

- Establishment Type: The establishment type model tags each synthetic establishment from the firm synthesis model with an aggregated industry type to match with observed distributions of establishment behavior constructed from the commercial vehicle survey data. The model then applies a Monte Carlo simulation method to draw from the observed distributions of establishments by industry type to add a label that indicates whether the establishment makes goods deliveries or pickups, operates commercial vehicles to provide services, or does both.
- Stop Generation: The stop generation model predicts one day's worth of scheduled stops made by trucks operated by each establishment in each destination TAZ. The model uses a count formulation, which predicts positive integer values for the frequency of an event. Scheduled stops are grouped into two market segments: goods delivery or pickup stops and service stops.
- Vehicle Assignment: For each stop, the vehicle assignment model assigns a commercial vehicle type. The vehicle types are light (i.e., car, van, and pickups with two axles and single rear wheels), medium (single-unit trucks with two axles and double rear wheels or more than two axles), and heavy (multi-unit trucks). The model is formulated as a multinomial logit model (estimated using the commercial vehicle survey data) and predicts vehicle type as a function of the establishment's industry type, distance between establishment and stops to be served, and the stop's purpose—goods delivery or pickup, or providing services.
- Expected Stop Duration: The expected stop duration model is applied to scheduled stops generated by the stop generation model. For each stop, the expected stop duration is drawn from a smoothed, empirical distribution of observed stop distributions for each stop type and vehicle type.
- Tours and Routing
    - Stop Clustering: For each establishment, the stop clustering model groups scheduled goods delivery or pickup stops and service stops into feasible commercial vehicle tours, based on spatial proximity, vehicle type, total travel time, and expected stop duration.
    - Tour type: a tour type (whether start and end locations are the same or not and whether the tour starts and ends at the firm's base) is selected for each tour and appropriate start and end stops are added before and after the scheduled stops.
    - Routing Sequence: Given a set of scheduled stops and their locations on a tour, and the establishment location, the model uses a Travelling Salesman Problem algorithm to determine the sequence of stops on the tour.
- Arrival Time at First Stop: For each tour, the arrival time at the first stop on the tour is predicted using a multinomial logit model. Morning and afternoon arrival times from just before the AM peak to the end of the PM peak are modeled at half-hour intervals, while evening and night arrival times are modeled at one-hour intervals.
- Non-Scheduled Stop Choice: This component predicts any non-scheduled stops between scheduled stops on a tour. The model simulates whether the driver makes one or more non-scheduled stops prior to each scheduled goods delivery or pickup stop or service stop, or prior to returning to the establishment to complete the tour. Purposes for non-scheduled stops include breaks/meals, vehicle service/refueling, and personal business/other.
- Non-Scheduled Stop Destination: For each non-scheduled stop on a tour, this model predicts a destination TAZ. Specifically, for each non-scheduled stop, the model selects a set of eligible TAZs based on attraction factor(s), such as retail employment for break/meal stops, and an impedance factor accounting for travel distances or times. This model uses a "rubber banding" method that considers the travel distance or time from the current stop to each alternative destination and from each alternative destination to the next scheduled stop or returning to the establishment. This method minimizes distance or time deviations from direct paths between scheduled stop locations.

7.4 Commercial Vehicle Trip Tables

The step of Commercial Vehicle Trip Tables combines the trips from both the long-distance model and the CVTM aggregated by OD pair, vehicle type, and time periods. It exports the 18 trip tables CVM produces (three vehicle types by five time periods plus a daily table for each vehicle type) into the five time period .omx trip table files and the daily .omx trip table file.

In addition to saving the trip tables into the set of six .omx file used by the E8Plus model, there is also a user option to save a single consolidated set of CV model trip tables in one .omx file for more convenient analysis. The saved single CV model trip table could be used as one of input tables when choosing to run the E8Plus model with the option of “Static CV Trip Table”.

8.0 DTW Airport Model

The E7 DTW airport model remains unchanged from the E6 model. The airport model first generates and distributes trips based on socioeconomic data along with all other zones using the trip generation and destination choice models described previously. Additional airport person trips identified in **Table 8.1** are then added to the airport zones.

Table 8.1 Airport Special Generator Trips

Zone ID	Zone Description	Airport Vehicle Trips
682	North airport	28,214
683	South airport	14,108

Source: SEMCOG E7 Model, carried forward from the SEMCOG E6 Model.

Airport special generator trips are distributed using an origin choice model using the following utility function:

$$U_{ij} = 0.0012 \cdot Distance_{ij} + 0.7291 \cdot HH_j$$

Distributed airport special generator trips are converted to vehicle trips using the auto occupancy rates defined in **Table 8.2**, and then separated by time of day using the procedures described in **Section 9.2**.

Table 8.2 Airport Auto Occupancy

Period	SOV Share	SR2 Share	SR3+ Share
AM	0.493	0.329	0.178
MD	0.525	0.313	0.162
PM	0.419	0.332	0.249
EV	0.401	0.346	0.253
NT	0.401	0.346	0.253

Source: SEMCOG E7 Model, carried forward from the SEMCOG E6 Model.

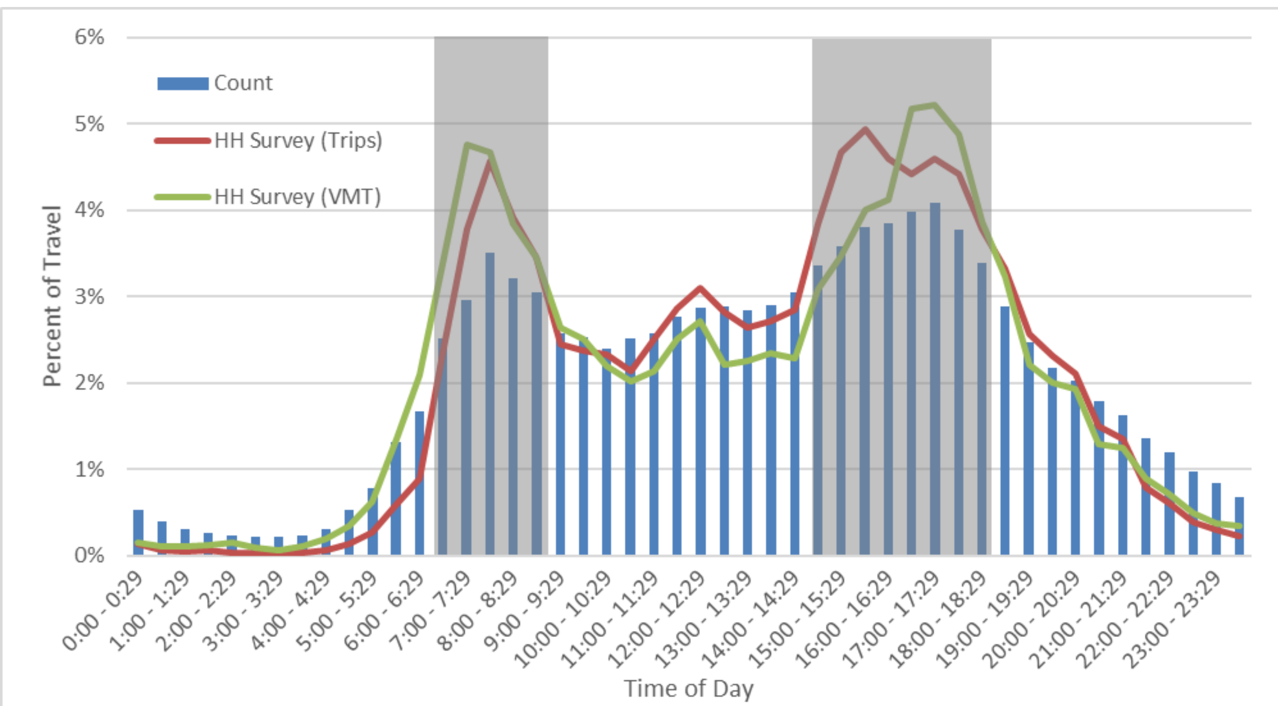
9.0 Time of Day

Trip assignment (see **Section 10.0**) is the final step in the E7 model. As documented in **Section 5.7**, trip distribution and mode choice are performed for peak and off-peak period trips. This pre-assignment step further disaggregates those trips prior to running the highway assignment. Vehicle and transit person trips from mode choice in production-attraction format are converted into directional vehicle trips by time of day (i.e. into origin-destination format by time of day). Peak period trips are divided into AM peak and PM peak trips while off-peak period trips are divided into mid-day, evening, and night trips.

9.1 Time of Day Analysis

Figure 9.1 shows a summary of the expanded 2015 household survey data juxtaposed on 30-minute traffic count data for the region. To define time of day for each trip in the household survey, the surveyed trips have been aggregated by the mid-point of their reported travel times. The surveyed VMT was estimated by multiplying the zone to zone distances by the number of trips for the interchange. As can be seen, all three summaries produce similar distributions of trips although the traffic count data are less peaked and show more night time traffic. The peak in surveyed trips 4:00 PM to 4:30 PM reflects school trips made at that time while the surveyed VMT peak from 5:00 PM to 7:00 PM reflects work trips. The shaded area in the figure represent the 2½ hour morning peak period and the 4-hour afternoon peak period used for highway traffic assignment in the E7 model.

Figure 9.1 Mode Choice Structure



Source: CS based on 2015 household travel survey data and SEMCOG traffic count data.

9.2 Calibrated Time of Day Factors

9.2.1 Vehicle Trips

In order to create time of day trip tables for traffic assignment, the peak period and the off-peak period vehicle trip tables in production-attraction format (i.e. from home to non-home location for home based trips, work to non-work location for non-home based-work trips) must be factored by time of day and directional factors. The production-attraction tables are multiplied by the proportions of trips traveling from the production location to the attraction location and the transposes of the production-attraction tables are multiplied by the proportions of trips traveling from the attraction location to the production location for each time of day. The mid-points of trips made by vehicle drivers were summarized from the expanded 2015 household travel survey data for the development of the time of day-direction split factors. The original factors were adjusted during the model calibration process so that the resulting traffic volumes and VMT would better match the observed traffic data.

Non-home based-other, truck, and external-external trips are modeled in origin-destination format, rather than production-attraction format. Consequently, only time of day factors need to be applied for those purposes; direction split factors are not required.

Table 9.1 shows the calibrated time of day-direction split factors for vehicle trips. The table is split into two primary sections: those trips and trip tables that are modeled by time of day, and those that are modeled on a daily basis. For the trips that are modeled by time of day, AM peak period and PM peak period factors are shown for each direction of travel, production zone to attraction zone and the transpose for attraction zone to production zone. The AM and PM peak period factors by direction sum to 100 percent for each trip purpose. Note that the factors by direction of travel are not symmetrical. For example, 51.62 percent of home based work trips travel from the production (home) zone to the attraction (work) zone and 48.38 percent travel from the attraction zone to the production zone. This does not mean that people are not returning home; rather, it implies that more non-home based trips are made on the trip home from work than on the trip to work. This is obvious by the non-home based-work production (work location) to attraction (non-work location) factor of 72.63 percent.

As with the peak period trip percentages, off-peak period trip percentages by direction over the three off-peak time periods sum to 100 percent for each trip purpose. Directional splits occur in the off-peak periods for reasons similar to those for the peak periods.

Trucks, external-external, and airport trips are modeled on a daily basis. Truck and external-external trips are modeled in origin to destination format, while Detroit airport trips are modeled in production (non-airport zone) to attraction (airport zone) format. The truck, external-external, and airport trip factors were taken from the E6 model without change. Since they are modeled on a daily basis, the sum of the total peak and total off-peak percentages sum to 100 percent for each trip purpose.

Table 9.1 Calibrated Time of Day / Direction Split Factors for Vehicle Trips

		Peak Period			Off-Peak Period			
Trip Purpose	Direction	AM (6:30 AM–8:59 AM)	PM (2:30 PM–6:29 PM)	Total	Midday (9:00 AM–2:29 PM)	Evening (6:30 PM–9:59 PM)	Night (10:00 PM–6:29 AM)	Total
Trips Distributed by Peak & Off-Peak Time Periods								
Home Based Work	P→A	44.14%	7.48%	51.62%	27.68%	4.40%	26.38%	58.46%
	A→P	1.80%	46.58%	48.38%	11.96%	14.04%	15.54%	41.54%
Home Based Other	P→A	23.58%	31.07%	54.65%	24.55%	14.91%	6.38%	45.84%
	A→P	5.39%	39.96%	45.35%	16.97%	23.45%	13.74%	54.16%
Home Based Shop	P→A	5.08%	27.91%	32.99%	23.44%	14.87%	4.14%	42.45%
	A→P	1.87%	65.14%	67.01%	25.87%	23.92%	7.76%	57.55%
Home Based School	P→A	61.66%	0.24%	61.90%	6.06%	0.16%	0.93%	7.15%
	A→P	0.03%	38.07%	38.10%	88.20%	4.35%	0.30%	92.85%
Home Based University	P→A	43.29%	16.09%	59.38%	30.87%	16.30%	0.68%	47.85%
	A→P	1.91%	38.71%	40.62%	20.40%	21.27%	10.48%	52.15%
Non-Home Based-Work	P→A	9.46%	63.17%	72.63%	41.00%	18.67%	8.11%	67.78%
	A→P	19.06%	8.31%	27.37%	20.61%	7.55%	4.06%	32.22%
Non-Home Based-Other	P→A	8.09%	41.91%	50.00%	26.94%	17.29%	5.77%	50.00%
	A→P	8.09%	41.91%	50.00%	26.94%	17.29%	5.77%	50.00%
Trips Distributed on a Daily Basis								
Light Truck	O→D	10.50%	15.80%	26.30%	66.00%	3.90%	3.80%	73.70%
Medium Truck	O→D	13.00%	14.80%	27.80%	65.20%	3.50%	3.50%	72.20%
Heavy Truck	O→D	12.80%	14.80%	27.60%	60.60%	5.90%	5.90%	72.40%
External - External	O→D	11.60%	26.10%	37.70%	25.10%	18.60%	18.60%	62.30%
Airport	P→A	7.00%	9.82%	16.82%	15.78%	8.10%	7.49%	31.37%
	A→P	2.00%	10.18%	12.18%	10.22%	14.40%	15.01%	39.63%

Source: CS based on 2015 household travel survey data.

9.2.2 Transit Person Trips

Similar to vehicle trips, the peak period and the off-peak period transit person trip tables in production-attraction format must be factored by time of day and directional factors prior to transit assignment. The production-attraction tables are multiplied by the proportions of trips traveling from the production location to the attraction location and the transposes of the production-attraction tables are multiplied by the proportions of trips traveling from the attraction location to the production location for each time of day. The mid-points of person trips made by transit were summarized from the expanded 2010 on-board transit survey data for the development of the time of day-direction split factors. Non-home based-other trips are modeled in origin-destination format, rather than production-attraction format. Consequently, only time of day factors need to be applied for those trips; direction split factors are not required.

Unlike the roadway network, transit routes may not be active for each of the time periods. No transit service is modeled for the night time period and some services provided in the AM and PM peak periods is not offered in the mid-day or evening periods. Since the destination choice and mode choice models are based on AM peak period and mid-day transit networks and skims, additional processing is required during the application of the time of day-direction split factoring to ensure that reverse trips can be made (i.e. when the transpose of the production-attraction trip table is factored). The following hierarchy of checks and adjustments are applied within the E7 application code:

1. Any OD trip that cannot be made in the PM or evening period is moved to the AM or mid-day period. This includes both attraction-production trips and production-attraction trips that cannot be made in the corresponding time period.

2. Any OD trip that cannot be made in the AM or mid-day period is reversed from attraction-production format to production-attraction format. This may include trips moved from the PM and evening periods, as well as attraction-production trips in the PM or mid-day periods.

Table 9.2 shows the time of day-direction split factors for transit trips. AM peak period and PM peak period factors are shown for each direction of travel, production zone to attraction zone and the transpose for attraction zone to production zone. The AM and PM peak period factors by direction sum to 100 percent for each trip purpose. The factors by direction of travel are not symmetrical. For example, 60 percent of home based work trips travel from the production (home) zone to the attraction (work) zone and 40 percent travel from the attraction zone to the production zone. As with the peak period trip percentages, off-peak period trip percentages by direction over the three off-peak time periods sum to 100 percent for each trip purpose. Directional splits occur in the off-peak periods for reasons similar to those for the peak periods.

Table 9.2 Calibrated Time of Day / Direction Split Factors for Transit Trips

		Peak Period			Off-Peak Period			
Trip Purpose	Direction	AM (6:30 AM–8:59 AM)	PM (2:30 PM–6:29 PM)	Total	Midday (9:00 AM–2:29 PM)	Evening (6:30 PM–9:59 PM)	Night (10:00 PM–6:29 AM)	Total
Home Based Work	P→A	42%	18%	60%	50%	13%	63%	42%
	A→P	4%	36%	40%	18%	19%	37%	4%
Home Based Other	P→A	34%	35%	69%	55%	14%	69%	34%
	A→P	6%	25%	31%	23%	8%	31%	6%
Home Based Shop	P→A	13%	45%	58%	59%	7%	66%	13%
	A→P	1%	41%	42%	22%	12%	34%	1%
Home Based School	P→A	56%	10%	66%	29%	12%	41%	56%
	A→P	1%	33%	34%	32%	27%	59%	1%
Home Based University	P→A	34%	20%	54%	54%	7%	61%	34%
	A→P	1%	45%	46%	28%	11%	39%	1%
Non-Home Based-Work	P→A	19%	31%	50%	45%	5%	50%	19%
	A→P	19%	31%	50%	45%	6%	50%	19%
Non-Home Based-Other	P→A	10%	40%	50%	42%	8%	50%	10%
	A→P	10%	40%	50%	42%	8%	50%	10%

Source: CS based on 2010 on-board survey data.

10.0 Highway and Transit Assignment Procedures

10.1 Highway Assignment Procedures

Traffic assignment is performed for each of the five time periods described in **Section 9.2**. The SEMCOG E7 model utilizes a multi-class equilibrium assignment approach. Updates to traffic assignment in the E7 model include revisions to volume-delay parameter functions to better represent reduced travel speeds due to congestion. Assignment is set to run up to 100 iterations, or until reaching a relative gap of 0.001.

10.1.1 Volume-Delay Functions

The SEMCOG E7 model uses a generalized cost function, which combines travel time and auto operating cost based on a value of time (VOT). The generalized cost function can also consider tolls, but the E7 model does not currently contain any tolled links. The generalized cost for each link is computed as follows:

$$GeneralizedCost = TollCost + OperatingCost + VOT \cdot FFTime \cdot \left[1 + \alpha\left(\frac{Volume}{Capacity}\right)^{\beta}\right]$$

The generalized cost function assumes an auto operating cost of $0.11 per mile, and a value of time of $9 per hour. Freeflow speed, capacity, alpha, and beta parameters are defined based on link facility type and area type and are defined in Appendix J. Because assignment is performed for peak periods rather than individual hours, hourly capacities are converted to peak period capacities using the factors that reflect the share of observed traffic volumes occurring during the peak hour within each period. These factors are defined in **Table 10.1**.

Table 10.1 Peak Hour to Peak Period Capacity Factors

Time Period	Hourly to Period Capacity Factor
AM (6:30 AM-8:59 AM)	2.252
Midday (9:00 AM-2:29 PM)	5.102
PM (2:30 PM-6:29 PM)	3.236
Evening (6:30 PM-6:29 PM)	2.638
Night (10:00 PM-6:29 AM)	3.436

Source: SEMCOG E7 Model.

10.1.2 Vehicle Classes

Traffic assignment is performed for six separate vehicle classes: single occupant vehicle (SOV), shared ride 2 (SR2), shared ride 3+ (SRS3+), light commercial vehicle (LCV), medium commercial vehicle (MCV), and heavy commercial vehicle (MCV). Vehicle classes are selectively excluded from links such as HOV lanes and links where trucks are prohibited using the mode ID flags defined in Table 10.2. Medium and heavy commercial vehicles are assigned passenger car equivalent (PCE) values of 1.89 and 3.35, respectively[13].

[13] Source: Mingo and Zhuang; *Passenger Car Equivalents of Larger rucks Derived from Use of FRESIM Model*; 1994.

Table 10.2 Vehicle Class Exclusions

Mode ID	Description	Excluded vehicle classes
1	Drive Only	None, all vehicles permitted
2	Drive and Walk	None, all vehicles permitted
4	AM and PM HOV Lane	SOV; light, medium, and heavy commercial vehicles. All vehicles permitted in the off-peak periods.
5	Management Lane - AM HOV Only	SOV; light, medium, and heavy commercial vehicles. Link disabled outside of the corresponding peak period.
6	Management Lane - PM HOV Only	
7	Management Lane - AM Light Vehicle Only	Light, medium, and heavy commercial vehicles. Link disabled outside of the corresponding peak period.
8	Management Lane - PM Light Vehicle Only	

Source: SEMCOG E7 Model, carried forward from the SEMCOG E6 Model.

10.2 Transit Assignment Procedures

Transit person trips resulting from the mode choice model are assigned to the transit route system in origin to destination format. Each trip is assigned from zone centroid to zone centroid using walk or drive access links, transit routes, and walk egress links. The transit assignment step does not include capacity constraint, so increasing transit volumes do not result in diversion of transit trips to other transit service. Transit assignment is performed using transit network and pathfinding parameters descried in **Section** Error! Reference source n ot found.

11.0 Model Calibration and Validation

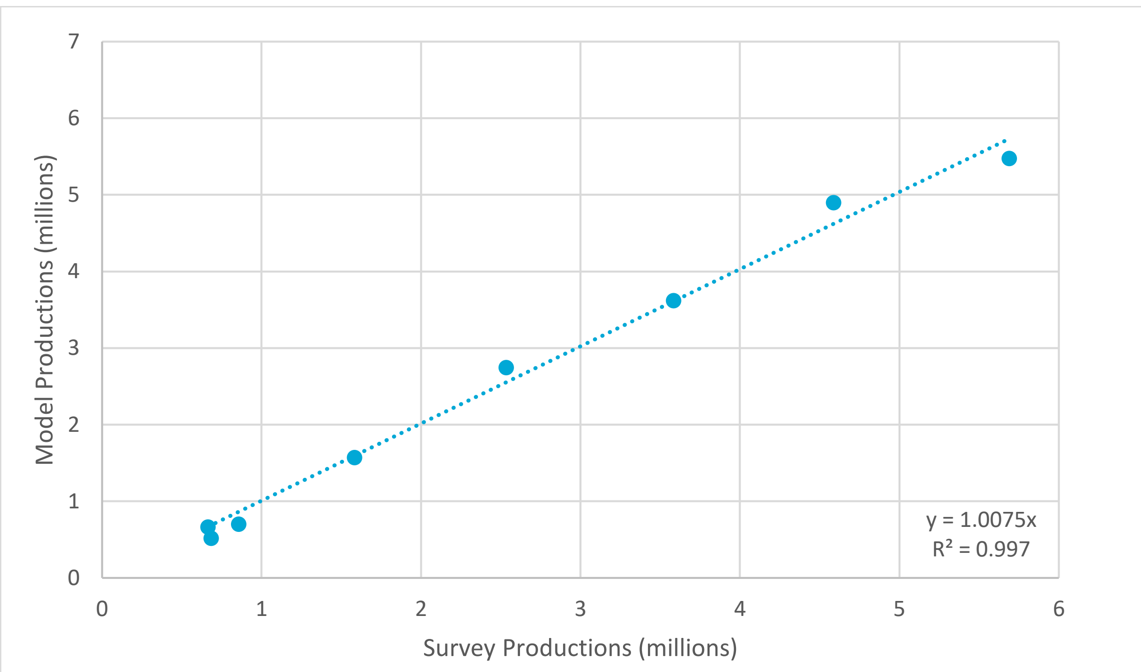
Results from each step of the updated E7 model were validated against observed data. Validation statistics are presented in this chapter.

11.1 Trip Generation Validation

Total balanced productions and attraction values resulting from the model were compared to aggregated survey data at the county level as shown in **Figure 11.1** and **Figure 11.2**. Trip generation rates were initially developed using the 2005/2004 household survey and later updated based on the 2015 household survey. Because trip generation rates were scaled to account for underreporting, the total number of trips from the survey was scaled to match the total modeled trip generation results.

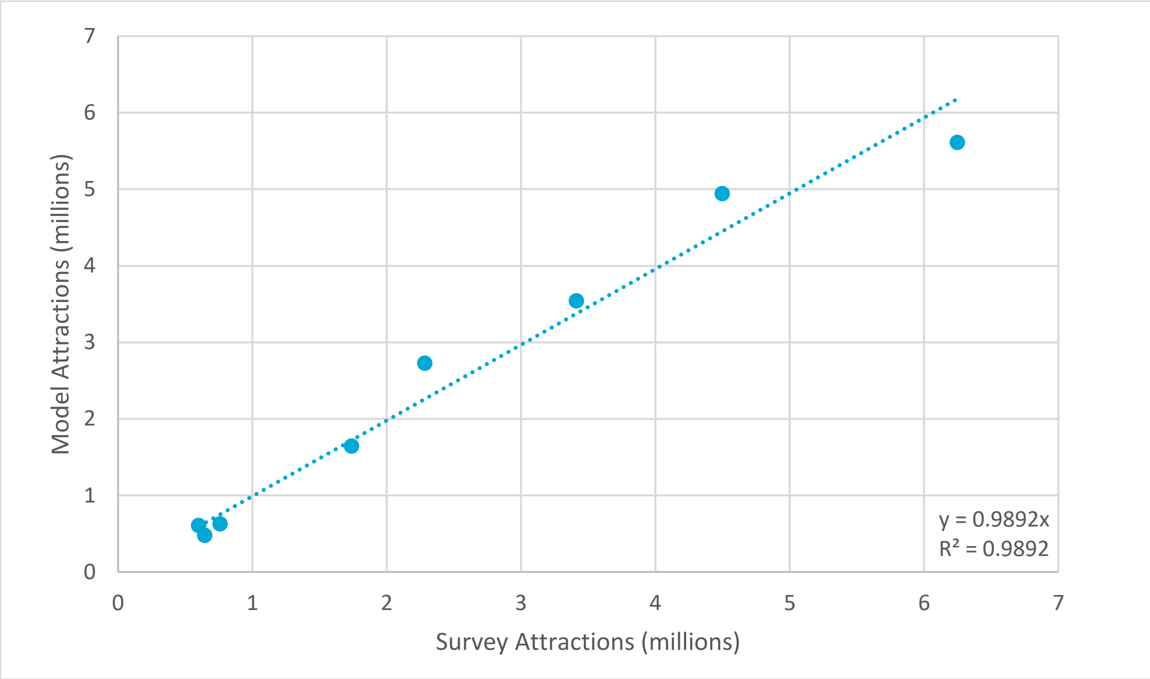
In addition, trip generation rates were compared for 25 super-districts defined by SEMCOG. This comparison is shown in **Figure 11.3** and **Figure 11.4**.

Figure 11.1 County-Level Comparison of Trip Production Totals



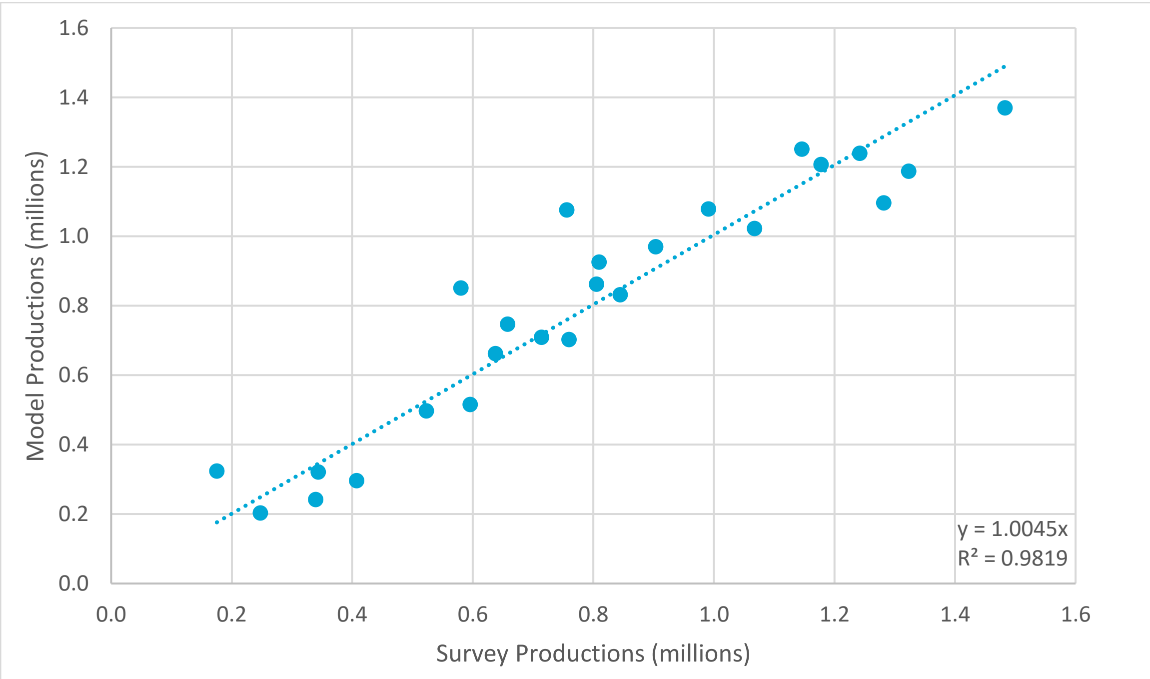
Source: CS analysis of E7 Model results and 2015 household survey data.

Figure 11.2 County-Level Comparison of Trip Attraction Totals



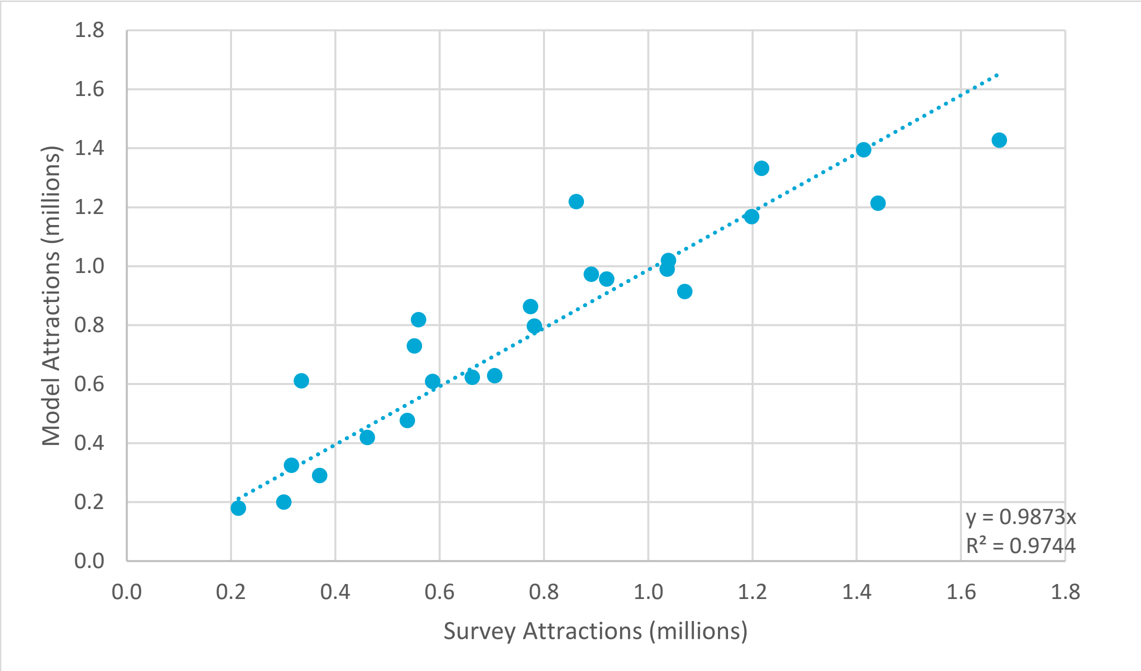
Source: CS analysis of E7 Model results and 2015 household survey data.

Figure 11.3 Super-District Comparison of Trip Production Totals



Source: CS analysis of E7 Model results and 2015 household survey data.

Figure 11.4 Super-District Comparison of Trip Attraction Totals



Source: CS analysis of E7 Model results and 2015 household survey.

11.2 Trip Distribution Validation

Trip distribution was estimated using 2004/2005 household survey and then calibrated to 2015 household survey data. Trip length frequency distributions are documented in **Section 5.3**. Validation of county level interchanges are documented here. A county to county table of surveyed trips is shown in **Table 11.1**, with a table of modeled trips shown in **Table 11.2**. To account for trip generation rate adjustments, surveyed trips were scaled to match the total number of modeled trips. Comparisons between modeled and surveyed trips are shown graphically in **Figure 11.5**.

Table 11.1 County to County Trips (Survey)

	Detroit	Wayne	Oakland	Macomb	Washtenaw	Monroe	St. Clair	Livingston	TOTAL
Detroit	2,014,354	363,541	233,720	138,981	10,842	2,026	1,940	2,062	2,767,464
Wayne	353,229	4,023,834	304,214	94,075	119,074	25,445	1,210	16,605	4,937,686
Oakland	209,241	322,564	4,634,870	251,323	36,824	1,844	3,719	57,003	5,517,387
Macomb	152,979	94,091	359,622	3,000,645	3,522	848	34,766	1,981	3,648,454
Washtenaw	8,914	100,685	31,612	1,639	1,408,442	12,393	0	20,021	1,583,707
Monroe	4,944	42,225	3,618	913	31,065	436,542	60	189	519,557
St. Clair	3,384	2,205	8,322	80,218	135	457	571,819	779	667,320
Livingston	2,998	33,674	83,209	3,822	46,715	1,070	777	535,849	708,114
TOTAL	2,750,043	4,982,818	5,659,187	3,571,616	1,656,619	480,626	614,291	634,489	20,349,688

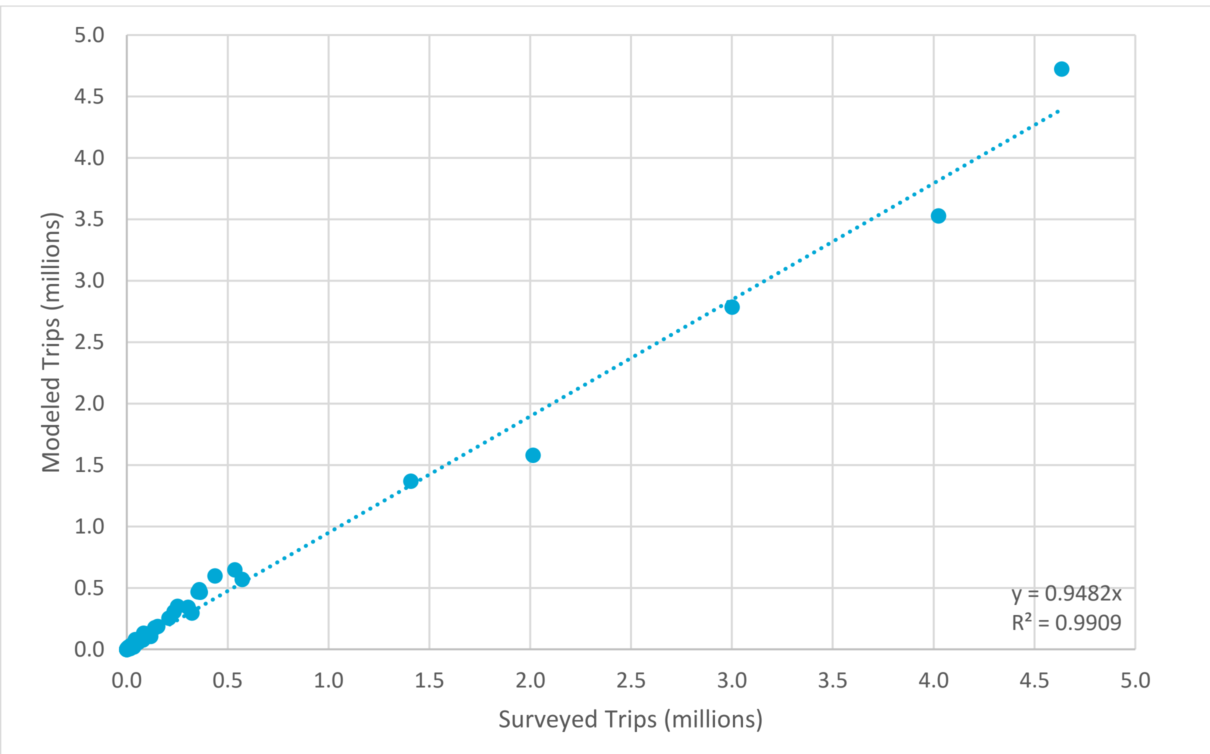
Source: CS analysis of 2015 household survey.

Table 11.2 County to County Trips (Model)

Model	Detroit	Wayne	Oakland	Macomb	Washtenaw	Monroe	St. Clair	Livingston	TOTAL
Detroit	1,580,348	464,377	306,145	177,007	5,628	2,431	357	1,388	2,537,680
Wayne	466,775	3,529,660	341,816	107,663	105,655	34,144	560	7,434	4,593,707
Oakland	253,818	294,976	4,725,344	350,198	31,566	3,651	2,169	55,985	5,717,708
Macomb	186,373	105,396	485,487	2,785,752	2,449	1,485	19,478	1,741	3,588,161
Washtenaw	13,388	125,985	42,712	3,830	1,368,708	18,299	72	32,513	1,605,506
Monroe	10,762	79,988	10,115	3,034	38,707	598,040	64	1,196	741,907
St. Clair	5,851	4,215	18,634	76,427	281	235	569,053	200	674,895
Livingston	8,348	28,169	132,007	6,241	65,573	1,459	99	648,229	890,124
TOTAL	2,525,662	4,632,765	6,062,261	3,510,153	1,618,566	659,745	591,852	748,685	20,349,688

Source: CS analysis of E7 model results.

Figure 11.5 Comparison of County to County Trip Interchange Totals



Source: CS analysis of E7 Model results and 2015 household survey.

11.3 Mode Choice Validation

As described in **Section 6.2**, the mode choice model has been calibrated to match observed trips by mode. A comparison of model results and mode choice calibration targets is shown in **Table 11.3** through **Table 11.5**.

Table 11.3 Daily Mode Choice Target Summary

Mode	HBW	HBO	HBSh	HBSc	HBU	NHBW	NHBO	Total
Drive Alone	2,124,708	2,754,823	954,294	58,842	276,483	1,390,918	1,614,750	9,174,818
Shared Ride 2	565,164	2,521,718	602,268	275,701	82,361	417,176	1,697,255	6,161,643
Shared Ride 3+	109,991	1,779,096	201,924	343,247	14,520	157,659	902,999	3,509,436
Walk	69,817	583,535	153,733	117,079	73,226	108,559	246,415	1,352,364
Bike	49,919	101,236	16,157	13,856	12,120	9,879	38,658	241,824
Walk to Transit	35,603	19,325	6,203	4,898	26,018	5,983	15,172	113,202
PnR to Transit	5,335	502	44	101	1,618	818	498	8,916
KnR to Transit	3,596	1,738	565	960	1,566	489	765	9,679
Auto Total	2,799,864	7,055,637	1,758,485	677,790	373,364	1,965,753	4,215,004	18,845,898
Non-Motorized Total	119,736	684,771	169,890	130,935	85,346	118,438	285,073	1,594,188
Transit Total	44,534	21,565	6,812	5,959	29,202	7,290	16,435	131,797
Total	**2,964,134**	**7,761,973**	**1,935,187**	**814,685**	**487,912**	**2,091,481**	**4,516,512**	**20,571,883**

Source: CS and AECOM analysis of 2015 household survey, 2010 on-board survey, and transit boarding data.

Table 11.4 Daily Mode Choice Model Results

Mode	HBW	HBO	HBSh	HBSc	HBU	NHBW	NHBO	Total
Drive Alone	2,125,432	2,757,013	945,140	60,131	276,612	1,391,130	1,614,877	9,170,336
Shared Ride 2	565,985	2,522,881	596,639	275,276	82,413	417,150	1,697,602	6,157,946
Shared Ride 3+	110,029	1,781,310	200,055	342,699	14,524	157,747	903,063	3,509,428
Walk	69,161	581,817	165,040	116,624	73,605	108,265	246,013	1,360,526
Bike	49,909	102,597	17,395	13,836	12,057	9,906	38,749	244,449
Walk to Transit	34,812	19,781	6,545	4,949	25,587	5,880	14,966	112,521
PnR to Transit	5,315	549	56	134	1,604	925	497	9,080
KnR to Transit	3,485	1,764	585	965	1,510	477	743	9,529
Auto Total	2,801,445	7,061,205	1,741,835	678,106	373,549	1,966,027	4,215,542	18,837,710
Non-Motorized Total	119,070	684,414	182,436	130,460	85,662	118,171	284,762	1,604,975
Transit Total	43,613	22,094	7,186	6,049	28,700	7,282	16,206	131,129
Total	2,964,128	7,767,713	1,931,456	814,615	487,911	2,091,481	4,516,510	20,573,814

Source: CS analysis of E7 model results.

Table 11.5 Comparison of Daily Model Results to Mode Choice Targets

Mode	HBW	HBO	HBSh	HBSc	HBU	NHBW	NHBO	Total
Drive Alone	724 (0.0%)	2,190 (0.1%)	-9,153 (-1.0%)	1,289 (2.2%)	129 (0.0%)	212 (0.0%)	127 (0.0%)	-4,483 (0.0%)
Shared Ride 2	820 (0.1%)	1,163 (0.0%)	-5,629 (-0.9%)	-425 (-0.2%)	52 (0.1%)	-26 (0.0%)	347 (0.0%)	-3,697 (-0.1%)
Shared Ride 3+	37 (0.0%)	2,215 (0.1%)	-1,868 (-0.9%)	-548 (-0.2%)	4 (0.0%)	88 (0.1%)	64 (0.0%)	-8 (0.0%)
Walk	-656 (-0.9%)	-1,718 (-0.3%)	11,307 (7.4%)	-456 (-0.4%)	379 (0.5%)	-293 (-0.3%)	-402 (-0.2%)	8,162 (0.6%)
Bike	-10 (0.0%)	1,361 (1.3%)	1,239 (7.7%)	-20 (-0.1%)	-63 (-0.5%)	27 (0.3%)	91 (0.2%)	2,625 (1.1%)
Walk to Transit	-791 (-2.2%)	456 (2.4%)	342 (5.5%)	51 (1.0%)	-431 (-1.7%)	-103 (-1.7%)	-206 (-1.4%)	-681 (-0.6%)
PnR to Transit	-20 (-0.4%)	47 (9.3%)	12 (27.6%)	33 (32.9%)	-14 (-0.9%)	107 (13.0%)	-1 (-0.2%)	164 (1.8%)
KnR to Transit	-111 (-3.1%)	26 (1.5%)	20 (3.5%)	5 (0.6%)	-56 (-3.6%)	-12 (-2.4%)	-22 (-2.9%)	-150 (-1.6%)
Auto Total	1,581 (0.1%)	5,568 (0.1%)	-16,650 (-0.9%)	316 (0.0%)	185 (0.0%)	274 (0.0%)	539 (0.0%)	-8,188 (0.0%)
Non-Motorized Total	-665 (-0.6%)	-357 (-0.1%)	12,546 (7.4%)	-475 (-0.4%)	316 (0.4%)	-266 (-0.2%)	-311 (-0.1%)	10,787 (0.7%)
Transit Total	-921 (-2.1%)	529 (2.5%)	374 (5.5%)	90 (1.5%)	-502 (-1.7%)	-8 (-0.1%)	-229 (-1.4%)	-668 (-0.5%)
Total	-6 (0.0%)	5,740 (0.1%)	-3,730 (-0.2%)	-70 (0.0%)	-1 (0.0%)	(0.0%)	-2 (0.0%)	1,931 (0.0%)

Source: CS and AECOM analysis of 2015 household survey, 2010 on-board survey, and transit boarding data and CS analysis of E7 model results.

Note: Values show Model results minus targets, followed by percent difference.

11.4 Highway Assignment Validation

Roadway volumes resulting from traffic assignment were compared to traffic count data. This process ensured the model reasonably represents observed traffic volumes. SEMCOG provided traffic count data attached to the roadway network, allowing a direct comparison of model results to traffic count data. Travel model results were compared to traffic count data using a variety of techniques, including regional comparisons, screenline comparisons, and inspection of individual link values.

11.4.1 Overall Activity Level

Overall vehicle trip activity was validated by comparing count data to model results on all links with available data. Comparisons included model volume to count volume ratio and model VMT as compared to count VMT. These statistics were reviewed by county and by facility type as shown in **Table 11.6** and **Table 11.7**.

Table 11.6 Activity Level by County

County	Number of Links with Counts	Volume to Count Ratio	Model VMT / Count VMT
Detroit	629	1.00	1.02
Other Wayne	634	0.94	0.96
Oakland	1,226	1.04	1.04
Macomb	702	0.99	0.97
Washtenaw	497	1.05	1.04
Monroe	255	1.00	1.02
St Clair	240	0.83	0.95
Livingston	551	0.98	0.94
SEMCOG Region	**4,734**	**1.00**	**1.00**

Source: SEMCOG E7 Model Summary Report.

Table 11.7 Activity Level by Facility Type

Facility Type	Number of Links with Counts	Volume to Count Ratio	Model VMT / Count VMT
Interstate Fwy	92	1.01	1.00
Other Fwy	82	1.07	1.08
Principal Arterial	1,054	1.00	0.98
Minor Arterial	1,179	0.99	1.00
Major Collector	985	0.97	0.97
Minor Collector	85	1.46	1.50
Local Road	105	0.92	0.76
Ramp	1,136	0.98	0.99
Collector Distributor	16	0.95	0.89
Total	**4,734**	**1.00**	**1.00**

Source: SEMCOG E7 Model Summary Report.

11.4.2 Activity by Time of Day

While most model validation has been performed at the daily level, assignment is run separately for the five time periods described in **Chapter 9.0** (AM, MD, PM, Evening, and Night). Time of day assignment was compared to traffic counts available by time of day to validate that the model is assigning the correct share of traffic to each of these time periods. **Table 11.8** presents a comparison of model VMT to counted VMT.

Table 11.8 Validation by Time of Day

Time Period	Counts	Count VMT	Model VMT	Difference	% Difference
AM	4,612	4,152,240	4,146,091	-6,149	-0.1%
MD	4,612	7,651,356	7,733,433	82,077	1.1%
PM	4,612	7,864,575	7,531,553	-333,022	-4.2%
EV	4,612	3,675,857	3,596,610	-79,247	-2.2%
NT	4,612	2,719,109	2,719,990	881	0.0%
Total	4,612	26,063,137	25,727,677	-335,460	-1.3%

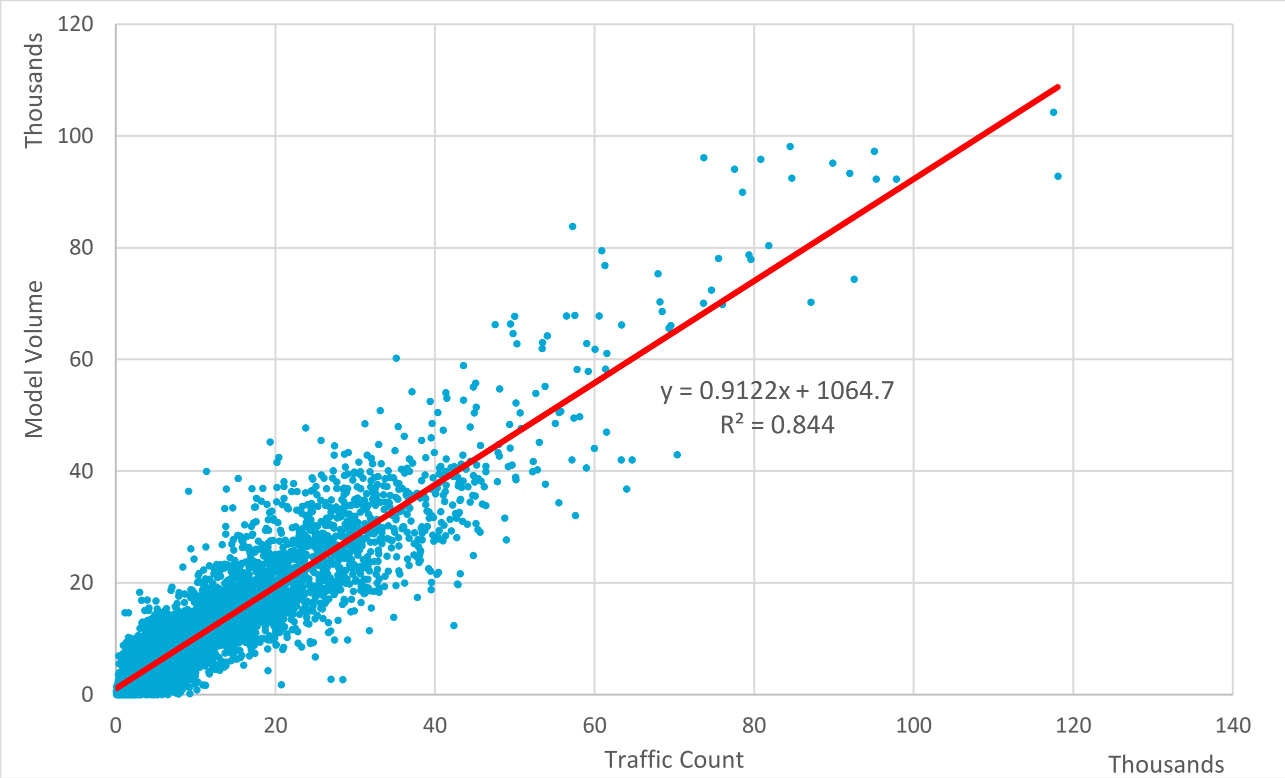
Source: SEMCOG E7 Model Summary Report.

11.4.3 Measures of Error

While the model should accurately represent the overall level of activity, it is also important to verify the model has an acceptably low level of error on individual links. It is expected the model will not perfectly reproduce count volumes on every link, but the level of error should be monitored. The plot shown in **Figure 11.6** demonstrates the ability of the E7 Model to match individual traffic count data points and notes the resulting R-squared value. **Table 11.9** and **Table 11.10** list root mean square error (RMSE) and % RMSE values for each county facility type. General guidelines suggest that % RMSE should be near 40 percent region-wide, with values below 30 percent for high volume facility types such as freeways. The E7 model achieves a % RMSE of 40% or better for arterial and freeway links. The % RMSE measure tends to over-represent errors on low volume facilities, so values on collectors are not particularly meaningful. **Table 11.11** shows % RMSE values by volume group.

Cutline analysis provides another measure of error. **Table 11.12** shows the total counted and modeled volume across each of ten cutlines in the E7 Model. These cutlines, shown in **Figure 11.7** and **Figure 11.8**, capture major movements in the region.

Figure 11.6 Model Volume and Count Comparison



Source: SEMCOG E7 Model.

Table 11.9 Root Mean Square Error by County

County	Number of Links with Counts	RMSE	% RMSE
Detroit	629	4,974	50.7%
Other Wayne	634	5,271	40.6%
Oakland	1,226	5,478	34.8%
Macomb	702	6,791	32.9%
Washtenaw	497	3,361	41.7%
Monroe	255	3,171	56.4%
St Clair	240	3,514	53.0%
Livingston	551	3,528	62.2%
SEMCOG Region	**4,734**	**5,039**	**40.9%**

Source: SEMCOG E7 Model Summary Report.

Table 11.10 Root Mean Square Error by Facility Type

Facility Type	Number of Links with Counts	RMSE	% RMSE
Interstate Fwy	92	9,179	19.7%
Other Fwy	82	8,938	28.1%
Principal Arterial	1,054	7,453	31.7%
Minor Arterial	1,179	4,384	37.9%
Major Collector	985	2,936	78.5%
Minor Collector	85	1,356	141.5%
Local Road	105	2,433	116.3%
Ramp	1,136	3,631	47.1%
Collector Distributor	16	6,705	35.1%
Total	**4,734**	**5,039**	**40.9%**

Source: SEMCOG E7 Model Summary Report.

Table 11.11 Root Mean Square Error by Volume Group

Volume Group	Number of Links with Counts	RMSE	% RMSE
0 - 1,000	315	1,508	254.8%
1,000 - 5,000	1,285	2,730	94.0%
5,000 - 10,000	1,122	3,549	49.4%
10,000 - 20,000	1,026	5,253	36.3%
20,000 - 30,000	569	7,011	28.5%
30,000 - 50,000	346	9,114	24.6%
50,000 - 100,000	69	12,183	18.6%
100,000 and up	2	28,509	24.2%
All Links	**4,734**	**5,039**	**40.9%**

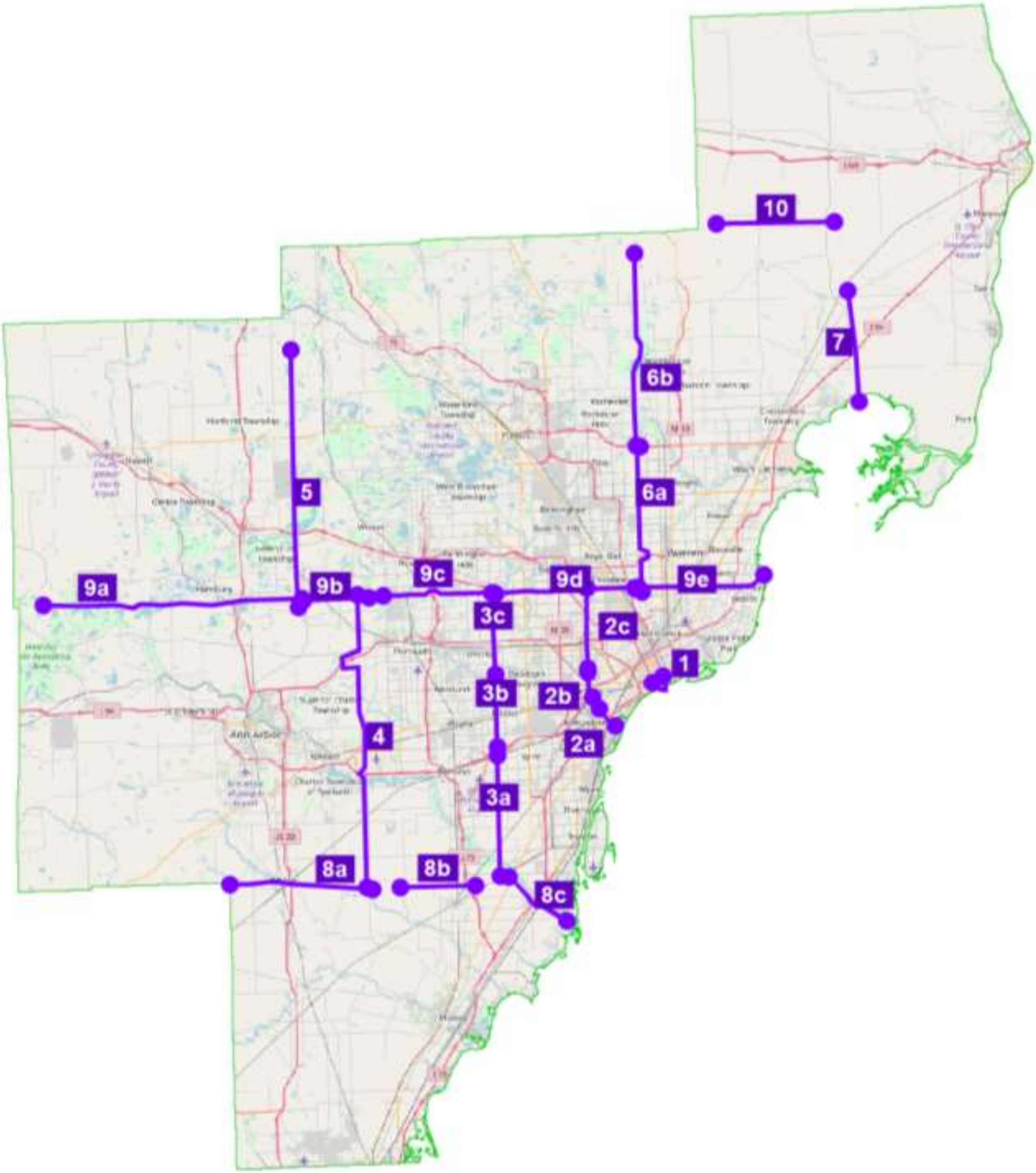
Source: SEMCOG E7 Model Summary Report.

Table 11.12 Cutline Volume Comparison

Cutline	Number of Links	Count Volume	Model Volume	Difference	Percent Difference
Cutline 1	25	119,605	169,444	49,839	42%
Cutline 2a	*5*	*200,665*	*214,354*	*13,689*	*7%*
Cutline 2b	*7*	*198,356*	*196,841*	*-1,515*	*-1%*
Cutline 2c	*21*	*96,794*	*104,071*	*7,277*	*8%*
Cutline 2 Total	33	495,815	515,266	19,451	4%
Cutline 3a	*12*	*144,716*	*161,959*	*17,243*	*12%*
Cutline 3b	*14*	*305,342*	*312,909*	*7,567*	*2%*
Cutline 3c	*14*	*297,409*	*359,791*	*62,382*	*21%*
Cutline 3 Total	40	747,467	834,659	87,192	12%
Cutline 4	25	189,524	231,665	42,141	22%
Cutline 5	14	684,523	694,860	10,337	2%
Cutline 6a	*22*	*82,593*	*102,198*	*19,605*	*24%*
Cutline 6b	*12*	*87,731*	*90,106*	*2,375*	*3%*
Cutline 6 Total	34	170,324	192,304	21,980	13%
Cutline 7	8	81,143	76,174	-4,969	-6%
Cutline 8a	*9*	*51,185*	*54,243*	*3,058*	*6%*
Cutline 8b	*5*	*81,214*	*84,966*	*3,752*	*5%*
Cutline 8c	*6*	*102,102*	*116,834*	*14,732*	*14%*
Cutline 8 Total	20	234,501	256,043	21,542	9%
Cutline 9a	*16*	*27,911*	*25,357*	*-2,554*	*-9%*
Cutline 9b	*4*	*341,640*	*351,548*	*9,908*	*3%*
Cutline 9c	*13*	*692,493*	*818,515*	*126,022*	*18%*
Cutline 9d	*32*	*378,770*	*465,529*	*86,759*	*23%*
Cutline 9e	*19*	*19,069*	*28,311*	*9,242*	*48%*
Cutline 9 Total	84	1,459,883	1,689,260	229,377	16%
Cutline 10	5	671,785	585,095	-86,690	-13%
Total	**288**	**4,854,570**	**5,244,770**	**390,200**	**8%**

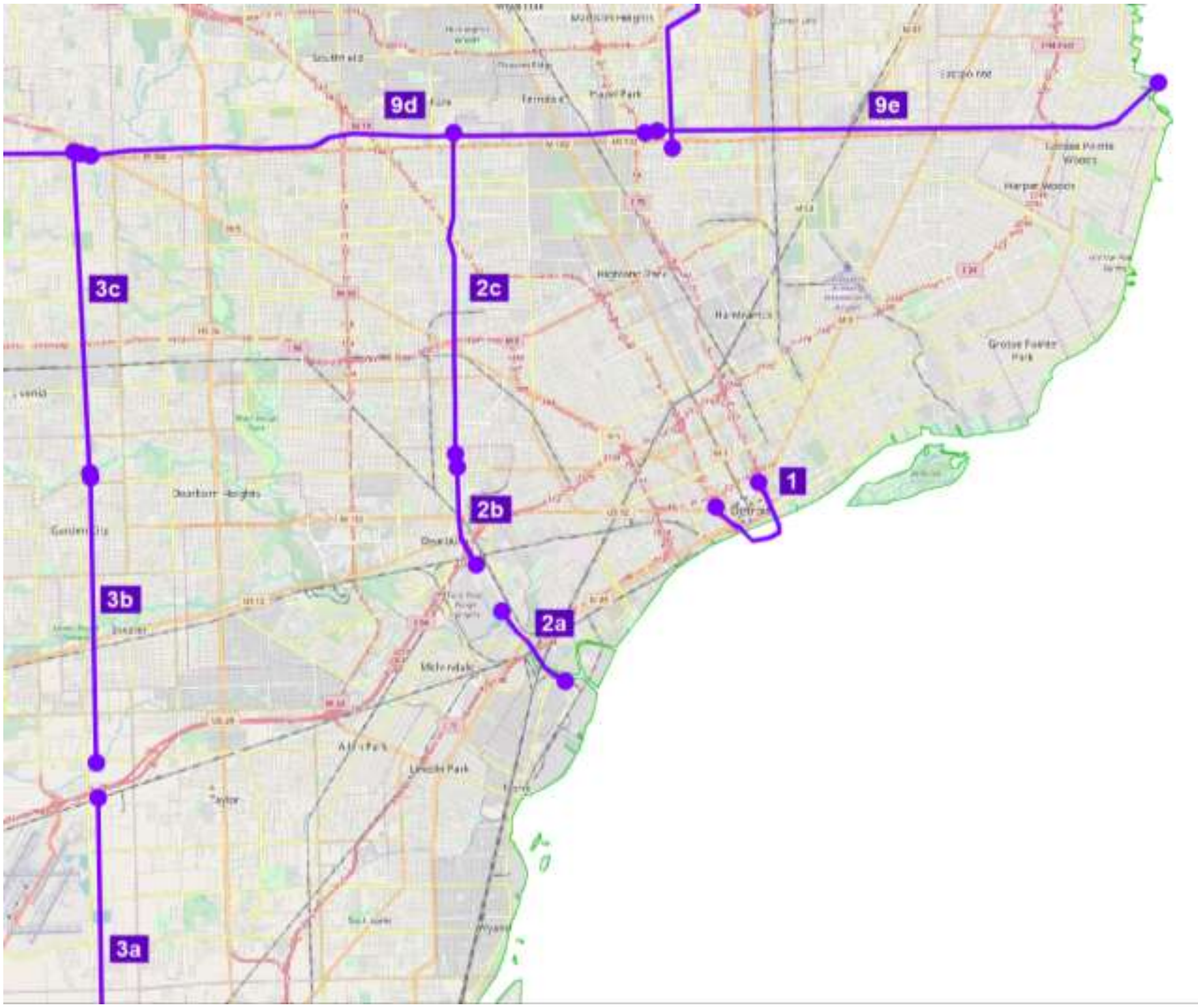
Source: SEMCOG E7 Model Summary Report.

Figure 11.7 Cutline Definitions



Source: SEMCOG E7 Model.

Figure 11.8 Cutline Definitions (Detail)



Source: SEMCOG E7 Model.

11.5 Transit Assignment Validation

Transit assignment results include the total number of boardings at each transit stop, as well as transit volumes on all stop to stop transit route segments. However, transit assignment in the E7 model have been validated to the operator level. Individual route, stop, and segment values have not been validated to observed conditions. Prior to using the model to support detailed transit corridor studies, a focused transit model calibration and validation effort is recommended.

11.5.1 Transit Assignment Validation

Transit assignment has been validated to observed route boardings by operator. As shown in **Table 11.13**, the overall number of boardings is within 2 percent of observed values. Most transit operators validate within 15% of observed values, but the Blue Water Area Transit System (BWAT) has a higher percent error. This error of about 2,100 daily trips represents less than 2 percent of the total number of transit trips in the region.

Table 11.13 Transit Assignment Validation Summary

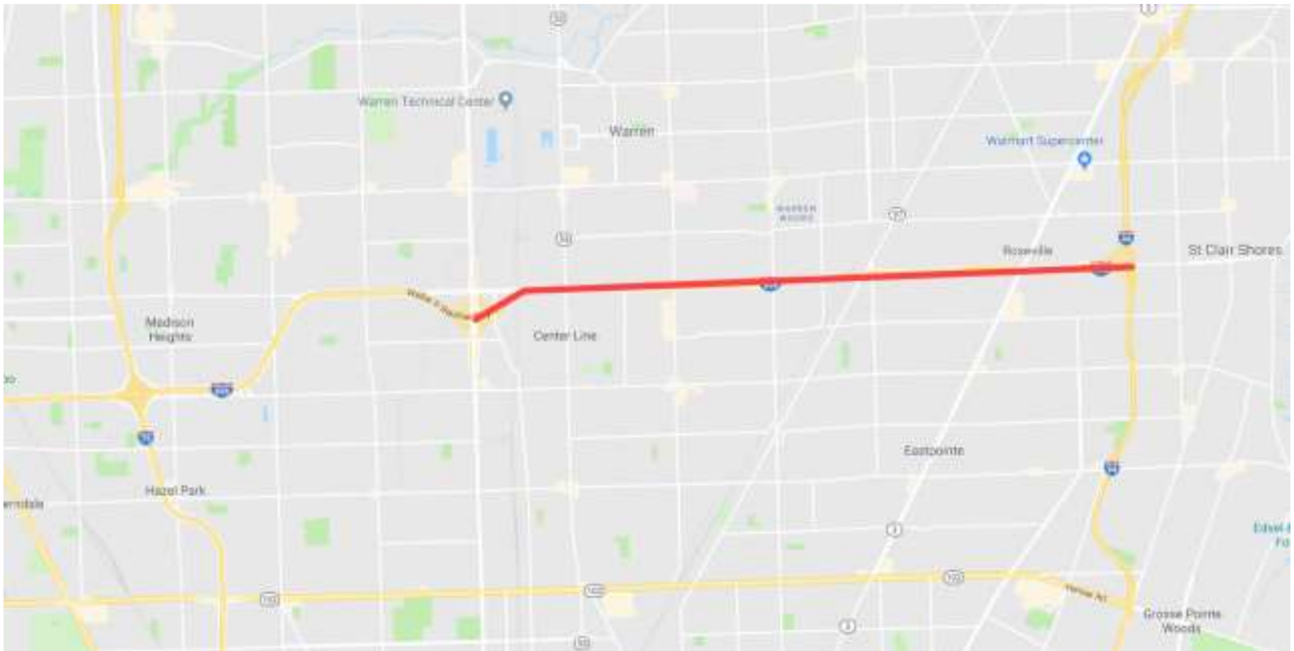
Operator	Observed	Modeled	Difference	% Difference
AATA	26,540	25,901	-639	-2.4%
BWAT	5,494	2,153	-3,341	-61%
DDOT	77,304	75,462	-1,842	-2.4%
DPM	6,061	6,702	641	11%
LETC	877	1,000	123	14%
SMART	30,313	31,881	1,568	5.2%
UMI	32,149	33,067	918	2.9%
Total Boardings	**178,738**	**176,166**	**-2,572**	**-1.4%**

Source: CS analysis of SEMCOG E7 Model Results.

11.6 Highway Closure Sensitivity Test

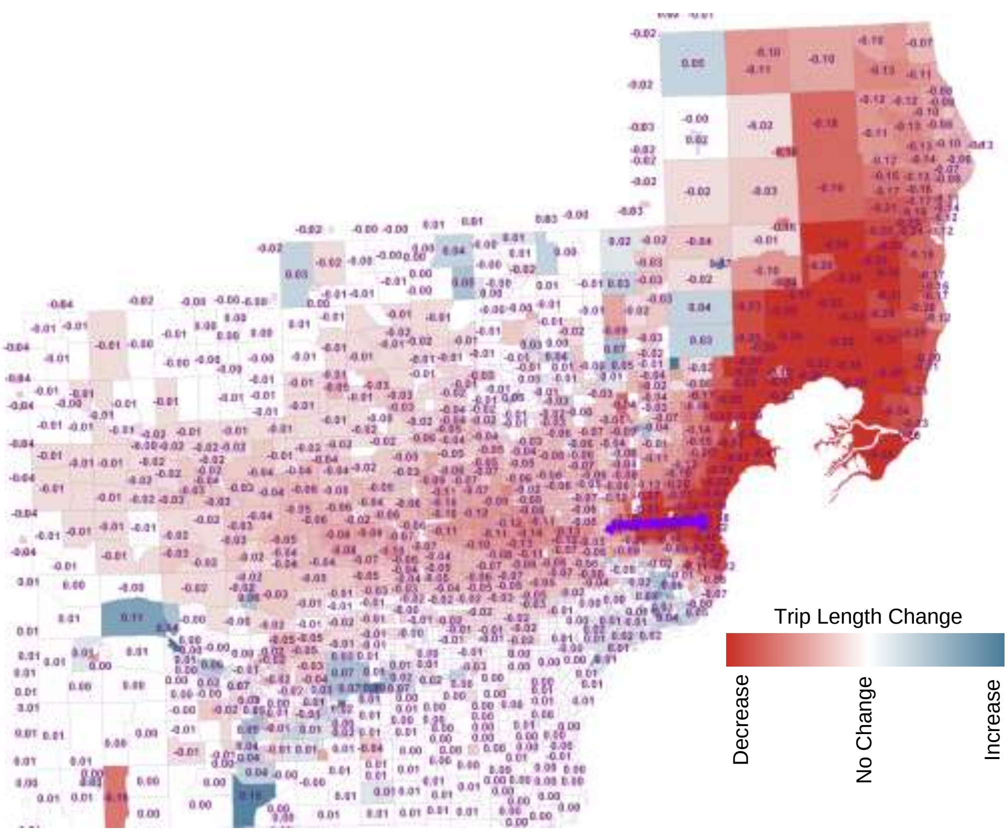
A sensitivity test was performed to evaluate the model's response to a potential highway closure. This test removed links representing I-696 between Mount Rd. and I-94, as indicated in **Figure 11.9**. Closure of this segment resulted in a regional VMT reduction of 475 thousand, representative of about 45% of the 1.26 million VMT on the closed segment. Due to increased congestion in the roadway network, regional VHT increases by 84 thousand. Because this model run included speed feedback, the destination choice model produced slightly shorter trips as a result of decreased accessibility and increased congestion in the network. **Figure 11.10** demonstrates changes in average trip lengths for TAZs in the vicinity of the tested closure.

Figure 11.9 Segment of I-696 closed for sensitivity testing



Source: CS markup of Google Maps imagery.

Figure 11.10 Change in trip lengths by TAZ due to I-696 Closure Test



Source: CS analysis of E7 sensitivity test model results.

11.7 Forecast Year Test

A test using draft 2045 socioeconomic data inputs on the existing conditions highway and transit networks produced an increase in VMT of about 4.8% over the base year. This VMT increase is somewhat lower than the forecast population growth of 8.0%. Closer investigation demonstrated in **Table 11.14** showed an increase in passenger vehicle VMT of about 6.0%, combined with a decrease in truck VMT of about 2%. The decrease in truck VMT was caused by a forecast decrease in several employment sectors associated with truck traffic, including manufacturing and retail. The remaining difference between population and VMT growth can be attributed to a slight decrease in average trip lengths.

A review of transit assignment results showed a total increase in boardings of about 2%. However, nearly all of this increase was modeled to occur on the Detroit people mover. Boardings on the AATA and DDOT systems remained relatively constant, while boardings on the SMART system decreased by about 1,400 trips (4.1%). This led to an investigation of forecast household and employment growth assumptions. This led to the following observations.

- Household and employment growth occurs in zones with access to transit, but at a slower rate than the region as a whole. Furthermore, zones with access to transit see a decrease in low income households (and persons) and an increase in households with higher incomes. Since high income households are considerably less likely to use transit, the model forecasts little or no increase in transit use in many areas.
- The draft 2045 run did not include any growth at universities. As a result, university-bound trip productions are allocated to both existing activity and new growth. Since considerable growth is forecast in areas with no access to transit, the share of university trips having transit as an available mode decreases in this test run.
- The draft 2045 socioeconomic dataset represents a large amount of growth near the Detroit people mover, significantly increasing the number of trips that can be made using this mode.

Table 11.14 2045 Summary Statistics

Statistic	Base	Forecast	Difference	% Difference
Population	4,549,756	4,913,757	364,001	8.0%
Total VMT	129,791,100	135,985,928	6,194,828	4.8%
Passenger Vehicle VMT	110,288,082	116,872,246	6,584,164	6.0%
Truck VMT	19,503,018	19,113,682	-389,336	-2.0%
Transit Boardings	183,228	186,823	3,595	2.0%

Source: CS analysis of draft 2045 model results.

12.0 Model Limitations and Next Steps

The SEMCOG E7 Model is an advanced trip-based model, and has been continually improved and updated over many years. The E7 model update continued this process, but there are some known limitations of the current model. Notable limitations and suggested next steps for further incremental improvement are listed below.

- ***Commercial Vehicle Model:*** The E7 Model retains the basic truck model structure carried forward from previous versions of the model. As SEMCOG has recently completed a commercial vehicle survey, truck components of the E7 model could be replaced by a more robust commercial vehicle model that is based on recent survey data.

- ***Airport Special Generator Model:*** Treatment of the DTW airport have been carried forward from previous versions of the model with little modification. Analysis of airport trip generation and distribution as compared to travel patterns obtained from Big Data sources may suggest further refinements to airport components of the E7 model. With the proliferation of TNC options, a more robust airport mode choice model could also be beneficial.

- ***Hospital Analysis:*** The E7 model does not specifically address large regional hospitals such as the University of Michigan Hospital. Review of trip generation and distribution patterns as compared to travel patterns obtained from Big Data sources may suggest introduction of special treatment of these facilities.

- ***External Trip Patterns:*** The E7 model has been updated with improved handling of external trips, resulting in an improved calibration as compared to previous versions of the model. Distribution of trips to and from different external stations is varied by modifying external approach distances, but could be further refined by calibrating external trip distribution models separately for several groups of external stations.

- ***Updated Survey Data:*** The E7 model was estimated using data from the 2004/2005 household travel survey, while many elements of model calibration and validation have been performed using the more recent 2015 household travel survey. Given changes in travel behavior, technology, and demographics in the region, continued updates to the SEMCOG model to make use of the latest available observed data will be necessary.

- **Limitations in Calibration and Validation:** While the E7 model update included an extensive calibration and validation effort, limitations in available data and resources were encountered. When applying the model, especially at a corridor or subarea level, it is important to conduct a localized validation exercise, followed by either implementation of a post processing routine or targeted model adjustments.

In addition, the SEMCOG model suffers from more general limitations common to all trip based models. As SEMCOG seeks to answer challenging policy questions related to technology, transit, land use, and transportation, eventual transition to an activity-based modeling approach may prove beneficial.

Appendix A. Detailed Household Expansion Results

Tables included in this appendix present household expansion results by geographic summary area.

Table A.1 Household Expansion for Livingston County

Variable	Value	ACS Control	Updated Expansion	Previous Expansion
Household Size	1	13,717	13,717	16,588
	2	24,508	24,508	21,951
	3	10,678	10,678	11,485
	4	11,565	11,565	12,290
	5	4,830	4,830	2,955
	6+	2,101	2,101	2,120
Household Workers	0	15,764	15,764	12,960
	1	24,802	24,802	26,831
	2	21,936	21,936	21,202
	3+	4,897	4,897	6,396
Household Vehicles	0	1,974	1,974	3,040
	1	16,453	16,453	15,681
	2	29,820	29,820	27,019
	3+	19,152	19,152	21,649
Household Income Group	Low	10,928	9,655	5,829
	Medium-Low	16,371	14,464	15,066
	Medium-High	18,840	16,646	11,588
	High	21,260	18,784	26,624
	Unknown	n/a	7,849	8,282
Household Lifecycle	1	25,469	25,469	23,969
	2	4,603	4,603	3,120
	3	23,208	23,208	28,218
	4	14,119	14,119	12,082
Total Households		**67,399**	**67,399**	**67,389**

Source: CS Analysis of 2008-2012 ACS Data and 2004/2005 Combined Household Survey Data with updated expansion factors. Previous expansion is based on an initial expansion performed by SEMCOG staff.

Table A.2 Household Expansion for Macomb County

Variable	Value	ACS Control	Updated Expansion	Previous Expansion
Household Size	1	95,581	88,210	100,066
	2	105,108	105,321	96,879
	3	52,308	54,223	56,647
	4	47,330	51,667	50,631
	5	20,285	21,678	21,107
	6+	9,984	6,762	6,434
Household Workers	0	99,075	81,388	77,868
	1	125,959	123,422	138,997
	2	85,257	97,780	88,521
	3+	20,305	25,271	26,378
Household Vehicles	0	21,143	21,762	20,121
	1	117,248	100,199	112,849
	2	129,825	133,693	129,083
	3+	62,380	72,207	69,711
Household Income Group	Low	77,102	38,330	39,605
	Medium-Low	82,605	89,380	96,655
	Medium-High	70,840	94,360	66,626
	High	58,971	65,895	87,490
	Unknown	41,078	39,896	41,388
Household Lifecycle	1	105,251	104,578	105,268
	2	29,639	23,901	24,349
	3	111,727	124,884	130,518
	4	83,979	74,498	71,629
Total Households		**330,596**	**327,861**	**331,764**

Source: CS Analysis of 2008-2012 ACS Data and 2004/2005 Combined Household Survey Data with updated expansion factors. Previous expansion is based on an initial expansion performed by SEMCOG staff.

Table A.3 Household Expansion for Monroe County

Variable	Value	ACS Control	Updated Expansion	Previous Expansion
Household Size	1	14,002	14,002	15,745
	2	20,995	20,995	18,043
	3	9,747	9,747	9,757
	4	7,929	7,929	9,737
	5	4,056	4,056	3,764
	6+	1,563	1,563	1,176
Household Workers	0	17,611	17,611	13,842
	1	21,285	21,285	23,555
	2	15,646	15,646	15,600
	3+	3,750	3,750	5,225
Household Vehicles	0	3,121	3,121	2,438
	1	17,883	17,883	15,107
	2	23,656	23,656	23,915
	3+	13,632	13,632	16,762
Household Income Group	Low	15,085	13,022	6,690
	Medium-Low	16,791	14,494	18,550
	Medium-High	15,138	13,067	12,322
	High	11,278	9,735	13,476
	Unknown	n/a	7,973	7,184
Household Lifecycle	1	19,768	19,768	19,871
	2	3,991	3,991	2,540
	3	19,752	19,752	22,992
	4	14,782	14,782	12,819
Total Households		**58,292**	**58,292**	**58,222**

Source: CS Analysis of 2008-2012 ACS Data and 2004/2005 Combined Household Survey Data with updated expansion factors. Previous expansion is based on an initial expansion performed by SEMCOG staff.

Table A.4 Household Expansion for Oakland County

Variable	Value	ACS Control	Updated Expansion	Previous Expansion
Household Size	1	139,524	139,524	146,188
	2	162,330	162,330	144,479
	3	74,277	74,277	83,871
	4	67,455	67,455	75,444
	5	26,730	26,730	25,938
	6+	12,662	12,662	7,851
Household Workers	0	124,374	124,374	98,746
	1	198,028	198,028	211,897
	2	134,534	134,534	142,036
	3+	26,042	26,042	31,092
Household Vehicles	0	26,460	26,460	20,390
	1	164,674	164,674	167,817
	2	202,985	202,985	198,175
	3+	88,859	88,859	97,389
Household Income Group	Low	106,317	91,866	42,435
	Medium-Low	116,037	100,265	114,100
	Medium-High	111,681	96,501	95,142
	High	148,943	128,698	173,067
	Unknown	n/a	65,649	59,027
Household Lifecycle	1	153,304	153,304	164,439
	2	44,557	44,557	27,273
	3	180,427	180,427	201,495
	4	104,690	104,690	90,564
Total Households		**482,978**	**482,978**	**483,771**

Source: CS Analysis of 2008-2012 ACS Data and 2004/2005 Combined Household Survey Data with updated expansion factors. Previous expansion is based on an initial expansion performed by SEMCOG staff.

Table A.5 Household Expansion for St. Clair County

Variable	Value	ACS Control	Updated Expansion	Previous Expansion
Household Size	1	16,457	16,457	17,721
	2	23,854	23,854	20,981
	3	9,419	9,419	10,751
	4	8,527	8,527	9,174
	5	3,863	3,863	3,400
	6+	1,963	1,963	1,879
Household Workers	0	21,898	21,898	17,328
	1	23,064	23,064	26,234
	2	15,740	15,740	14,189
	3+	3,381	3,381	6,155
Household Vehicles	0	4,390	4,390	5,260
	1	19,993	19,993	22,279
	2	25,898	25,898	21,735
	3+	13,802	13,802	14,632
Household Income Group	Low	19,595	18,196	11,711
	Medium-Low	19,152	17,785	21,537
	Medium-High	15,359	14,263	15,390
	High	9,977	9,265	10,910
	Unknown	n/a	4,574	4,358
Household Lifecycle	1	20,480	20,480	21,028
	2	4,875	4,875	3,415
	3	21,308	21,308	22,444
	4	17,419	17,419	17,019
Total Households		**64,083**	**64,083**	**63,906**

Source: CS Analysis of 2008-2012 ACS Data and 2004/2005 Combined Household Survey Data with updated expansion factors. Previous expansion is based on an initial expansion performed by SEMCOG staff.

Table A.6 Household Expansion for Washtenaw County

Variable	Value	ACS Control	Updated Expansion	Previous Expansion
Household Size	1	41,891	41,891	45,686
	2	45,672	45,672	42,795
	3	20,695	20,695	20,657
	4	17,154	17,154	20,702
	5	6,151	6,151	5,718
	6+	3,320	3,320	1,527
Household Workers	0	33,515	33,515	25,983
	1	55,625	55,625	59,914
	2	38,529	38,529	46,267
	3+	7,214	7,214	4,921
Household Vehicles	0	10,570	10,570	7,111
	1	49,835	49,835	51,415
	2	51,464	51,464	55,392
	3+	23,014	23,014	23,167
Household Income Group	Low	35,007	32,614	13,278
	Medium-Low	33,281	31,006	33,795
	Medium-High	28,776	26,809	26,915
	High	37,819	35,234	48,400
	Unknown	n/a	9,220	14,697
Household Lifecycle	1	39,622	39,622	45,104
	2	24,785	24,785	13,903
	3	46,635	46,635	56,246
	4	23,841	23,841	21,832
Total Households		**134,883**	**134,883**	**137,085**

Source: CS Analysis of 2008-2012 ACS Data and 2004/2005 Combined Household Survey Data with updated expansion factors. Previous expansion is based on an initial expansion performed by SEMCOG staff.

Table A.7 Household Expansion for East Wayne County

Variable	Value	ACS Control	Updated Expansion	Previous Expansion
Household Size	1	105,873	105,873	93,463
	2	77,870	77,870	64,181
	3	42,836	42,836	42,167
	4	32,767	32,767	36,311
	5	17,782	17,782	17,490
	6+	15,956	15,956	15,782
Household Workers	0	128,750	128,750	92,177
	1	116,788	116,788	124,852
	2	39,921	39,921	39,649
	3+	7,625	7,625	12,716
Household Vehicles	0	65,123	65,123	56,077
	1	133,488	133,488	126,725
	2	70,524	70,524	63,387
	3+	23,949	23,949	23,205
Household Income Group	Low	150,418	140,296	80,735
	Medium-Low	76,978	71,798	96,766
	Medium-High	39,376	36,726	44,051
	High	26,312	24,541	31,693
	Unknown	n/a	19,723	16,149
Household Lifecycle	1	99,853	99,853	102,980
	2	25,542	25,542	12,798
	3	77,939	77,939	79,698
	4	89,750	89,750	73,918
Total Households		**293,084**	**293,084**	**269,394**

Source: CS Analysis of 2008-2012 ACS Data and 2004/2005 Combined Household Survey Data with updated expansion factors. Previous expansion is based on an initial expansion performed by SEMCOG staff.

Table A.8 Household Expansion for Other Wayne County

Variable	Value	ACS Control	Updated Expansion	Previous Expansion
Household Size	1	113,652	113,652	133,512
	2	119,651	119,651	124,426
	3	60,703	60,703	70,768
	4	51,536	51,536	66,032
	5	22,328	22,328	26,853
	6+	13,309	13,309	11,818
Household Workers	0	118,664	118,664	108,268
	1	148,320	148,320	176,230
	2	93,389	93,389	112,342
	3+	20,806	20,806	36,569
Household Vehicles	0	26,064	26,064	28,863
	1	141,788	141,788	154,728
	2	147,628	147,628	164,482
	3+	65,699	65,699	85,336
Household Income Group	Low	105,160	92,115	52,065
	Medium-Low	107,513	94,176	131,547
	Medium-High	90,122	78,942	94,134
	High	78,384	68,660	108,636
	Unknown	n/a	47,286	47,027
Household Lifecycle	1	124,266	124,266	145,737
	2	33,266	33,266	27,629
	3	126,916	126,916	160,797
	4	96,732	96,732	99,246
Total Households		**381,179**	**381,179**	**433,409**

Source: CS Analysis of 2008-2012 ACS Data and 2004/2005 Combined Household Survey Data with updated expansion factors. Previous expansion is based on an initial expansion performed by SEMCOG staff.

Appendix B. Detailed Person Expansion Results

Tables included in this appendix present person expansion results by geographic summary area.

Table B.1 Person Expansion for Livingston County

Variable	Value	ACS Control	Updated Expansion	Previous Expansion
Age	Under 15	36,877	36,876	40,166
	15 to 24	21,813	21,813	12,074
	25 to 34	17,539	17,539	12,758
	35 to 44	26,082	26,082	28,184
	45 to 54	32,029	32,029	31,060
	55 to 64	24,260	24,260	25,875
	65 +	21,927	21,927	22,461
Gender	Female	90,339	90,339	85,514
	Male	90,187	90,187	87,064
Employment Status	Employed	87,386	87,386	89,580
	Not Employed	93,140	93,140	82,998
School Enrollment	Preschool	5,563	5,563	2,789
	K-12	33,377	33,377	33,596
	University	10,191	10,191	6,292
	Not in School	131,396	131,396	129,901
Total Persons		**180,526**	**180,526**	**172,578**

Source: CS Analysis of 2008-2012 ACS Data and 2004/2005 Combined Household Survey Data with updated and previous expansion factors.

Appendix C. Transit Network Settings

Table C.1 lists transit network settings in the E7 Model.

Table C.1 Transit Network Settings – Input Group

Setting Name / Description	Value / Notes
Fare Currency	ZoneFare.mtx, core "Fare (mode 22). Zonal fare used for mode 22, AADD Commuter Rail.
Transit RS	Route system (*.rts) file named in the scenario manager.
Transit Network	Transit network (*.tnw) named in the scenario manager.
Centroid Set	Centroid <> null
Mode Table	Mode table (*.bin) named in the scenario manager.
Mode Cost Table	Mode transfer table (*.bin) named in the scenario manager.
OP Time Currencies	Origin to parking node time skims named in the scenario manager.
OP Dist Currencies	Origin to parking node distance skims named in the scenario manager.
PD Time Currencies	Parking to destination node time skims named in the scenario manager.
PD Dist Currencies	Parking to destination node distance skims named in the scenario manager.

Source: Source text here.

Table C.2 Transit Network Settings – Flag Group

Setting Name / Description	Value / Notes
Use Mode	Yes
Combine By Mode	Yes
Use Mode Cost	Yes
Fare System	3 (Mixed fare, Mode 33 uses zone fares, others use route fares)
Use Transit Access	No
Use All Walk Path	No
Use Stop Access	Yes
Use Park and Ride	Yes for drive access, No for drive egress and walk access.
Use Egress Park and Ride	Yes for drive egress, No for drive access and walk access.
Use P&R Walk Access	No for drive access (blank for others)
Use P&R Walk Egress	No for drive egress (blank for others)

Table C.3 Transit Network Settings – Global Group

Setting Name / Description	Value / Notes
Class Names	List of class names and descriptions (period, transit mode, access/egress mode)
Class Description	
current class	Active class, set when skimming or assigning transit
Value of Time	0.111 dollars per minute (Set in the Transit Parameter Table)
Max Xfer Number	3 (Set in the Transit Parameter Table)
Global Max WACC Path	10
Path Threshold	0.1
Global Fare Type	1 (Flat fare)
Zonal Fare Method	1 (Applied by route)
Global Fare Value	1.25 (overridden by fare on individual routes)
Global Xfer Fare	0.25 (overridden by fares in mode table and mode transfer table)
Global Fare Core	Fare (mode 22) – overridden by fare core listed in mode table
Global IWait Weight	2.5 (Set in the Transit Parameter Table)
Global XWait Weight	2.5 (Set in the Transit Parameter Table)
Global Dwell Weight	1.0 (Set in the Transit Parameter Table)
Walk Weight	2.5 (Set in the Transit Parameter Table)
Drive Time Weight	2.5 (Set in the Transit Parameter Table)
Global Dwell On Time	0.16
Global Dwell On Time	0.16
Global Xfer Time	3.0 (Set in the Transit Parameter Table)
Global Max IWait	60 (Set in the Transit Parameter Table)
Global Max XWait	60 (Set in the Transit Parameter Table)
Global Min IWait	2 (Set in the Transit Parameter Table)
Global Min XWait	2 (Set in the Transit Parameter Table)
Global Layover Time	5 (Set in the Transit Parameter Table)
Global Max Access	36 (Set in the Transit Parameter Table)
Global Max Egress	36 (Set in the Transit Parameter Table)
Global Max Transfer	18 (Set in the Transit Parameter Table)
Max Acce Drive Time	45 (Set in the Transit Parameter Table)
Max Egre Drive Time	45 (Set in the Transit Parameter Table)

Table C.4 Transit Network Settings – Field Group

Setting Name / Description	Value / Notes
Mode Used	USE_[MODE] -- Used to limit available modes when skimming and assigning transit.
Mode Impedance	[PER]_ImpFld
Mode Xfer Fare	XferFare
Mode Fare Type	Fare_Type
Mode Max IWait	Max_IWait
Mode Max XWait	Max_XWait
Mode Fare Core	Fare_Core
Mode Imp Weight	WT_[MODE] -- Used to prioritize primary modes when skimming assigning transit. Set in the Mode table to 1.0 for the primary mode, 5.0 for secondary modes.
Inter-Mode Xfer From	FROM
Inter-Mode Xfer To	TO
Inter-Mode Xfer Stop	STOP
Inter-Mode Xfer Proh	Prohibit
Inter-Mode Xfer Wait	Wait
Inter-Mode Xfer Fare	XferFare
Link Impedance	[PER]_IVTT_1
Route Fare	Ave_Fare
Route Headway	[PER]_HDWY
Stop Zone ID	FAREZONE
Stop Access	Access

Notes: [MODE] indicates primary mode (PMov, Bus, StCar, UrbRail, ComRail)
[PER] indicates time period (AM,MD, PM, EV)

Table C.5 Person Expansion for Macomb County

Variable	Value	ACS Control	Updated Expansion	Previous Expansion
Age	Under 15	155,997	155,997	181,238
	15 to 24	104,883	104,883	68,496
	25 to 34	101,768	101,768	74,164
	35 to 44	117,015	117,015	129,945
	45 to 54	130,891	130,891	140,447
	55 to 64	103,502	103,502	111,137
	65 +	119,970	119,970	107,328
Gender	Female	428,276	428,276	430,602
	Male	405,750	405,750	382,153
Employment Status	Employed	379,129	379,129	403,113
	Not Employed	454,897	454,897	409,642
School Enrollment	Preschool	21,288	21,288	13,283
	K-12	134,466	134,466	154,163
	University	61,578	61,578	42,080
	Not in School	616,694	616,694	603,229
Total Persons		**834,026**	**834,026**	**812,755**

Source: CS Analysis of 2008-2012 ACS Data and 2004/2005 Combined Household Survey Data with updated and previous expansion factors.

Table C.6 Person Expansion for Monroe County

Variable	Value	ACS Control	Updated Expansion	Previous Expansion
Age	Under 15	29,281	29,281	32,051
	15 to 24	19,583	19,583	11,886
	25 to 34	16,316	16,316	12,898
	35 to 44	20,158	20,158	20,986
	45 to 54	24,525	24,525	24,171
	55 to 64	20,194	20,194	24,957
	65 +	20,330	20,330	18,977
Gender	Female	76,156	76,156	78,867
	Male	74,231	74,231	67,059
Employment Status	Employed	66,891	66,892	71,258
	Not Employed	83,496	83,495	74,668
School Enrollment	Preschool	3,753	3,753	3,451
	K-12	25,780	25,780	25,085
	University	9,049	9,049	5,578
	Not in School	111,804	111,804	111,812
Total Persons		**150,387**	**150,387**	**145,926**

Source: CS Analysis of 2008-2012 ACS Data and 2004/2005 Combined Household Survey Data with updated and previous expansion factors.

Table C.7 Person Expansion for Oakland County

Variable	Value	ACS Control	Updated Expansion	Previous Expansion
Age	Under 15	226,601	226,600	276,706
	15 to 24	144,420	144,420	84,042
	25 to 34	143,803	143,803	97,601
	35 to 44	168,973	168,973	202,505
	45 to 54	195,158	195,158	205,595
	55 to 64	157,347	157,347	165,104
	65 +	159,741	159,741	141,246
Gender	Female	615,525	615,525	619,947
	Male	580,517	580,517	552,852
Employment Status	Employed	575,230	575,231	595,410
	Not Employed	620,812	620,811	577,389
School Enrollment	Preschool	35,398	35,398	22,779
	K-12	197,420	197,420	232,911
	University	91,010	91,010	56,704
	Not in School	872,214	872,214	860,405
Total Persons		**1,196,042**	**1,196,042**	**1,172,799**

Source: CS Analysis of 2008-2012 ACS Data and 2004/2005 Combined Household Survey Data with updated and previous expansion factors.

Table C.8 Person Expansion for St. Clair County

Variable	Value	ACS Control	Updated Expansion	Previous Expansion
Age	Under 15	30,739	30,739	34,043
	15 to 24	20,362	20,362	13,117
	25 to 34	16,690	16,690	14,602
	35 to 44	21,790	21,790	25,174
	45 to 54	26,393	26,393	24,749
	55 to 64	21,759	21,759	21,746
	65 +	23,607	23,607	23,931
Gender	Female	81,433	81,433	84,946
	Male	79,907	79,907	72,416
Employment Status	Employed	67,837	67,837	74,961
	Not Employed	93,503	93,503	82,401
School Enrollment	Preschool	4,476	4,476	1,868
	K-12	27,140	27,140	29,710
	University	9,850	9,850	7,405
	Not in School	119,874	119,874	118,379
Total Persons		**161,340**	**161,340**	**157,362**

Source: CS Analysis of 2008-2012 ACS Data and 2004 Combined Household Survey Data with updated and previous expansion factors.

Table C.9 Person Expansion for Washtenaw County

Variable	Value	ACS Control	Updated Expansion	Previous Expansion
Age	Under 15	55,503	55,503	76,981
	15 to 24	68,352	68,352	15,905
	25 to 34	46,145	46,145	48,414
	35 to 44	41,414	41,414	49,393
	45 to 54	44,034	44,034	51,288
	55 to 64	36,837	36,837	41,161
	65 +	33,414	33,414	33,919
Gender	Female	164,957	164,957	167,027
	Male	160,743	160,743	150,034
Employment Status	Employed	159,725	159,725	167,791
	Not Employed	165,975	165,975	149,270
School Enrollment	Preschool	8,739	8,739	8,885
	K-12	45,936	45,936	55,463
	University	63,347	63,347	22,578
	Not in School	207,678	207,678	230,135
Total Persons		**325,700**	**325,700**	**317,061**

Source: CS Analysis of 2008-2012 ACS Data and 2004/2005 Combined Household Survey Data with updated and previous expansion factors.

Table C.10 Person Expansion for East Wayne County

Variable	Value	ACS Control	Updated Expansion	Previous Expansion
Age	Under 15	172,246	172,246	189,281
	15 to 24	129,905	129,905	67,850
	25 to 34	96,555	96,555	59,526
	35 to 44	102,840	102,840	92,239
	45 to 54	111,681	111,681	97,347
	55 to 64	93,733	93,733	80,387
	65 +	94,668	94,668	97,768
Gender	Female	422,659	422,659	386,889
	Male	378,970	378,970	297,509
Employment Status	Employed	249,326	249,326	246,276
	Not Employed	552,303	552,303	438,122
School Enrollment	Preschool	24,127	24,127	7,621
	K-12	152,546	152,546	172,538
	University	61,137	61,137	35,254
	Not in School	563,819	563,819	468,985
Total Persons		**801,629**	**801,629**	**684,398**

Source: CS Analysis of 2008-2012 ACS Data and 2004/2005 Combined Household Survey Data with updated and previous expansion factors.

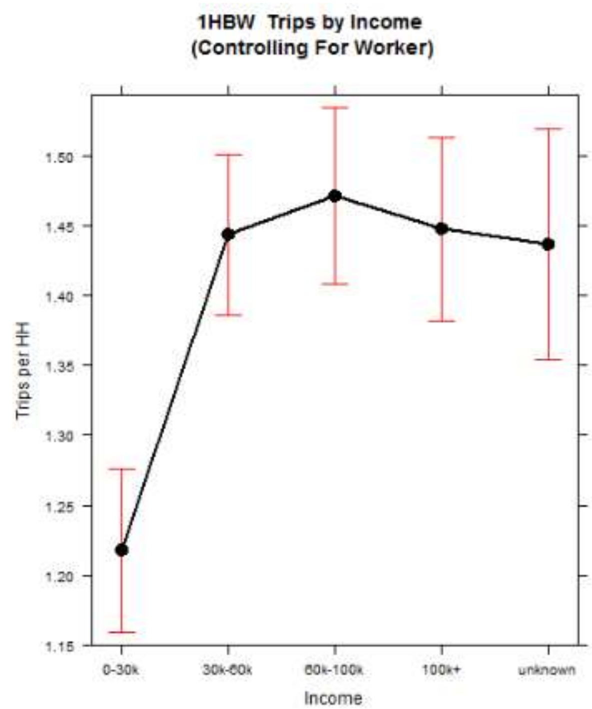
Table C.11 Person Expansion for Other Wayne County

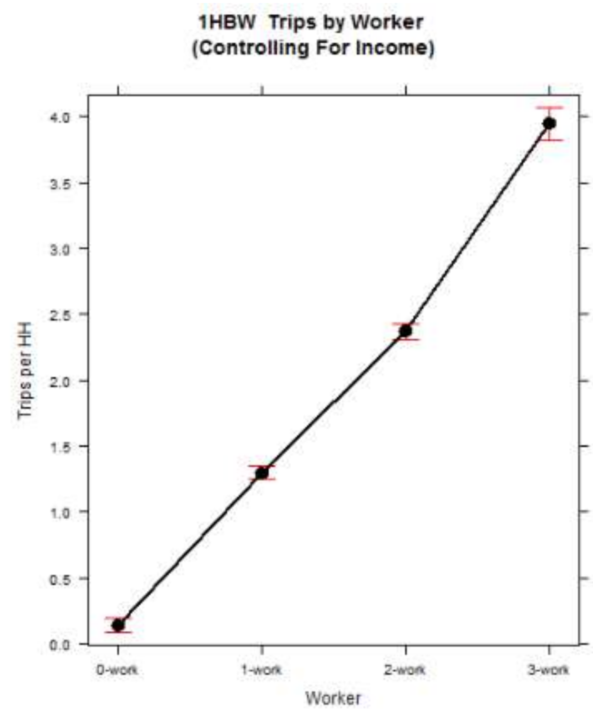
Variable	Value	ACS Control	Updated Expansion	Previous Expansion
Age	Under 15	197,627	197,627	236,303
	15 to 24	130,620	130,620	97,498
	25 to 34	122,516	122,516	103,625
	35 to 44	139,015	139,015	148,406
	45 to 54	152,231	152,231	200,031
	55 to 64	122,990	122,990	135,178
	65 +	134,196	134,196	149,640
Gender	Female	513,141	513,141	574,668
	Male	486,055	486,055	496,013
Employment Status	Employed	433,816	433,816	525,239
	Not Employed	565,380	565,380	545,442
School Enrollment	Preschool	29,393	29,393	23,270
	K-12	166,260	166,260	203,579
	University	76,373	76,373	61,380
	Not in School	727,169	727,169	782,452
Total Persons		**999,196**	**999,196**	**1,070,681**

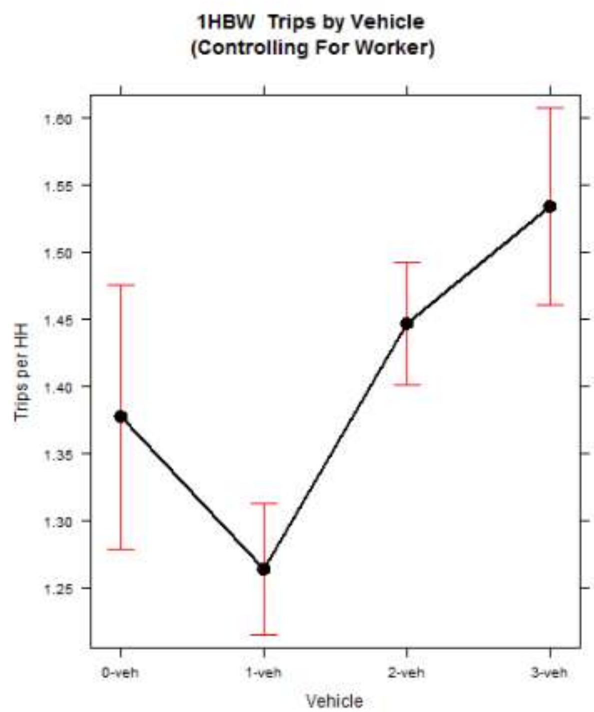
Source: CS Analysis of 2008-2012 ACS Data and 2004/2005 Combined Household Survey Data with updated and previous expansion factors.

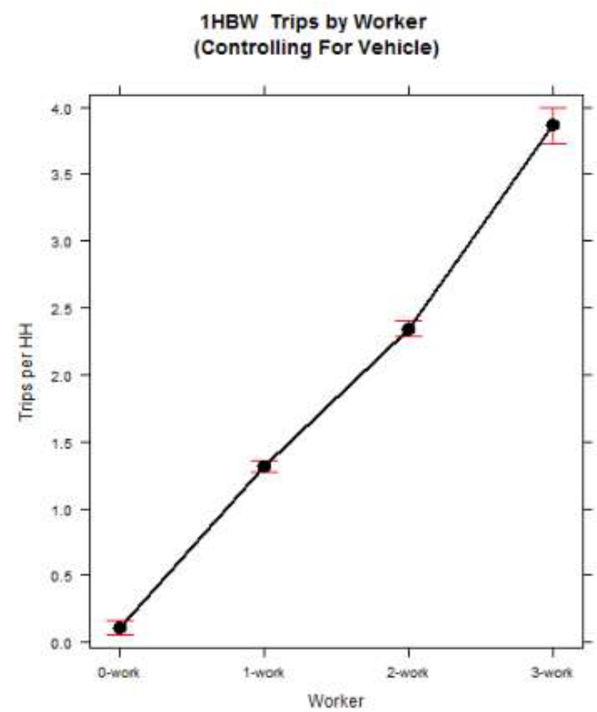
Appendix D. Trip Production Exploratory Analysis Using 2004/2005 Combined Household Travel Survey Data

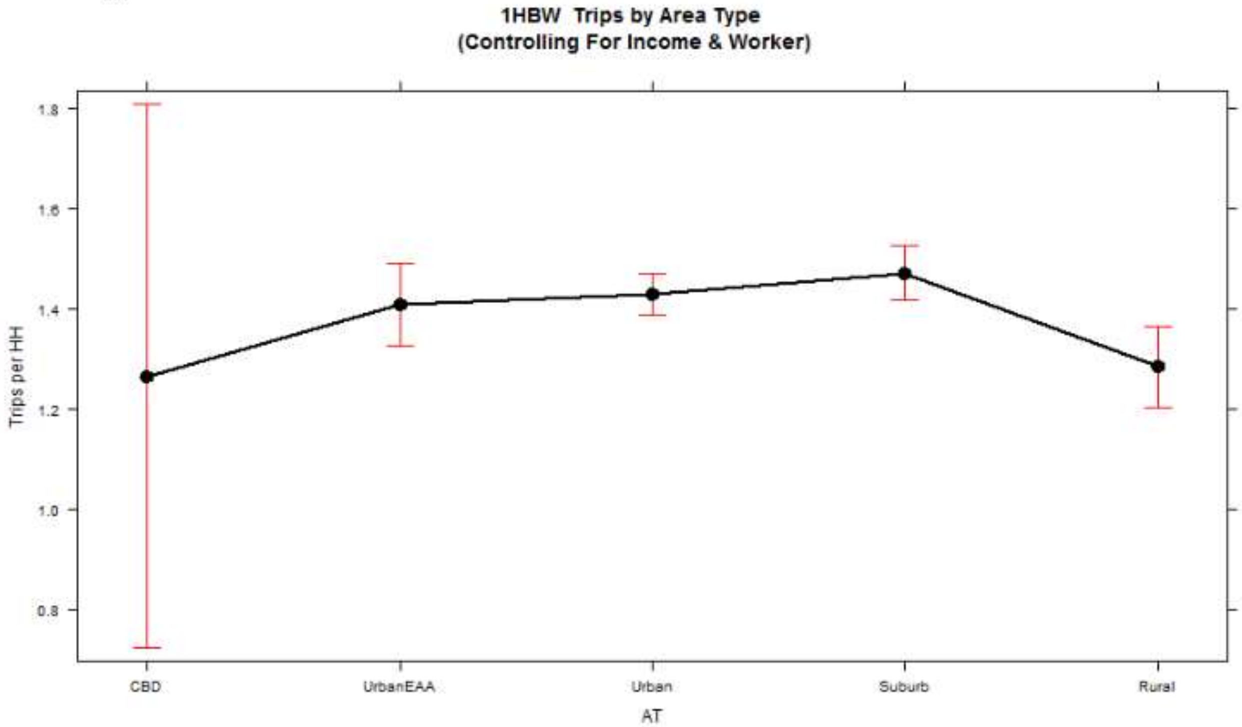
D.1 Home-Based Work



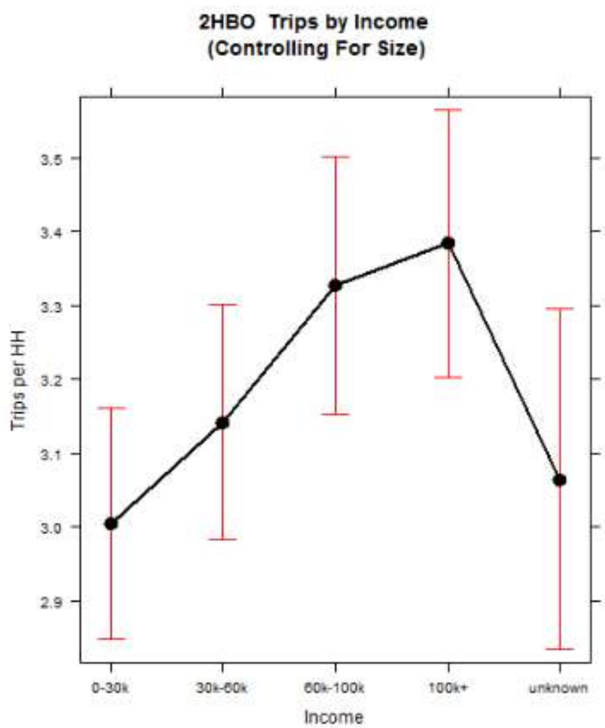


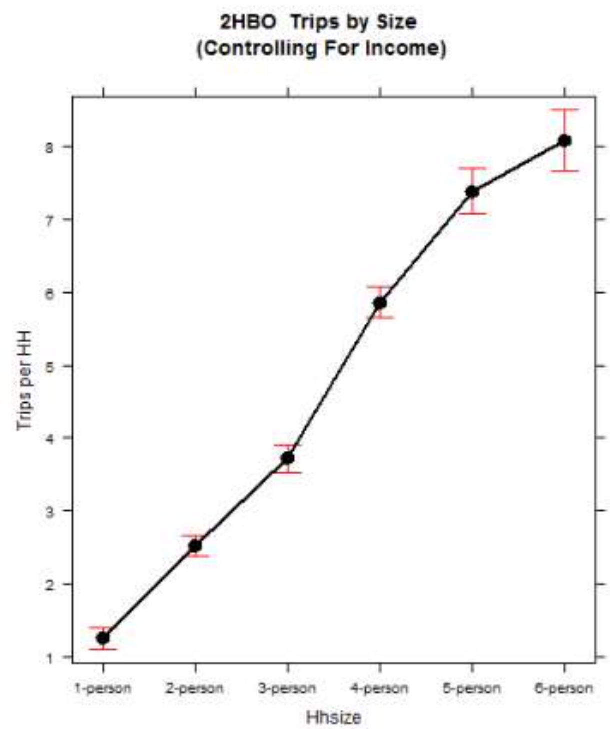


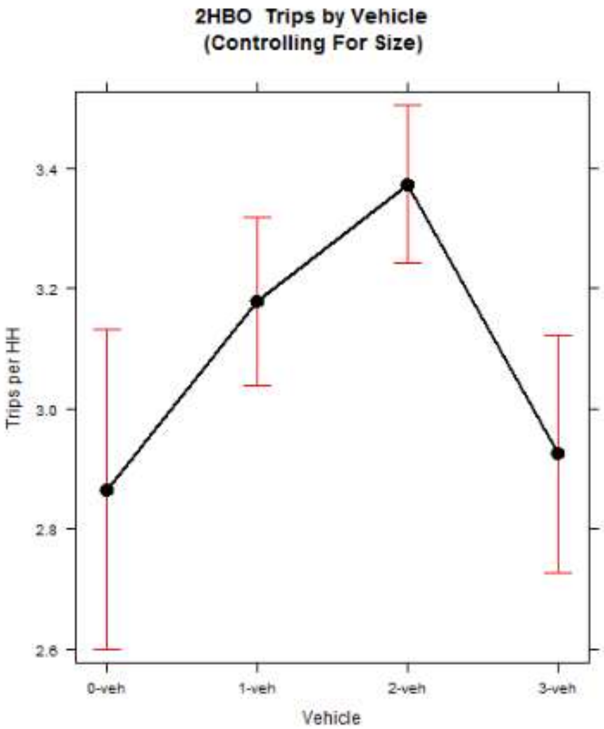


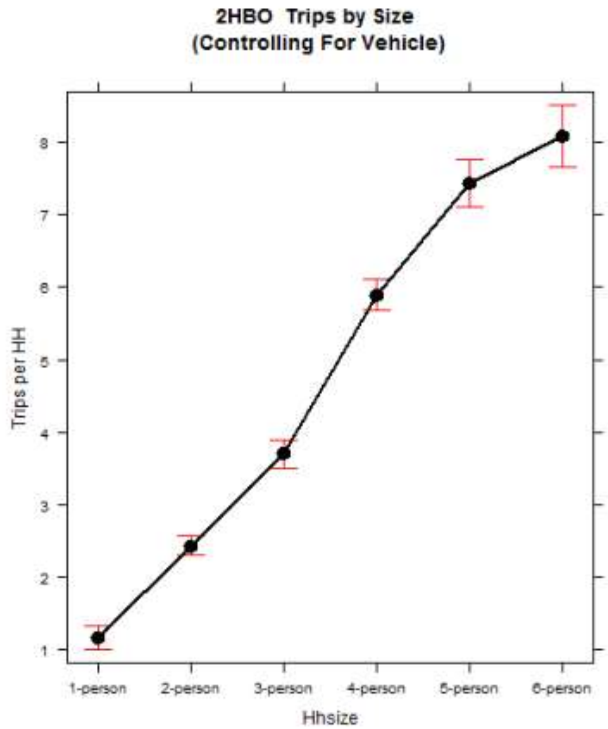


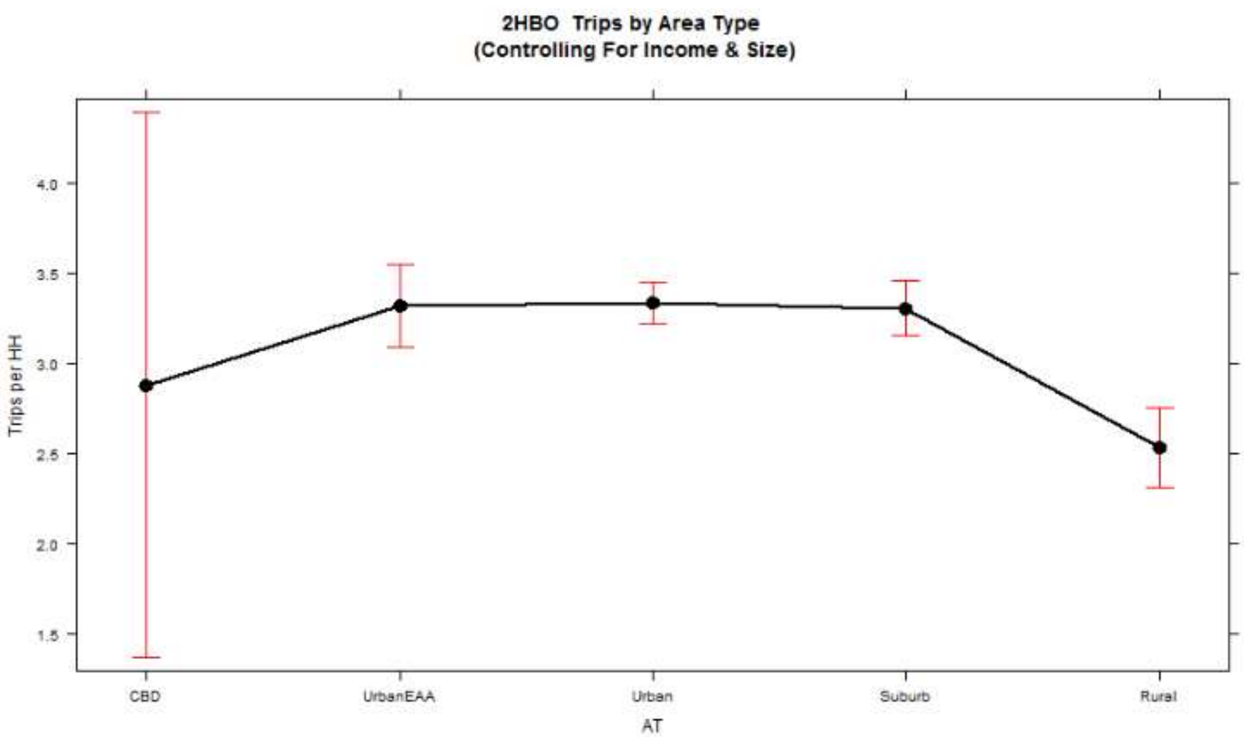
D.2 Home-Based Other



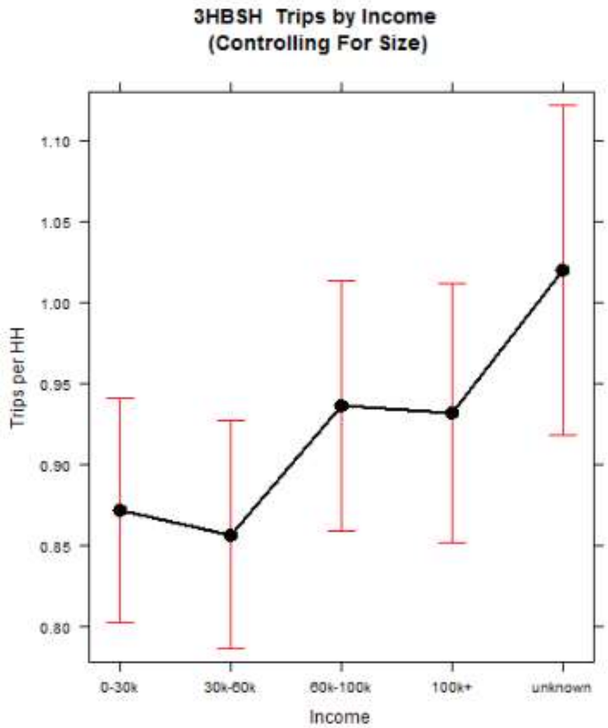


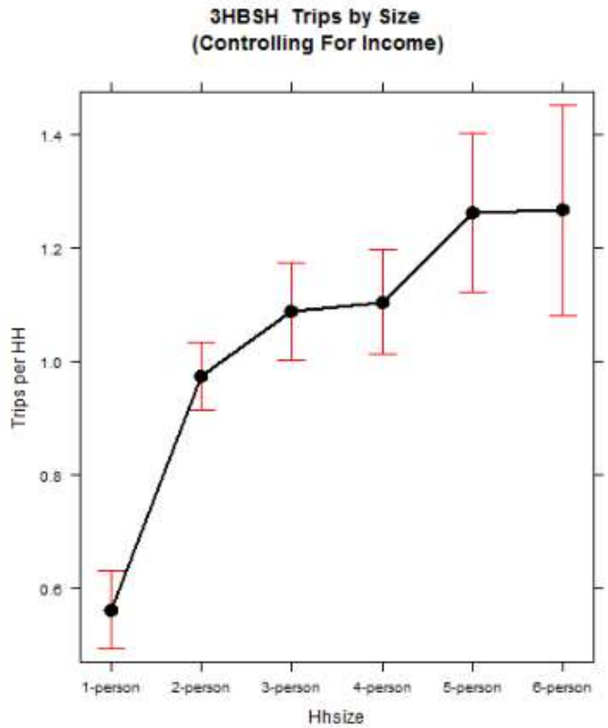

2HBO Trips by Vehicle
(Controlling For Size)
Trips per HH
2.6
2.8
3.0
3.2
3.4
0-veh
1-veh
2-veh
3-veh
Vehicle

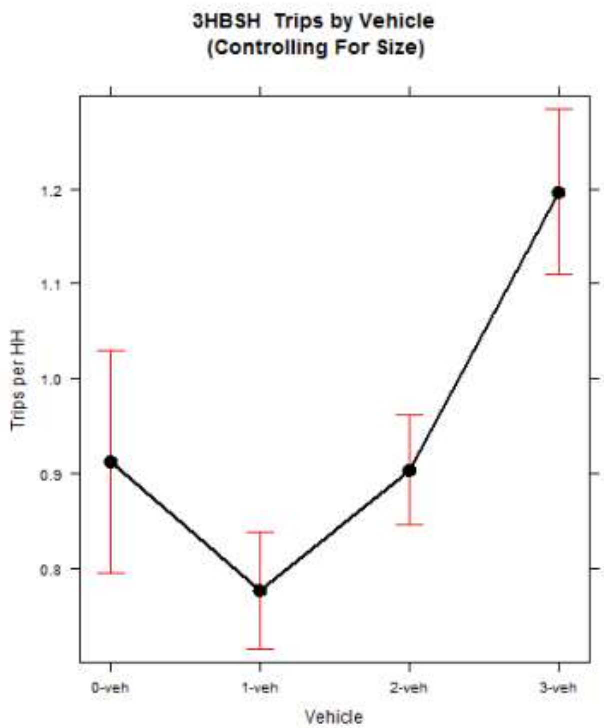

2HBO Trips by Size
(Controlling For Vehicle)
Trips per HH
1
2
3
4
5
6
7
8
1-person
2-person
3-person
4-person
5-person
6-person
Hhsize

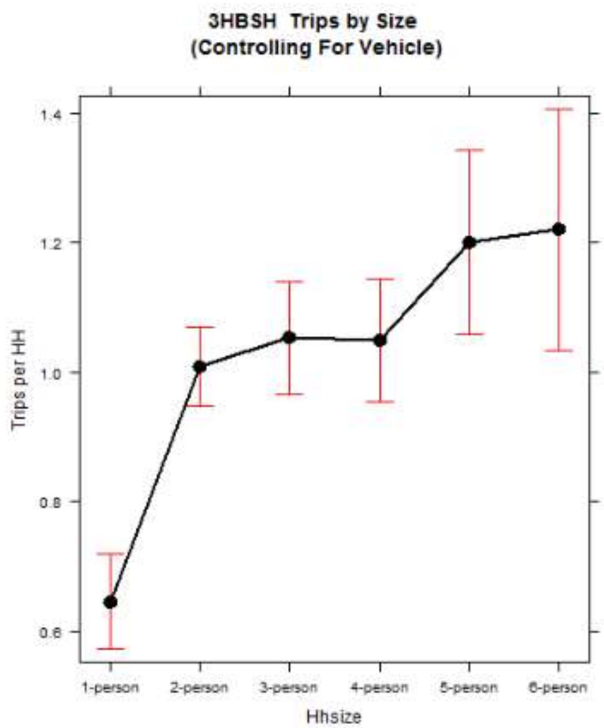

2HBO Trips by Area Type
(Controlling For Income & Size)
Trips per HH
1.5
2.0
2.5
3.0
3.5
4.0
CBD
UrbanEAA
Urban
Suburb
Rural
AT

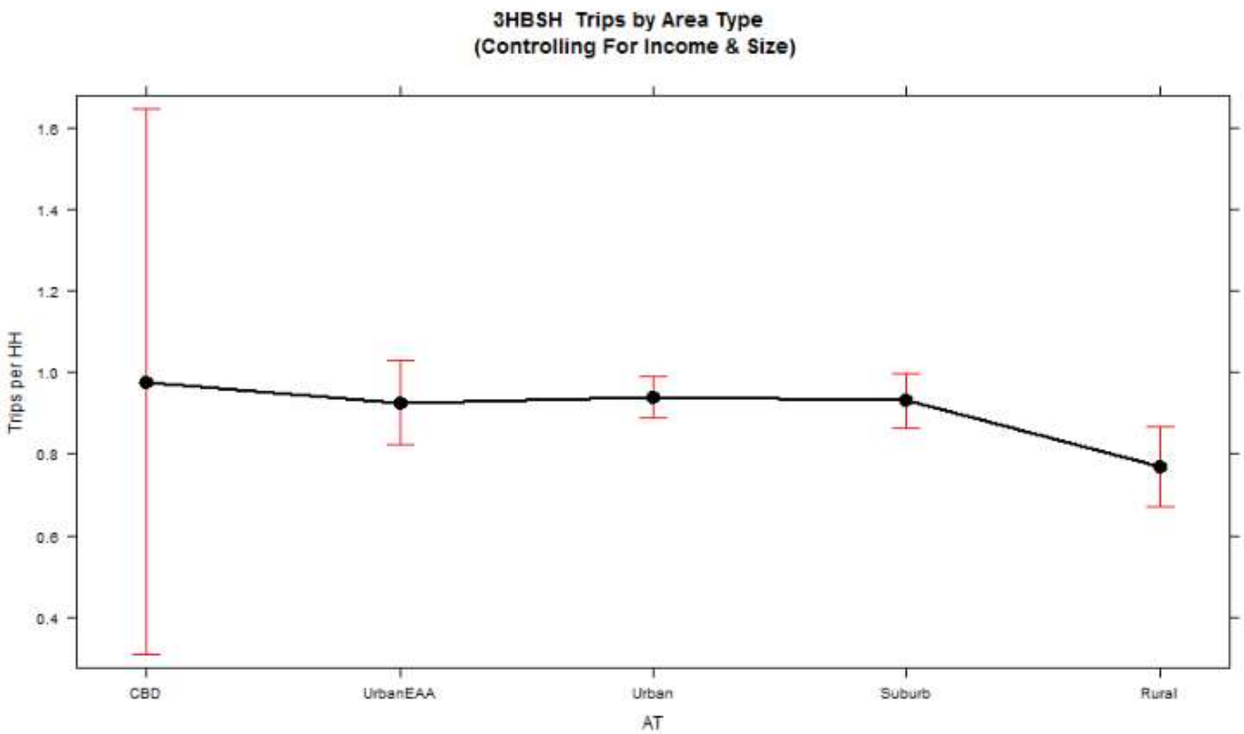
D.3 Home-Based Shop



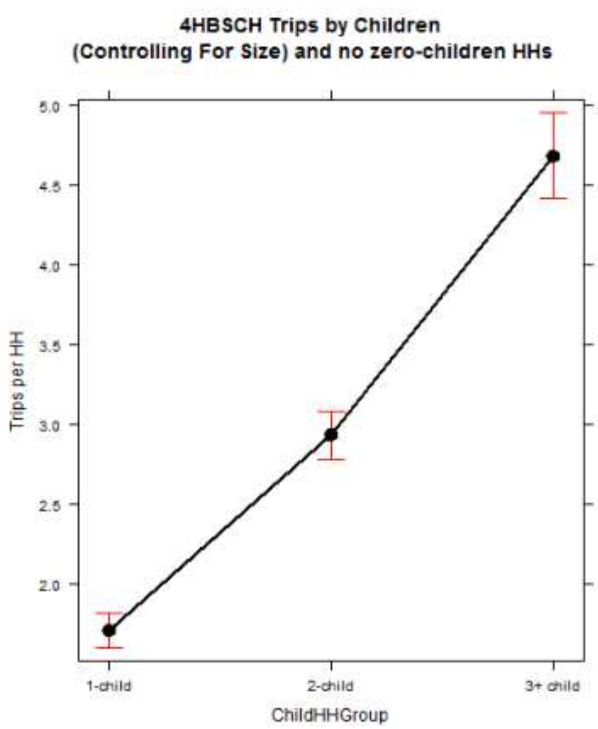


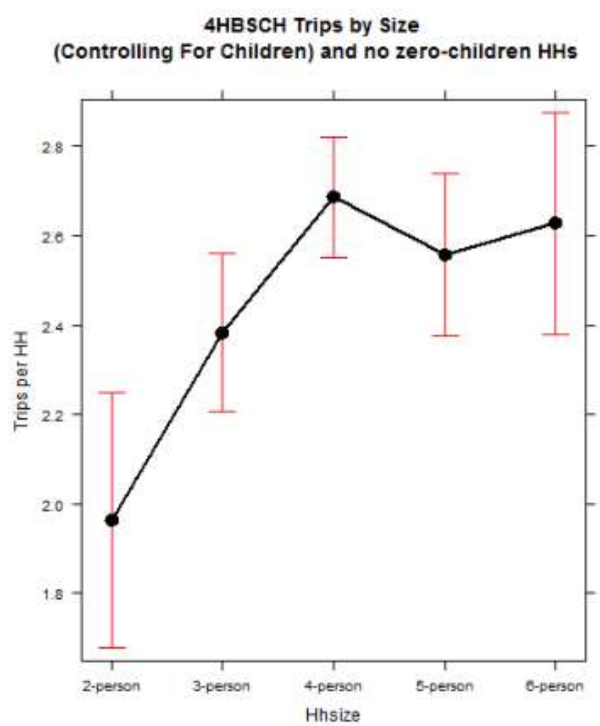


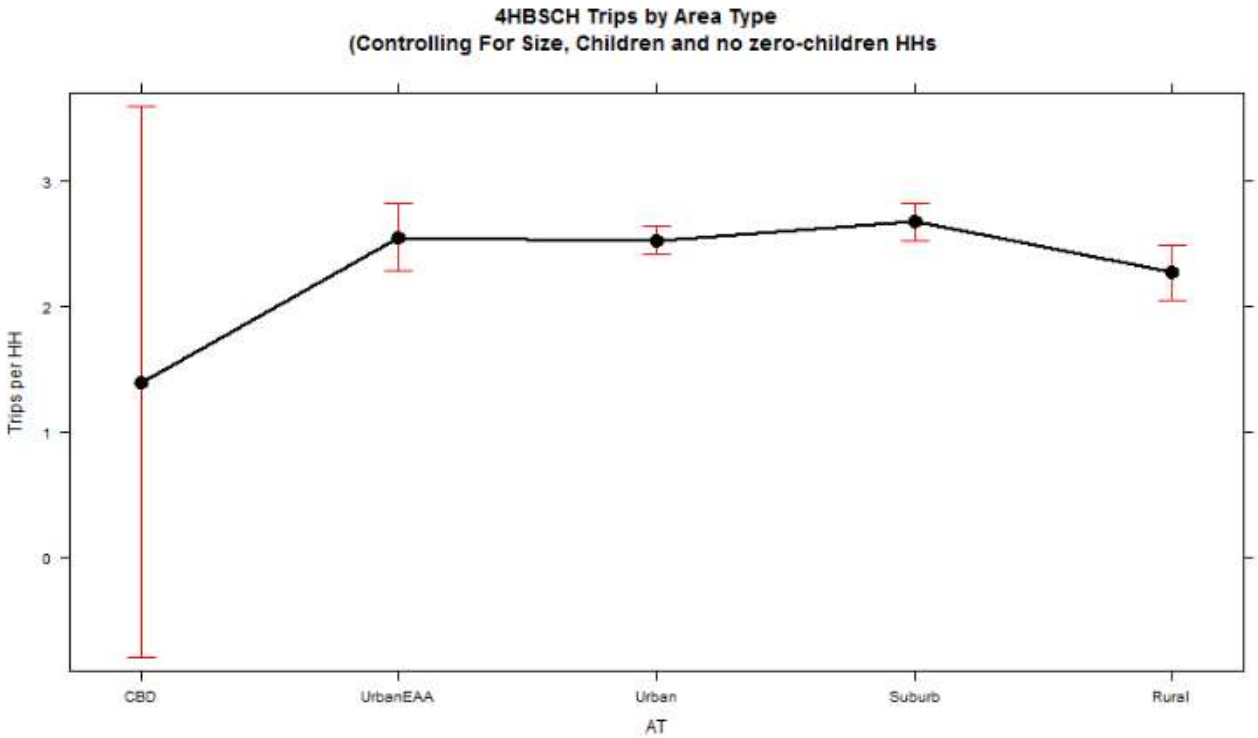




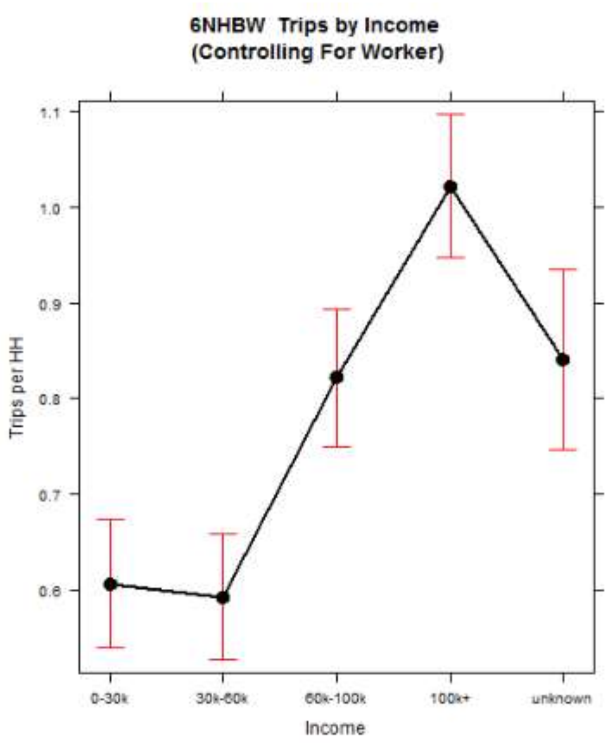
D.4 Home-Based School

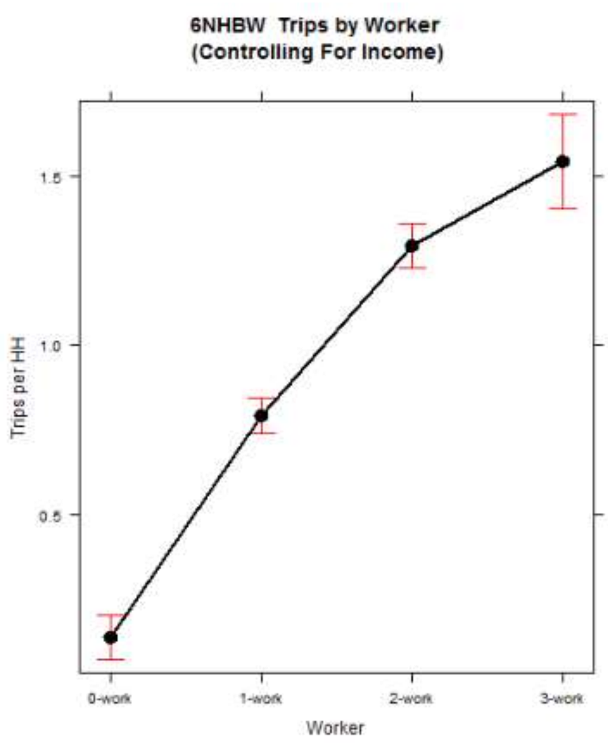


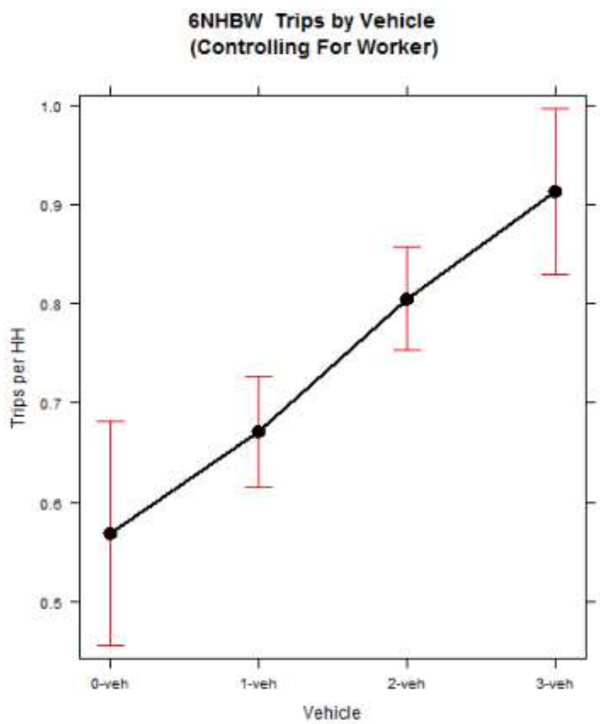


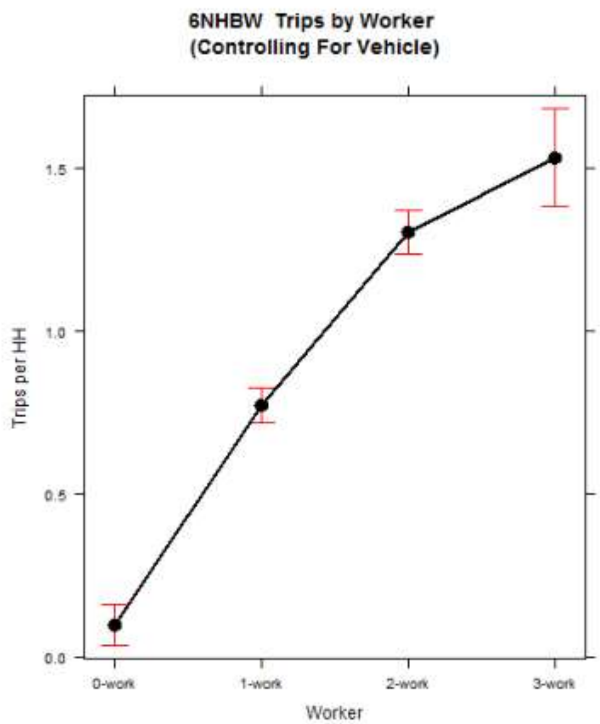


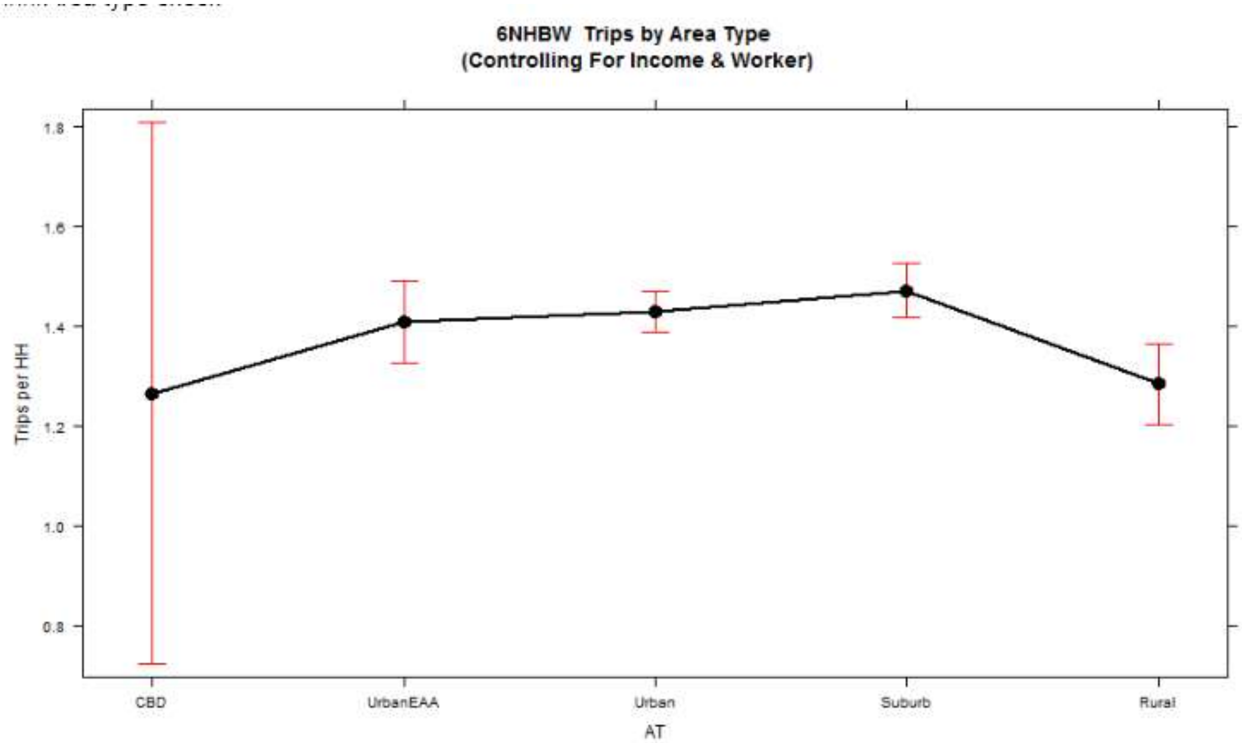
D.5 Non-Home-Based Work



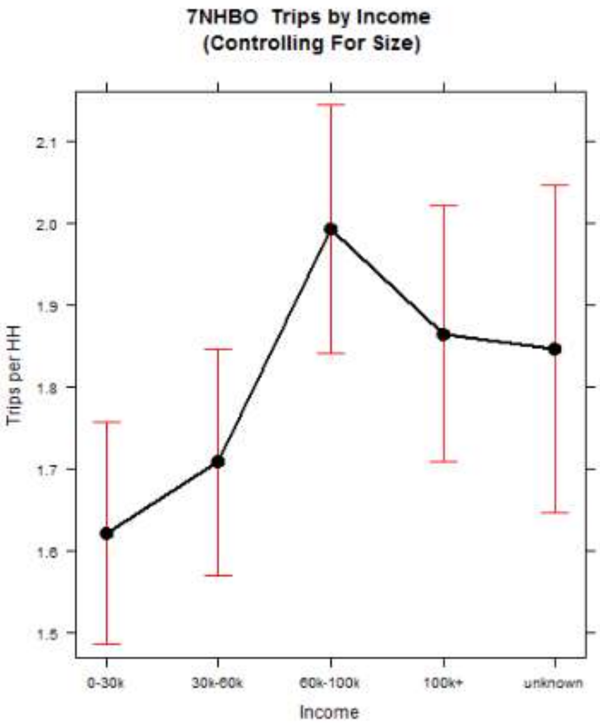


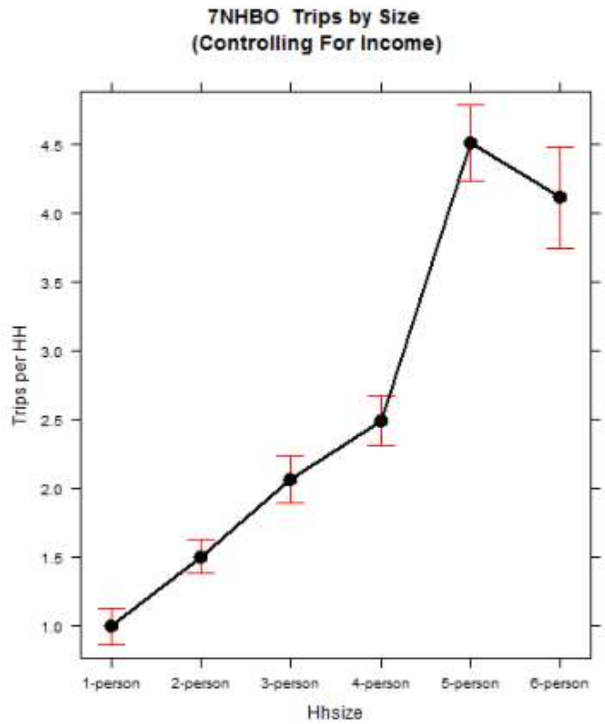

6NHBW Trips by Vehicle
(Controlling For Worker)
Trips per HH
1.0
0.9
0.8
0.7
0.6
0.5
0-veh
1-veh
2-veh
3-veh
Vehicle

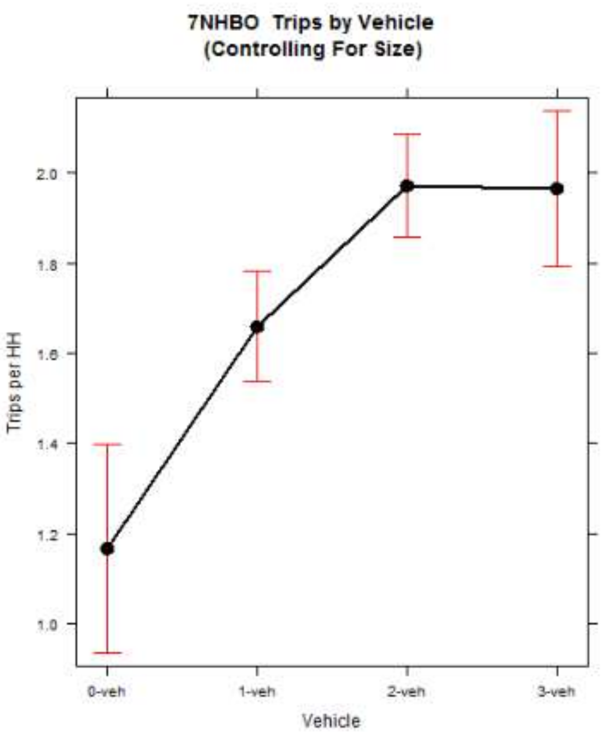

6NHBW Trips by Worker
(Controlling For Vehicle)
Trips per HH
1.5
1.0
0.5
0.0
0-work
1-work
2-work
3-work
Worker

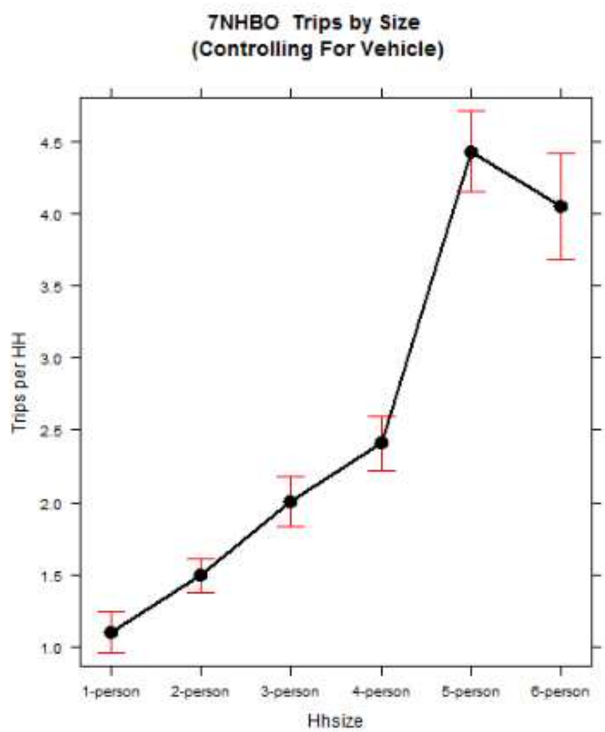

6NHBW Trips by Area Type
(Controlling For Income & Worker)
Trips per HH
1.8
1.6
1.4
1.2
1.0
0.8
CBD
UrbanEAA
Urban
Suburb
Rural
AT

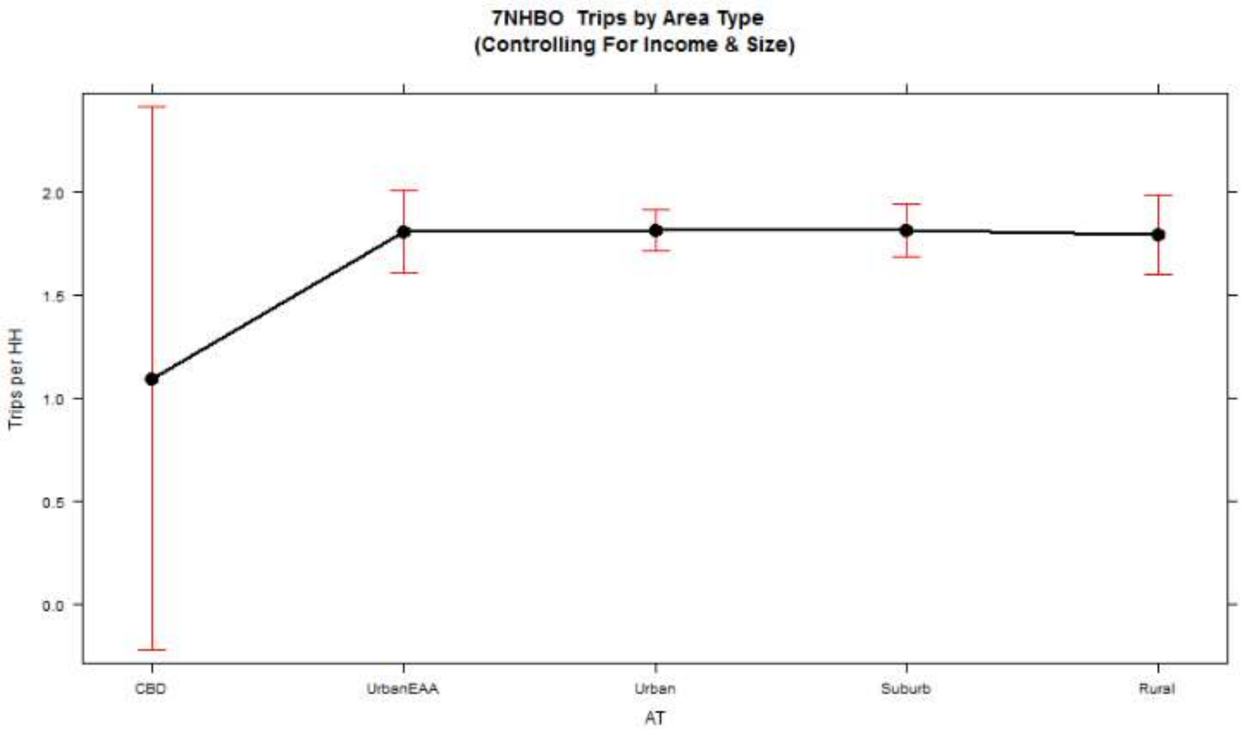
D.6 Non-Home-Based Other











D.7 Trip Production Rates Based on 2004/2005 Combined Household Travel Survey Data

Table D.1 Draft Home Based Work (HBW) Trip Production Rates

Household Income	0 Worker	1 Worker	2 Worker	3+ Worker	Overall
0-30K	0.06	0.98	2.44	2.99	**0.52**
30k-60k	0.06	1.47	2.49	4.04	**1.31**
60k-100k	0.06	1.47	2.49	4.04	**1.69**
100k+	0.06	1.47	2.49	4.04	**2.19**
Overall	**0.06**	**1.35**	**2.48**	**4.02**	**1.36**

Source: CS analysis of 2004/2005 combined household survey data.

Table D.2 Draft Home Based School (HBSc) Trip Production Rates

Children	2 person	3 person	4 person	5+ person	Overall
1 Child	1.70	1.70	1.70	1.70	**1.70**
2 Children	-	3.13	3.13	3.13	**3.13**
3+ Children	-	-	4.97	4.97	**4.97**
Overall	**0.11**	**0.69**	**1.52**	**2.57**	**0.62**

Source: CS analysis of 2004/2005 combined household survey data.
Note: Children are defined as household members 5 to 17 years old. The average rates in the "Overall" row include households with no children, which are assumed not to generate Home Based School trips.

Table D.3 Draft Home Based Shop (HBSh) Trip Production Rates

Household Income	1 person	2 person	3 person	4 person	5+ person	Overall
0-30K	0.56	1.00	1.00	1.00	1.00	**0.77**
30k-60k	0.56	1.00	1.00	1.00	1.39	**0.89**
60k-100k	0.56	1.00	1.00	1.25	1.39	**0.98**
100k+	0.56	1.00	1.25	1.25	1.39	**1.14**
Overall	**0.56**	**1.00**	**1.07**	**1.17**	**1.34**	**0.93**

Source: CS analysis of 2004/2005 combined household survey data.

Table D.4 Draft Home Based Other (HBO) Trip Production Rates

Household Income	1 person	2 person	3 person	4 person	5+ person	Overall
0-30K	1.20	2.63	3.55	6.18	6.80	**2.39**
30k-60k	1.20	2.63	3.55	6.18	6.80	**3.07**
60k-100k	1.20	2.63	4.11	6.18	8.97	**3.74**
100k+	1.20	2.63	4.11	6.18	8.97	**4.71**
Overall	**1.20**	**2.63**	**3.84**	**6.18**	**8.14**	**3.38**

Source: CS analysis of 2004/2005 combined household survey data.

Table D.5 Draft Non-Home-Based Work (NHBW) Trip Production Rates

Household Vehicles	0 Worker	1 Worker	2 Worker	3+ Worker	Overall
0 Vehicles	0.02	0.22	0.72	0.72	**0.09**
1 Vehicle	0.02	0.81	1.41	1.73	**0.53**
2 Vehicles	0.02	0.81	1.41	1.73	**0.91**
3 Vehicles	0.02	0.81	1.41	1.73	**1.18**
Overall	**0.02**	**0.78**	**1.41**	**1.73**	**0.75**

Source: CS analysis of 2004/2005 combined household survey data.

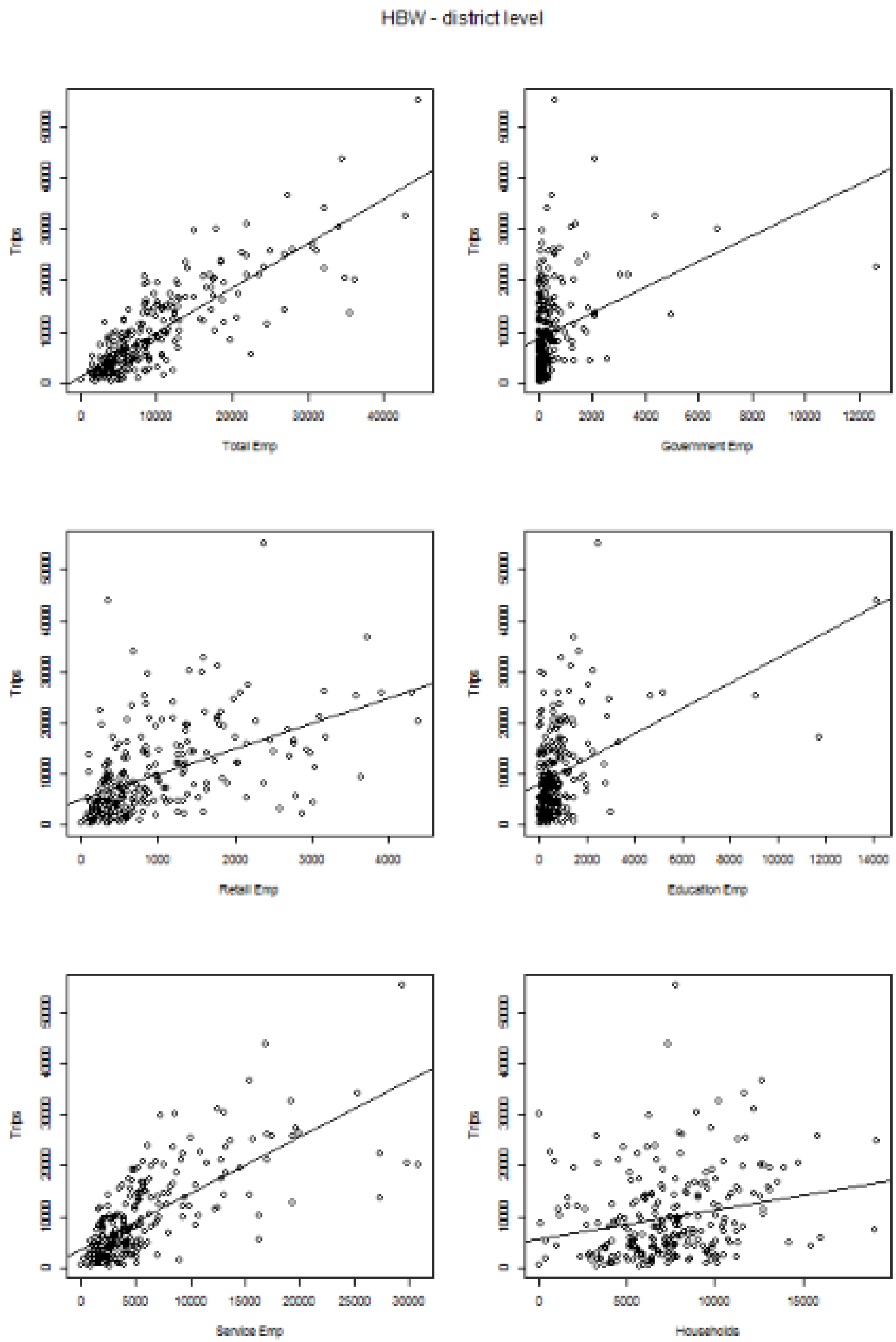
Table D.6 Draft Non-Home-Based Other (NHBO) Trip Production Rates

Household Income	1 person	2 person	3 person	4 person	5+ person	Overall
0 Vehicles	0.95	0.95	0.95	1.90	1.90	**1.02**
1 Vehicle	0.95	1.61	2.24	2.65	4.64	**1.44**
2 Vehicles	0.95	1.61	2.24	2.65	4.64	**2.20**
3 Vehicles	0.95	1.61	2.24	2.65	4.64	**2.61**
Overall	**0.95**	**1.56**	**2.16**	**2.63**	**4.59**	**1.89**

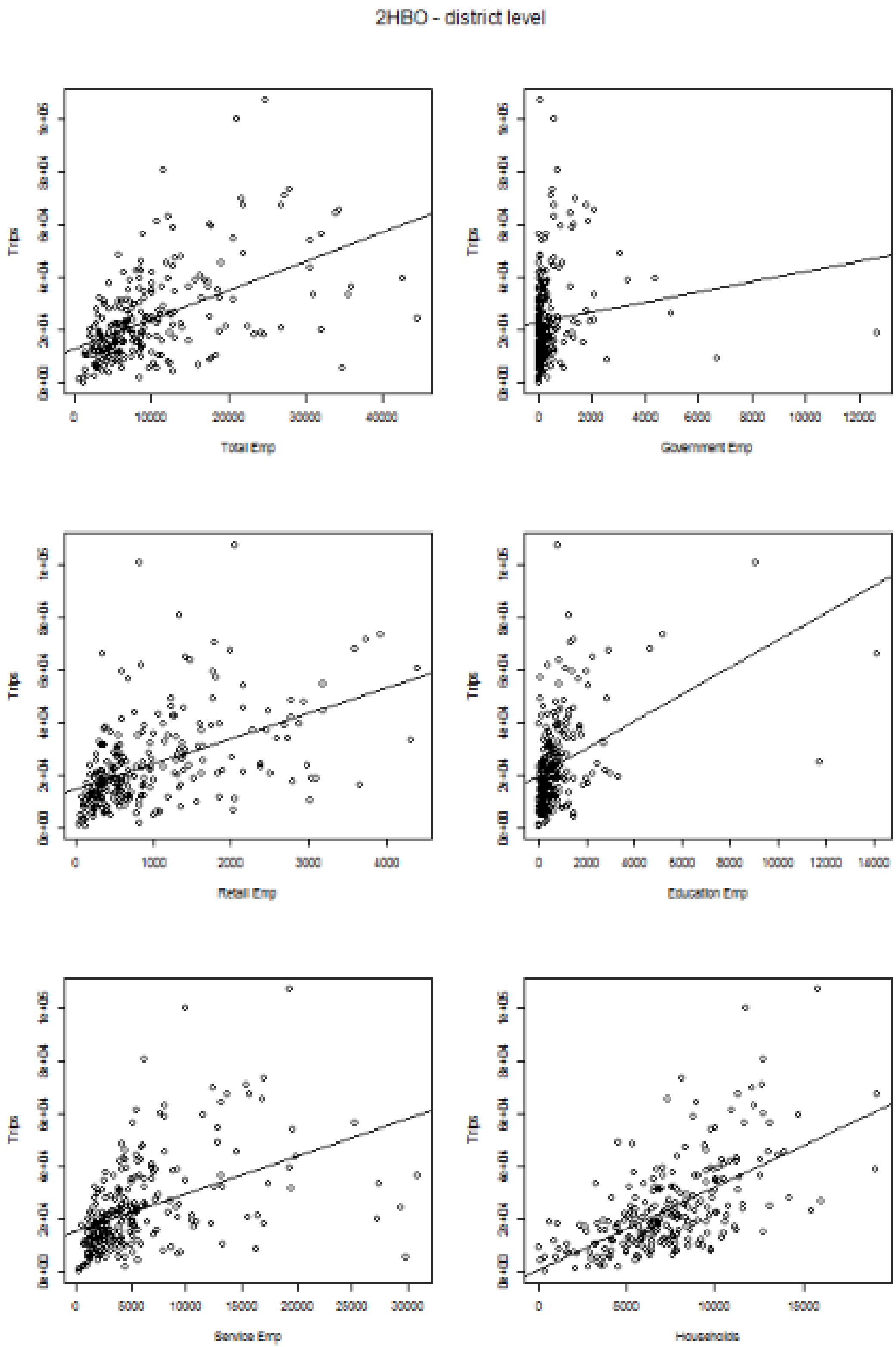
Source: CS analysis of 2004/2005 combined household survey data.

Appendix E. Trip Attraction Exploratory Analysis Using 2004/2005 Combined Household Travel Survey Data

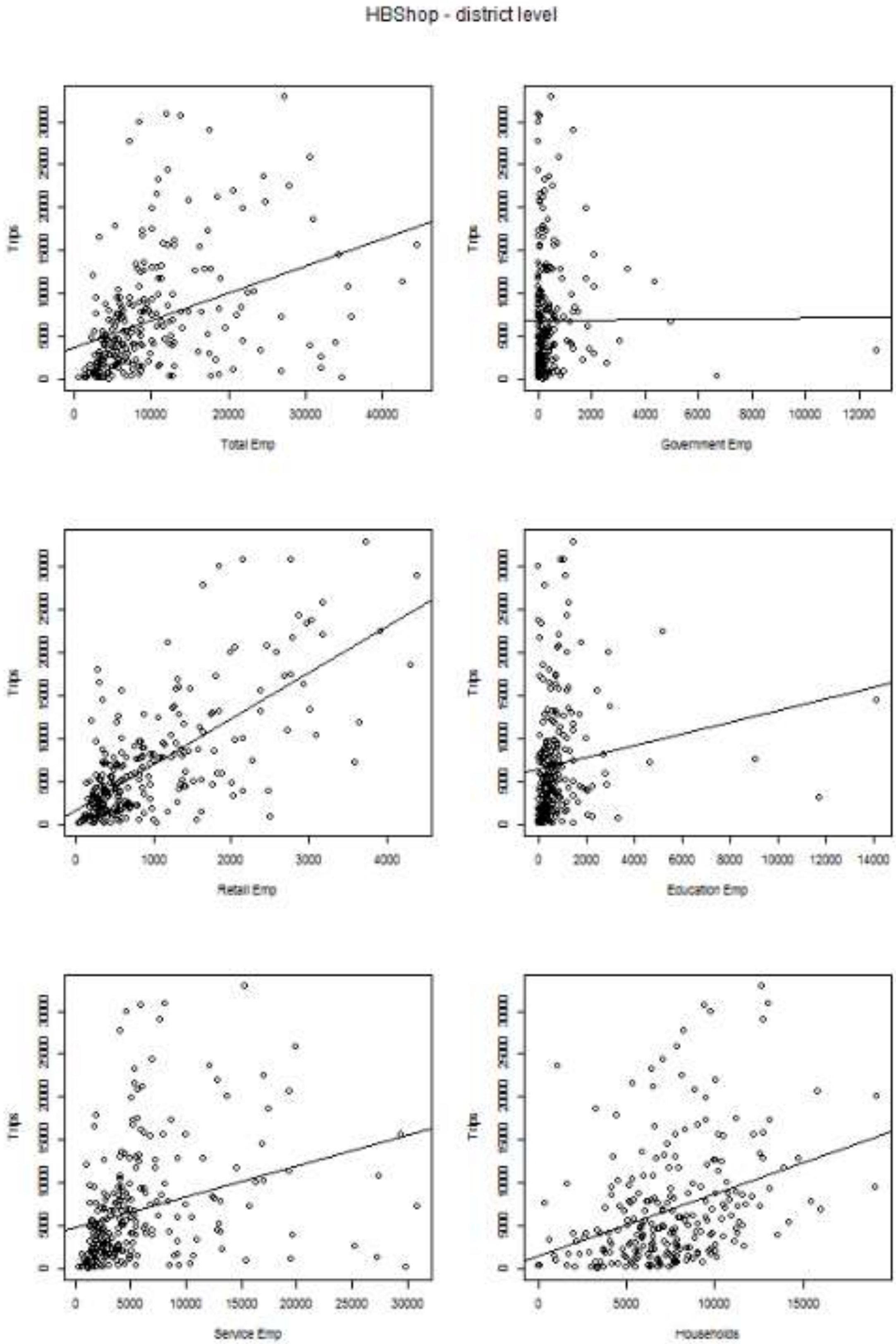
E.1 Home-Based Work Correlation



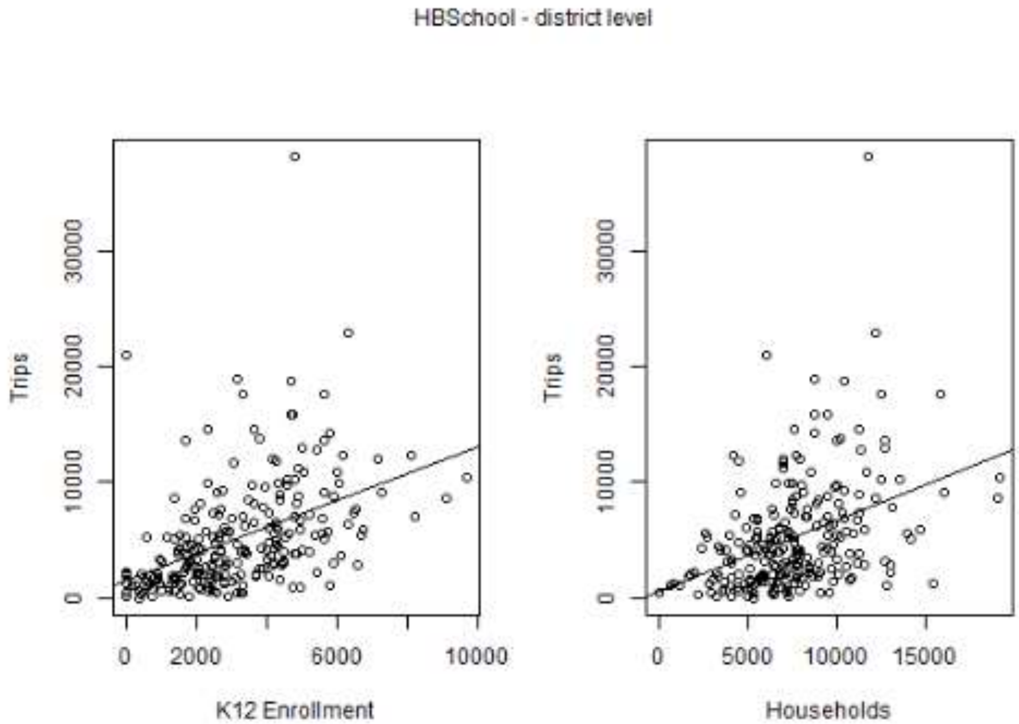
E.2 Home-Based Other Correlation



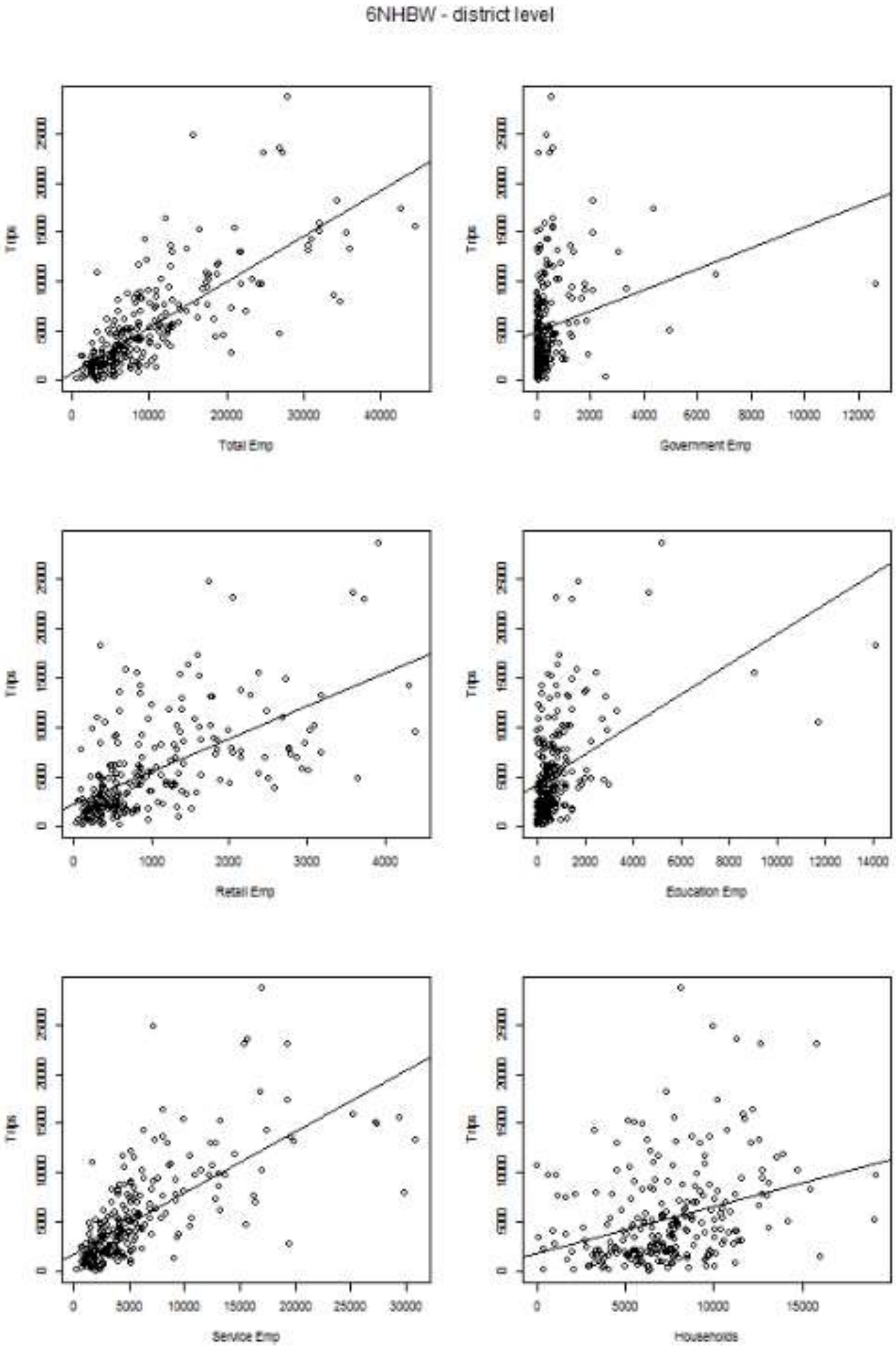
E.3 Home-Based Shop Correlation



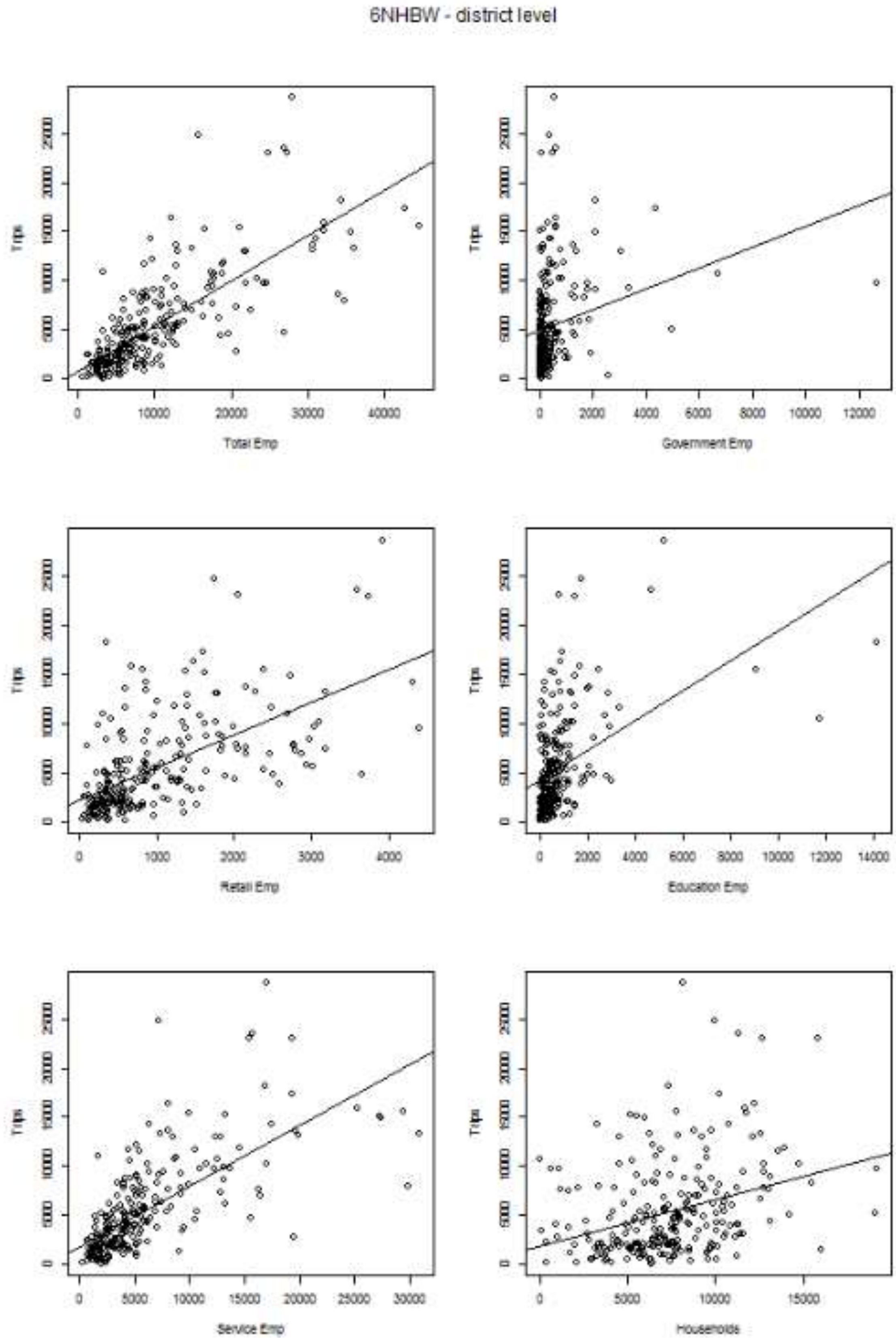
E.4 Home-Based School Correlation



E.5 Non-Home-Based Work Production Correlation



E.6 Non-Home-Based Work Attraction Correlation



E.7 Non-Home-Based Other Correlation

7NHBO - district level

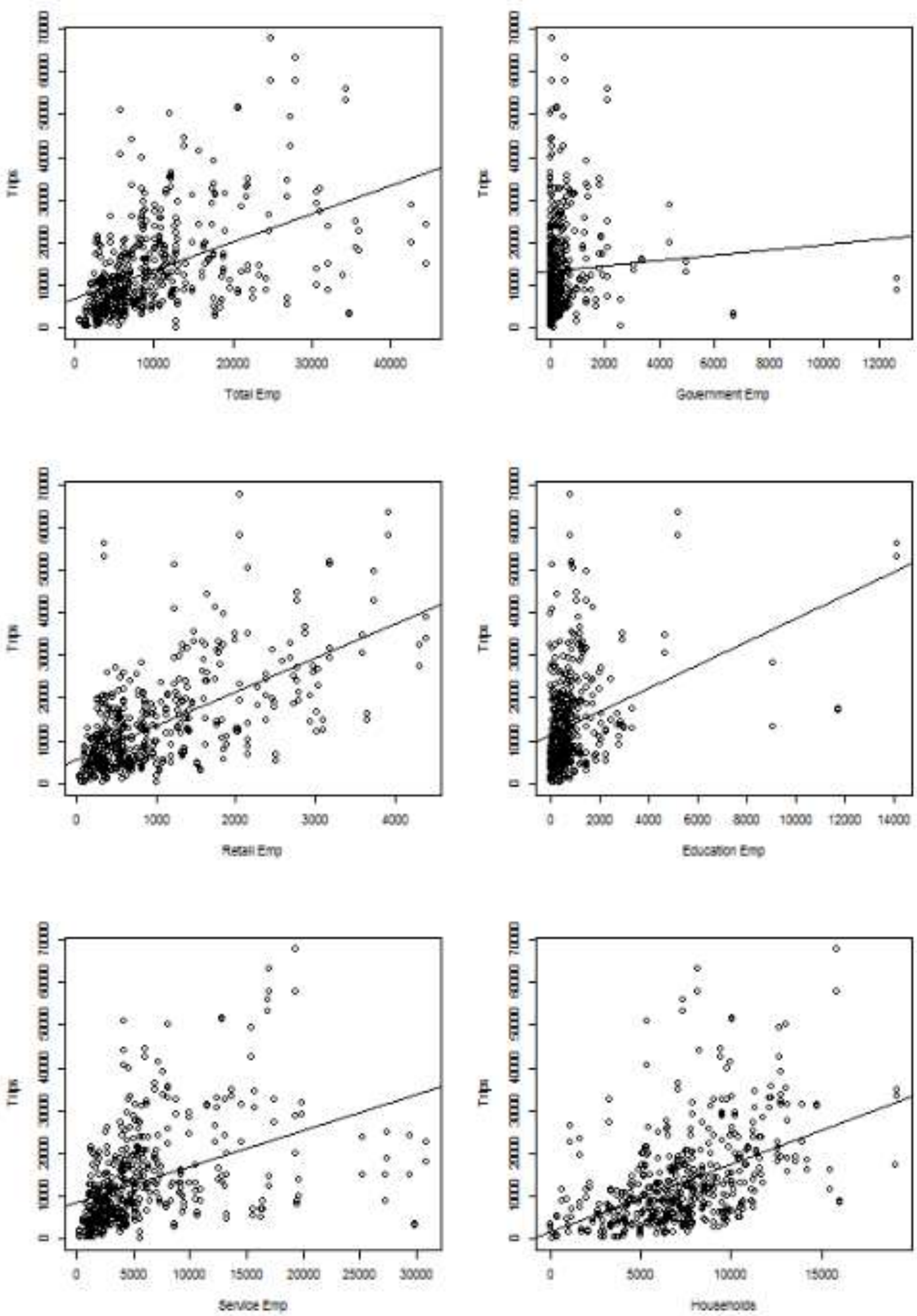


Table E.1 Home Based Trip Regression Results

	Regional		Area Type: Urban or Denser	
HBW		R: 0.86		R: 0.87
Variable	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**
Total Employment	0.94	39.06	0.93	29.6
HBSc		R: 0.62		R: 0.62
Variable	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**
K-12 Enrollment	1.51	19.65	1.77	14.07
HBSh		R: 0.74		R: 0.71
Variable	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**
Retail Trade	6.2	26.49	6.28	18.2
HBO		R: 0.86		R: 0.87
Variable	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**
Households	2.03	14.17	2.55	11.5
Service Employment	0.35	2.17	0.07	0.35
Public Administration	1.48	2.26	1.45	1.97
Retail Trade	4.49	4.57	5.08	3.56
Education Services	3.27	6.16	3.05	5.03

Note: R-squared values are not comparable between regional and urban or denser due to a different number of samples.

Table E.2 Non-Home Based-Work Trip Regression Results

	Regional		Area Type: Urban or Denser	
NHBW - Production Allocation	R: 0.84		R: 0.81	
Variable	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**
Total Employment	0.53	36.27	0.51	24.18
NHBWork - Attractions	R: 0.84		R: 0.86	
Variable	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**
Households	0.13	3.32	0.15	2.49
Service Employment	0.35	8.41	0.28	5.33
Public Administration	0.59	3.42	0.57	2.93
Retail Trade	1.65	6.41	2.21	5.82
Education Services	0.81	5.84	0.86	5.32

Note: R-squared values are not comparable between regional and urban or denser due to a different number of samples.

Table E.3 Non-Home Based-Other Trip Regression Results

	Regional		Area Type: Urban or Denser	
NHBO - Initial	R: 0.81		R: 0.82	
Variable	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**
Households	0.8	11.43	1.07	9.71
Service Employment	**0**	**0.02**	-0.16	-1.66
Public Administration	0.42	1.3	0.5	1.37
Retail Trade	6.33	13.2	6.67	9.43
Education Services	1.77	6.83	1.78	5.92
NHBO - Revised	R: 0.81		R: 0.82	
Variable	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**
Households	0.8	11.67	1.03	9.54
Public Administration	0.42	1.34	0.36	1.02
Retail Trade	6.33	15.5	6.01	10.22
Education Services	1.77	7.13	1.67	5.68

Notes: R-squared values are not comparable between regional and urban or denser due to a different number of samples. The revised results omit service employment, as it is not statistically significant.

Appendix F. Comparison of Expanded Trips by Person Expansion vs. Household Expansion Factors

Table F.1 Person and Household Weighted Trips by Origin County

Person Weights	Trip Purpose							
Origin County	1HBW	2HBO	3HBSH	4HBSCH	5HBU	6NHBW	7NHBO	Total
LIVINGSTON	76,649	192,281	47,842	43,001	549	25,170	120,444	505,934
MACOMB	464,821	1,016,269	350,333	202,531	22,875	205,605	595,940	2,858,374
MONROE	66,275	129,525	40,614	35,962	2,907	21,333	68,422	365,037
OAKLAND	719,463	1,719,955	505,545	312,049	36,922	475,287	1,025,898	4,795,120
ST. CLAIR	75,731	203,294	49,944	47,378	5,120	30,989	101,838	514,296
WASHTENAW	192,048	487,761	113,255	88,868	69,625	125,018	284,024	1,360,599
WAYNE-DETROIT	320,229	856,114	210,826	237,541	53,197	164,975	368,746	2,211,627
WAYNE-OUTCOUNTY	540,727	1,399,388	390,512	260,062	49,031	302,746	813,434	3,755,900
NA	32,893	70,239	9,365	7,816	2,090	7,407	47,300	177,109
Total	2,488,836	6,074,825	1,718,236	1,235,208	242,315	1,358,531	3,426,047	16,543,996
Household Weights	Trip Purpose							
Origin County	1HBW	2HBO	3HBSH	4HBSCH	5HBU	6NHBW	7NHBO	Total
LIVINGSTON	74,693	189,923	47,152	42,703	547	24,487	118,812	498,316
MACOMB	450,977	993,754	342,238	198,954	22,420	198,555	579,438	2,786,337
MONROE	64,165	126,384	39,565	35,205	2,804	20,606	66,737	355,467
OAKLAND	695,501	1,685,176	494,381	308,642	35,898	458,090	999,864	4,677,554
ST. CLAIR	74,045	199,171	48,920	46,558	5,019	30,265	99,817	503,795
WASHTENAW	187,935	473,202	110,059	85,322	66,170	122,008	275,406	1,320,102
WAYNE-DETROIT	291,229	765,004	188,325	211,718	49,096	152,250	332,441	1,990,064
WAYNE-OUTCOUNTY	507,983	1,315,326	366,623	244,955	46,097	285,911	764,777	3,531,672
NA	31,613	67,232	8,980	7,625	2,066	7,032	45,596	170,144
Total	2,378,143	5,815,172	1,646,241	1,181,683	230,118	1,299,205	3,282,887	15,833,449

Difference (Person - HH)	Trip Purpose							
Origin County	1HBW	2HBO	3HBSH	4HBSCH	5HBU	6NHBW	7NHBO	Total
LIVINGSTON	1,955	2,358	690	299	2	682	1,632	7,618
MACOMB	13,844	22,515	8,095	3,577	454	7,051	16,502	72,037
MONROE	2,109	3,141	1,049	757	102	727	1,685	9,570
OAKLAND	23,962	34,779	11,164	3,407	1,024	17,197	26,034	117,566
ST. CLAIR	1,687	4,124	1,025	820	101	724	2,021	10,501
WASHTENAW	4,112	14,559	3,196	3,546	3,455	3,010	8,618	40,497
WAYNE-DETROIT	29,000	91,109	22,501	25,823	4,101	12,725	36,306	221,564
WAYNE-OUTCOUNTY	32,743	84,061	23,890	15,107	2,934	16,835	48,658	224,228
NA	1,279	3,007	385	191	24	375	1,703	6,965
Total	110,692	259,653	71,994	53,525	12,198	59,326	143,160	710,548

Percentage Difference (Person - HH)/Person	Trip Purpose							
Origin County	1HBW	2HBO	3HBSH	4HBSCH	5HBU	6NHBW	7NHBO	Total
LIVINGSTON	3%	1%	1%	1%	0%	3%	1%	2%
MACOMB	3%	2%	2%	2%	2%	3%	3%	3%
MONROE	3%	2%	3%	2%	4%	3%	2%	3%
OAKLAND	3%	2%	2%	1%	3%	4%	3%	2%
ST. CLAIR	2%	2%	2%	2%	2%	2%	2%	2%
WASHTENAW	2%	3%	3%	4%	5%	2%	3%	3%
WAYNE-DETROIT	9%	11%	11%	11%	8%	8%	10%	10%
WAYNE-OUTCOUNTY	6%	6%	6%	6%	6%	6%	6%	6%
NA	4%	4%	4%	2%	1%	5%	4%	4%
Total	4%	4%	4%	4%	5%	4%	4%	4%

Table F.2 Person and Household Weighted Trips by Destination County

Person Weights	Trip Purpose							
Destination County	1HBW	2HBO	3HBSH	4HBSCH	5HBU	6NHBW	7NHBO	Total
LIVINGSTON	70,442	189,245	51,743	42,764	514	26,462	124,232	505,401
MACOMB	453,967	1,023,052	352,394	201,705	21,954	214,015	593,507	2,860,595
MONROE	64,440	130,454	40,943	35,738	2,862	22,222	67,830	364,488
OAKLAND	721,218	1,726,036	492,009	315,219	35,055	472,170	1,029,947	4,791,654
ST. CLAIR	74,548	204,182	51,538	47,157	4,711	31,573	100,675	514,384
WASHTENAW	188,614	492,369	117,702	89,248	69,078	125,051	277,611	1,359,672
WAYNE-DETROIT	331,700	859,252	227,314	233,288	56,915	151,774	353,693	2,213,936
WAYNE-OUTCOUNTY	555,388	1,388,200	370,427	261,845	48,940	304,919	829,177	3,758,896
NA	28,519	62,035	14,165	8,244	2,286	10,345	49,376	174,970
Total	2,488,836	6,074,825	1,718,236	1,235,208	242,315	1,358,531	3,426,047	16,543,996

Household Weights	Trip Purpose							
Destination County	1HBW	2HBO	3HBSH	4HBSCH	5HBU	6NHBW	7NHBO	Total
LIVINGSTON	68,635	186,918	50,948	42,471	508	25,764	122,564	497,808
MACOMB	440,308	1,000,261	344,460	198,028	21,524	206,596	577,262	2,788,438
MONROE	62,367	127,302	39,895	34,986	2,758	21,477	66,142	354,928
OAKLAND	696,826	1,690,669	481,523	311,693	34,112	455,339	1,003,979	4,674,142
ST. CLAIR	72,880	200,030	50,477	46,340	4,617	30,841	98,685	503,871
WASHTENAW	184,577	477,722	114,439	85,694	65,671	121,961	269,017	1,319,081
WAYNE-DETROIT	303,014	767,542	202,993	207,832	52,572	139,375	319,112	1,992,439
WAYNE-OUTCOUNTY	522,146	1,305,080	347,915	246,612	46,097	288,036	778,550	3,534,435
NA	27,390	59,649	13,593	8,026	2,258	9,815	47,576	168,307
Total	2,378,143	5,815,172	1,646,241	1,181,683	230,118	1,299,205	3,282,887	15,833,449

Appendix G. Detailed External Station Data

Table G.1 External Station Counts, Shares, and Volumes by Vehicle Class

			Daily Volumes				External-External Trip Share			Total External-External Trips			Total Internal-External and External-Internal Trips		
Station ID	Station Name	Station Group	Total	Autos	Medium Trucks	Heavy Trucks	Autos	Medium Trucks	Heavy Trucks	Autos	Medium Trucks	Heavy Trucks	Autos	Medium Trucks	Heavy Trucks
2812	Summit St	Ohio	3,314	3,125	164	25	14%	19%	19%	427	31	5	2,698	133	20
2813	I-75 S	Ohio	64,315	38,511	2,122	23,682	4%	26%	10%	1483	544	2348	37,028	1,578	21,334
2814	Suder Rd	Ohio	1,239	1,154	67	19	17%	32%	47%	192	21	9	962	46	10
2815	Dixie Hwy	Ohio	5,732	4,945	486	301	17%	32%	47%	824	156	143	4,121	330	158
2816	Telegraph Rd	Ohio	12,053	11,045	778	230	13%	19%	11%	1420	147	26	9,625	631	204
2817	Lewis Ave	Ohio	13,870	13,212	596	62	4%	14%	27%	488	82	17	12,724	514	45
2818	Jackman Rd	Ohio	7,170	6,869	290	11	4%	14%	27%	254	40	3	6,615	250	8
2819	Douglas Rd	Ohio	6,411	6,199	205	8	4%	14%	27%	229	28	2	5,970	177	6
2820	Secor Rd	Ohio	16,918	15,477	1,349	92	4%	14%	27%	572	186	25	14,905	1,163	67
2821	Cloverlane Rd	Ohio	1,177	1,140	36	1	4%	14%	27%	42	5	0	1,098	31	1
2822	Whiteford Rd	Ohio	4,500	4,356	137	7	4%	14%	27%	161	19	2	4,195	118	5
2823	US 23 S	Ohio	58,191	43,687	1,789	12,715	18%	36%	42%	7856	641	5301	35,831	1,148	7,414
2824	Main St	Ohio	5,489	5,202	272	16	17%	23%	38%	880	62	6	4,322	210	10
2825	Clark Rd	Ohio	2,290	2,038	165	87	17%	23%	38%	345	37	33	1,693	128	54
2826	Yankee Rd	Michigan	894	852	40	2	17%	23%	38%	144	9	1	708	31	1
2827	Ottawa Lake Rd	Michigan	492	441	38	13	17%	23%	38%	75	9	5	366	29	8
2828	US 223 W	Michigan	9,265	7,336	768	1,161	61%	61%	67%	4483	466	777	2,853	302	384
2829	Deerfield Rd	Michigan	2,969	2,672	230	67	17%	19%	39%	441	43	26	2,231	187	41
2830	Brewer Rd	Michigan	362	314	30	18	17%	19%	39%	52	6	7	262	24	11
2831	Tecumseh St	Michigan	6,398	5,412	525	462	17%	19%	39%	894	98	181	4,518	427	281

Station ID	Station Name	Station Group	Daily Volumes				External-External Trip Share			Total External-External Trips			Total Internal-External and External-Internal Trips		
			Total	Autos	Medium Trucks	Heavy Trucks	Autos	Medium Trucks	Heavy Trucks	Autos	Medium Trucks	Heavy Trucks	Autos	Medium Trucks	Heavy Trucks
2832	Milwaukee Rd	Michigan	212	191	21	0	17%	19%	39%	32	4	0	159	17	0
2833	Ridge Rd	Michigan	6,176	5,934	230	12	17%	19%	39%	980	43	5	4,954	187	7
2834	Britton Hwy	Michigan	1,860	1,792	52	17	17%	19%	39%	296	10	7	1,496	42	10
2835	Ford Hwy	Michigan	273	237	32	4	17%	19%	39%	39	6	2	198	26	2
2836	Tecumseh-Clinton Hwy	Michigan	7,486	6,917	421	148	11%	28%	36%	760	117	53	6,157	304	95
2837	Matthews Hwy	Michigan	2,163	2,025	122	16	11%	28%	36%	223	34	6	1,802	88	10
2838	MI-52 W	Michigan	6,179	5,439	452	287	11%	28%	36%	598	126	104	4,841	326	183
2839	Tipton Hwy	Michigan	1,502	1,397	96	9	9%	14%	39%	121	13	4	1,276	83	5
2840	US-12	Michigan	5,645	5,037	403	205	9%	14%	39%	436	56	81	4,601	347	124
2841	Wellwood Rd	Michigan	627	587	38	1	9%	14%	39%	51	5	1	536	33	0
2842	Horning Rd	Michigan	654	615	36	4	9%	14%	39%	53	5	2	562	31	2
2843	Austin Rd	Michigan	1,906	1,743	139	24	9%	14%	39%	151	19	10	1,592	120	14
2844	Sharon Valley Rd	Michigan	766	713	39	14	9%	14%	39%	62	5	6	651	34	8
2845	Curtis Rd	Michigan	155	140	13	2	9%	14%	39%	12	2	1	128	11	1
2846	Grass Lake Rd	Michigan	304	278	21	5	9%	14%	39%	24	3	2	254	18	3
2847	E Michigan Ave	Michigan	5,188	4,870	274	43	9%	14%	39%	421	38	17	4,449	236	26
2848	I-94 W	Michigan	59,970	45,906	1,400	12,664	3%	15%	9%	1249	205	1176	44,657	1,195	11,488
2849	Harvey Rd	Michigan	715	670	41	4	8%	7%	36%	53	3	1	617	38	3
2850	Waterloo Rd	Michigan	835	775	57	4	8%	7%	36%	61	4	1	714	53	3
2851	MI-52	Michigan	5,190	4,710	319	161	13%	23%	25%	633	74	40	4,077	245	121
2852	Morton Rd	Michigan	1,765	1,597	143	25	12%	10%	6%	188	15	2	1,409	128	23
2853	Dexter Trail	Michigan	556	509	44	2	12%	10%	6%	60	5	0	449	39	2
2854	E MI-36	Michigan	987	879	75	33	2%	14%	33%	16	10	11	863	65	22

			Daily Volumes				External-External Trip Share			Total External-External Trips			Total Internal-External and External-Internal Trips		
Station ID	Station Name	Station Group	Total	Autos	Medium Trucks	Heavy Trucks	Autos	Medium Trucks	Heavy Trucks	Autos	Medium Trucks	Heavy Trucks	Autos	Medium Trucks	Heavy Trucks
2855	Dansville Rd	Michigan	146	123	22	1	7%	19%	10%	9	4	0	114	18	1
2856	E Howell Rd	Michigan	2,597	2,378	164	55	7%	19%	10%	174	31	6	2,204	133	49
2857	I-96 W	Michigan	57,551	50,341	1,590	5,620	5%	14%	21%	2412	218	1180	47,929	1,372	4,440
2858	Grand River Ave	Michigan	5,562	4,949	438	175	20%	13%	9%	972	56	15	3,977	382	160
2859	Allen Rd	Michigan	441	395	45	0	20%	13%	9%	78	6	0	317	39	0
2860	Bell Oak Rd	Michigan	105	89	16	0	20%	13%	9%	17	2	0	72	14	0
2861	Fowlerville Rd	Michigan	1,707	1,628	69	10	20%	13%	9%	320	9	1	1,308	60	9
2862	Byron Rd	Michigan	1,728	1,600	106	21	20%	13%	9%	314	14	2	1,286	92	19
2863	Seymour Rd	Michigan	3,478	3,211	237	30	20%	13%	9%	631	30	3	2,580	207	27
2864	Linden Rd	Michigan	4,723	4,430	270	22	20%	13%	9%	870	34	2	3,560	236	20
2865	Jennings Rd	Michigan	2,504	2,394	106	4	20%	13%	9%	470	13	0	1,924	93	4
2866	US-23 N	Michigan	63,064	57,275	1,021	4,768	13%	16%	42%	7479	160	2007	49,796	861	2,761
2867	Adelaide St	Michigan	6,397	5,994	379	24	43%	45%	52%	2587	172	12	3,407	207	12
2868	South Olly Rd	Michigan	5,170	4,877	277	16	43%	45%	52%	2105	126	8	2,772	151	8
2869	Grange Hall Rd	Michigan	13,987	13,143	730	113	43%	45%	52%	5672	331	59	7,471	399	54
2870	Thompson Rd	Michigan	538	504	32	1	43%	45%	52%	218	15	1	286	17	0
2871	N Holly Rd	Michigan	7,724	7,297	377	50	43%	45%	52%	3149	171	26	4,148	206	24
2872	I-75 N	Michigan	50,454	46,992	1,069	2,392	45%	48%	51%	21037	509	1220	25,955	560	1,172
2873	Saginaw Rd	Michigan	11,381	10,746	549	86	24%	9%	13%	2571	52	11	8,175	497	75
2874	Van Rd	Michigan	372	336	34	1	24%	9%	13%	80	3	0	256	31	1
2875	Ortonville Rd	Michigan	13,711	12,985	659	67	24%	9%	13%	3107	62	9	9,878	597	58
2876	Hadley Rd	Michigan	2,532	2,332	186	13	24%	9%	13%	558	18	2	1,774	168	11
2877	Baldwin Rd	Michigan	1,152	1,064	82	5	24%	9%	13%	255	8	1	809	74	4
2878	MI-24 N	Michigan	18,423	16,743	1,375	305	4%	8%	13%	739	105	41	16,004	1,270	264

			Daily Volumes				External-External Trip Share			Total External-External Trips			Total Internal-External and External-Internal Trips		
Station ID	Station Name	Station Group	Total	Autos	Medium Trucks	Heavy Trucks	Autos	Medium Trucks	Heavy Trucks	Autos	Medium Trucks	Heavy Trucks	Autos	Medium Trucks	Heavy Trucks
2879	Hosner Rd	Michigan	478	439	38	1	22%	27%	22%	98	10	0	341	28	1
2880	Rochester Rd	Michigan	3,732	3,498	208	27	22%	27%	22%	784	55	6	2,714	153	21
2881	Earle Memorial Hwy	Michigan	19,347	17,467	1,422	458	10%	12%	13%	1697	164	61	15,770	1,258	397
2882	Almont Rd	Michigan	1,773	1,647	113	13	19%	24%	32%	305	27	4	1,342	86	9
2883	Dryden Rd	Michigan	1,030	893	109	28	19%	24%	32%	165	26	9	728	83	19
2884	Burt Rd	Michigan	133	113	16	4	19%	24%	32%	21	4	1	92	12	3
2885	I-69 W	Michigan	14,169	10,076	294	3,800	29%	51%	34%	2902	148	1280	7,174	146	2,520
2886	Imlay City Rd	Michigan	3,652	3,305	280	68	18%	25%	14%	586	69	9	2,719	211	59
2887	Norman Rd	Michigan	141	126	14	1	18%	25%	14%	22	3	0	104	11	1
2888	Fisher Rd	Michigan	200	164	33	3	18%	25%	14%	29	8	0	135	25	3
2889	Maple Valley Rd	Michigan	850	737	108	5	21%	10%	22%	152	11	1	585	97	4
2890	Shephard Rd	Michigan	785	722	56	7	21%	10%	22%	149	6	2	573	50	5
2891	Brockway Rd	Michigan	3,687	3,316	288	82	21%	10%	22%	684	29	18	2,632	259	64
2892	Bricker Rd	Michigan	534	496	37	1	21%	10%	22%	102	4	0	394	33	1
2893	Todd Rd	Michigan	678	625	48	6	21%	10%	22%	129	5	1	496	43	5
2894	Wildcat Rd	Michigan	3,614	3,325	170	119	21%	10%	22%	686	17	26	2,639	153	93
2895	Lakeshore Rd	Michigan	7,869	7,194	491	184	5%	12%	34%	345	57	63	6,849	434	121
2896	Blue Water Bridge	Ontario	14,113	9,385	1,891	2,837	40%	47%	31%	3799	896	885	5,586	995	1,952
2897	Detroit Windsor Tunnel	Ontario	12,314	12,227	28	59	14%	7%	19%	1755	2	11	10,472	26	48
2898	Ambassador Bridge	Ontario	20,408	13,155	2,321	4,932	23%	44%	34%	3019	1026	1682	10,136	1,295	3,250
2899	Proposed Crossing	Ontario	0	0	0	0	0%	0%	0%	0	0	0	0	0	0

Appendix H. Destination Choice Model Estimation Results

This appendix presents the raw destination choice model estimation results and the resulting application terms by market segment and distance range. The model estimation file posted time period specific (AM peak or midday), income-based skim and logsum data for each observed trip. Thus, estimated model coefficients vary only for the vehicle availability market segments. Zero-vehicle households are more sensitive to distance, have a greater utility for zones with walk-transit connectivity, and are more attracted to zones with mixed-use density. Zero-vehicle households are also more likely to make intrazonal trips. Households with at least as many vehicles as workers are less sensitive to distance and are less likely to make intrazonal trips. Table H.1 shows the raw model estimation results for home based work, home based shop, and home based other trip purposes.

The estimated variable terms are marginal terms to be applied in combination. **Table H.2**,Table H**.3**, and **Table H.4** show the resulting application terms for each vehicle availability market segment for the home based work, home based other, and home based shop trip purposes. Home-based other does not have distance-specific segmentation by vehicle availability market. Only the intrazonal and mixed-use density terms are segmented.

The home-based school and non-home based trips are not segmented by market. Note that the non-home-based trips cannot be segmented in application because there is no connection between a given non-home-based trip and the household that produced that trip. **Table H.5** shows the raw model estimation results for the home-based school and non-home based trips and **Table H.6** shows the resulting application terms.

Table H.1 Model Estimation with Vehicle Availability Segments

	Home-Based Work		Home-Based Other		Home-Based Shop	
Variable	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
ZERO VEHICLES						
logsum	1.000	*	1.000	*	1.000	*
distance (miles)	-0.020	-1.11	-0.674	-105.33	-0.022	-0.57
max(distance - 5, 0)	0.241	11.14	0.397	43.72	0.420	16.70
max(distance - 10, 0)	0.013	0.73			0.053	1.37
max(distance - 15, 0)	0.023	1.72	0.153	18.42	0.099	1.66
max(distance - 20, 0)					0.077	1.58
max(distance - 30, 0)	0.025	3.24	-0.019	-0.96		
max(distance - 40, 0)			0.123	5.11	0.075	2.19
walk-transit	0.263	1.04				
intrazonal	0.561	1.38	0.667	4.79	0.357	1.07
mixed use density			0.163	13.00		
ln(attractions)	1.000	*	1.000	*	1.000	*
VEHICLES > 0 AND VEHICLES < WORKERS						
distance (miles)	-0.390	-25.51	-0.674	-105.33	-0.839	-25.04
intrazonal	1.605	8.64	0.727	6.73	0.591	2.01
VEHICLES > 0 AND VEHICLES >= WORKERS						
distance (miles)	0.029	4.23	-0.674	-105.33	0.075	2.33
intrazonal	-1.247	-6.15	-0.299	-2.72	-0.473	-1.57
Observations	7,952		19,064		5,126	
Log Likelihood at Zero	-62,276		-153,326		-41,938	
Log Likelihood at Convergence	-50,638		-98,262		-24,384	
Rho Squared with respect to Zero	0.187		0.359		0.419	

Source: CS analysis of 2004/2005 combined household survey data.

Table H.2 Home-Based Work Application Terms

Term	Zero Vehicles	Vehicles > 0 AND Vehicles < Workers	Vehicles > 0 AND Vehicles >= Workers
logsum	1.000	1.000	1.000
ln(attractions)	1.000	1.000	1.000
distance (0-5 miles)	-0.410	-0.390	-0.361
distance (5-10 miles)	-0.169	-0.149	-0.120
distance (10-15 miles)	-0.156	-0.135	-0.106
distance (15-20 miles)	-0.133	-0.113	-0.084
distance (20-30 miles)	-0.133	-0.113	-0.084
distance (30-40 miles)	-0.108	-0.087	-0.059
distance (40+ miles)	-0.108	-0.087	-0.059
walk-transit	0.263	0.000	0.000
intrazonal	2.167	1.605	0.358
mixed use density	0.000	0.000	0.000

Source: CS analysis of 2004/2005 combined household survey data.

Table H.3 Home-Based Other Application Terms

Term	Zero Vehicles	Vehicles > 0 AND Vehicles < Workers	Vehicles > 0 AND Vehicles >= Workers
logsum	1.000	1.000	1.000
ln(attractions)	1.000	1.000	1.000
distance (0-5 miles)	-0.674	-0.674	-0.674
distance (5-10 miles)	-0.276	-0.276	-0.276
distance (10-15 miles)	-0.276	-0.276	-0.276
distance (15-20 miles)	-0.124	-0.124	-0.124
distance (20-30 miles)	-0.124	-0.124	-0.124
distance (30-40 miles)	-0.143	-0.143	-0.143
distance (40+ miles)	-0.020	-0.020	-0.020
walk-transit	0.000	0.000	0.000
intrazonal	1.394	0.727	0.428
mixed use density	0.163	0.000	0.000

Source: CS analysis of 2004/2005 combined household survey data.

Table H.4 Home-Based Shop Application Terms

Term	Zero Vehicles	Vehicles > 0 AND Vehicles < Workers	Vehicles > 0 AND Vehicles >= Workers
logsum	1.000	1.000	1.000
ln(attractions)	1.000	1.000	1.000
distance (0-5 miles)	-0.861	-0.839	-0.765
distance (5-10 miles)	-0.441	-0.419	-0.345
distance (10-15 miles)	-0.389	-0.367	-0.292
distance (15-20 miles)	-0.290	-0.268	-0.193
distance (20-30 miles)	-0.213	-0.191	-0.116
distance (30-40 miles)	-0.213	-0.191	-0.116
distance (40+ miles)	-0.138	-0.116	-0.041
walk-transit	0.000	0.000	0.000
intrazonal	0.948	0.591	0.118
mixed use density	0.000	0.000	0.000

Source: CS analysis of 2004/2005 combined household survey data.

Table H.5 Model Estimation for Non-Segmented Models

	Home-Based School		Non-Home-Based Work		Non-Home-Based Other	
Variable	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
logsum	1.000	*	1.000	*	1.000	*
distance (miles)	-0.967	-54.74	-0.509	-33.74	-0.585	-64.99
max(distance - 5, 0)	0.637	17.76	0.285	11.21	0.286	16.85
max(distance - 10, 0)	-0.180	-2.84	0.115	5.90	0.070	2.88
max(distance - 15, 0)	0.375	5.01			0.054	1.50
max(distance - 20, 0)			0.049	4.00	0.090	3.11
max(distance - 30, 0)	-0.216	-1.08				
max(distance - 40, 0)					0.062	2.97
intrazonal	0.146	2.12	0.419	5.53	0.664	17.81
mixed use density					0.005	0.79
ln(attractions)	1.000	*	1.000	*	1.000	*
Observations	10,646		4,864		10,646	
Log Likelihood at Zero	-85,758		-34,556		-85,758	
Log Likelihood at Convergence	-54,497		-25,973		-54,497	
Rho Squared wrt Zero	0.365		0.248		0.365	

Source: CS analysis of 2004/2005 combined household survey data.

Table H.6 Non-Segmented Model Application Terms

Term	Home-Based School	Non-Home-Based Work	Non-Home-Based Other
logsum	1.000	1.000	1.000
ln(attractions)	1.000	1.000	1.000
distance (0-5 miles)	-0.967	-0.509	-0.585
distance (5-10 miles)	-0.330	-0.225	-0.299
distance (10-15 miles)	-0.510	-0.109	-0.229
distance (15-20 miles)	-0.135	-0.109	-0.176
distance (20-30 miles)	-0.135	-0.060	-0.085
distance (30-40 miles)	-0.351	-0.060	-0.085
distance (40+ miles)	-0.351	-0.060	-0.023
walk-transit	0.000	0.000	0.000
intrazonal	0.146	0.419	0.664
mixed use density	0.000	0.000	0.005

Source: CS analysis of 2004/2005 combined household survey data.

Appendix I. 2010 Transit On-Board Survey Factoring to 2015 Observed Ridership

2015 growth factors were developed and applied to the 2010 on-board survey at the route level in order to derive 2015 transit linked trip targets. The targets were prepared using the 2010 transit on-board survey and then scaled to 2015 conditions using available boarding counts and service level data from the National Transit Database (NTD). **Table I.1** through **Table I.7** show the expanded survey boardings from the 2010 transit on-board survey, the observed 2015 average weekday ridership, and the resulting growth factors used to expand the 2010 survey data to 2015. For AAATA, DDOT, DPM, SMART, and UMI services, route level data were used to develop the 2010 survey to 2015 expansion factors. For BWAT, 2015 NTD average weekday ridership was used to develop the expansion factors. Updated LET data were unavailable, so the 2010 data were not expanded for that service.

Table I.1 Ann Arbor Area Transportation Authority (AAATA) 2015 Observed Average Weekday Route Ridership

ROUTE	2010 On-Board Survey	2015 Route Level Ridership Estimate (October 2014 Passenger Counts)	Growth Factor (2015 / 2010 Ridership)
AAT-..1	810	1,096	1.35
AAT-..2	1,771	2,409	1.36
AAT-..3	1,337	1,371	1.03
AAT-..5	2,319	2,168	0.93
AAT-..6	2,248	2,310	1.03
AAT-..7	1,241	1,338	1.08
AAT-..9	708	578	0.82
AAT-.10	506	679	1.34
AAT-.11	243	560	2.30
AAT-.13	211	172	0.81
AAT-.14	196	184	0.94
AAT-.15	253	279	1.10
AAT-.16	468	530	1.13
AAT-.17	46	80	1.74
AAT-.18	435	577	1.33
AAT-.1U	128	102	0.80
AAT-.20	544	576	1.06
AAT-.22	772	723	0.94
AAT-.2A	94	128	1.36
AAT-.2B	468	637	1.36
AAT-.2C	129	175	1.36

ROUTE	2010 On-Board Survey	2015 Route Level Ridership Estimate (October 2014 Passenger Counts)	Growth Factor (2015 / 2010 Ridership)
AAT-.33	611	742	1.21
AAT-.36	1,697	1,747	1.03
AAT-.4A	2,328	3,919	1.68
AAT-.4B	560	942	1.68
AAT-.4C	165	277	1.68
AAT-.8L	78	97	1.25
AAT-.8P	668	833	1.25
AAT-12A	460	458	1.00
AAT-12B	374	373	1.00
AAT-609	142	481	3.39
Total	22,010	26,540	1.21

Source: CS analysis of 2010 transit on-board survey data and 2015 AAATA boarding counts.

Table I.2 Blue Water Area Transit (BWAT) 2015 Observed Average Weekday Route Ridership

ROUTE	2010 On-Board Survey	2015 Route Level Ridership Estimate - 2015 NTD Service Level Average Weekday Unlinked Passenger Trips	Growth Factor (2015 / 2010 Ridership)
BWT-..01	369	772	2.09
BWT-..02	300	628	2.09
BWT-..03	402	841	2.09
BWT-..04	151	316	2.09
BWT-..05	369	772	2.09
BWT-..06	441	923	2.09
BWT-..09	383	802	2.09
BWT-..29	33	69	2.09
BWT-..94	9	19	2.09
BWT-SHOP	168	352	2.09
Total	2,625	5,494	2.09

Source: CS analysis of 2010 transit on-board survey data and 2015 NTD data.

Table I.3 Detroit Department of Transportation (DDOT) 2015 Observed Average Weekday Route Ridership

ROUTE	2010 On-Board Survey	2015 Route Level Ridership - Average Weekday Estimated from 2015 Annual Passenger Trips Reported by DDOT	Growth Factor (2015 / 2010 Ridership)
DOT-007	2,739	1,282	0.47
DOT-008	489	0	0.00
DOT-009	1,478	424	0.29
DOT-010	1,778	814	0.46
DOT-011	1,208	289	0.24
DOT-012	932	624	0.67
DOT-013	1,392	494	0.35
DOT-014	6,330	3,433	0.54
DOT-015	2,582	1,279	0.50
DOT-016	10,040	6,425	0.64
DOT-017	5,306	5,200	0.98
DOT-018	4,143	1,783	0.43
DOT-019	1,498	1,119	0.75
DOT-021	8,939	6,806	0.76
DOT-022	5,226	3,977	0.76
DOT-023	2,945	1,435	0.49
DOT-025	3,112	2,282	0.73
DOT-027	2,932	1,656	0.56
DOT-029	2,089	925	0.44
DOT-030	1,962	856	0.44
DOT-031	3,971	2,137	0.54
DOT-032	5,492	2,342	0.43
DOT-034	6,461	5,138	0.80
DOT-036	456	0	0.00
DOT-037	1,250	1,818	1.45
DOT-038	1,886	1,847	0.98
DOT-039	913	324	0.35
DOT-040	645	354	0.55
DOT-041	1,933	846	0.44
DOT-043	1,093	726	0.66
DOT-045	7,944	4,725	0.59
DOT-046	1,379	554	0.40

ROUTE	2010 On-Board Survey	2015 Route Level Ridership - Average Weekday Estimated from 2015 Annual Passenger Trips Reported by DDOT	Growth Factor (2015 / 2010 Ridership)
DOT-047	1,414	387	0.27
DOT-048	4,208	2,337	0.56
DOT-049	1,172	663	0.57
DOT-053	12,466	9,399	0.75
DOT-054	1,271	739	0.58
DOT-060	2,866	1,866	0.65
DOT-076	176	0	0.00
DOT-078	398	0	0.00
Total	124,514	77,304	0.62

Source: CS analysis of 2010 transit on-board survey data and 2015 DDOT data.

Table I.4 Detroit People Mover (DPM) 2015 Observed Average Weekday Route Ridership

ROUTE	2 010 On-Board Survey	2015 Route Level Ridership Estimate - 2015 NTD Service Level Average Weekday Unlinked Passenger Trips	Growth Factor (2015 / 2010 Ridership)
DPM-DPM	4,011	6,061	1.51
Total	4,011	6,061	1.51

Source: CS analysis of 2010 transit on-board survey data and 2015 DDOT data.

Table I.5 Lake Erie Transit (LET) 2015 Observed Average Weekday Route Ridership

ROUTE	2010 On-Board Survey	2015 Route Level Ridership Estimate - 2010 On-Board Survey	Growth Factor (2015 / 2010 Ridership)
LET-2	93	93	1.00
LET-3	84	84	1.00
LET-4	106	106	1.00
LET-5	131	131	1.00
LET-6	103	103	1.00
LET-7	87	87	1.00
LET-8	173	173	1.00
LET-9	100	100	1.00
Total	877	877	1.00

Source: CS analysis of 2010 transit on-board survey data.

Table I.6 Suburban Mobility Authority for Region Transportation (SMART) 2015 Observed Average Weekday Route Ridership

ROUTE	2010 On-Board Survey	2015 Route Level Ridership Estimate (June 2015 Average Weekday Ridership Monthly Operations Report)	Growth Factor (2015 / 2010 Ridership)
SMT-.125	1,871	1,529	0.82
SMT-.135	35	0	0.00
SMT-.140	314	276	0.88
SMT-.145	63	0	0.00
SMT-.150	56	0	0.00
SMT-.160	189	141	0.75
SMT-.190	11	0	0.00
SMT-.200	2,531	1,706	0.67
SMT-.202	37	0	0.00
SMT-.245	217	0	0.00
SMT-.250	307	457	1.49
SMT-.255	225	260	1.16
SMT-.265	262	0	0.00
SMT-.275	1,234	1,422	1.15
SMT-.280	277	377	1.36
SMT-.330	385	492	1.28

ROUTE	2010 On-Board Survey	2015 Route Level Ridership Estimate (June 2015 Average Weekday Ridership Monthly Operations Report)	Growth Factor (2015 / 2010 Ridership)
SMT-.385	97	0	0.00
SMT-.400	288	246	0.85
SMT-.405	513	515	1.00
SMT-.420	1,304	1,235	0.95
SMT-.430	97	92	0.95
SMT-.450	4,259	3,053	0.72
SMT-.455	287	306	1.07
SMT-.465	242	251	1.04
SMT-.494	562	625	1.11
SMT-.495	1,791	1,347	0.75
SMT-.510	2,599	2,298	0.88
SMT-.525	15	0	0.00
SMT-.530	143	133	0.93
SMT-.550	307	276	0.90
SMT-.559	24	0	0.00
SMT-.560	5,512	5,101	0.93
SMT-.610	1,046	825	0.79
SMT-.620	89	284	3.19
SMT-.635	102	229	2.25
SMT-.710	1,846	1,925	1.04
SMT-.730	636	781	1.23
SMT-.740	1,384	1,275	0.92
SMT-.752	201	180	0.90
SMT-.753	256	266	1.04
SMT-.756	204	173	0.85
SMT-.760	401	530	1.32
SMT-.780	786	760	0.97
SMT-.805	297	407	1.37
SMT-.830	268	234	0.87
SMT-.851	306	306	1.00
Total	33,876	30,313	0.89

Source: CS analysis of 2010 transit on-board survey data and 2015 SMART data.

Table I.7 University of Michigan (UMI) 2015 Observed Average Weekday Route Ridership

ROUTE	2010 On-Board Survey	2015 Route Level Ridership Estimate (2015 UMI Transit Average Weekday Ridership September through April)	Growth Factor (2015 / 2010 Ridership)
UMI-BURSLEYBAITS	13,484	11,528	0.85
UMI-COMMUTER	9,450	7,881	0.83
UMI-DIAGTODIAG	1,833	1,309	0.71
UMI-INTERCAMPUS	516	716	1.39
UMI-MITCHELLGLAZIER	1,547	1,999	1.29
UMI-NORTHCAMPUS	201	990	4.92
UMI-NORTHWOOD	4,961	5,707	1.15
UMI-NORTHWOODEXPRESS	702	986	1.40
UMI-OXFORD	1,021	834	0.82
UMI-OXFORDSHUTTLE	512	200	0.39
Total	34,227	32,149	0.94

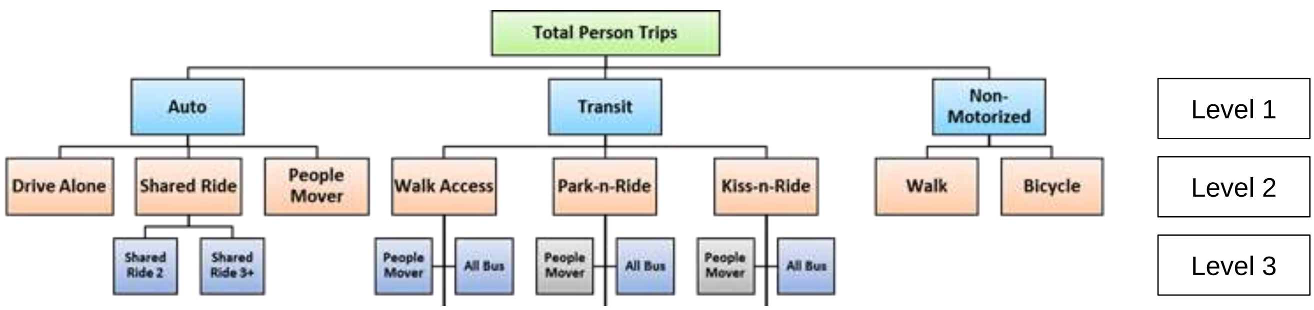
Source: CS analysis of 2010 transit on-board survey data and 2015 UMI data.

Appendix J. Final Mode Choice Model Calibration Constants

J.1 Mode and Sub-Mode Constants

There are three levels of the mode choice nesting structure where constants are applied (**Figure J.1**). This approach simplifies model calibration since travel for the main modes in Level 1 can be calibrated first, followed by Level 2 sub-modes, and finally by Level 3 sub-modes. Mode and sub-mode constants are cumulative. For example, a transit constant would apply to all Level 2 sub-modes and then Park-n-Ride and Kiss-n-Ride constants would be added. All constants are specified at Level 1 even though the mode choice model utilities are estimated from the "bottom-up" with the constants being applied to the appropriate modes and submodes at the lowest level of the nesting structure. The constants are divided by both nesting coefficient(s) prior to application at the lowest levels of the nesting structure: 0.7 for Level 1 to Level 2, and 0.5 for Level 2 to Level 3. **Table J.1** shows an example for the transit modes and sub-modes and their effective values at the lowest level of the nesting structure. **Table J.2** through **Table J.5** show the calibrated peak and off-peak mode and sub-mode constants by income group and by auto sufficiency level.

Figure J.1 Mode Choice Structure (for Model Calibration)



Source: E6B Model

Table J.1 Constant Calculation Example

	Level	Constant	Theta 1	Theta 2	Effective Value at Lowest Level
Transit	1	-0.9746	0.7	0.5	-2.7846
Park-n-Ride	2	-2.8760	n/a	0.5	-8.2171
Kiss-n-Ride	2	-0.4822	n/a	0.5	-1.3778
People Mover	3	-0.6133	n/a	n/a	-1.7523
Walk Access-People Mover in Path					-4.5369
Walk Access-All Bus					-2.7846
Park-n-Ride Access-People Mover in Path					-12.7541
Park-n-Ride Access-All Bus					-11.0017
Kiss-n-Ride Access-People Mover in Path					-5.9147
Kiss-n-Ride Access-All Bus					-4.1624

Source: CS

Table J.2 Peak Mode and Sub-Mode Specific Constants by Income Group[1]

Constant	Nest Level	Income	Home Based Work	Home Based Other	Home Based Shop	Home Based School	Home Based Univer-sity	Non-Home Based-Work	Non-Home Based-Other
Transit	1	Low	-0.9746	-2.5734	-2.4197	-1.8946	-1.1539	-4.5031	-3.7044
	1	Middle-Low	0.2167	-3.2643	-2.7721				
	1	Middle High & High	0.7459	-4.4072	-4.0433				
Non-Motorized	1	Low	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	1	Middle-Low	0.0000	0.0000	0.0000				
	1	Middle High & High	0.0000	0.0000	0.0000				
Shared Ride	2	Low	0.0000	0.1326	-0.4419	1.4582	-1.3562	-1.4688	0.5308
	2	Middle-Low	0.0000	0.0623	-0.6418				
	2	Middle High & High	0.0000	0.0623	-0.6418				
Park-n-Ride	2	Low	-2.8760	-2.0130	2.9469	-2.6621	-0.9439	0.0605	-0.9039
	2	Middle-Low	-2.0527	-0.8778	-0.0442				
	2	Middle High & High	-2.1266	-1.2192	3.1175				
Kiss-n-Ride	2	Low	-0.4822	-1.2268	-1.5470	-0.4951	-1.5758	-1.2257	-1.5139
	2	Middle-Low	-1.1177	-1.4356	-2.1768				
	2	Middle High & High	-1.3644	-0.7533	-1.9188				
Bicycle	2	Low	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	2	Middle-Low	0.0000	0.0000	0.0000				
	2	Middle High & High	0.0000	0.0000	0.0000				
Shared Ride 3+	3	Low	0.0000	0.0341	-0.3935	0.3725	-0.2174	-0.4695	0.0404
	3	Middle-Low	0.0000	-0.0469	-0.3388				
	3	Middle High & High	0.0000	-0.0469	-0.3388				
Drive to People Mover	2	Low	-6.4513	-3.4434	-2.9553	-4.6570	-4.6570	-4.5013	-3.8213
	2	Middle-Low	-4.0580	-3.1001	-2.4966				
	2	Middle High & High	-4.9340	-4.2009	-4.3069				
People Mover (in Transit Path)	3	Low	-0.6133	-0.1237	-0.3967	-0.9082	4.0546	0.5393	0.4542
	3	Middle-Low	-0.0186	2.2415	0.7093				
	3	Middle High & High	-0.6997	0.0000	0.0000				

Source: CS

[1] All constants are specified at Level 1 of the nesting structure.

Table J.3 Peak Mode and Sub-Mode Specific Constants by Vehicle Sufficiency[1]

Constant	Nest Level	Income	Home Based Work	Home Based Other	Home Based Shop	Home Based School	Home Based Univer-sity	Non-Home Based-Work	Non-Home Based-Other
Transit	1	0 Autos	5.7492	1.5646	1.9560	-0.8790	-1.3898	-0.2164	-0.4980
	1	Autos>0 & < Workers	-1.9511	-1.1586	-1.0093				
	1	Autos ≥ Workers	-3.2266	-2.0767	-3.1850				
Non-Motorized	1	0 Autos	9.8660	2.8201	3.4163	1.2730	1.8762	-0.8866	-0.4681
	1	Autos>0 & < Workers	0.5706	0.5110	-0.1043				
	1	Autos ≥ Workers	-0.7479	-0.5750	-1.1929				
Shared Ride	2	0 Autos	0.6583	0.8162	1.9286	0.0686	0.5185	0.6662	-0.1657
	2	Autos>0 & < Workers	-0.5046	0.2818	0.9205				
	2	Autos ≥ Workers	-0.9924	0.2071	0.3640				
Park-n-Ride	2	0 Autos	-1.8229	-2.1612	-6.4988	-1.2061	-1.5206	-1.1702	-1.5017
	2	Autos>0 & < Workers	-0.0081	-0.2443	-5.5740				
	2	Autos ≥ Workers	1.3747	-0.2940	-5.4318				
Kiss-n-Ride	2	0 Autos	-1.4457	-0.2724	-0.1197	0.1004	-0.4998	-0.3430	-0.5288
	2	Autos>0 & < Workers	-0.1250	0.7088	0.1101				
	2	Autos ≥ Workers	-0.3194	-0.1979	1.1593				
Bicycle	2	0 Autos	-5.7975	-3.4365	-3.5509	-2.4713	-3.5384	-2.9446	-2.6333
	2	Autos>0 & < Workers	-2.2265	-2.2259	-2.4855				
	2	Autos ≥ Workers	-2.4811	-2.2243	-2.4062				
Shared Ride 3+	3	0 Autos	-0.8019	-0.0807	-0.2695	-0.2719	-0.2068	0.0865	-0.0986
	3	Autos>0 & < Workers	-0.4178	0.1074	0.1844				
	3	Autos ≥ Workers	-0.5853	-0.0066	0.0993				
Drive to People Mover	2	0 Autos	0.0000	0.0000	0.0000	0.0000	0.0000	0.1557	0.8357
	2	Autos>0 & < Workers	0.0000	0.0000	0.0000				
	2	Autos ≥ Workers	1.3296	1.6879	0.0000				
People Mover (in Transit Path)	3	0 Autos	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	3	Autos>0 & < Workers	0.0000	0.0000	0.0000				
	3	Autos ≥ Workers	0.0000	0.0000	0.0000				

Source: CS

[1] All constants are specified at Level 1 of the nesting structure.

Table J.4 Off-Peak Mode and Sub-Mode Specific Constants by Income Group[1]

Constant	Nest Level	Income	Home Based Work	Home Based Other	Home Based Shop	Home Based School	Home Based Univer-sity	Non-Home Based-Work	Non-Home Based-Other
Transit	1	Low	-0.1772	-2.5351	-2.5631	-1.5714	-1.1752	-4.3491	-3.8768
	1	Middle-Low	0.5058	-2.9686	-2.5662				
	1	Middle High & High	1.3063	-4.0764	-4.1030				
Non-Motorized	1	Low	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	1	Middle-Low	0.0000	0.0000	0.0000				
	1	Middle High & High	0.0000	0.0000	0.0000				
Shared Ride	2	Low	0.0000	0.1326	-0.4419	1.4582	-1.3562	-1.4688	0.5308
	2	Middle-Low	0.0000	0.0623	-0.6418				
	2	Middle High & High	0.0000	0.0623	-0.6418				
Park-n-Ride	2	Low	-2.9016	-1.3461	0.8834	-1.6606	-0.9636	-0.2047	-0.9060
	2	Middle-Low	-2.7302	-1.6405	-0.0442				
	2	Middle High & High	-3.0317	-2.3736	-0.0442				
Kiss-n-Ride	2	Low	-0.7326	-1.2017	-0.8477	-0.5815	-1.5211	-1.2877	-1.6300
	2	Middle-Low	-0.9990	-1.7603	-1.2952				
	2	Middle High & High	-1.5557	-1.6179	-1.0875				
Bicycle	2	Low	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	2	Middle-Low	0.0000	0.0000	0.0000				
	2	Middle High & High	0.0000	0.0000	0.0000				
Shared Ride 3+	3	Low	0.0000	0.0341	-0.3935	0.3725	-0.2174	-0.4695	0.0404
	3	Middle-Low	0.0000	-0.0469	-0.3388				
	3	Middle High & High	0.0000	-0.0469	-0.3388				
Drive to People Mover	2	Low	-1.0422	-2.9041	-2.7725	-0.5007	-1.4965	-1.9895	-2.0173
	2	Middle-Low	-0.4800	-2.0310	-1.8008				
	2	Middle High & High	-0.6430	-2.9253	-3.4233				
People Mover (in Transit Path)	3	Low	-1.2855	0.1050	-0.9519	-1.4579	2.9441	0.3068	0.8008
	3	Middle-Low	-0.4163	1.7721	0.0436				
	3	Middle High & High	0.6969	2.8598	0.0000				

Source: CS

[1] All constants are specified at Level 1 of the nesting structure.

Table J.5 Off-Peak Mode and Sub-Mode Specific Constants by Vehicle Sufficiency[1]

Constant	Nest Level	Income	Home Based Work	Home Based Other	Home Based Shop	Home Based School	Home Based Univer-sity	Non-Home Based-Work	Non-Home Based-Other
Transit	1	0 Autos	5.4475	1.6969	1.9238	-0.5558	-1.4111	-0.0624	-0.6704
	1	Autos>0 & < Workers	-1.8680	-1.2183	-1.6065				
	1	Autos ≥ Workers	-3.5796	-2.2349	-2.7811				
Non-Motorized	1	0 Autos	6.9508	2.4907	3.2407	0.7053	2.8419	0.2678	-0.3582
	1	Autos>0 & < Workers	1.0832	-0.5248	-0.1674				
	1	Autos ≥ Workers	-0.3518	-1.1538	-1.4110				
Shared Ride	2	0 Autos	0.6804	0.7085	1.8498	-0.7942	0.5598	0.7921	-0.4769
	2	Autos>0 & < Workers	-0.3873	0.1856	0.3993				
	2	Autos ≥ Workers	-1.0768	-0.1791	0.2422				
Park-n-Ride	2	0 Autos	-2.0370	-1.9562	-3.9340	-0.2046	-1.5403	-1.4354	-1.5038
	2	Autos>0 & < Workers	0.1956	-1.3310	-3.6300				
	2	Autos ≥ Workers	1.2366	-0.6778	-5.4889				
Kiss-n-Ride	2	0 Autos	-1.1669	-0.4152	-0.1797	0.0140	-0.4451	-0.4050	-0.6449
	2	Autos>0 & < Workers	-0.0940	0.1066	-0.5253				
	2	Autos ≥ Workers	-0.2919	0.0871	-0.4318				
Bicycle	2	0 Autos	-3.2977	-3.2340	-3.1938	-2.9802	-4.2438	-3.8632	-2.9155
	2	Autos>0 & < Workers	-2.0308	-1.4162	-2.5611				
	2	Autos ≥ Workers	-1.9790	-2.0587	-2.4599				
Shared Ride 3+	3	0 Autos	-0.8179	-0.3938	-0.0565	-0.4997	-0.5699	0.1566	-0.4566
	3	Autos>0 & < Workers	-0.3825	0.0437	0.0256				
	3	Autos ≥ Workers	-0.7075	-0.2475	-0.1607				
Drive to People Mover	2	0 Autos	4.1000	1.9561	0.0000	0.0000	-0.9958	-1.4888	-1.5166
	2	Autos>0 & < Workers	-0.5711	1.3296	0.0000				
	2	Autos ≥ Workers	-1.5762	0.2405	0.0000				
People Mover (in Transit Path)	3	0 Autos	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	3	Autos>0 & < Workers	0.0000	0.0000	0.0000				
	3	Autos ≥ Workers	0.0000	0.0000	0.0000				

Source: CS

[1] All constants are specified at Level 1 of the nesting structure.

The geographic-based constants shown in **Table J.6** were developed in addition to the mode and sub-mode specific constants. The geographic-based constants were used to improve transit assignment results. They are applied at the top level of the nesting structure and are divided by the nesting coefficients in the model application code. The geographic constants are applied to the transit modes whenever the value for the parameter covered by the constant is true for an interchange.

Table J.6 Geographic-Based Transit Constants[1]

Parameter	Home Based Work	Home Based Other	Home Based Shop	Home Based School	Home Based University	Non-Home Based-Work	Non-Home Based-Other
CBD Attraction	1.44	0.98	1.44	1.78	2.13	1.44	1.32
Detroit Attraction	0.43	0.32	0.43	0.52	0.60	0.43	0.40
Detroit Production	0.86	0.63	0.86	1.04	1.21	0.86	0.81
University of Michigan Attraction	1.25	1.25	1.25	1.25	1.25	1.25	1.25
University of Michigan Production	1.25	1.25	1.25	1.25	1.25	1.25	1.25
KCURB	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Source: CS

[1] All constants are specified at Level 1 of the nesting structure.

Finally, area type specific constants by county shown in **Table J.7** were developed to improve transit assignment results. They are applied at the top level of the nesting structure and are divided by the nesting coefficients in the model application code. The geographic constants are applied to the transit modes whenever the production zone and area type are of the type specified.

Table J.7 Area Type/County Transit Constants[1]

County	Area Type 1	Area Type 2	Area Type 3	Area Type 4	Area Type 5
Detroit	0.0	0.0	0.0	1.0	0.0
Wayne	0.0	0.0	-1.0	0.0	0.0
Oakland	0.0	0.0	-1.0	0.0	0.0
Macomb	0.0	0.0	-1.0	0.0	0.0
Washtenaw	0.0	0.0	1.5	1.0	0.0
Monroe	0.0	0.0	1.5	1.0	0.0
St Clair	0.0	0.0	1.5	1.0	0.0
Livingston	0.0	0.0	1.5	1.0	0.0

Source: CS

[1] All constants are specified at Level 1 of the nesting structure.

Appendix K. Roadway Link Lookup Tables

Table K.1 Freeflow Speed Lookup Table

Facility Type	All	Urban Business	Urban Fringe	Urban	Suburban	Rural
Interstate Fwy		60	65	65	70	70
Interstate Fwy_FCD		55	60	60	65	65
Interstate Fwy_RFF		50	55	55	65	70
Interstate Fwy_RFS		40	45	45	45	45
Interstate Fwy_ROF		35	35	35	40	40
Interstate Fwy_RON		40	40	40	45	45
Other Fwy		60	65	65	70	70
Other Fwy_FCD		55	60	60	65	65
Other Fwy_RFF		50	55	55	65	70
Other Fwy_RFS		40	45	45	45	45
Other Fwy_ROF		35	35	35	40	40
Other Fwy_RON		40	40	40	45	45
Other Principal		30	30	35	40	50
Other Principal_DIV		35	35	40	45	55
Other Principal_DV2		30	30	35	40	50
Other Principal_RSF		25	25	25	30	40
Minor Arterial		28	28	33	38	40
Minor Arterial_DIV		33	33	38	43	45
Minor Arterial_DV2		28	28	33	38	40
Minor Arterial_GRV		13	13	13	18	23
Minor Arterial_RSF		23	23	23	28	33
Major Collector		20	20	25	27	30
Major Collector_DIV		25	25	30	32	35
Major Collector_DV2		20	20	25	27	30
Major Collector_GRV		10	10	10	15	20
Major Collector_RSF		15	15	20	20	25
Minor Collector		20	20	25	27	30
Minor Collector_DIV		25	25	30	32	35
Minor Collector_DV2		20	20	25	27	30
Minor Collector_GRV		15	15	15	20	25
Minor Collector_RSF		15	15	20	25	30
Local Road		20	20	20	25	25
Local Road_DIV		25	25	25	30	30
Local Road_DV2		20	20	20	25	25
Local Road_GRV		15	15	15	20	20
Local Road_RSF		15	15	15	20	20
Uncertified Road		20	20	20	25	35
Centroid Connector		10	10	10	15	15
DPM	12					
AADD	38					
WALLY	44					
DTOGS	26					
External Station	15					
Walk Only Rd	2					

Source: SEMCOG E7 Model.

Table K.2 Hourly Capacity Lookup Table

Facility Type	All	Urban Business	Urban Fringe	Urban	Suburban	Rural
Interstate Fwy		2,200	2,200	2,200	2,200	2,200
Interstate Fwy_FCD		1,900	1,900	1,900	2,100	2,100
Interstate Fwy_RFF		1,900	1,900	1,900	2,100	2,100
Interstate Fwy_RFS		1,400	1,400	1,475	1,500	1,500
Interstate Fwy_ROF		1,400	1,400	1,475	1,500	1,500
Interstate Fwy_RON		1,400	1,400	1,475	1,500	1,500
Other Fwy		2,200	2,200	2,200	2,200	2,200
Other Fwy_FCD		1,900	1,900	1,900	2,100	2,100
Other Fwy_RFF		1,900	1,900	1,900	2,100	2,100
Other Fwy_RFS		1,400	1,400	1,475	1,500	1,500
Other Fwy_ROF		1,400	1,400	1,475	1,500	1,500
Other Fwy_RON		1,400	1,400	1,475	1,500	1,500
Other Principal		800	800	1,100	1,100	900
Other Principal_DIV		800	800	1,000	1,100	1,200
Other Principal_DV2		800	800	1,100	1,100	900
Other Principal_RSF		850	850	1,000	1,000	1,100
Minor Arterial		700	700	750	900	900
Minor Arterial_DIV		700	700	850	1,000	1,000
Minor Arterial_DV2		700	700	750	900	900
Minor Arterial_GRV		500	500	550	600	650
Minor Arterial_RSF		600	600	750	800	800
Major Collector		600	600	700	750	750
Major Collector_DIV		700	700	800	850	850
Major Collector_DV2		600	600	700	750	750
Major Collector_GRV		500	500	550	600	650
Major Collector_RSF		500	500	600	650	650
Minor Collector		500	500	600	650	650
Minor Collector_DIV		550	550	650	700	700
Minor Collector_DV2		500	500	600	650	650
Minor Collector_GRV		500	500	550	600	650
Minor Collector_RSF		400	400	500	550	550
Local Road		500	500	550	600	600
Local Road_DIV		550	550	600	650	650
Local Road_DV2		500	500	550	600	600
Local Road_GRV		500	500	550	600	650
Local Road_RSF		400	400	450	500	500
Uncertified Road		500	500	550	600	600
Centroid Connector		10,000	10,000	10,000	10,000	10,000
DPM	10,000					
AADD	10,000					
WALLY	10,000					
DTOGS	10,000					
External Station	10,000					
Walk Only Rd	10,000					

Source: SEMCOG E7 Model.

Table K.3 Alpha Lookup Table

Facility Type	All	Urban Business	Urban Fringe	Urban	Suburban	Rural
Interstate Fwy		0.32	0.32	0.58	0.8	1.02
Interstate Fwy_FCD		0.32	0.32	0.58	0.8	0.8
Interstate Fwy_RFF		0.32	0.32	0.58	0.8	1.02
Interstate Fwy_RFS		0.22	0.22	0.22	0.22	0.22
Interstate Fwy_ROF		3.07	3.07	2.24	2.24	2.24
Interstate Fwy_RON		1.09	1.09	1.09	1.09	1.09
Other Fwy		0.32	0.32	0.58	0.8	1.02
Other Fwy_FCD		0.32	0.32	0.58	0.8	0.8
Other Fwy_RFF		0.32	0.32	0.58	0.8	1.02
Other Fwy_RFS		0.22	0.22	0.22	0.22	0.22
Other Fwy_ROF		3.07	3.07	2.24	2.24	2.24
Other Fwy_RON		1.09	1.09	1.09	1.09	1.09
Other Principal		6	6	5	3.7	1.7
Other Principal_DIV		6	6	5	3.7	1.7
Other Principal_DV2		6	6	5	3.7	1.7
Other Principal_RSF		5	5	5	3.7	1.7
Minor Arterial		8	8	6	4.5	3
Minor Arterial_DIV		8	8	6	4.5	3
Minor Arterial_DV2		8	8	6	4.5	3
Minor Arterial_GRV		8.5	8.5	7	6.55	5.55
Minor Arterial_RSF		8	8	6	4.5	1.7
Major Collector		8.5	8.5	8	5.8	3.7
Major Collector_DIV		8.5	8.5	8	5.8	3.7
Major Collector_DV2		8.5	8.5	8	5.8	3.7
Major Collector_GRV		8.5	8.5	7	6.55	5.55
Major Collector_RSF		8.5	8.5	8	5.8	3.7
Minor Collector		8.5	8.5	7	6.55	5.8
Minor Collector_DIV		8.5	8.5	7	6.55	5.8
Minor Collector_DV2		8.5	8.5	7	6.55	5.8
Minor Collector_GRV		8.5	8.5	7	6.55	5.55
Minor Collector_RSF		8.5	8.5	7	6.55	5.8
Local Road		8.5	8.5	7	6.55	5.8
Local Road_DIV		8.5	8.5	7	6.55	5.8
Local Road_DV2		8.5	8.5	7	6.55	5.8
Local Road_GRV		8.5	8.5	7	6.55	5.55
Local Road_RSF		8.5	8.5	7	6.55	5.8
Uncertified Road		8.5	8.5	7	6.55	5.8
Centroid Connector		0.15	0.15	0.15	0.15	0.15
DPM	0.15					
AADD	0.15					
WALLY	0.15					
DTOGS	0.15					
External Station	0.15					
Walk Only Rd	0.15					

Source: SEMCOG E7 Model.

Table K.4 Beta Lookup Table

Facility Type	All	Urban Business	Urban Fringe	Urban	Suburban	Rural
Interstate Fwy		8.5	8.5	7	7.5	7
Interstate Fwy_FCD		8.5	8.5	7	7.5	7
Interstate Fwy_RFF		8.5	8.5	7	7.5	7
Interstate Fwy_RFS		6	6	6	6	6
Interstate Fwy_ROF		5	5	5	5	5
Interstate Fwy_RON		4	4	4	4	4
Other Fwy		8.5	8.5	7	7.5	7
Other Fwy_FCD		8.5	8.5	7	7.5	7
Other Fwy_RFF		8.5	8.5	7	7.5	7
Other Fwy_RFS		6	6	6	6	6
Other Fwy_ROF		5	5	5	5	5
Other Fwy_RON		4	4	4	4	4
Other Principal		5	5	5	5	4
Other Principal_DIV		5	5	5	5	4
Other Principal_DV2		5	5	5	5	4
Other Principal_RSF		5	5	5	5	4
Minor Arterial		4.5	4.5	4.5	4.5	4
Minor Arterial_DIV		4.5	4.5	4.5	4.5	4
Minor Arterial_DV2		4.5	4.5	4.5	4.5	4
Minor Arterial_GRV		4.5	4.5	4.5	4.5	5
Minor Arterial_RSF		4.5	4.5	4.5	4.5	4
Major Collector		4.5	4.5	4.5	4.5	5
Major Collector_DIV		4.5	4.5	4.5	4.5	5
Major Collector_DV2		4.5	4.5	4.5	4.5	5
Major Collector_GRV		4.5	4.5	4.5	4.5	5
Major Collector_RSF		4.5	4.5	4.5	4.5	5
Minor Collector		4.5	4.5	4.5	4.5	6
Minor Collector_DIV		4.5	4.5	4.5	4.5	6
Minor Collector_DV2		4.5	4.5	4.5	4.5	6
Minor Collector_GRV		4.5	4.5	4.5	4.5	5
Minor Collector_RSF		4.5	4.5	4.5	4.5	6
Local Road		4.5	4.5	4.5	4.5	6
Local Road_DIV		4.5	4.5	4.5	4.5	6
Local Road_DV2		4.5	4.5	4.5	4.5	6
Local Road_GRV		4.5	4.5	4.5	4.5	5
Local Road_RSF		4.5	4.5	4.5	4.5	6
Uncertified Road		4.5	4.5	4.5	4.5	6
Centroid Connector		4	4	4	4	4
DPM	4					
AADD	4					
WALLY	4					
DTOGS	4					
External Station	4					
Walk Only Rd	4					

Source: SEMCOG E7 Model.

Appendix L. Transit Model Update Using the 2019 OBTS

SEMCOG conducted an on-board transit survey (OBTS) which was completed in October 2020. Cambridge Systematics (CS) and Caliper Co were retained as contractors to improve SEMCOG E7 KC20 travel model. The following updates have been made by CS and will be described in this appendix.

1. Understanding the SE data: ISE19 updated social economic data review,
2. Trip generation assessment,
3. Review on Transit trips: trip length, ridership with KC20 & OBTS,
4. Actions to improve KC20 model: mode choice recalibration, transfer rate, SMART & UMI ridership adjustment - KG20A,
5. Additional effort to build KG20B with UMI & SMART ridership improvement,
6. E8 Plus Model LA20 Results and Discussion.

The project started in early 2021 and completed in early 2023. Due to slightly different versions of SE data and transit network coding, minor inconsistencies are shown in the tables of this report. However, the conclusions derived from the project work are correct. Table L.1 provides a brief description of the models discussed in this report.

Table L.1 Different Models Discussed in the Report

Model Name	KC20	KG20A	KG20B	LA20
Model Year	2020			
Social Economic	2010 Census, updated to 2015, & projected to 2020	2020 Census, initial version, ISE19	2020 Census, interim version, ISE19	2020 Census, Final
Highway network	2020			2020 w/ minor adjustment
Transit Routes	Assumed 2020 routes based on 2015	2019 OBTS observed		
Mode Choice	Calibrated in 2015 w/ 2010 OBTS	calibrated to 2019 OBTS target	Same as KG20A, added SMART & UMI adjustment	
External Travel	Projected using 2015 base			Updated using 2018/19 counts
International Crossing	Based on 2015 projection			2019 Observed counts
Airport Travel	Based on 2015 projection			2019 observation
Commercial Vehicle (CV) Model	1996 surveyed CV travel pattern, Trip based.			2017 surveyed CV travel pattern, Tour-based

L.1 Understanding New 2020 SE Data

The socioeconomic (SE) data utilized in SEMCOG's 2020 E7 KC20 model, developed in 2015, was based on the 2010 Census. This dataset contained household numbers, distribution of household sizes, auto ownership and its distribution, all derived from SEMCOG developed forecasts. A new 2019/2020 socio-economic dataset, ISE19, based on the 2020 Census and SEMCOG's surveyed local information, became available after the transit model update project commenced. Multiple drafts of the ISE19 data were produced for CS to review. Finally, the July 2023 version served for the E8 plus 2020 base year model (LA20) in this report.

The early version of ISE19 was derived from the synthetic population generated for both trip-based and activity-based models. The synthetic population outputs comprised a household file, detailing household demographics such as income, number of persons, number of workers, and number of children, and a person file, detailing individual demographics including age, gender, and worker/student status. The household ID was included in the person file to enable correlation with the household file. Additionally, a separate model component estimated the number of vehicles owned by each household based on demographic information and other variables such as transportation accessibility. This produced data, added to each household, served as inputs for the trip production models.

Inconsistencies were also identified in household workers by comparing county totals to the numbers from census. Additionally, SEMCOG observed significant differences in both transit trip ends and origin-destination pairs between the OBTS data and KC20 estimated numbers. Utilizing updated household worker data for the E7 transit model update was recommended. Table L.2 illustrates that with the newer ISE19 initial numbers, approximately 11% more workers are observed compared to the estimates in E7 KC20. The percentage increases at the county level vary.

Table L.2 Year 2020 HH Workers: KG20A vs. KC20

County	KC20	KG20A	Difference	% diff
Detroit	195,425	244,160	48,735	24.9%
Wayne	468,577	514,499	45,922	9.8%
Oakland	576,676	642,274	65,598	11.4%
Macomb	382,818	425,301	42,483	11.1%
Washtenaw	171,082	185,255	14,173	8.3%
Monroe	63,969	68,386	4,417	6.9%
St Clair	66,504	71,476	4,972	7.5%
Livingston	93,446	96,673	3,227	3.5%
Total	2,018,497	2,248,024	229,527	11.4%

For reference, Table L.3 provides an overview comparing the SE data in KG20A (with ISE19) and the original KC20 datasets. While the total population and number of households for the region in the revised ISE19 data differ by less than 1% from the KC20 data, the totals for most individual TAZs exhibit disparities. Many TAZs display significant increases in population and households, while others demonstrate substantial decreases. Presumably, these changes reflect shifts in population within the region and the updated data sources.

Table L.3 SE Data Sets Difference Overview: KG20A vs. KC20

	KC20	KG20A	Difference	% Diff
Households	1,905,823	1,889,267	-16,556	-0.9%
HHPop	4,686,367	4,691,917	5,550	0.1%
HHWorkers	2,018,497	2,248,024	229,527	11.4%
EmpPrinc	2,865,770	2,865,770	0	0.0%
Univ_Enrollment	248,962	248,962	0	0.0%
K12Enroll	628,841	647,104	18,263	2.9%

Employment by type and school enrollment data are separately produced at the TAZ level. The base year employment data and enrollment data in KG20 have not been revised from the KC20 model. However, in the LA20 model, as depicted in Table L.4 below, the employment numbers were updated. Significant increases are observed in manufacturing, transportation & warehousing, financial services, and management of CompEnt (companies and enterprises) segments, while administrative support is the only segment that experiences a drop of about 20,000. These data items, alongside household totals, serve as inputs to trip attraction models.

Table L.4 Changes in Employment by Industry: LA20 vs. KC20

	KC20	LA20	Difference	% Diff
Natural_Resource_and_Mining	13,586	12,252	-1,334	-9.8%
Manufacturing	381,430	411,964	30,534	8.0%
Wholesale_Trade	103,073	101,294	-1,779	-1.7%
Retail_Trade	275,922	271,928	-3,994	-1.4%
Transportation & Warehousing	94,283	137,605	43,322	45.9%
Utilities	8,143	8,945	802	9.8%
Information	43,623	42,353	-1,270	-2.9%
Financial_Service	258,981	297,533	38,552	14.9%
Professional_Science_Tec	303,472	298,488	-4,984	-1.6%
Management_of_CompEnt	44,391	56,908	12,517	28.2%
Administrative_Support_and_WM	214,523	193,512	-21,011	-9.8%
Education_Services	201,549	196,508	-5,041	-2.5%
Health_Care_and_SocialSer	403,908	395,637	-8,271	-2.0%
Leisure_and_Hospitality	259,527	269,180	9,653	3.7%
Other_Services	167,058	170,609	3,551	2.1%
Public_Administration	92,301	97,053	4,752	5.1%
Total	2,865,770	2,961,769	95,999	3.3%

In summary, the overall revised household and population numbers in KG20A appear reasonable. Total regional population and households are approximately one percent higher compared to KC20. Distributions of household size, number of children, and autos per household closely resemble those in KC20. As indicated in Table L.3, the most notable difference lies in the total number of workers, which is approximately 11% higher than KC20. Within the two-worker household category, shown in Table L.5, households with medium-low, medium-high, and high incomes experienced the most significant increases. For one-worker households, low and medium-low income households saw increases, while total zero-worker households experienced a substantial drop of 28%. This difference aligns with CS communications with SEMCOG and is thus deemed reliable.

Table L.5 Changes in HH with 0-3+ workers and Income levels, KG20A vs. KC20

KC20	Low Income	Med-Low Income	Med-High Income	High Income	Total
0 Worker	283,901	174,718	89,676	46,602	594,897
1 Worker	162,917	214,934	210,136	149,341	737,328
2 Worker	27,236	75,255	145,622	211,370	459,483
3+ Worker	2,978	11,501	31,508	68,128	114,115
Total	477,032	476,408	476,942	475,441	1,905,823
KG20A	**Low Income**	**Med-Low Income**	**Med-High Income**	**High Income**	**Total**
0 Worker	246,600	105,349	46,404	27,588	425,941
1 Worker	194,055	243,451	213,727	131,976	783,209
2 Worker	37,080	106,322	191,706	256,492	591,600
3+ Worker	2,439	8,342	23,610	54,126	88,517
Total	480,174	463,464	475,447	470,182	1,889,267
Difference	**Low Income**	**Med-Low Income**	**Med-High Income**	**High Income**	**Total**
0 Worker	-37,301	-69,369	-43,272	-19,014	**-168,956**
1 Worker	31,138	28,517	3,591	-17,365	45,881
2 Worker	9,844	31,067	46,084	45,122	**132,117**
3+ Worker	-539	-3,159	-7,898	-14,002	-25,598
Total	3,142	-12,944	-1,495	-5,259	-16,556

L.2 Trip Generation Assessment

CS has executed the entire KG20A model, encompassing trip generation, using the revised socioeconomic data (ISE19). The trip generation outcomes indicated that the total number of trips for each purpose in the new model run closely align with the numbers derived from the original KC20 input data (differing by 1%-2%), except for home-based work and non-home-based work trips. These two purposes exhibited an increase of 556,000 trips (12%). This outcome was anticipated as it concurs with the rise in the number of workers in the person and household data. The overall increase in the total number of trips resulting from the increases in home-based work and non-home-based work trips is approximately 3%. The internal trip summary is presented in Table L.6.

The results of the complete model (KG20) run with ISE19 showed a slight increase in travel compared to KC20. Overall, KG20A VMT increased by 3% to 131.3 million from KC20's 127.7 million. This increase is logical considering the increase in total trips. Other travel components, apart from personal travel by residents of the region, including external and through trips, truck trips, and airport trips, remained unchanged from KC20.

Table L.6 Internal Person Trips, KG20A vs. KC20

Purpose	KC20	KG20A	Difference	% Diff
HBW	2,688,167	3,011,882	323,715	12.0%
HBO	7,600,237	7,603,539	3,302	0.0%
HBSH	1,927,893	1,926,231	-1,662	-0.1%
HBSC	1,127,732	1,148,338	20,606	1.8%
HBUniv	451,078	451,078	0	0.0%
NHBW	1,944,501	2,178,421	233,920	12.0%
NHBO	4,388,262	4,385,153	-3,109	-0.1%
Total Internal	20,127,870	20,704,642	576,772	2.9%

L.3 Review Transit Trips

Transit Ridership

In the 2019 SEMCOG OBTS dataset, the estimated unlinked trips are 170K, corresponding to 138K linked trips, whereas KC20 produced 186K unlinked trips or 140K linked trips. Table L.7 provides an overview of both sets of results. This yields a transfer rate of 0.23 for OBTS and 0.33 for KC20, representing an over 40% difference.

Table L.7 KC20 and OBTS Transit System Performance

Measures	OBTS	KC20	% Difference
Linked Trips	138,181	140,295	1.5%
Unlinked Trips	169,832	186,426	9.8%
Transfer Rate	0.229	0.329	43.6%
Avg Trip Length	6.81	5.43	-20.2%

When examining ridership by transit service provider, the disparities are diverse. The most notable overestimations in the KC20 model are observed in AAATA, Q-Line, and SMART service areas. However, the UMI area exhibits a 22% deficit. Table L.8 illustrates the breakdown of boardings by service provider.

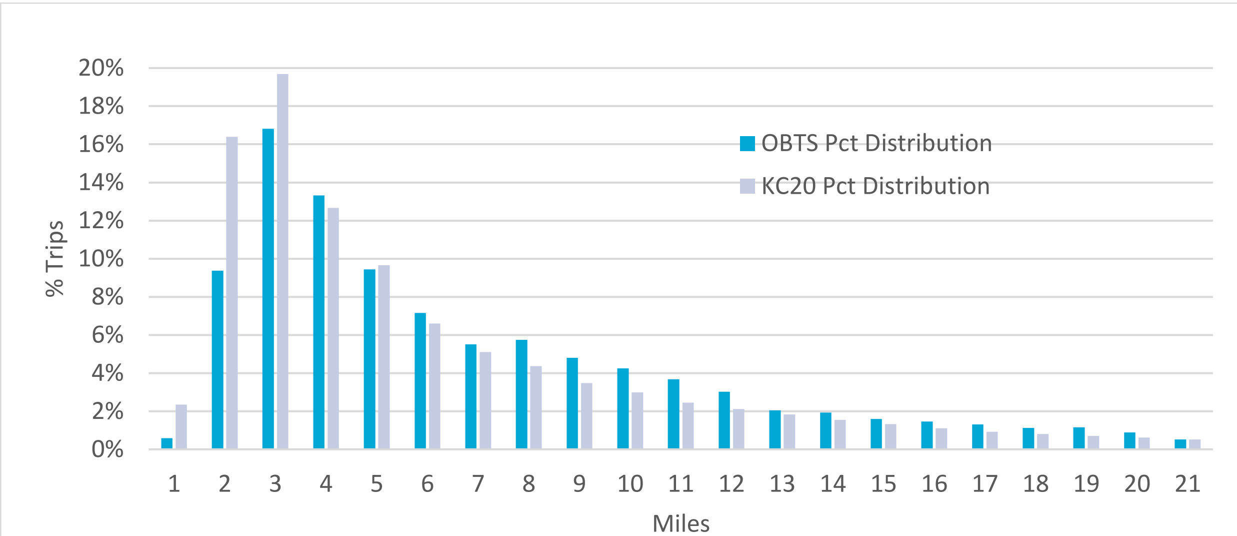
Table L.8 OBTS and KC20 Transit ridership (Unlinked Trips)

Operator	KC20	OBTS	Difference	% Diff
AAATA	32,314	24,985	7,329	29.3%
BWAT	2,211	3,038	(827)	-27.2%
DDOT	70,770	68,273	2,497	3.7%
DPM	7,126	4,598	2,528	55.0%
LETC	971	1,088	(117)	-10.8%
Q-Line	6,632	3,100	3,532	113.9%
SMART	35,167	24,640	10,527	42.7%
UMI	31,236	40,110	(8,874)	-22.1%
Total	186,426	169,832	16,594	9.8%

Transit Trip Length Distribution

The disparity between OBTS and the KC20 model extends beyond ridership to trip length distribution. As depicted in Table L.7, OBTS records an average linked transit trip length of 6.8 miles, whereas KC20 indicates only 5.4 miles, reflecting a 20% difference. Figure L.1 provides a visual representation of how these variances are distributed across travel distances. The travel distance was computed using the KG20 mode mid-day highway skim. The KC20 model generated significantly more short trips (less than 4 miles) than observed in reality, while underestimating longer trips exceeding 4 miles.

Figure L.1 Trip distribution pattern, KC20 vs, OBTS



L.4 Actions to Improve KC20 Model to KG20A

Calibration Target

CS's efforts to enhance the KC20 model primarily focused on recalibrating the mode choice model, taking into account market segmentation in the Ann Arbor and Detroit suburban areas, as well as transit riders' transfer rate. KG20A serves as a working version for this improvement. The process is iterative due to the nature of transit model performance and mode choice model calibration.

Table L.9 Summary of Mode Choice Calibration Target Files: 2015 vs. 2019

Modes	Target 2015	Target 2019
[Drv PMov]	1,800	942
[WLK Pmov]	3,335	3,177
[WLK Bus]	109,867	123,815
[DRV Bus]	8,916	9,107
[KNR Bus]	9,680	3,059
Total	133,598	140,100

Before commencing with the calibration process, CS created a mode choice calibration target file named "MC Targets2019.bin" for the KG20A model. In the KC20 model, this file is named "MC Targets2015.bin".

These target files define transit calibration targets by trip purpose, income groups, vehicle ownership groups, and peak/off-peak periods. Table L.9 and Table L.10 provide a summary of calibration files and modeled transit output from both KC20 and KG20A models.

Table L.10 KC20 and KG20A Mode Choice Model Output

Modes	KC20 Output	KG20A Output
[WLK PMov]	3,829	3,135
[Drv PMov]	2,572	922
KNR PMov	222	50
[WLK Bus]	108,210	122,052
[DRV Bus]	9,006	7,443
[KNR Bus]	9,443	3,011
WLK StCar	4,623	3,772
DRV StCar	2,155	1,607
KNR StCar	193	46
Total	133,282	142,038

Mode Choice Model Recalibration

In addition to recalibrating the mode choice model to the targets by market segmentation, developed from 2019 OBTS, CS also suggested to improve the E7 model by implementing a new mode choice utility term based on trip distance, which can be utilized to calibrate the transit trip-length distributions. CS anticipated that this variable would take the form of a piecewise linear function, likely increasing transit attractiveness with distance. CS would calibrate a function to enhance the alignment between the modeled results and OBTS data (See Appendix 3).

Table L.11 presents these additional parameters from the updated “MC Param.bin” file for the piecewise linear distance adjustment for transit. Basically, the distance skims are adjusted using these parameters prior to their being used in mode choice model application.

Table L.11 Additional Parameters Used for Mode Choice in KG20A Model

Parameters	HBW	HBSH	HBSC	HBU	HBO	NHBW	NHBO
PK_CDIST	0.01	0.34	0.31	-0.02	0.14	0.09	0.26
PK_CDIST_MIN	4	2	3	3	3	3	4
PK_CDIST_MAX	10	12	12	15	20	14	14
OP_CDIST	0.039	0.31	0.28	-0.12	0.195	0.072	0.14
OP_CDIST_MIN	2	4	3	2	4	3	4
OP_CDIST_MAX	20	15	12	10	20	14	20

For the model calibration process, CS utilized the 2019 target data, as summarized in Table L.9, along with 6 additional records from the mc_param file, as shown in Table L.11, to adjust mode choice constant values by trip purpose, travel mode, peak and off-peak periods, etc., through an automated iterative process.

Mode Choice Calibration Results

Compared to OBTS, the calibrated transit model, KG20A, outperformed KC20 in three key areas:

1. Transfer Rate,
2. Average Trip Length,
3. Ridership by Provider.

The calibrated KG20A model exhibited an overall improvement compared to KC20 estimates. Table L.12 provides an overview of transit system performance measures from the KG20A model versus OBTS.

Table L.12 KG20A Performance and OBTS

Measures	OBTS	KG20A	% Difference
Linked Trips	138,181	142,038	2.8%
Unlinked Trips	169,832	175,875	3.6%
Transfer Rate	0.229	0.238	3.8%
Avg Trip Length	6.81	6.27	-7.8%

To improve the transfer rate, SEMCOG and CS increased the transfer penalty setting in the transit assignment model from 3 minutes to 15 minutes. This discourages unnecessary transfers in the system and has proven to be effective. In the KG20A model, the transfer rate is now at 0.24, only 4% lower than OBTS, while KC20 differs by over 40%. Table L.13 below displays the sensitivity of transfer penalty and transfer rate tested by CS.

Table L.13 Transfer Rate and Transfer Penalty

Xfer Penalty	Xfer Rate
5 minutes	1.43
8 minutes	1.34
15 minutes	**1.24**
20 minutes	1.21

Regarding average trip length, the KG20A model produces an estimated average trip distance of 6.27 miles compared to KC20's 5.43 miles, representing an 8% difference from OBTS observations. Interestingly, with a five-minute transfer penalty, the modeled average transit trip length (6.7 miles) closely matches the OBTS observed value (6.8 miles). Once the transfer penalty is increased to 15 minutes, the average trip length becomes 6.3 miles. Table L.14 shows daily average trip lengths by trip purpose.

Additional analysis revealed that the KG20A model reduced the number of short trips, particularly those with distances less than 2 miles, thereby significantly improving overall trip length estimation. SEMCOG staff analyzed transit trip length distribution patterns estimated from both KG20A and KC20 models using PRMSE and R square measurements. The improvement is evident, as shown in Table L.15, with a 28% reduction in PRMSE and a 4% increase in R Square.

Table L.14 Observed Trip Length vs. KG20A Modeled

Daily	Trips		Avg Trip Length	
	OBTS	KG20A	OBTS	KG20A
HBW	53,790	59,401	9.11	7.95
HBSh	6,597	4,692	5.74	5.71
HBSc	4,432	2,865	6.23	6.05
HBU	24,308	22,332	4.00	3.75
HBO	26,707	27,687	6.78	6.59
NHBW	7,727	8,350	5.76	5.13
NHBO	14,620	15,791	4.29	3.63
Total All Day	138,181	141,117	6.81	6.26

Table L.15 PRMSE and R Square statistics, using OBTS as Reference

Statistics	KC20	KG20A	% Difference
PRMSE	54%	39%	-28.3%
R Square	0.880	0.913	3.8%

Regarding the OD distribution pattern, CS provided Figure L.2 and Figure L.3 comparing KG20A modeled origins and destinations with those from the expanded OBTS at the 250-district level. The overall fit between the two is strong, with R^2 values exceeding 0.9 for both origins and destinations. There are a few outliers, notably district 217, where both the origins and destinations from the survey substantially exceed those from the model. District 217 covers the northern half of the UMI campus and was improved through adjustments to the UMI district and Bursley Baits route, as described below.

Figure L.2 Comparison of Modeled and Survey Origins

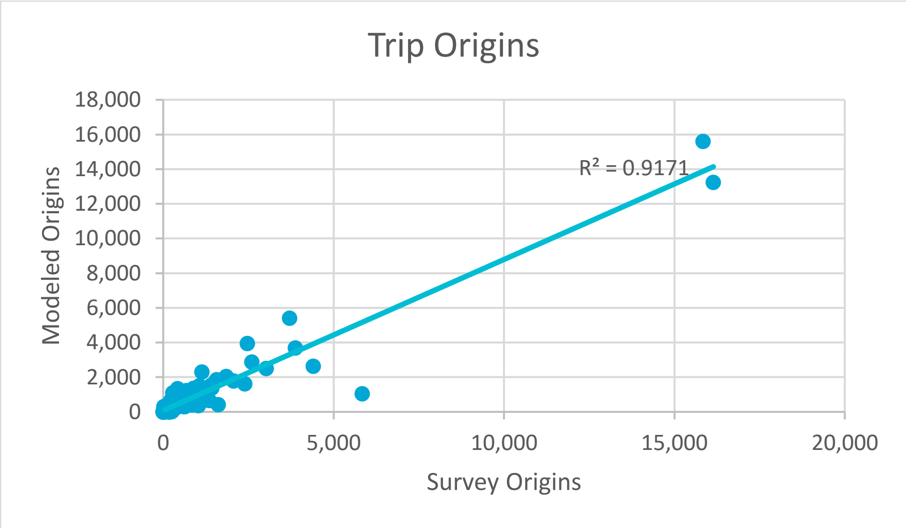
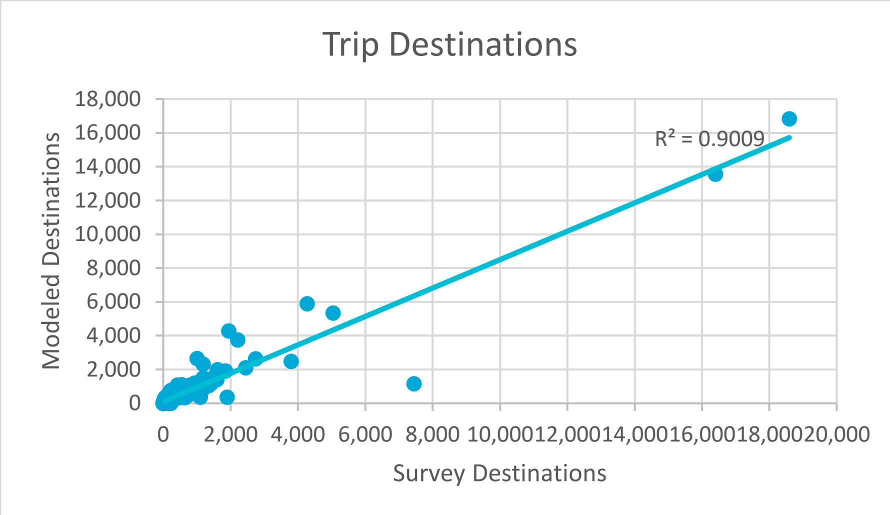


Figure L.3 Comparison of Modeled and Survey Destinations



Upon closer examination of ridership by service providers, the KG20A model output closely matches the observed ridership from OBTS, except for SMART and UMI service areas. See Table L.16 from CS below.

Table L.16 Transit Boardings & Transfer Rates by Provider, KG20A vs. OBTS

Operator	KG20A Modeled		OBTS Observed	
	Boardings	Transfer Rate	Boardings	Transfer Rate
AATA	25,696	1.18	24,491	1.19
BWAT	2,032	1.09	2,187	1.44
DDOT	69,986	1.31	71,430	1.34
DPM	4,303	1.02	4,413	1.09
LETC	925	1.04	1,082	1.44
M-1	5,221	1.16	3,305	1.05
SMART	39,899	1.40	29,123	1.30
UMI	27,814	1.03	34,262	1.02
Total	**175,875**	**1.24**	**170,293**	**1.22**

L.5 Final Adjustment on Mode Choice and KG20B Model

As indicated in Table L.16, the KG20A model exhibited larger than expected ridership variations in the UMI and SMART service areas. In response to SEMCOG's feedback, CS made further adjustments and developed the KG20B model, which serves as a base for the E8Plus model LA20. Among the adjustments made were:

1. Reviewing O-D Patterns for SMART and UMI areas,
2. Reducing SMART boardings overestimation by the KG20A model,
3. Improving the modeling of UMI transit boardings, which were underestimated in the original 2022 validation (particularly the Bursley Baits route).

4 x 4 Area Matrix Adjustment

CS reviewed the OD travel pattern from the four subregions to the four subregions. Table L.17 illustrates the comparison between OBTS and KG20A results. The final adjustment factors of the 4x4 subregion-to-subregion constants for KG20B are in the MC Param.bin file with the names: KCBD, KDET, KDETO, KUMI, and KUMIO.

Table L.17 Adjustment Results used for KG20A Model

Target	Detroit CBD	:troit - Non-C	UMI	All Other	Total
Detroit CBD	2,454	1,499	784	1,565	6,301
Detroit - Non-CBD	9,016	29,040	43	14,258	52,357
UMI	442	0	18,274	3,159	21,875
All Other	8,699	5,985	14,554	30,314	59,552
Total	20,611	36,524	33,654	49,296	140,085

Model	Detroit CBD	:troit - Non-C	UMI	All Other	Total
Detroit CBD	1,298	755	518	467	3,038
Detroit - Non-CBD	12,803	32,019	49	13,051	57,922
UMI	144	1	16,914	2,100	19,160
All Other	6,913	8,635	14,744	31,627	61,919
Total	21,158	41,409	32,225	47,246	142,038

Difference	Detroit CBD	:troit - Non-C	UMI	All Other	Total
Detroit CBD	-1,156	-744	-266	-1,097	-3,263
Detroit - Non-CBD	3,787	2,978	7	-1,207	5,565
UMI	-298	1	-1,360	-1,058	-2,715
All Other	-1,787	2,650	190	1,313	2,366
Total	547	4,886	-1,429	-2,050	1,954

% Difference	Detroit CBD	:troit - Non-C	UMI	All Other	Total
Detroit CBD	-47%	-50%	-34%	-70%	-52%
Detroit - Non-CBD	42%	10%	15%	-8%	11%
UMI	-67%		-7%	-34%	-12%
All Other	-21%	44%	1%	4%	4%
Total	3%	13%	-4%	-4%	1%

Improve SMART boardings

In the original validation work completed in 2022, the KG20A modeled daily SMART ridership was nearly 40,000, compared to about 29,100 observed SMART boardings. There seemed to be two issues causing this overestimation: too many linked transit trips in the SMART service area and a high transfer rate for SMART service.

In the 2022 validation effort, CS attempted to match observed transit origin-destination flows (linked trips) at a broad level while obtaining reasonable matches of modeled boardings to observed (from the transit survey) by transit provider. The spatial resolution for the O-D flow summaries included four subregions—Detroit CBD, Detroit non-CBD, Ann Arbor (UMI), and “all other”—for a total of 16 inter-district flows. All SMART bus trips must have either an origin or destination in the “all other” subregion.

In the 2022 validation (KG20A was produced), “all other” origins were 4% higher than observed while “all other” destinations were 4% lower than observed. It was therefore apparent that the number of transit trips from the survey in the SMART service was higher than the observed number from the boarding counts. It was therefore decided to add some intraregional constants to the mode choice model in KG20B model to reduce the number of trips within the SMART service area, specifically within Oakland and Macomb Counties. The value of the constant was set at -1.

Another apparent issue regarding the overestimation of SMART boardings concerns the fact that the modeled linked transit trips in the SMART service area are closer to the observed totals than the modeled boardings are to observed. This implies that the modeled transfer rate for SMART is too high. To address this concern, CS tested increasing the transfer penalty from its original value of 15 minutes in KG20A for SMART services. While several values were tested, a final value of 30 minutes for SMART in KG20B was determined to work best.

As a result of the changes in the intraregional constants and the transfer rate, KG20B modeled SMART boardings were reduced to 29,600, about two percent higher than observed.

Improve UMI boardings

In the original validation work completed in 2022, the KG20A modeled daily UMI bus ridership was about 27,800, compared to about 34,300 observed UMI boardings. One specific route was a particular outlier: The UMI Bursley-Baits route has observed ridership of nearly 12,000 while in the June 2022 validation, the modeled boardings on this route were only about 4,000.

To address the general underestimation of UMI ridership by the model, an intraregional constant within the UMI subregion was created. After trying different values, the best results reflected in KG20B model were obtained with a value of +0.45.

An issue regarding the Bursley-Baits route was that the modeled headway of 10 minutes did not reflect a note on the UMI schedule that “frequent additional service operates between 7:30 a.m. and 7:00 p.m. on class days.” To address this issue, the headway on this route was reduced to 5 minutes.

As a result of the changes in the intraregional constants and the headway for the Bursley-Baits route, modeled UMI boardings were increased to 34,100 in KG20B, very close to the observed ridership. The modeled boardings on the Bursley-Baits route increased to 9,200 with the changes.

Table L.18 provides a summary of the KG20 model mode choice outputs compared to the OBTS. The term 'previous model' refers to KG20A before the final CS adjustment, while 'latest model' denotes KG20B, serving as the base for LA20 development.

Table L.18 Final KG20A and KG20B Mode Choice Model and OBTS Summary

		Previous Model		Latest Model	
Operator	Observed Boardings	Boardings	Difference	Boardings	Difference
AATA	24,491	25,696	1,205	25,653	1,162
BWAT	2,187	2,032	-155	2,030	-157
DDOT	71,430	69,986	-1,444	70,088	-1,342
DPM	4,413	4,303	-110	4,304	-109
LETC	1,082	925	-157	925	-157
M-1	3,305	5,221	1,916	5,242	1,937
SMART	**29,123**	**39,899**	**10,776**	29,417	294
UMI	**34,262**	**27,814**	**-6,448**	34,142	-120
Total	170,293	175,876	5,583	171,801	1,508

L.6 LA20 Transit Model Result and Discussion

Put LA20 Together

LA20 was assembled after CS completed the mode choice model calibration for KG20B. It incorporated:

1. Final mode choice model settings developed by CS for KG20B,

2. A new tour-based commercial vehicle model (CVM) to replace the old trip-based CVM,
3. Updated external travel model,
4. Updated 2020 international crossings traffic volumes, and
5. Updated 2020 DTW airport travel.

LA20 Transit Model Performance

The LA20 model showed improved ridership for SMART and UMI service areas. However, other performance measures, such as transfer rate and average trip length, were not as favorable as the previous KG20A estimates. Table L.19 presents boardings of the three models compared with OBTS:

1. Original KC20 E7 model,
2. Interim KG20A E7 model with ISE19, and
3. Final LA20 E8Plus model with new CVM and other updates.

The trip length distribution variation, measured with PRMSE, increased in LA20 to 48% from KG20's 39%, marking a 25% change. SEMCOG noted an increase in trips with a length of less than 2 miles in LA20, resulting in a 6% drop (5.91 vs 6.27) in average trip length. Additionally, the transfer rate in LA20 decreased by 10% (0.208 vs 0.229) compared to OBTS. Table L.20 provides performance statistics of the three models.

Table L.19 LA20, KG20A, and KC20 Modeled Boardings Vs. OBTS

Operator	OBTS Observed	KC20		KG20A		LA20	
		Boarding	Difference	Boarding	Difference	Boarding	Difference
AATA	24,491	32,314	7,823	25,696	1,205	25,760	1,269
BWAT	2,187	2,211	24	2,032	(155)	2,159	(28)
DDOT	71,430	70,770	(660)	69,986	(1,444)	69,382	(2,048)
DPM	4,413	7,126	2,713	4,303	(110)	4,286	(127)
LETC	1,082	971	(111)	925	(157)	912	(170)
Q-Line	3,305	6,632	3,327	5,221	1,916	5,100	1,795
SMART	29,123	35,167	6,044	39,899	10,776	29,276	153
UMI	34,262	31,236	(3,026)	27,814	(6,448)	35,684	1,422
Total	170,293	186,426	16,133	175,875	5,582	172,559	2,266

Table L.20 Performance Statistics LA20, KG20A, KC20 Models & OBTS

Measures	OBTS	KC20	KG20A	LA20
Transfer Rate	0.229	0.329	0.238	0.208
Boardings	169,832	186,426	175,875	172,559
Linked Trips	138,181	140,295	142,038	142,811
PMT		762,326	733,260	786,860
Average Trip Length*	6.96	5.44	6.27	5.91
Trip Length PRMSE		54.3%	38.9%	48.3%

* Based on mid-day highway skim