CAMPO

capital area metropolitan planning organization

TRAVEL DEMAND MODEL

DOCUMENTATION

HDR

Capital Area Metropolitan Planning Organization

Travel Demand Forecasting Model Documentation

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Chapter 1: Introduction

The purpose of this report is to document the development and validation of a travel demand model for the Capital Area Metropolitan Planning Organization (CAMPO). The model was developed using the TransCAD transportation forecasting microcomputer software (version 5.0 r4 Build 2110). **Figure 1-1** illustrates the geographic coverage of the model's roadway network extents.

The CAMPO model was calibrated using the base year 2010 transportation network and 2010 socioeconomic data. CAMPO provided a GIS-based roadway network, which was utilized as a starting point in the development of the existing conditions 2010 transportation model network characteristics. The U.S. Census 2010 block structure was used to create the model's Traffic Analysis Zones (TAZs). Other model files, which are described later in this document, were developed based on the most recent available data from CAMPO, MoDOT, U.S. Census Bureau, LEHD, and others. After the 2010 base-year daily model was honed to meet calibration standards, 2010 diurnal models were created to reflect the PM peak period. The-base year model was then modified to project future forecasts for the years 2020 and 2035. The 2020 and 2035 daily models were constructed in coordination with CAMPO.

This chapter presents a brief description of the overall transportation demand modeling process: trip generation, trip distribution, trip assignment, and model calibration. Chapter 2 details the 2010 model, including calibration and validation. Chapters 3 and 4 describe the future models (2020 and 2035, respectively). Chapter 5 provides details on the model electronic structure and processes, as well as instructions on how to run the model. A glossary of modeling terms is also included at the end of the document.

Transportation Modeling Process

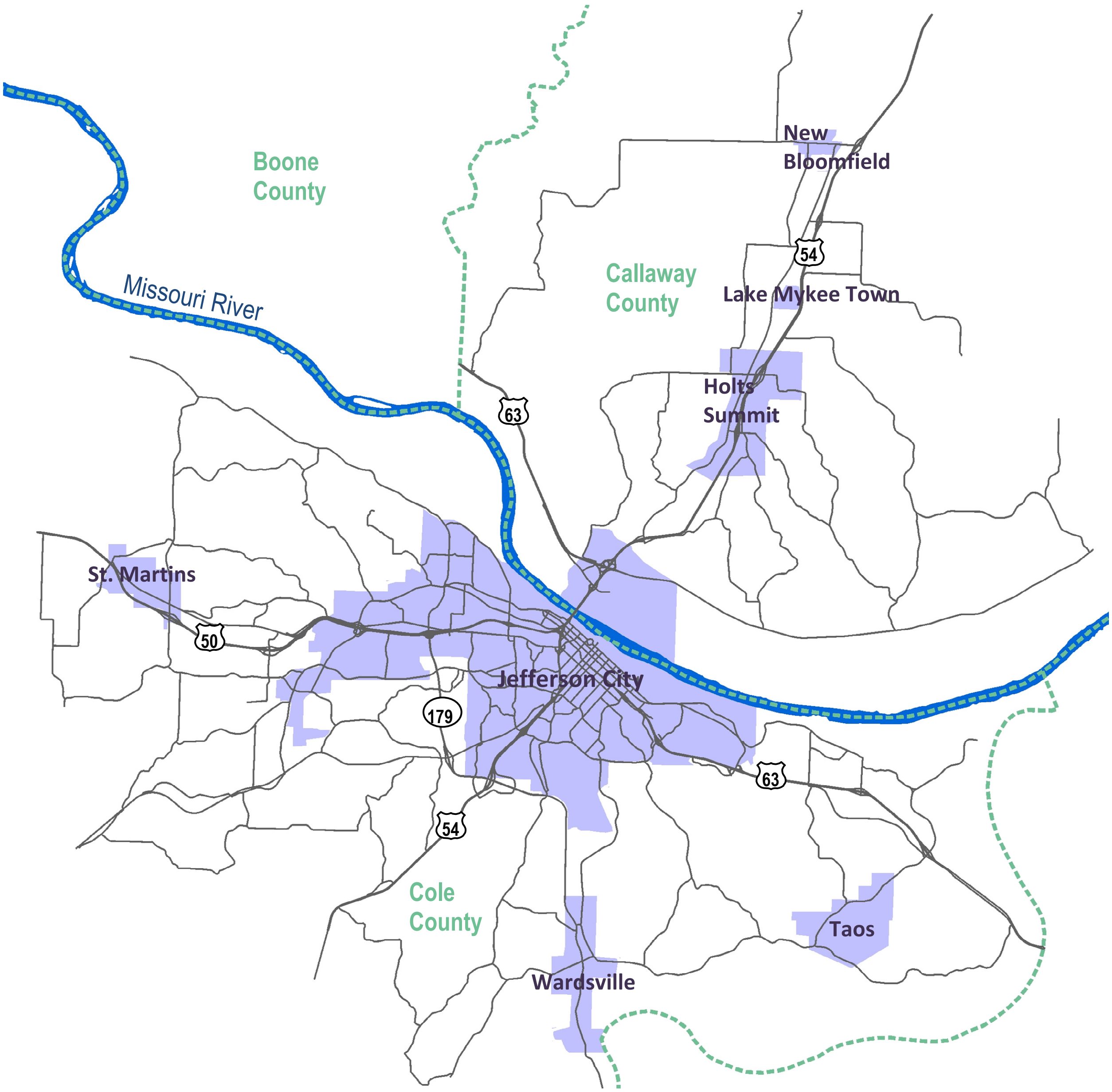
In general, the traffic model process consists of several steps, including estimating the number of vehicle trips generated per TAZ based on the socioeconomic inventory, distributing vehicle trip origins and destinations by TAZ, and then assigning the vehicle trips to the street network. The diagram below illustrates the major components of the CAMPO Travel Demand Model.

The travel demand model is a representation of the transportation facilities and the travel patterns of the vehicles using these facilities in the CAMPO area and portions of the surrounding area. The model contains inventories of the existing roadway facilities and of residential units and non-residential buildings/land-uses by TAZ.

For the existing (2010) scenarios, the model output assignment volumes were compared with current traffic counts. The goal of model calibration is to have the model output assignment volumes match the traffic counts as closely as possible. The model is deemed calibrated when these two sets of traffic volumes match within acceptable ranges of error. The model can then be used to test alternative scenarios with a level of confidence. These scenarios may encompass changes in housing unit counts, employment, travel behavior patterns, or roadway capacity/characteristics.

For future scenarios, a transportation planner or engineer can use the travel demand model to project future traffic volumes. These future-year volumes can aid in making planning and project programming decisions.

Figure 1-1: Model Extents



The model steps are briefly described below.

Trip Generation

The number of trips generated by a TAZ is a function of the land use and socioeconomic characteristics. Residential land uses are generally referred to as "producers" of trips; non-residential land uses are generally referred to as "attractors" of trips. Residential trip production is generally a function of the number of dwelling units and other demographic variables. Non-residential trip attraction is generally a function of employment.

The final product of the trip generation step is a table summarizing the total number of person-trips produced by, and attracted to, each TAZ. These trips are categorized by trip purpose (e.g., home-based work). A trip is defined as a one-way movement between two points.

Trip Distribution

The purpose of trip distribution is to produce a trip table of the estimated number of trips from each TAZ to every other TAZ within the model. The final product of the trip distribution phase is a person-trip matrix specifying the number of person-trips that travel between each pair of TAZs. Trip matrices are estimated for each of the five trip purposes. The matrices identify the production TAZ and the attraction TAZ for each trip, but they do not indicate the direction of travel. The distribution of trips between TAZs (for example, zone I and zone J) is a function of the "Gravity Model" that includes the following variables:

- The number of trips produced by zone I
- The number of trips attracted by zone J
- The travel time between zone I and zone J
- The magnitude of the total "attractiveness" of all the zones in the network

The number of trips traveling between zone I and zone J is directly proportional to the total number of trips produced by zone I and the total number of trips attracted by zone J. For example, the total number of trips traveling between zones I and J increase as the number of residential trips increases in zone I. Further, the number of trips between zones I and J are inversely proportional to the travel time between the two zones. (The number of trips decreases as travel time increases.)

Traffic Assignment

The traffic assignment phase converts the person-trip production and attraction matrices to vehicle-trip origin and destination (O-D) matrices based on vehicle occupancy information and direction of travel data. Directionality information is critical for peak-hour modeling. The traffic assignment then allocates each trip to one specific network route based on the travel "costs" (a function of travel time) between the various zones. The traffic assignment process includes the following:

- Computation of the minimum-cost paths between the TAZs based on free-flow link speeds (i.e., posted speed limits)
- Initial assignment of the trips to the links which lie on the minimum-cost paths between the TAZs
- Computation of volume-to-capacity (v/c) ratios on the links after initial assignment
- Computation of travel costs on the links as a function of the v/c ratio

- Reiteration of the assignment process until the model assignment reaches equilibrium where no traffic can be shifted without increasing the overall network travel cost

The final product of the traffic assignment process is a “loaded” network with traffic volumes on each link.

Model Calibration

Calibration involves adjusting model parameters and attributes to the point where modeled existing conditions match actual existing conditions within allowable tolerances. The travel demand model was calibrated using the 2010 transportation network, socioeconomic estimates, and traffic counts. The calibration process involved reviewing the assumptions and steps used to construct the model. The results of each model step were reviewed and adjustments made to achieve the desired results. During the distribution step, the parameters of the gravity model were examined. During the assignment step, the assumptions for link speeds, capacities, and delay parameters were studied. Any modifications made to the CAMPO model parameters were justified using available travel pattern data, local knowledge of travel conditions, or empirical modeling knowledge. The model calibration included a review of several performance measures such as percent assignment error, root mean square error (RMSE), and screenline analysis.

Chapter 2: 2010 Model

The primary goal of the existing daily model is to replicate daily travel patterns on the roadway network in the CAMPO region for a typical weekday in 2010. An accurate base year model, with its equations and parameters, can then be used to model future-year conditions by changing the land use and network input data. Developing an effective base-year model requires gathering, coding, and using a wide range of transportation-related data to create a "snapshot" in time.

2.1: Roadway Network

The initial step in the travel demand modeling process was the development of the geographical roadway network comprised of nodes and links. A **node** is an intersection of two or more links such as an intersection of two street segments. A **network link** is a street segment between two nodes (A node and B node). CAMPO provided a preliminary GIS-based roadway network file with necessary characteristics (i.e. street names, lanes, speeds, one-way links, etc) as well as additional non-model attribute data. In addition to converting the GIS file to a TransCAD file, refinements to the roadway network (modification and densification) were made in coordination with CAMPO staff.

Some roadways or roadway segments that may not carry substantial volumes may still be important to the model in other ways:

- They may alleviate traffic on other roadways by providing alternate routes or additional loading points for trips entering/exiting a Traffic Analysis Zone (TAZ).
- They also may provide a route through a TAZ (or TAZs) where a less dense model network might not. Most small neighborhood roads within a TAZ are modeled via centroid connectors. Since trips cannot be made through a TAZ on centroid connectors, trips that would normally travel through a TAZ may not be assigned correctly unless the neighborhood road is included as part of the network. (See the beginning of Section 2.2 for more on centroid connectors.)

Issues discovered during calibration also played a key role in refining the network assumptions. **Table 2-1** summarizes the key parameters of the network database. The remainder of Section 2.1 provides more detail on some of these parameters. **Figures 2-1, 2-2, and 2-3** illustrate functional class, number of lanes, and posted speeds, respectively.

Table 2-1: TransCAD Link Attributes
(2010 Model)

Attribute	Description
ID	Link ID Number
Length	Length (miles)
Dir	One-way (1, -1) or Two-way (0)
Name	Street Name
FunClass	Roadway Functional Classification Number 1. Freeway 5. Collector 2. Expressway* 6. Local Residential 3. Primary Arterial 7. Local Ramp 4. Secondary Arterial* 8. System Ramp **Reserved, but currently unused by model*
MedianType	1 = Undivided 2 = Undivided with turn lanes at intersections 3 = Through with left turn lanes (TWLTL) 4 = Raised Median – No turn lanes 5 = Raised Median – With turn lanes
AB_Lane BA_Lane	Number of Lanes
AB_Speed BA_Speed	Posted Speed (mph)
SlopePercent	Percent Slope / Grade 0 = 0 to 2.99% 3 = greater or equal to 3%
ADT	Estimated Base Year Daily Traffic Count
LaneCap_D	Directional Daily Lane Capacity (see Table 2)
AB_Cap_D BA_Cap_D	Directional Daily Roadway Capacity
Alpha	Volume Delay Function parameter
Beta	Volume Delay Function parameter

Figure 2-1: Functional Class, 2010

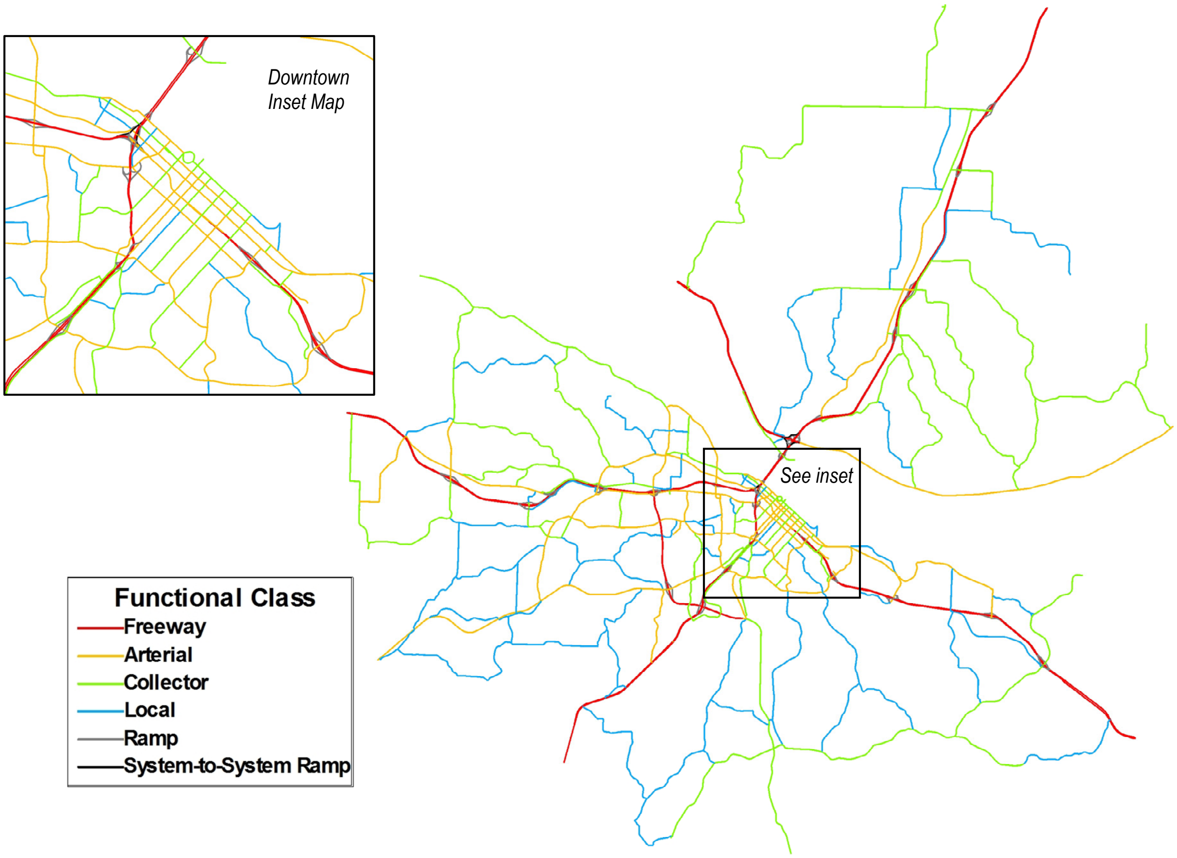
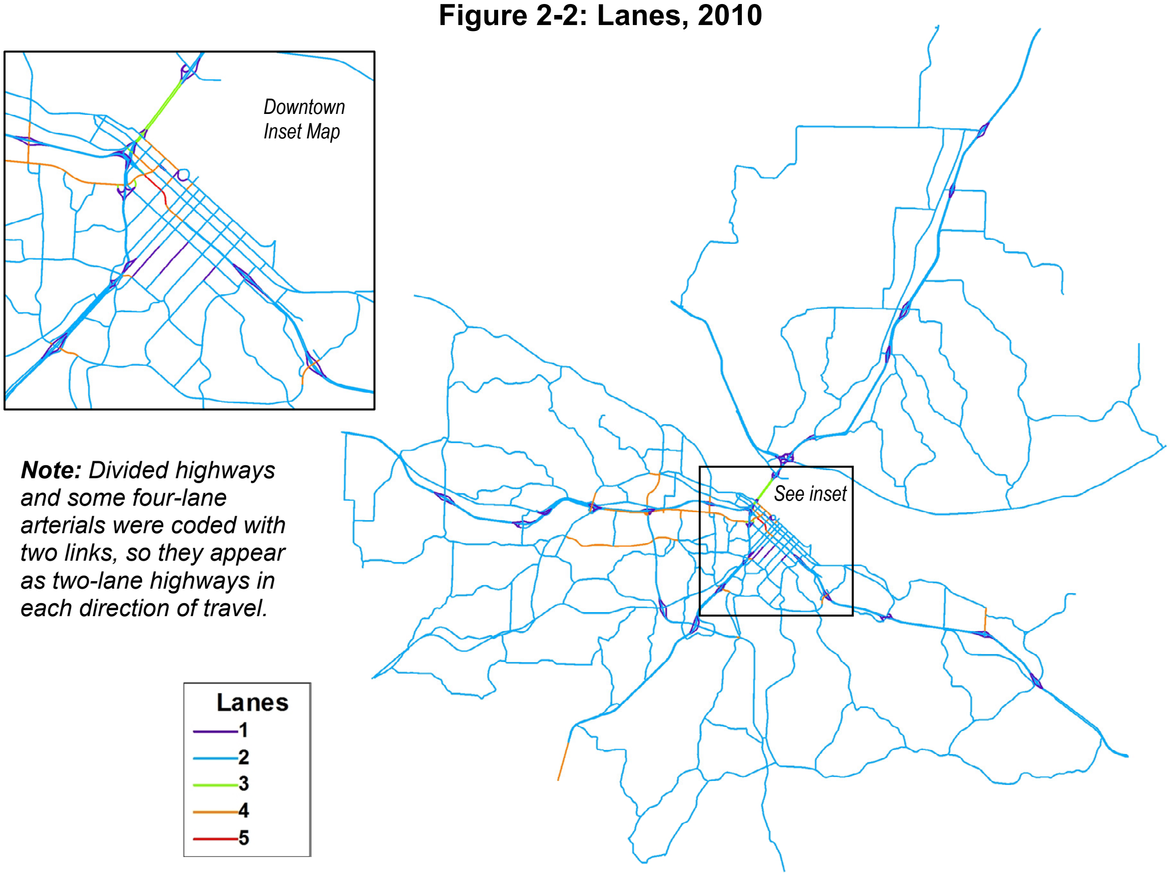
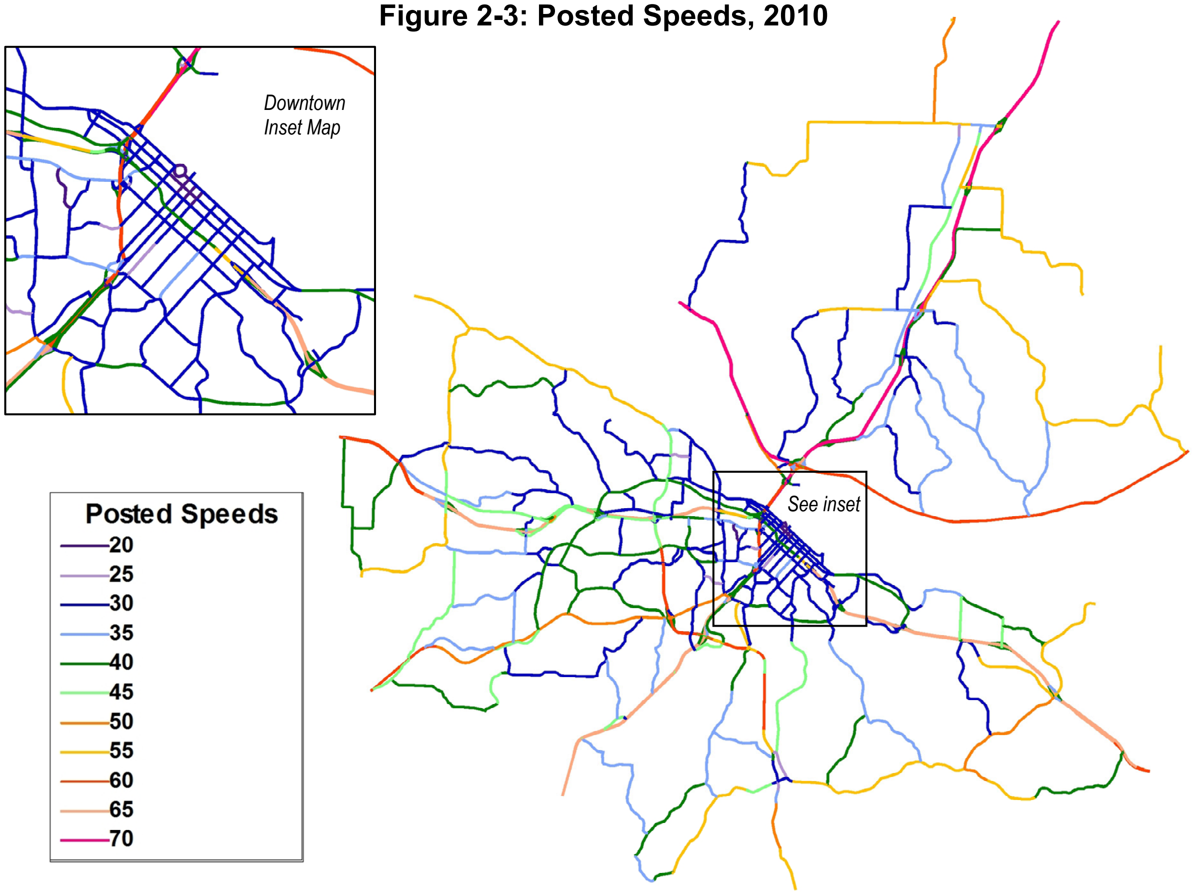


Figure 2-2: Lanes, 2010



***Note:** Divided highways and some four-lane arterials were coded with two links, so they appear as two-lane highways in each direction of travel.*

Figure 2-3: Posted Speeds, 2010



Roadway Link Capacity

The model computes link capacities at run time. Capacities are initially based on functional class and number of lanes, adjusted based on directionality, median type, and roadway slope. Capacity is expressed in terms of vehicles per day for each link by direction. Link capacities are not directly entered by the user, but are important parameters in model operation and network analysis.

In the context of model operation, the capacities are used in conjunction with link speeds, link lengths, and link delay functions to derive a realistic travel speed to be used in the trip distribution and assignment stages. In the context of network analysis, the capacities are used to identify deficiencies and recommend improvements. In both cases, it is desired that the capacities used in the model be as accurate and realistic as possible. However, it is also important to point out that these are planning-level calculations appropriate for modeling and long-range planning, as opposed to design-level capacities or calculations.

Table 2-2 includes the base directional capacities used for the model. These capacities are based on published sources and experience in developing travel demand model planning capacities. Functional classes 2 and 4 are not utilized in the model at present, but they could be used during future model updates.

To calculate a directional link capacity, the base values in **Table 2-2** are multiplied by the number of lanes in a specific direction and then multiplied by factors associated with the median type, slope percent, and one-way link adjustment factors, as appropriate.

The median type adjustment factor accounts for capacity changes due to median type and total number of lanes, particularly non-freeway and non-expressway links. A roadway without turn lanes is considered to have less capacity than the same type of roadway with turn lanes. A lack of a median also decreases the capacity of a roadway in comparison to the base capacity. These capacity increases and decreases are also based on guidance from the Florida Department of Transportation (FDOT) Generalized Service Volume Tables from 2010, a widely used transportation planning resource. **Figure 2-4** illustrates median types as coded in the 2010 model.

Table 2-2: Daily Link Capacities (per-lane)

Base Directional Daily Lane Capacity

Roadway Classification	
1. Freeway	20,000
*2. Expressway**	--
3. Primary Arterial	9,000
*4. Secondary Arterial**	--
5. Collector	7,500
6. Local	6,000
7. Ramp	12,000
8. System-to-system Ramp	40,000

**Reserved, but currently unused by model*
Source: FDOT, other Missouri models, HDR

Median Type Adjustment Factors

(multiplied by base capacity for two-way links of functional class 3+)

Median Type	Total Number of Lanes 1-2	Total Number of Lanes 3+
1 Undivided	0.67	0.75
2 Undivided with Turn Lanes	0.87	0.95
3 Two-Way-Left-Turn-Lane	0.9	0.98
4 Raised Median no Turn Lanes	0.72	0.8
5 Raised Median with Turn Lanes	0.92	1

One-Way Link Adjustment Factor

Multiply base capacity by **1.2** for one-way links of functional class 3+

The one-way link adjustment factor of 1.2 applies to one-way links that are not freeways or ramps. This 20-percent capacity increase is derived from the FDOT capacity tables. One-way links are considered to have relatively more capacity associated with a lack of opposing traffic. **Figure 2-5** illustrates one-way (non-freeway, non-ramp) links as coded in the 2010 model.

For all two-lane collectors and local links with slope percents defined as 3% or greater, the capacity is reduced by 5%. This applies to one-way links with between one and three lanes as well.

Based on the calculations described above, **Figure 2-6** illustrates the capacities computed for the 2010 Daily Model.

Figure 2-4: Median Type, 2010

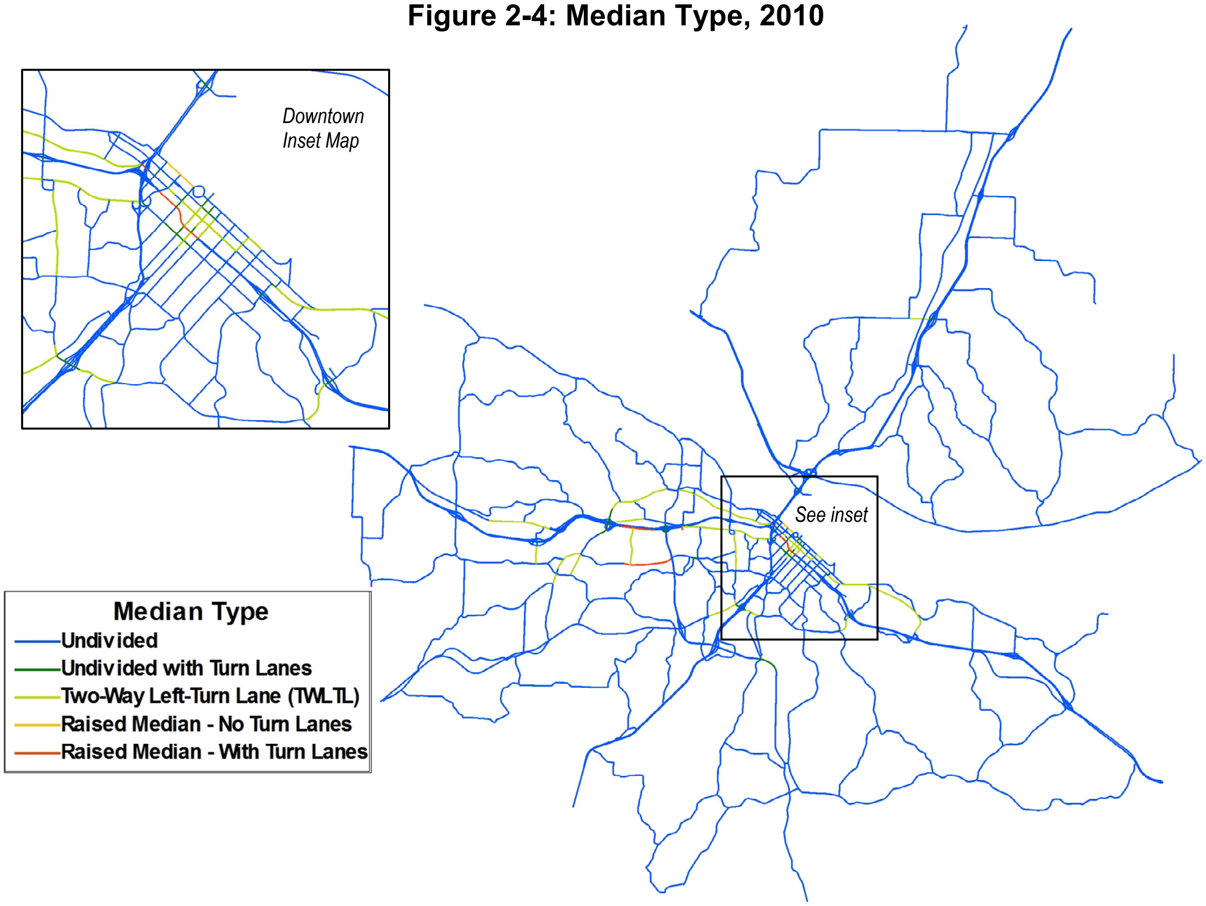


Figure 2-5: One-Way Links, 2010

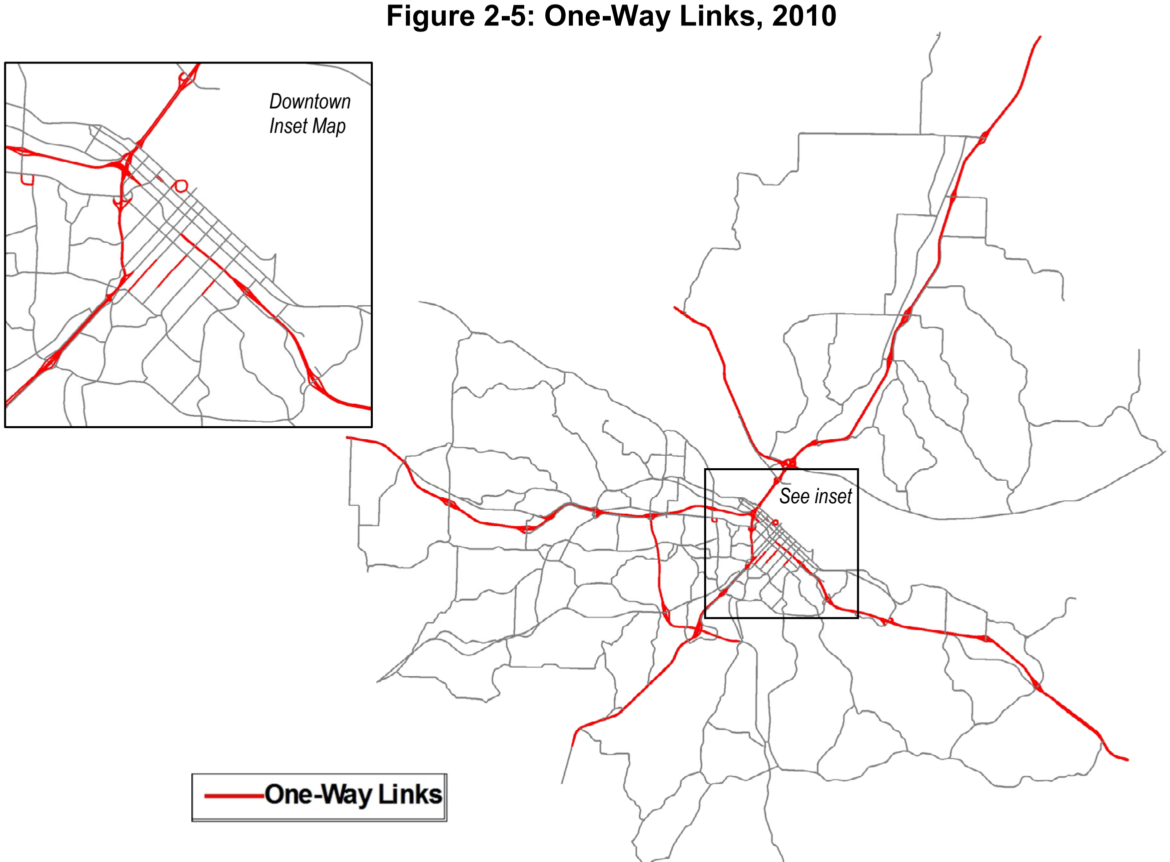
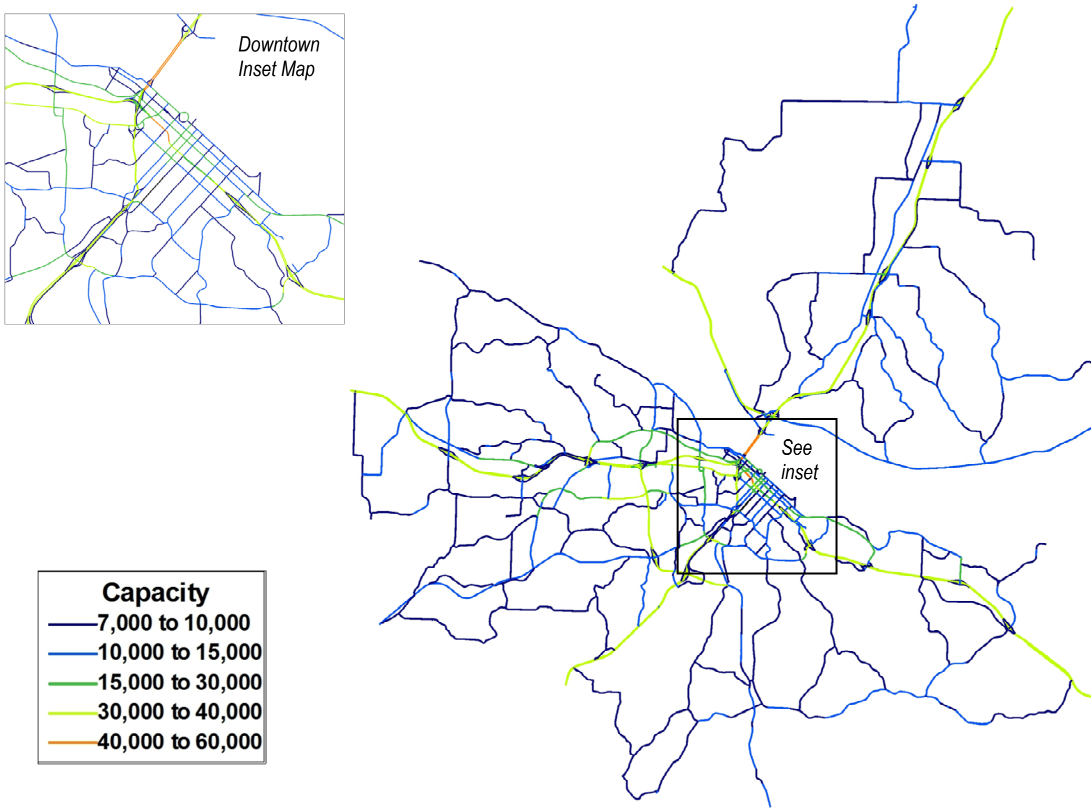


Figure 2-6: Computed Capacities, 2010



Link-Based Trip Distribution and Assignment Parameters

The alpha (α) and beta (β) parameters are used by the volume-delay function (VDF) to determine how sensitive volume on a link is to travel cost on the link. These parameters are assigned at run time based on the functional classification of the each link, and are therefore not user-modifiable at the link-level. **Table 2-3** summarizes these parameters for each functional classification. The values used are from National Cooperative Highway Research Program (NCHRP) Report 716: Travel Demand Forecasting Parameters and Techniques (TRB, 2012). Section 2.5 provides more detail on how α and β are used in the Trip Assignment stage of the model.

Table 2-3:
Volume-Delay Function Parameters

Functional Classification	Facility Type	α	β
1	Freeway	0.312	5.883
2	Expressway	0.312	5.883
3	Principal Arterial	0.514	3.001
4	Secondary Arterial	0.514	3.001
5	Collector	0.514	3.001
6	Local	0.514	3.001
7	Ramp	0.312	5.883
8	System-to-system Ramp	0.312	5.883

Turn Penalties

In order to accurately reflect travel behavior in the CAMPO area, both global and link-specific turn penalties were used in the model. Turn penalties add time (delay) to specific turn movements within the roadway network. This in turn can make particular routes less attractive relative to other travel routes. Penalties can even be used to prohibit certain movements. **Figure 2-7** summarizes the turn penalties used in the model, which fall into two categories (global and link-specific) as described below.

- Global - Turn penalties were applied to all left- and right-turn movements based on the functional classification of the street being turned onto and the street being turned from. A matrix of global turn penalties is shown in **Figure 2-7**. U-turns were prohibited throughout the model network, to prevent unrealistic vehicle assignments in areas with other turn penalties, especially near interchanges.

- Link-Specific - These penalties were assigned to locations where traffic is physically or legally prohibited from making the restricted movement.

In locations where one-way links are coded within the model, TransCAD automatically prohibits travel in the opposite direction. Therefore, turn penalties are not required at these locations. The link-specific turn penalties defined for use in the daily model are shown in red in **Figure 2-7**.

Other Adjustments

- Terminal Times - To account for the parking and walking time at either end of a trip, terminal time was added to all trips. One minute was added at either end of all trips, except for though trips in the downtown core, which had 1.5 minutes added.

- Speed Reductions - Due to noted over-assignment of volume on the freeway facilities (Functional Class 1), it was necessary to apply a universal speed reduction factor to those facilities. This factor allows the model to account for the observed travel behavior in the Jefferson City area, which includes drivers selecting routes based on distance, local preference, comfort, and past use; not just travel time.

- Link Time - A parameter was included in the network to add time to specific links that are over-assigned due to factors not captured by the other model elements. However, this feature was not needed to calibrate the daily model. It is available if needed in future model applications or updates/adjustments.

Figure 2-7: Turn Penalties, 2010

Global

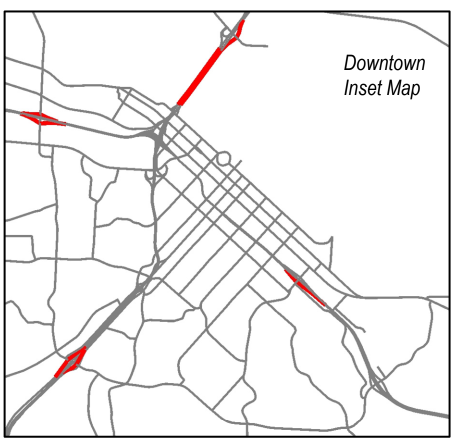
LEFT TURNS

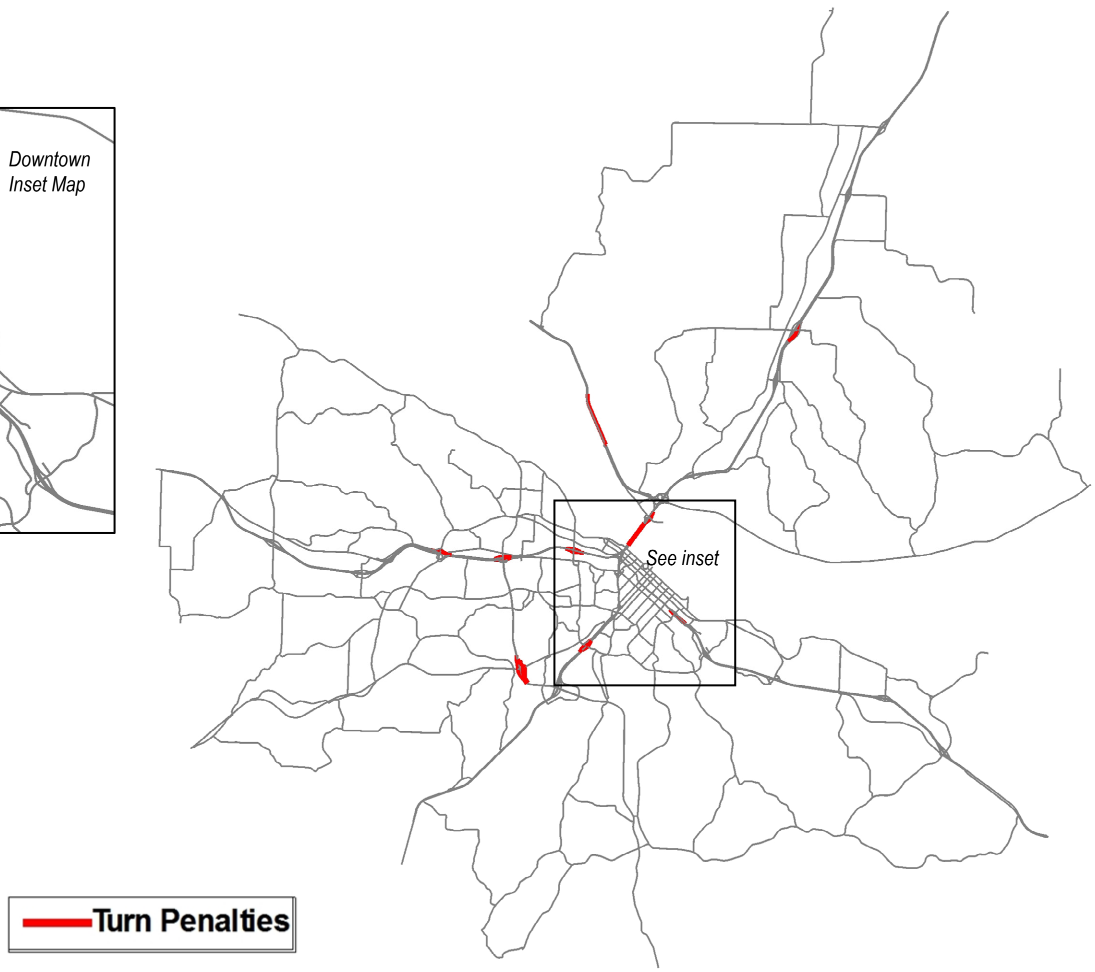
	Freeway	Arterial	Collector	Local	Ramp	System-to-System Ramp	Centroid Connector
Freeway	0.12	0.30	0.30	0.30	0.04	0.04	0.30
Arterial	0.30	0.12	0.10	0.08	0.10	0.10	0.06
Collector	0.30	0.12	0.04	0.02	0.08	0.08	0.02
Local	0.30	0.12	0.04	0.02	0.08	0.08	0.02
Ramp	0.02	0.10	0.08	0.08	0.08	0.08	0.06
System-to-System Ramp	0.02	0.10	0.08	0.08	0.08	0.08	0.06
Centroid Connector	0.30	0.06	0.02	0.02	0.06	0.06	0.02

RIGHT TURNS

	Freeway	Arterial	Collector	Local	Ramp	System-to-System Ramp	Centroid Connector
Freeway	0.12	0.30	0.30	0.30	0.04	0.04	0.30
Arterial	0.30	0.12	0.10	0.08	0.10	0.10	0.06
Collector	0.30	0.12	0.04	0.02	0.08	0.08	0.02
Local	0.30	0.12	0.04	0.02	0.08	0.08	0.02
Ramp	0.02	0.10	0.08	0.08	0.08	0.08	0.06
System-to-System Ramp	0.02	0.10	0.08	0.08	0.08	0.08	0.06
Centroid Connector	0.30	0.06	0.02	0.02	0.06	0.06	0.02

Link-Specific





2.2: Land Use/Socioeconomic Data

Traffic Analysis Zone (TAZ) Structures

Land-use and socioeconomic data provide the foundation for the Trip Generation stage of the model.

Land use was developed for different categories and allocated to TAZs. TAZs are generally bounded by some combination of roadways, geographic features (river, railroad, steep terrain), and municipal boundaries. They also generally follow Census 2010 block boundaries.

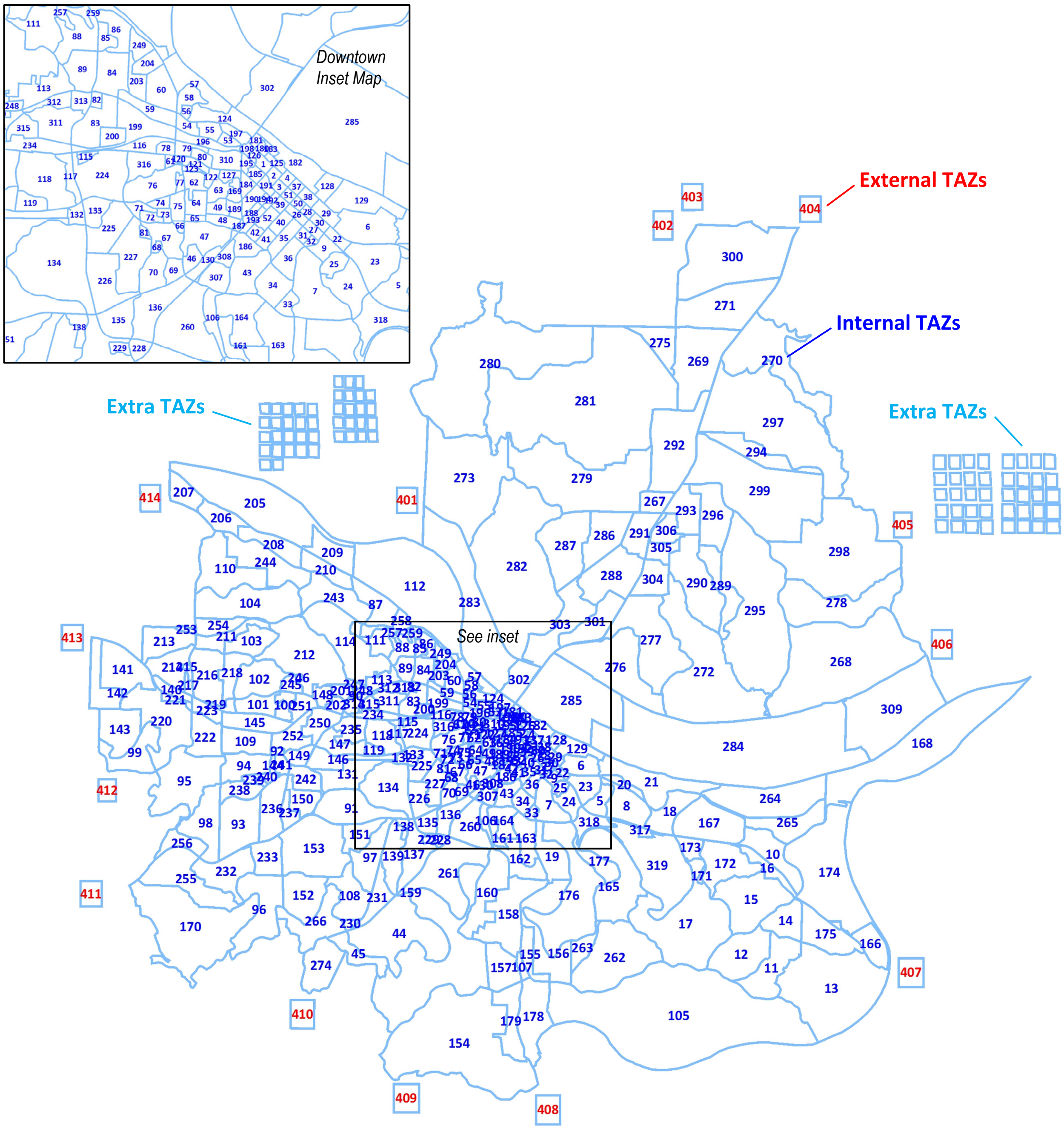
The TAZ polygon layer contains all relevant TAZ-related attributes. The network feature that ties the TAZ and the network layers to each other is the *centroid*, a special network node at which all trips within a TAZ are assumed to begin and end for modeling purposes. Each TAZ centroid is connected to at least one roadway link by centroid connectors. Centroid connectors are proxies for local streets within the TAZ that connect to the model roadway network.

The model also includes a special type of TAZ known as an *external station*. Because the model's land-use data cannot stretch on endlessly, external stations are used to represent the physical locations at which vehicles can enter or exit the model. Rather than land-use and socioeconomic data, these externals are coded with trip ends broken out by purpose based on available count and survey data.

Figure 2-8 depicts the TAZ structure for the 2010 model. There are 414 TAZs in total: 400 internal TAZs and 14 external stations. The external stations are numbered from 401 through 414. Note that 81 of the internal zones were created and reserved for future use to simplify coding when needed.

The TAZs developed for the 2010 model were created using the potential new urban area boundaries supplied by CAMPO. The approximated urban area includes New Bloomfield to the north of Jefferson City as well as Wardsville to the south. The zone structure was created based on aggregating the 2010 Census blocks using modeling judgment. In a few instances, it was necessary to split Census blocks, because the block geography did not adequately capture how the land use was divided in an area and/or how the land use was distributed within the area via the network.

Figure 2-8: TAZ Structure, 2010

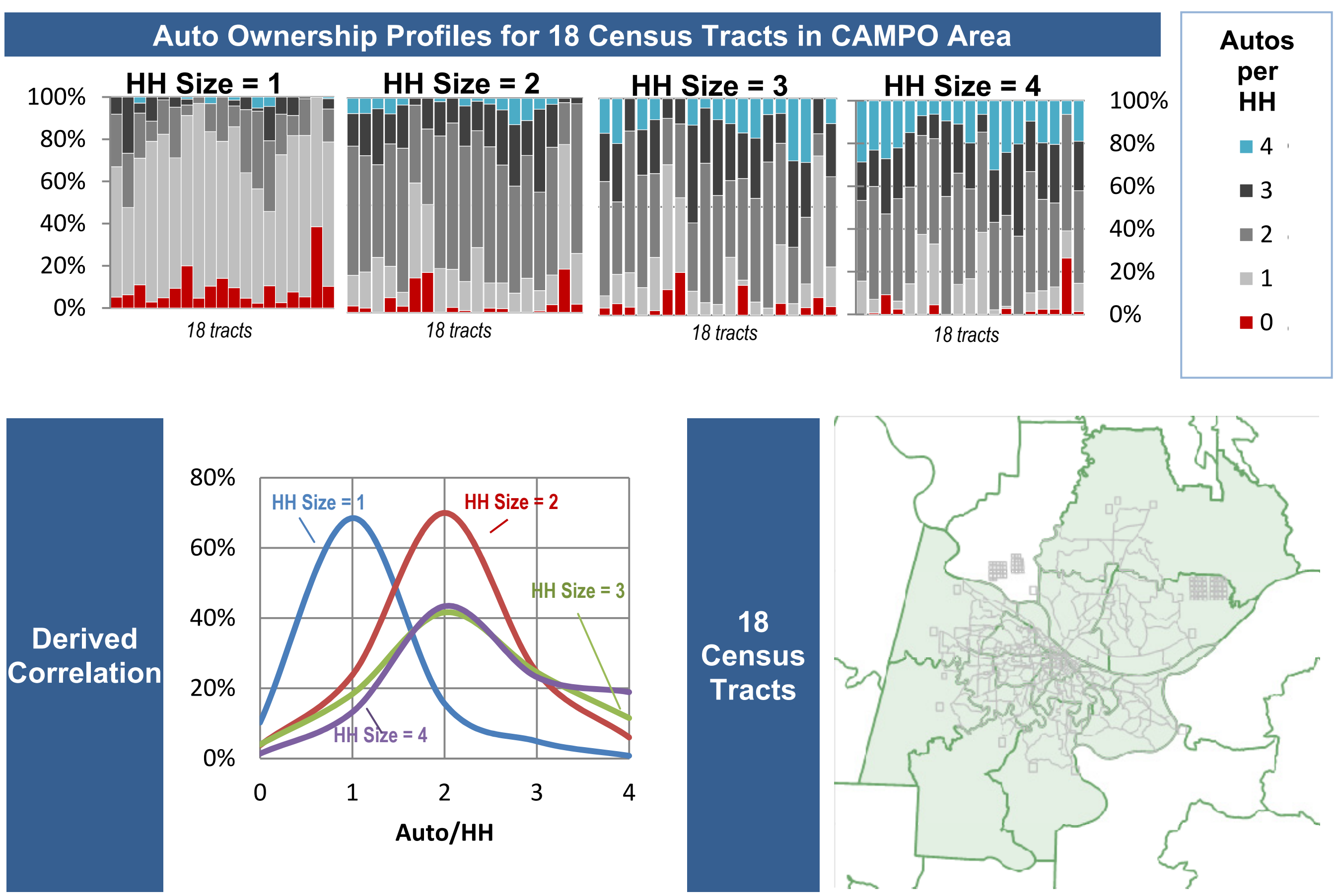


Household Source Data

As described in more detail in Section 2.3, the model's trip productions are based on data regarding population and household data (the latter including household size and auto ownership). The 2010 population and households entered into the model were derived from the 2010 Census Block data, aggregated into the model TAZs.

Section 2.3 also describes the use of auto-ownership data in the cross-classification methodology for determining trip productions. To derive a generalized model-wide relationship between household size and auto ownership, 2010 Census information was used (at the tract level, for tracts completely or partially in the model area) For each of 18 tracts, auto ownership data was available for each household size increment, and these values were averaged over the 18 tracts to yield reasonable model-wide estimates. **Figure 2-9** illustrates the individual tract data and includes a map illustrating the tracts that were selected for this analysis. The final correlation is included in Section 2.3.

Figure 2-9: 2010 Census Data Underlying Household Size / Auto Ownership Correlation



Employment Source Data

As described in more detail in Section 2.3, the model's trip attractions are based on employment totals in various categories. The US Bureau of the Census Longitudinal Employer-Household Dynamics (LEHD) data was used to estimate the 2010 employment totals for the model. This data provides employment estimates at the Census block level. The employment is categorized using the two-digit North American Industry Classification System (NAICS) codes. The employment data is derived from state and federal unemployment insurance system data. The two-digit NAICS codes and the assumed relationships provided in **Table 2-4** were used to consolidate the 20 employment categories into the eight basic CAMPO model land-use categories.

Table 2-4: LEHD Conversion to CAMPO Land Use Categories

NAICS Code	Description	Model Category
11	Agriculture, Forestry, Fishing and Hunting	Other
21	Mining, Quarrying, and Oil and Gas Extraction	Other
22	Utilities	Other
23	Construction	Other
31-33	Manufacturing	Industrial
42	Wholesale Trade	Warehouse
44-45	Retail Trade	Retail
48-49	Transportation and Warehousing	Warehouse
51	Information	Office/Service
52	Finance and Insurance	Office/Service
53	Real Estate and Rental and Leasing	Office/Service
54	Professional, Scientific, and Technical Services	Office/Service
55	Management of Companies and Enterprises	Office/Service
56	Administrative and Support and Waste Management and Remediation Services	Office/Service
61	Educational Services	Education
62	Health Care and Social Assistance	Medical
71	Arts, Entertainment, and Recreation	Entertain/Recr
72	Accommodation and Food Services	Retail
81	Other Services (except Public Administration)	Office/Service
92	Public Administration	Office/Service

The LEHD data was cross-checked against, and in many cases modified based upon, several other employment sources including ReferenceUSA, Dun & Bradstreet, other CAMPO-provided employment data, internet searches, and aerial photography.

Table 2-5: Land Use by Type, 2010

Category	Employees
Retail	4,670
Retail (High)	3,275
Office/Service	24,414
Education	2,678
Medical	4,905
Industrial	4,091
Warehouse	1,869
Entertain/Recr	578
Other	3,533
Total	**50,014**

The retail employees were also divided into standard and high-trip-generating retail categories. This was done as part of the calibration effort to better reflect trip-making in some of the high-intensity retail areas.

Total employees within each of the model categories are shown in **Table 2-5**. As the table indicates, just over 50,000 employees are included in the 2010 model.

2.3: Trip Generation

Trip generation has two primary components: trip productions and trip attractions. The CAMPO model's approach to each is described below.

Trip Productions

The CAMPO model generates trip productions for five different purposes:

- *Home-Based Work (HBW):* Trips that have one trip end at home and one trip end at work.
- *Home-Based School (HBSCH):* Trips that have one end at home and the other at a school (elementary through university).
- *Home-Based Shopping (HBSHOP):* Trips that have one end at home and one end at a retail-type shopping location.
- *Home-Based Other (HBO):* All other home-based trips.
- *Non-Home-Based (NHB):* Trips that do not begin or end at home.

Note that for all home-based trips, the home end is considered the production end and the non-home end is considered the attraction end, regardless of the direction of the trip. (In/Out percentages are used to obtain the correct directionality in the peak-hour modeling.)

The trip-production component of the model uses a cross-classification methodology that looks at both household size and auto ownership. **Table 2-6** includes the trip production rates for the five trip purposes for each auto-ownership/ household-size combination. **Figures 2-10, 2-11, and 2-12** show the per-TAZ values for number of households, average household size, and average auto-ownership, respectively.

The trip production rates employed in the CAMPO travel demand model are based on the rates presented in NCHRP 716. During the calibration process, it was hypothesized that the CAMPO region generates trips at a slightly higher rate than the average for the nation. This proposal was based in part on the low forecasted traffic volumes on the regional roadways using the national average trip production rates (in conjunction with other national average parameters such as trip lengths). Therefore, the following factors were applied to the NCHRP 716 rates: HBW - 1.1; HBSCH - 1.4; HBSHOP – 1.1 HBO – 1.1; NHB – 1.21.

Table 2-6: Trip Production Rates

Autos per Household	Persons per Household	Home-Based				Non-Home-Based	TOTAL
		Work	School	Shop	Other		
0	1	0.23	0.01	0.41	1.1	0.77	2.52
	2	0.81	0.14	1.06	2.71	1.87	6.59
	3	1.15	1.12	1.57	3.82	2.2	9.86
	4	1.15	2.10	1.85	4.51	4.07	13.68
	5+	1.15	2.24	2.2	7.02	4.29	16.9
1	1	0.69	0.01	0.67	1.39	1.54	4.3
	2	0.92	0.14	1.31	2.8	2.53	7.7
	3	1.38	1.12	2.17	3.9	3.85	12.42
	4	1.96	2.24	2.23	5.42	4.29	16.14
	5+	1.73	3.36	2.26	7.6	4.29	19.24
2	1	0.81	0.01	0.64	1.93	1.76	5.15
	2	1.5	0.14	1.35	2.97	2.86	8.82
	3	2.3	1.12	2.06	4.11	4.29	13.88
	4	2.3	2.38	2.14	7.7	6.05	20.57
	5+	2.65	3.64	2.65	9.23	6.16	24.33
3+	1	1.04	0.01	0.64	2.04	1.76	5.49
	2	1.61	0.14	1.38	2.94	2.97	9.04
	3	2.99	1.12	2.04	4.86	4.95	15.96
	4	3.34	2.52	2.12	7.72	6.38	22.08
	5+	3.80	3.78	3.08	10	7.81	28.47

Figure 2-10: Trip Production Variables – Households Per TAZ

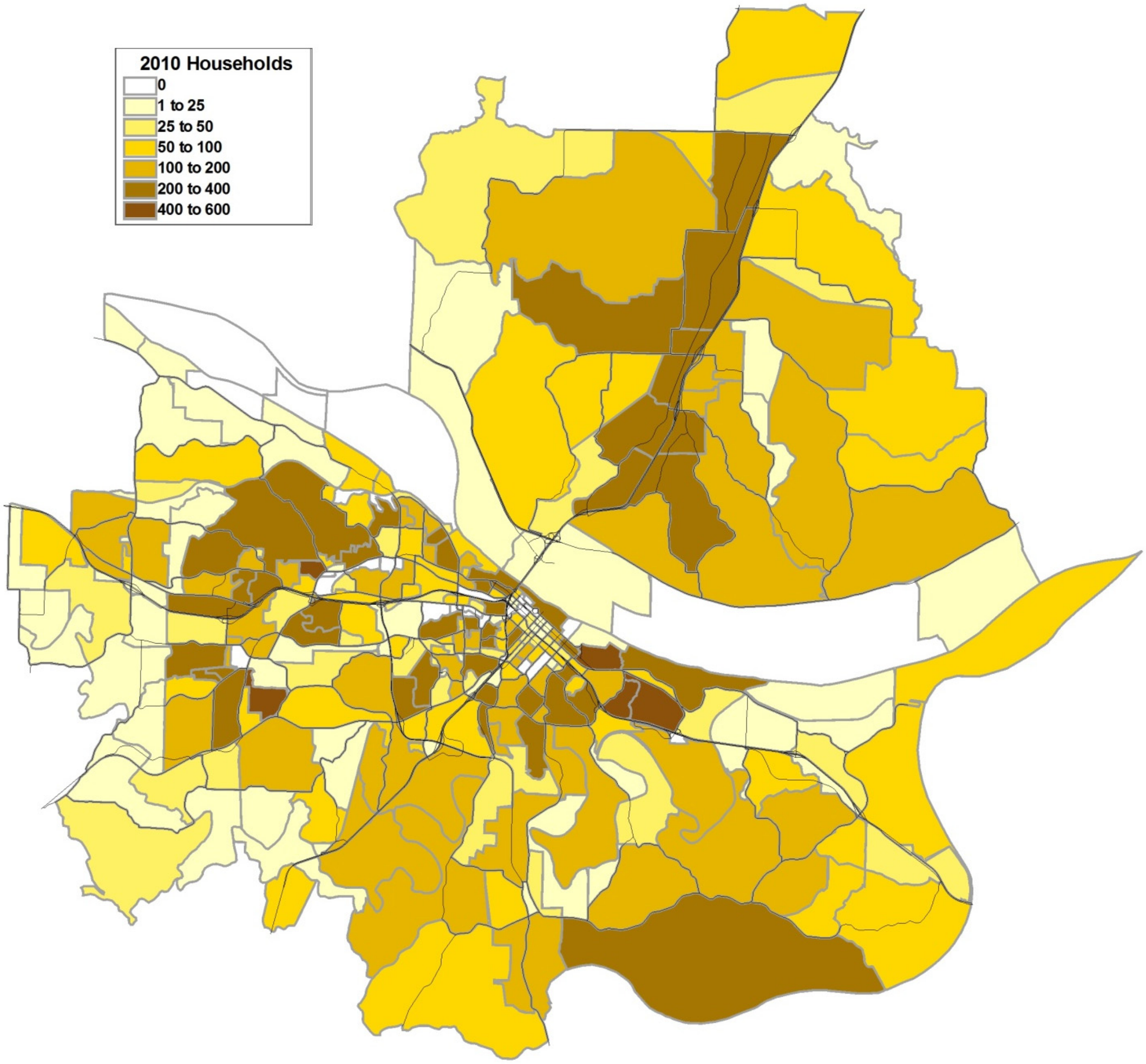


Figure 2-11: Trip Production Variables – Average Household Size Per TAZ

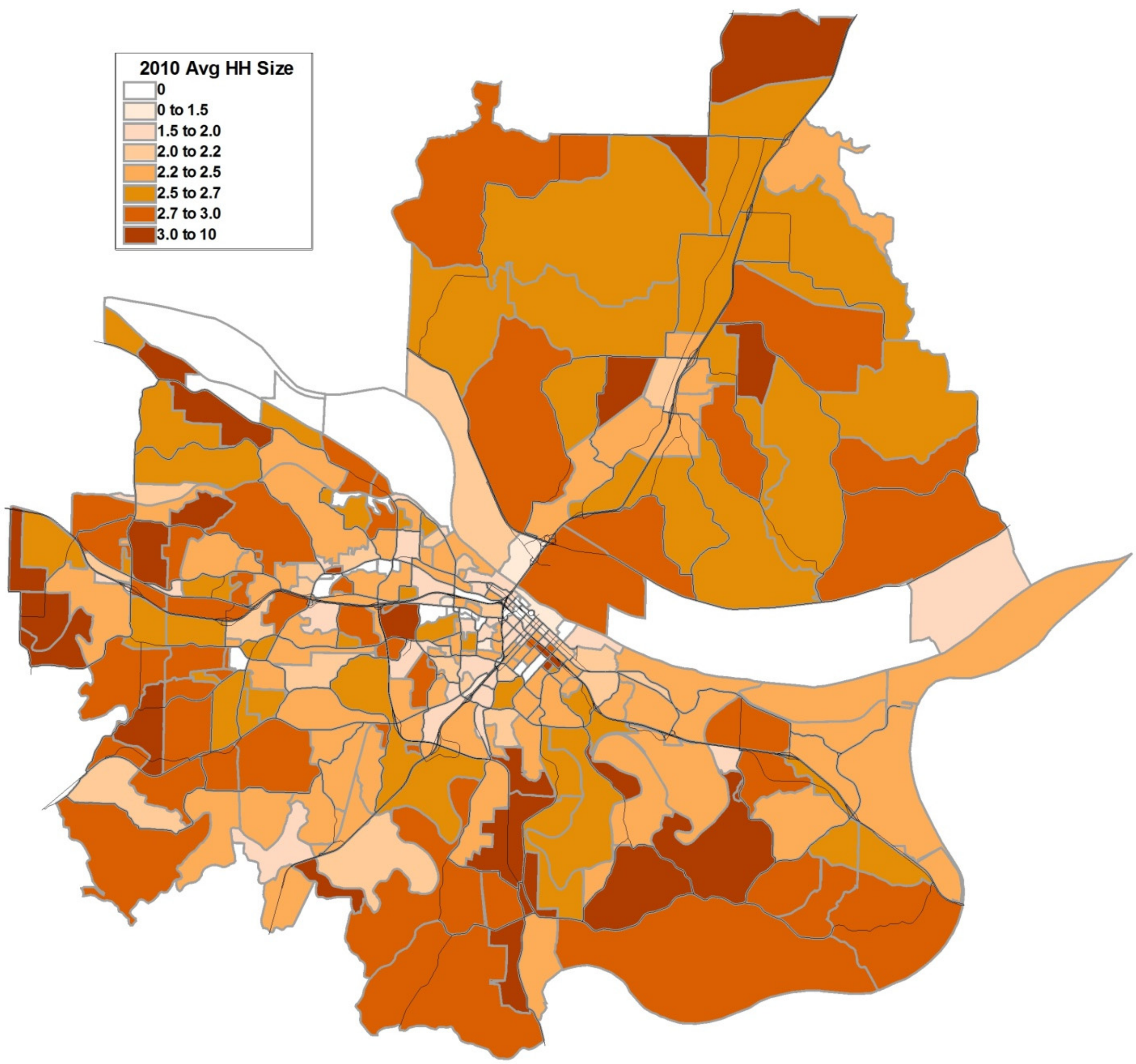
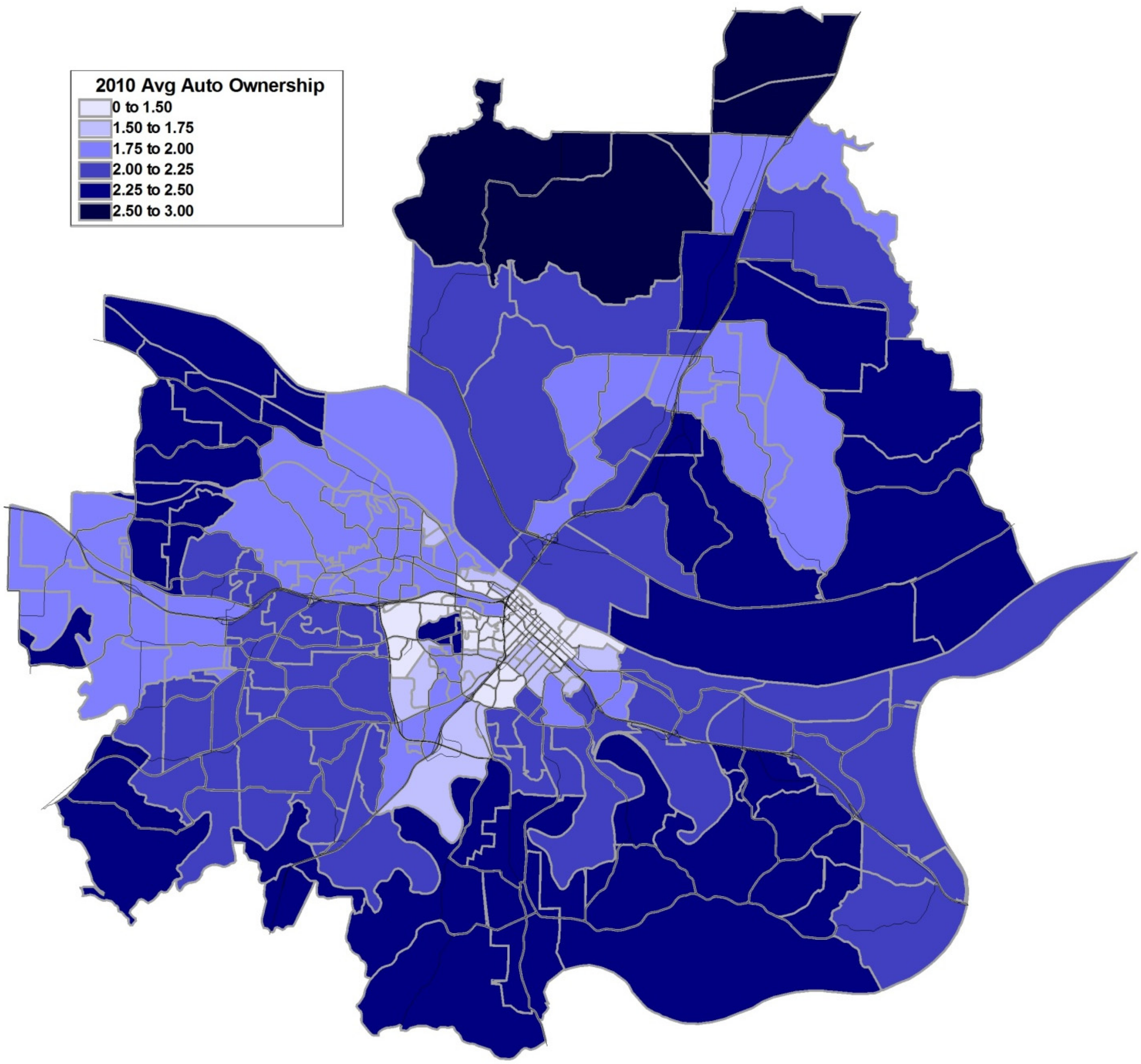


Figure 2-12: Trip Production Variables – Average Auto Ownership Per TAZ



Trip Attractions

Trip attractions are generally places of employment. Attractions are estimated based on the trip-generation characteristics of the land-uses within the TAZs, and (like productions) are broken out by trip purpose. The trip attraction rates employed in the CAMPO model were primarily derived from the rates provided in NCHRP 716 as well as other travel demand models for smaller urban areas. They were adjusted during the calibration phase to reflect local trip-making characteristics and to more closely match the calibrated trip productions. The final trip attraction rates used in the model compare well with, but are slightly higher than, the NCHRP 716 rates. **Table 2-7** summarizes the trip attraction rates by land-use category, broken out by trip purpose.

Table 2-7: Trip Attraction Rates

	Trip Purpose					
Land Use	HBW	HBSCH	HBSHOP	HBO	NHB	**Total**
HH	0	0	0	1.309	0.855	**2.164**
Retail	1.311	0	7.4	0.99	5.238	**14.939**
Office/Service	1.311	0	0	2.5	0.981	**4.792**
Education	1.311	10.0	0	0	1.5	**12.811**
Medical	1.311	0	0	3.751	0.981	**6.043**
Industrial	1.311	0	0	0.517	0.432	**2.26**
Warehouse	1.311	0	0	0.517	0.432	**2.26**
Entertain/Recr	1.311	0	0	0.517	0.432	**2.26**
Other	1.311	0	0	0.517	0.432	**2.26**
Retail - High Density	1.311	0	7.8	1.045	5.328	**15.484**

Figures 2-13, 2-14, 2-15, and 2-16 illustrate the per-TAZ values for many of the variables listed in **Table 2-7.**

Figure 2-13: Trip Attraction Variables – Retail Employees per TAZ

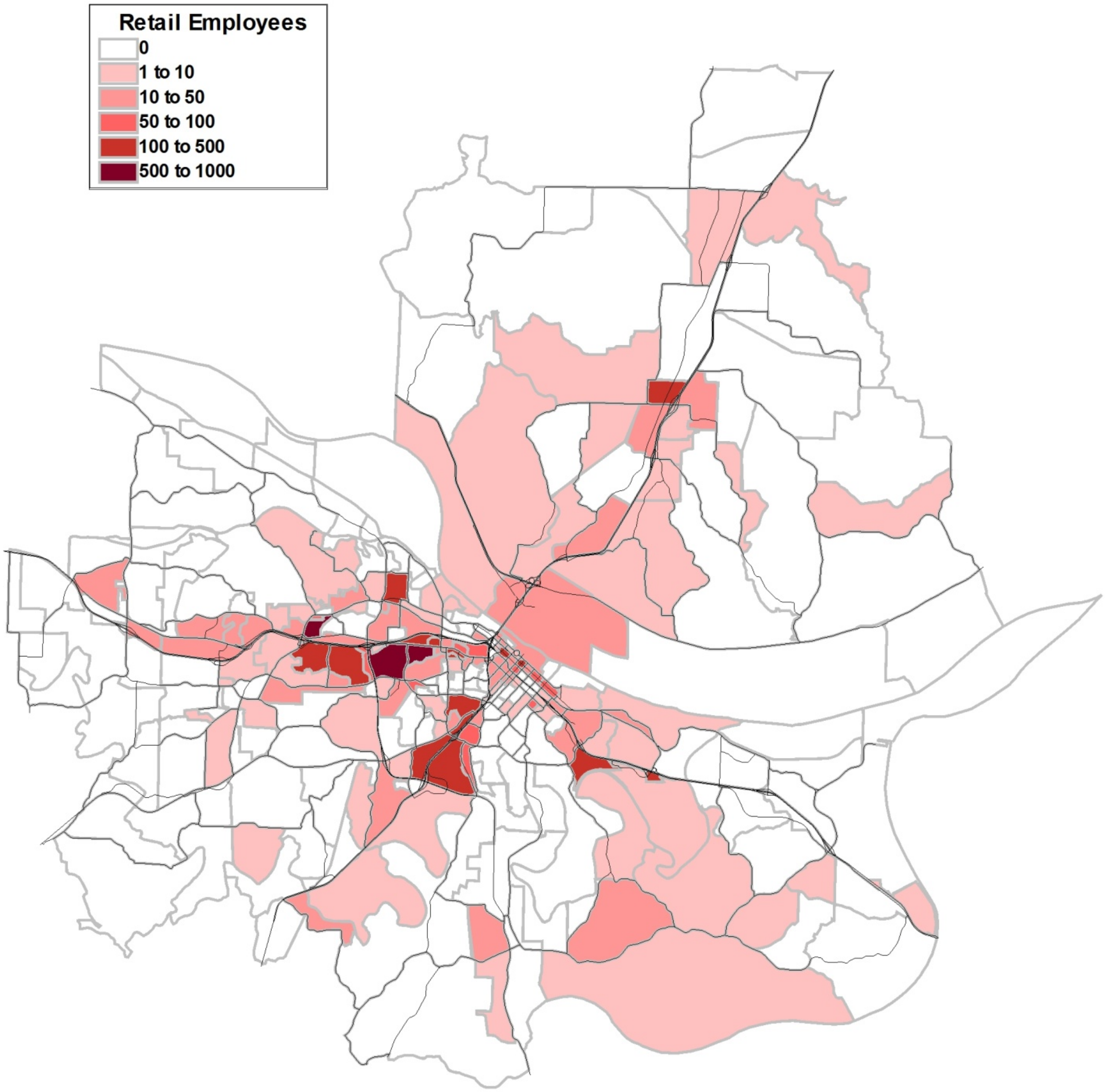


Figure 2-14: Trip Attraction Variables – Office/Service Employees per TAZ

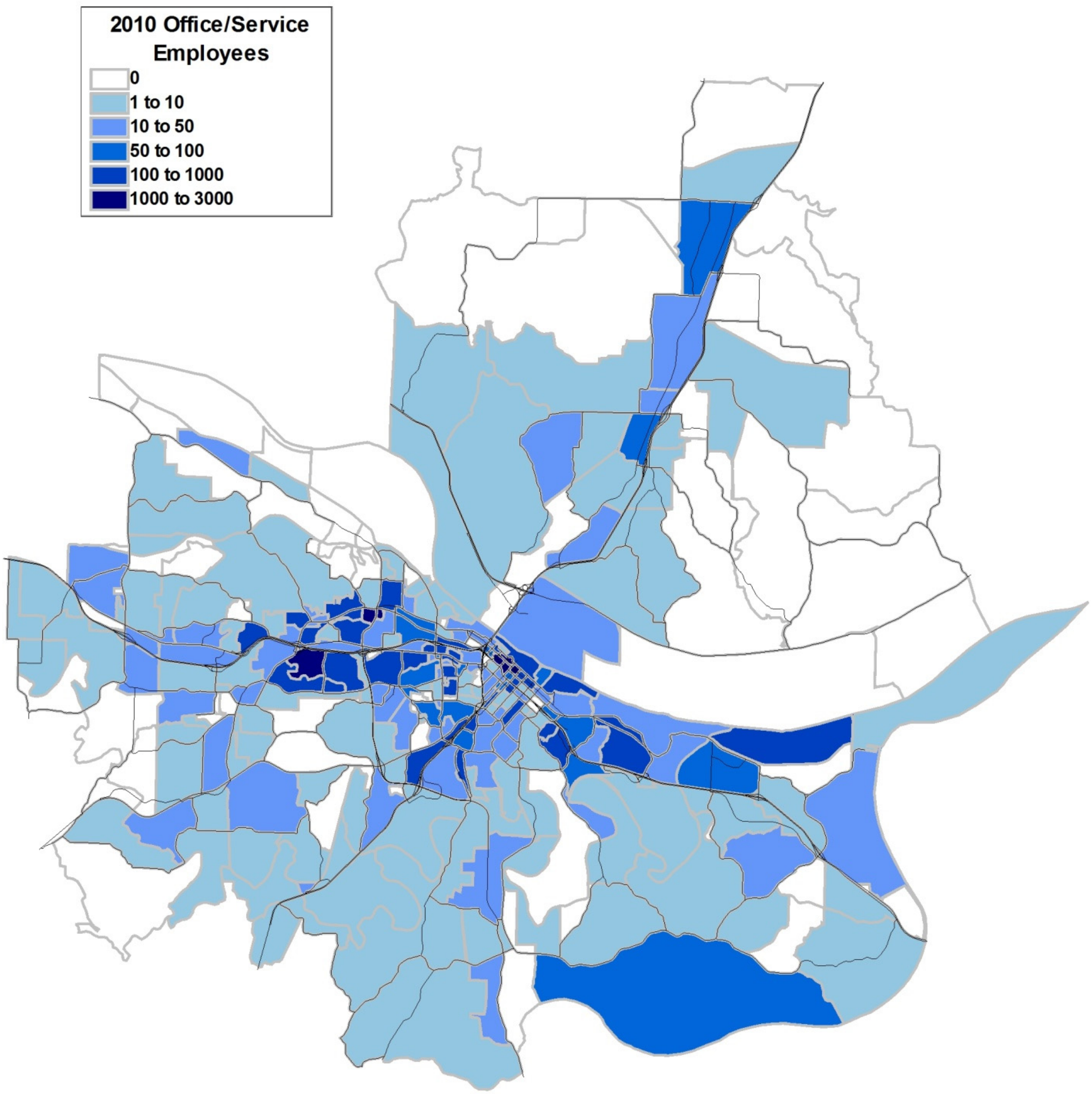


Figure 2-15: Trip Attraction Variables – Industrial/Warehouse Employees per TAZ

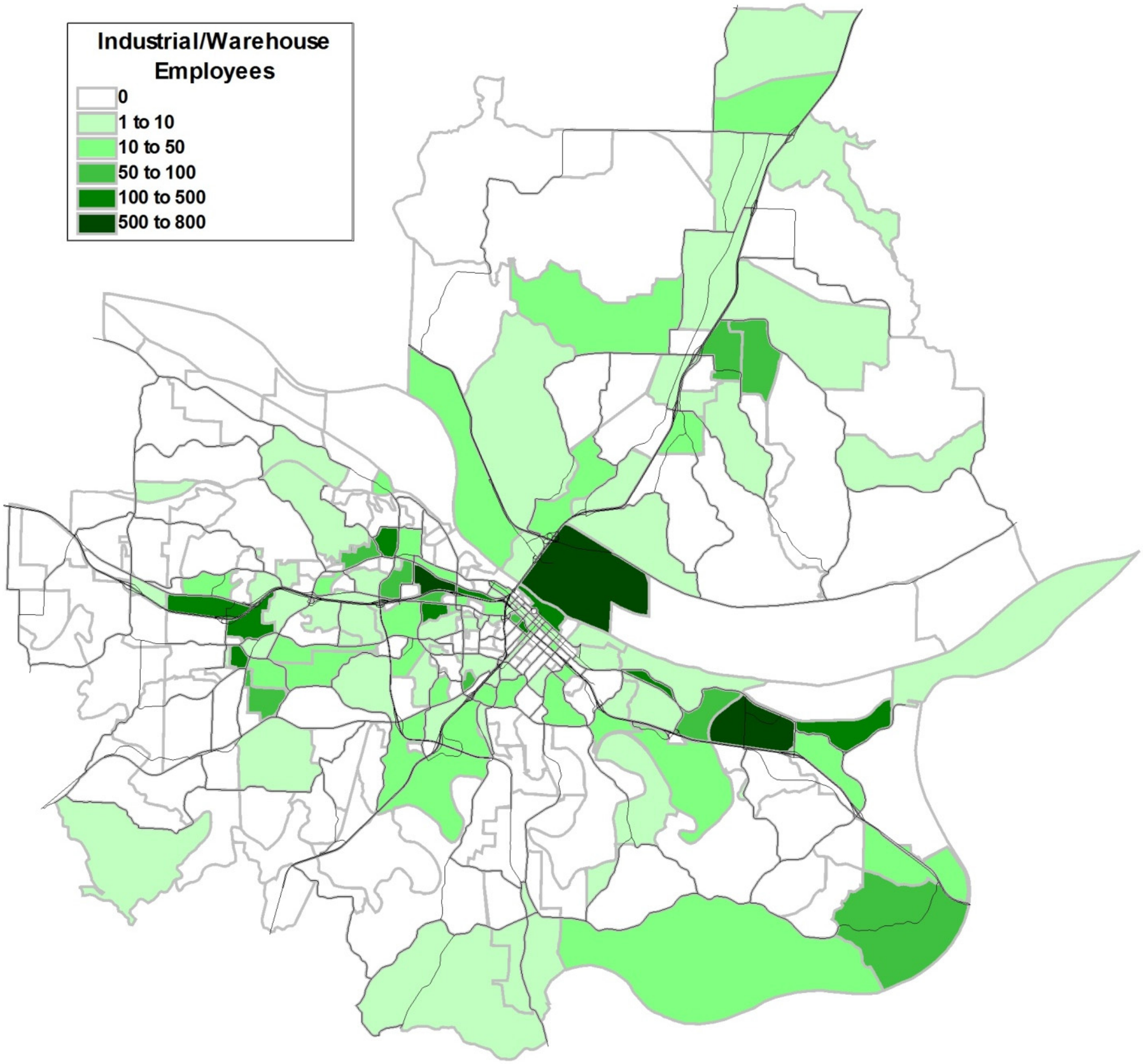
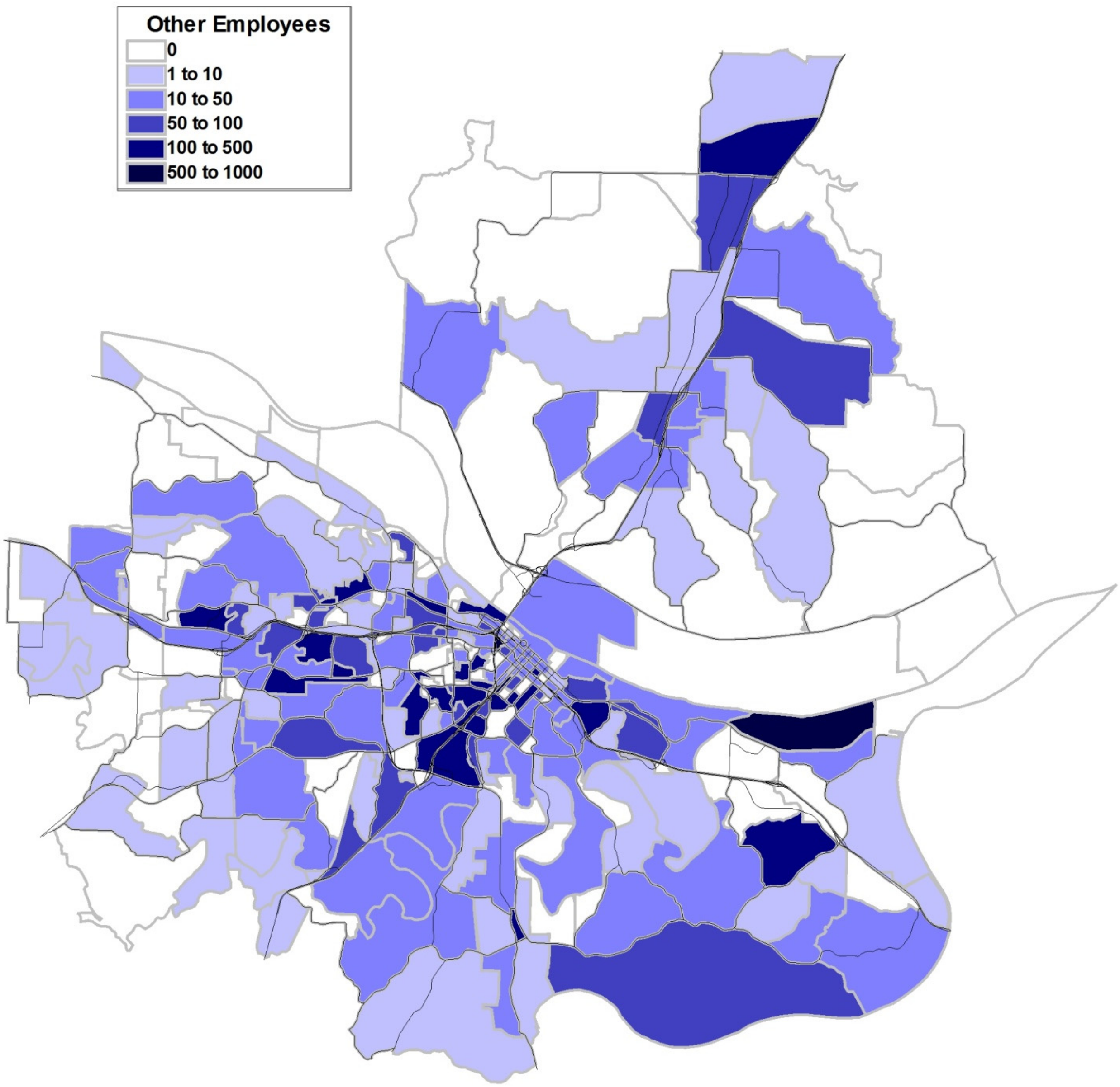


Figure 2-16: Trip Attraction Variables – All Other Employee Categories per TAZ



External Stations

Once the internal trip generation estimates were complete, it was necessary to prepare external station "trip generation" estimates. As mentioned previously, external stations are used to represent the physical locations at which vehicles can enter or leave the model. Rather than land-use and socioeconomic data, these externals are coded with trip ends broken out by purpose based on available count and survey data. **Figure 2-17** illustrates the counts at the model's 14 external stations.

Figure 2-17: External Station Volumes, 2010 Daily

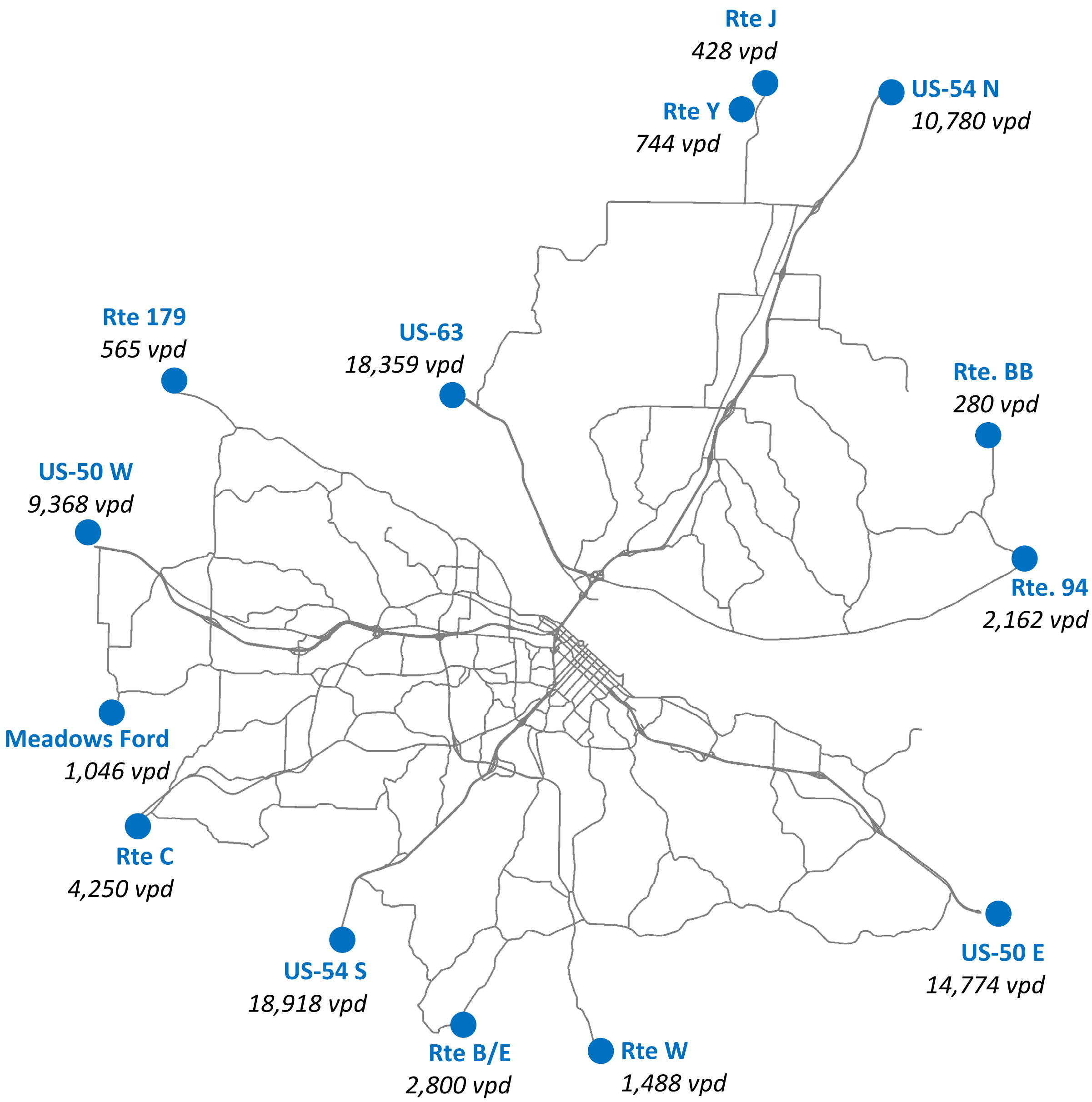


Table 2-8 contains the External-External (E-E) matrix, or “through” trip matrix, developed for the 2010 daily model. External station survey data was not available, therefore this matrix was developed using procedures from NCHRP 365 and NCHRP 716 as well as engineering judgment regarding regional travel patterns.

Table 2-8: E-E Matrix – 2010 Daily

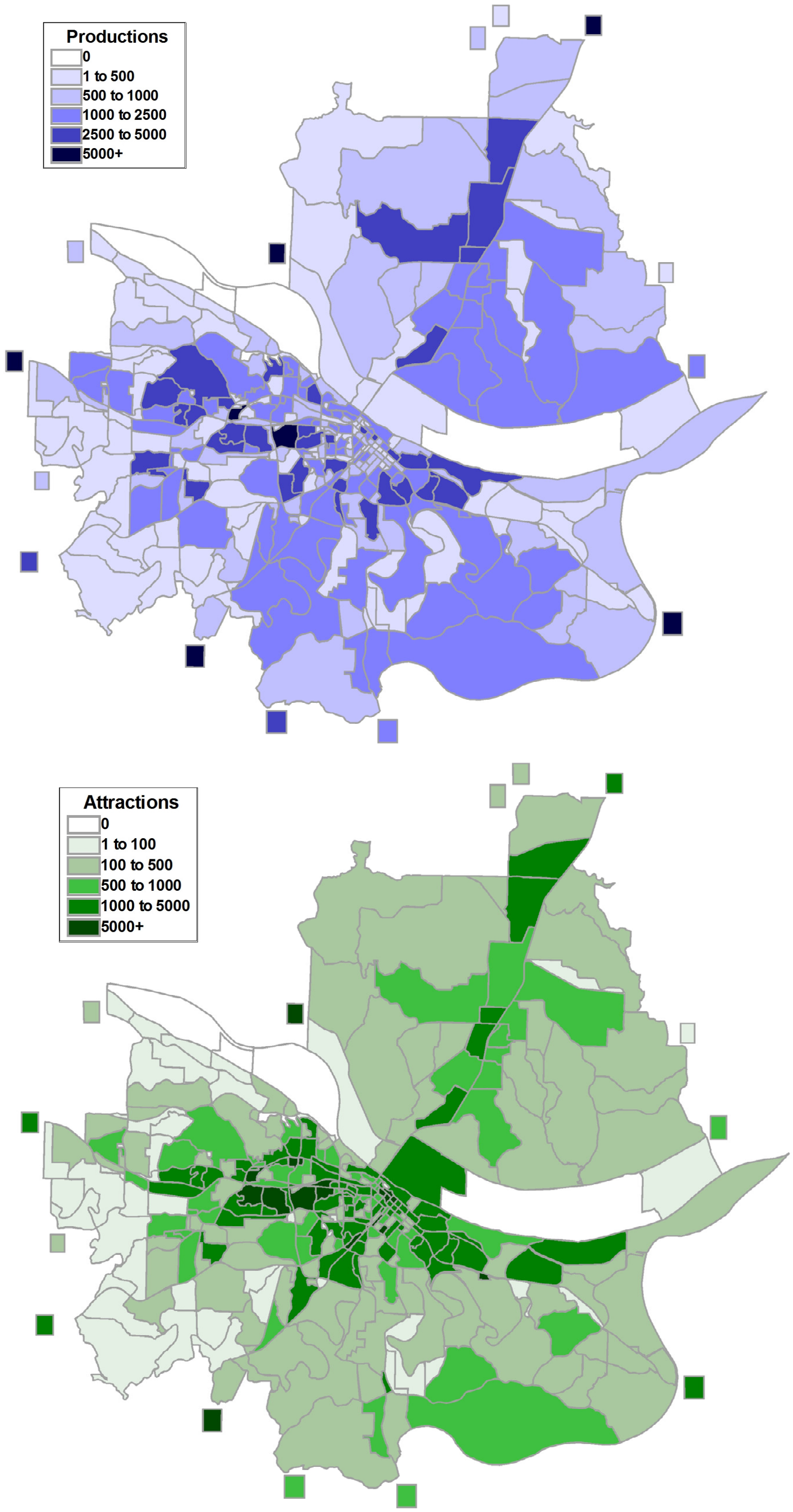
	401	402	403	404	405	406	407	408	409	410	411	412	413	414	E-E Sum	E-E 2-Way Sum	I-E/E-I Sum	Total External Volume
401	0	1	3	157	3	17	520	7	23	878	37	7	184	3	**1,840**	**3,687**	**14,679**	**18,359**
402	1	0	0	1	0	0	2	0	0	4	0	0	2	0	**10**	**22**	**724**	**744**
403	3	0	0	1	0	0	1	0	0	2	0	0	1	0	**10**	**13**	**408**	**428**
404	157	1	1	0	1	5	216	2	7	385	12	2	248	1	**1,040**	**2,077**	**8,700**	**10,780**
405	3	0	0	1	0	0	1	0	0	2	0	0	1	0	**10**	**28**	**260**	**280**
406	17	0	0	5	0	0	6	0	1	13	1	0	6	0	**50**	**108**	**2,062**	**2,162**
407	520	2	1	216	1	6	0	3	9	415	14	3	268	1	**1,460**	**2,913**	**11,854**	**14,774**
408	7	0	0	2	0	0	3	0	0	5	0	0	2	0	**20**	**45**	**1,448**	**1,488**
409	23	0	0	7	0	1	9	0	0	18	1	0	9	0	**70**	**140**	**2,660**	**2,800**
410	878	4	2	385	2	13	415	5	18	0	29	5	150	3	**1,910**	**3,815**	**15,098**	**18,918**
411	37	0	0	12	0	1	14	0	1	29	0	0	14	0	**110**	**213**	**4,030**	**4,250**
412	7	0	0	2	0	0	3	0	0	5	0	0	2	0	**20**	**31**	**1,006**	**1,046**
413	184	2	1	248	1	6	268	2	9	150	14	2	0	1	**890**	**1,779**	**7,588**	**9,368**
414	3	0	0	1	0	0	1	0	0	3	0	0	1	0	**10**	**28**	**545**	**565**
Sum	**1,840**	**10**	**10**	**1,040**	**10**	**50**	**1,460**	**20**	**70**	**1,910**	**110**	**20**	**890**	**10**	**7,450**	**14,901**	**71,062**	**85,962**

Balancing Productions and Attractions

As the trip productions and attractions are derived form different sources, the two values do not result in the same number of trips by purpose when summed over all TAZs. Therefore, it is necessary to balance the productions and attractions. Based on typical practice, and the fact that the resulting trip rates are reasonable compared to national averages, the trip production numbers were held constant across the trip purposes and the trip attraction numbers were modified to equal the trip productions. The trip attraction numbers, however, have distribution information regarding many non-home based trips that is useful for the allocation of non-home based trip productions. For example, an office-to-retail trip will be better assigned if the trip attraction locations (based on employment and other non-home variables) are used. Therefore, the NHB trip production locations were re-allocated to TAZs based on the distribution of NHB trip attractions.

Figure 2-18 illustrates the balanced productions and attractions per TAZ.

Figure 2-18: Productions and Attractions per TAZ, 2010



2.4: Trip Distribution

The purpose of the trip distribution step is to produce a trip table of the estimated number of trips from each TAZ to every other TAZ within the study area. The person-trip distribution for the CAMPO model uses TransCAD's Gravity Model routines. The Gravity Model assumes that the number of person-trips between two zones is (1) directly proportional to the person-trips produced and attracted to both zones, and (2) inversely proportional to the travel time between the zones.

For this model, the Gravity Model uses the gamma function shown at the bottom of **Table 2-9** as the primary travel-time-related impedance input. The gamma function calculates friction factors $F(t_{ij})$ for each zone pair based on the travel time (t_{ij}) between zones and three parameters (a, b, and c). Friction factors express the effect travel time has on the number of trips traveling between two zones. The calculation of friction factors differs by trip type reflecting the fact that some types of trips are more or less sensitive to trip length.

Table 2-9: Final Friction Factor (Gamma Function) Parameters

Trip Purpose	a	b	c
HBW	100	0.265	0.038
HBSCH	100	1.340	0.100
HBSR	100	1.017	0.085
HBO	100	1.017	0.065
NHBO	100	0.781	0.125

Gamma Function:

$$F(t_{ij}) = a t_{ij}^{-b} e^{-c(t_{ij})}$$

The parameters a, b, and c were initially derived from the "Small MPO" values in NCHRP Report 716. However, these parameters can vary based on model size and local travel behavior. During the model calibration process, these parameters were iteratively adjusted based on model results, including the reported trip lengths, keeping in mind the reasonable ranges described in NHCRP 716 (*Travel Demand Forecasting: Parameters and Techniques*). The final values used are displayed in **Table 2-9.**

The model also makes use of K-factors, which provide additional specific TAZ-to-TAZ attractiveness terms to the gravity equations. K-factors are developed for specific zone pairs and are then used in the Gravity Model equation.

Gravity Model Formulation

$$T_{ij}^{p} = P_{i}^{p} * \frac{A_{j}^{p} * f(t_{ij}) * K_{ij}}{\sum_{j' \in Zones} A_{j'}^{p} * f(t_{ij'}) * K_{ij'}}$$

Where:

T_{ij}^{p} = Trips produced in zone *i* and attracted to zone *j*;

P_{i}^{p} = Production of trips ends for purpose *p* in zone *i*;

A_{j}^{p} = Attraction of trip ends for purpose *p* in zone *j*;

$f(t_{ij})$ = Friction factor, a function of the travel impedance between zone *i* and zone *j*, often a specific function of impedance variables (represented compositely as t_{ij}) obtained from the model networks; and

K_{ij} = Optional adjustment factor, or "K-factor," used to account for the effects of variables other than travel impedance on trip distribution.

The default K-factor between two zones is 1; however, this can be increased or decreased to adjust the trip distribution to account for factors other than travel-time related impedance. For the CAMPO model K-factors were used during model calibration to improve the trip distribution results for specific trip purposes in specific geographic areas. For example, in order to minimize HBSCH trips from outside of Wardsville to the schools in Wardsville and vice versa, a k-factor of 0.01 was applied to all HBSCH trips traveling between the TAZs roughly representing the Blair Oaks School District and the rest of the model. The K-factors currently in use in the model include:

- HBSCH trips to/from TAZs representing Blair Oaks School District and TAZs in the remainder of the model (k-factor 0.01)
- HBSCH trips to/from TAZs in the vicinity of Belair elementary school to the TAZ with the school (k-factor greater than 1)

- HBSHOP trips within Holt's Summit and surrounding areas (k-factor 1.5)

Person-trips were distributed separately for the five trip purposes. The number of trips to be assigned was calculated using the base year land-use/socioeconomic data and trip production/attraction rates by trip purpose. Data from the external TAZs were combined with the internal TAZ trips to create the total productions and attractions for the model. The productions and attractions were balanced to ensure that for each production generated by the model, there was an attraction. **Table 2-10** summarizes the person trips by trip purpose for the complete model area.

Table 2-10: 2010 Person Trip Summary

Trip Purpose	Person Trips	Percent Trips
HBW	77,729	19%
HBSCH	27,562	7%
HBSHOP	59,453	14%
HBO	133,781	33%
NHB	112,273	27%
Total Trips	**410,798**	**100%**

Trip Length Distributions (TLDs)

The gamma function is the mathematical tool used to distribute trips in manner consistent with reasonable trip lengths by trip purpose. For example, HBW trips tend to be longer than HBSHOP trips. **Figure 2-19** shows the friction factors calculated based on the parameters shown in **Table 2-9**. This yielded average trip lengths that were generally consistent with, but also near the low end of, the values presented in NCHRP 365 and NCHRP 716. The resulting average trip lengths are presented in **Table 2-11** and the trip length distributions by trip purpose are presented in **Figure 2-20**.

Figure 2-19: Friction Factors

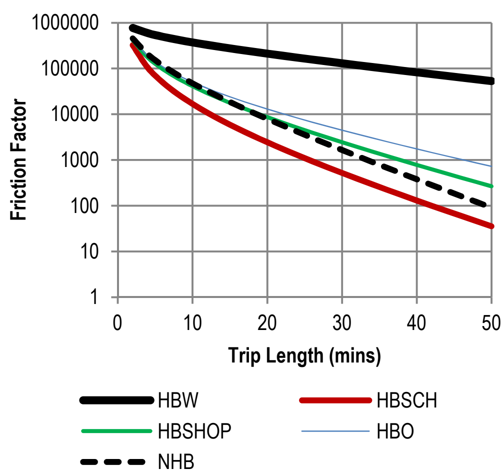
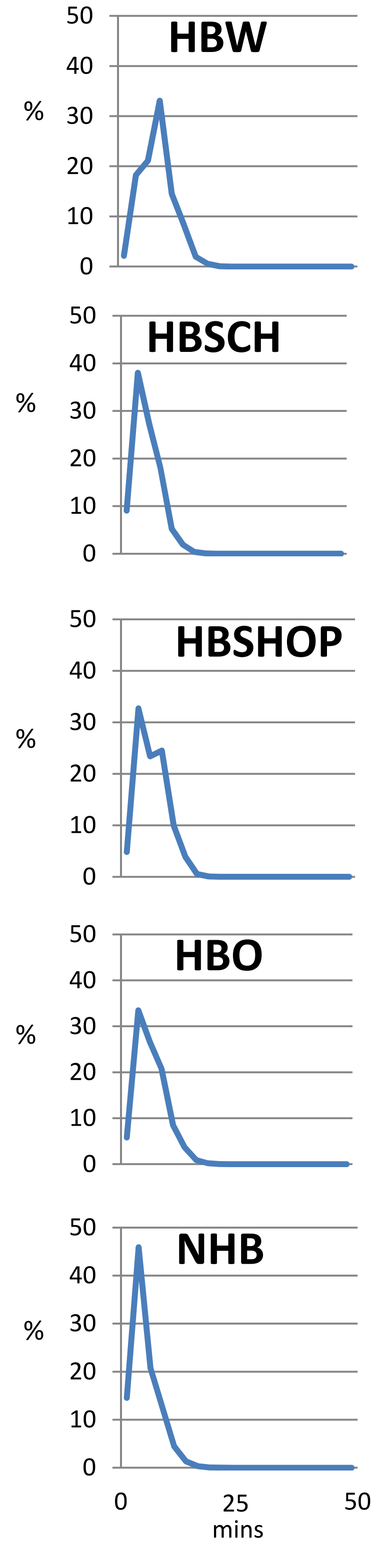


Table 2-11:
Average Trip Lengths (minutes)

Trip Purpose	CAMPO Model	Industry Guidelines NCHRP 716	NCHRP 365
HBW	16.22	20	15
HBSCH	11.43	15	11.25
HBSHOP	13.26	18	11.25
HBO	12.86	18	11.25
NHB	10.05	18	11.25

Figure 2-20: Trip Length Distribution Percentages



2.5: Daily Trip Assignment

The purpose of trip assignment is to assign vehicle trips to specific paths, or routes, in the transportation network. Trip assignment is a function of (1) the shortest travel time (or travel cost function) along paths between zones, and (2) the level of congestion on the links that make up those paths. Vehicle trips for the study area were assigned to the transportation network using the TransCAD Stochastic User Equilibrium (SUE) Assignment Algorithm.

TransCAD provides several traffic assignment methods. The SUE method is based on the commonly used User Equilibrium (UE) assignment method. The UE method uses an iterative process to achieve a convergence in which no travelers can improve their travel times by shifting routes. However, the SUE method produces more realistic assignment results compared to the UE method, because SUE permits use of less attractive as well as the most attractive routes. Less attractive routes will have lower utilization, but will not have zero flow as they do under the UE method.

Input to the SUE assignment is a vehicle origin-destination trip table and the roadway network. Then, the vehicle trip table is assigned to the network based on the modified equilibrium assignment method. The SUE assignment is premised on the assumption that travelers have imperfect information about the network paths and/or vary in their perceptions of network attributes. Equilibrium occurs when a trip in the system cannot be made by an alternate path without increasing the total travel time of all trips in the network. The model convergence is set at 0.005. Thus, when the relative gap between runs reaches this level, the assignment terminates successfully.

The assignment process assigns both **internal** and **external** vehicle trips to the network. **Internal** vehicle trips are those trips with either an origin or a destination inside the study area. The gravity model described in the previous section produces an internal person-trip table which is converted to a vehicle trip table using vehicle occupancies and directionality data. These trips can be classified as either internal-to-internal, internal-to-external, or external-to-internal. However, vehicle trips travelling through the study area must also be assigned to the network. **External-to-external** trips are through trips - those with both an origin and destination outside of the study area.

The production and attraction (PA) matrix defines the person-trips between zones, but it is based on where trips are produced and attracted, not origins and destinations. For example, a HBW round-trip will have two productions in the home zone and two attractions in the work zone. Therefore, a transformation is required to convert the PA person-trip matrix to an O-D vehicle trip matrix. For a daily run, it is assumed that trips are 50 percent in each direction (round-trips). Therefore, the model transforms productions and attractions into balanced origins and destinations, and a vehicle occupancy is applied to convert person-trips to vehicle trips. Therefore, assuming a vehicle occupancy greater than one person per vehicle, the sum of vehicle trips in the O-D matrix will be less than the sum of person-trips in the PA matrix.

Vehicle occupancy rates by trip purpose were based on national statistics and experience with other models. As shown in **Table 2-12**, the home-based school trips have the highest vehicle occupancy at 1.83 persons per vehicle. The other non-work trip types are in the 1.44 to 1.51-person-per-vehicle range. Home-Based Work trips are lowest, at 1.10 persons per vehicle.

Table 2-12: Vehicle Occupancy by Purpose – 2010 Daily

Trip Purpose	Vehicle Occupancy
HBW	1.10
HBSCH	1.83
HBSHOP	1.44
HBO	1.51
NHB	1.50

Volume-Delay Function

The SUE traffic assignment method uses a volume-delay function to estimate the travel time on any given link for a forecasted volume. In general, travel time on a link increases as the traffic volume on the link approaches capacity. The volume-delay function and parameters selected for a particular model define that relationship.

For the CAMPO model, a volume-delay function was selected that is based on the Bureau of Public Roads (BPR) Function. The basic BPR function has three key input variables: free-flow travel time, volume (flow), and capacity. The remaining inputs are based on the functional class of the roadway. The theory is that congested travel time is a function of free-flow travel and the volume-to-capacity ratio. **Table 2-13** includes the BPR function and the parameters used for the CAMPO model.

Figure 2-21 shows the results of the 2010 daily model assignment as a bandwidth plot with heavier volumes shown as heavier lines in the figure. The detailed results of the 2010 daily model are evaluated in the trip calibration section and available for review as GIS files.

Table 2-13: Volume-Delay Function Parameters – 2010 Daily

Functional Classification	Facility Type	α	β
1	Freeway	0.312	5.883
2	Expressway*	0.312	5.883
3	Principal Arterial	0.514	3.001
4	Secondary Arterial*	0.514	3.001
5	Collector	0.514	3.001
6	Local	0.514	3.001
7	Ramp	0.312	5.883
8	System-to-system Ramp	0.312	5.883

** Reserved, but currently unused by model*

Volume-Delay Function (Congested cost)

$$cc_i = fc_i \cdot \left[1 + \alpha_i \left(\frac{x_i}{C_i} \right)^{\beta_i} \right]$$

Where:

cc_i = Congested travel cost (time) on link *i*

fc_i = Free-flow travel cost (time) on link *i*

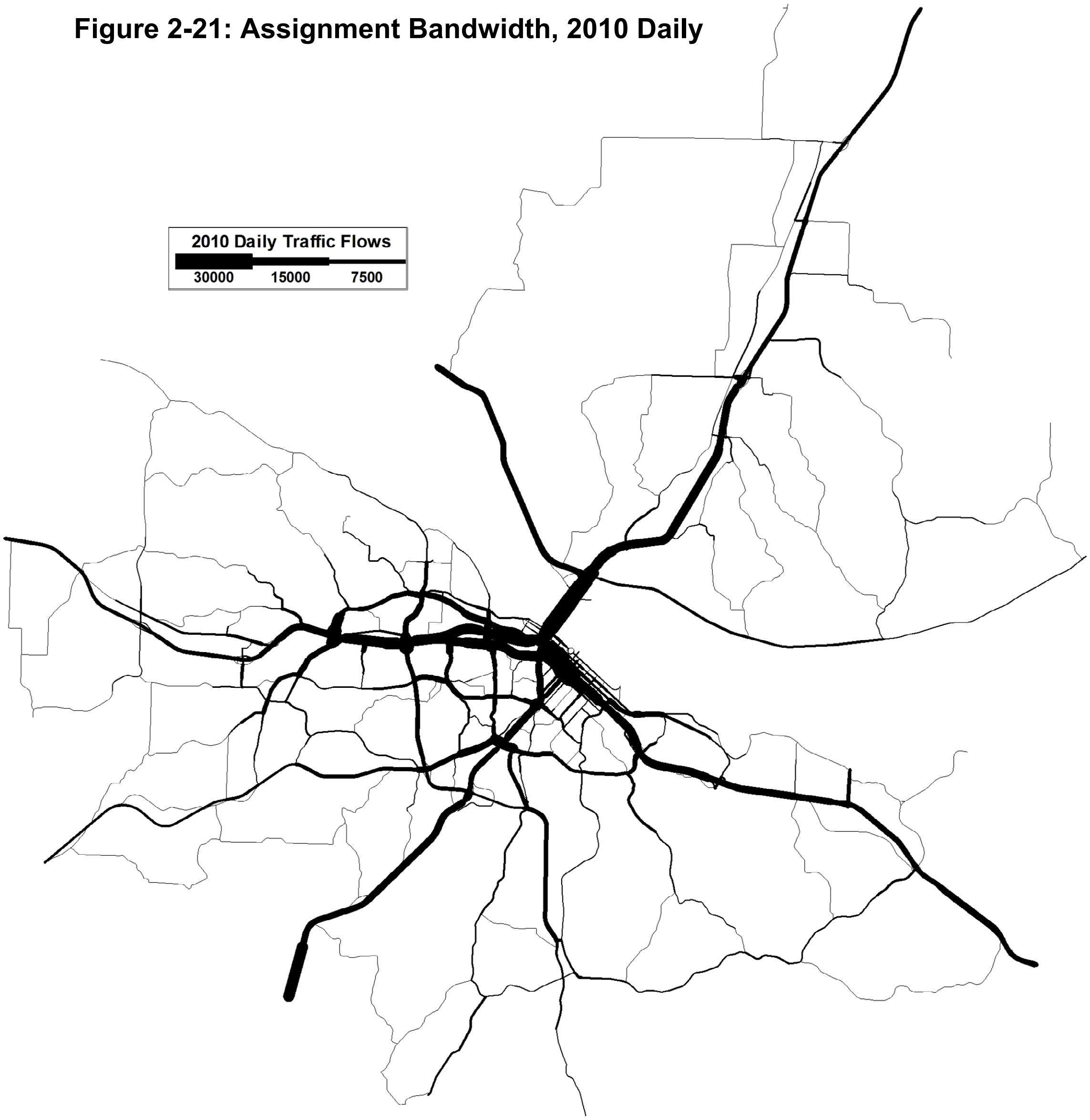
x_i = Volume (flow) on link *i*

C_i = Capacity of link *i*

α_i = Constant

β_i = Constant

Figure 2-21: Assignment Bandwidth, 2010 Daily



2.6: Peak Hour Trip Assignment

Peak-Hour Trip Table

The peak hour trip assignment procedure uses the daily model vehicle trip table and then estimates the portion of the daily trips that will occur during the peak hours of interest. The CAMPO model has been developed to provide PM peak hour volume estimates that can be used for future network planning.[1] The procedure for deriving the PM peak hour flows from the daily model flows includes the use of a table defining the percent of each trip purpose category (by direction) that is expected in that peak hour. The table also defines any peak hour adjustments to the daily vehicle occupancies. The values used to generate the PM peak hour volumes are listed in **Table 2-14**.

Table 2-14: P.M. Peak Hour Traffic Flows by Purpose

	% of Daily Flow	% Departing	% Returning	Vehicle Occupancy
HBW	12.7%	4%	96%	1.10
HBSCH	5.8%	26%	74%	1.83
HBSHOP	10.5%	43%	57%	1.44
HBO	10.5%	43%	57%	1.51
NHB	8.5%	50%	50%	1.50

The values used in **Table 2-14** were originally taken from NCHRP 716, with adjustments made based on a comparison of the model results to actual PM peak hour intersection turning movement counts at key locations (discussed below). These values are used to develop the PM peak-hour vehicle trip table. The summary of the PM peak hour vehicle trips (excluding external-external trips) by trip purpose is shown in **Table 2-15**.

Table 2-15: 2010 P.M. Vehicle Trips by Purpose

Trip Purpose	Trips
HBW	9,360
HBSCH	890
HBSHOP	4,067
HBO	9,589
NHB	6,729
Total	**30,635**

PM Peak-Hour Trip Assignment

The PM peak-hour vehicle trip table is assigned to the model network in a manner similar to the daily assignment. To accomplish this, additional PM peak-hour model parameters must be populated. First, peak hour link capacities were defined. For the CAMPO model, they were assumed to be 10 percent of the daily capacities. (The peak-hour speeds and number of lanes were assumed to be the same as in the daily model.) Second, it was necessary to develop a PM peak-hour external-external (E-E) matrix. The PM peak hour E-E matrix was assumed to be 10 percent of the daily E-E matrix. With these additional inputs, it was possible to assign the PM trip table to the model network and provide an estimate of PM peak hour flows.

Intersection Analysis

The eleven locations shown in **Figure 2-22** were selected as “critical” intersections. They are located all around the region and were selected together with, and approved by, the CAMPO Board and staff. The PM peak hour assignments were compared to actual traffic counts at these 11 intersections. (Dates of current available traffic counts ranged from 2009 to 2012). Based on that comparison, a variety of network and other model adjustments were made to improve the PM results. These changes had the benefit of improving the daily results as well. Overall, the PM peak hour assignment estimates the

[1] The model also includes data for AM peak hour estimates, but those results were not part of the original model scope and were therefore not calibrated.

intersection approach volumes at an adequate planning level. It does not focus on extreme accuracy at the turning-movement level, but it does appear sufficient for planning-level applications. A post-processing spreadsheet was used to calculate the model over/under–estimation; this spreadsheet was employed for the future year intersection analysis.

To provide a baseline level of service analysis for the 11 key locations, the existing traffic counts were adjusted to an assumed 2010 base year (using a 2% annual growth rate, which, in the case of 2011-2012 counts, meant "backwards factoring") and entered into the Synchro intersection analysis software. The existing intersection geometry and signal timing/traffic control were also entered. (CAMPO and its member agencies provided nine of the eleven traffic counts as well as all of the necessary signal timing data.) The summary results of the intersection analysis are presented in **Table 2-16**. From that table, it is clear that all of the signalized intersections, as well as the critical unsignalized movements, currently operate adequately (LOS D or better) at all 11 locations. Two intersections, however, have individual movements that operate at LOS E.

Figure 2-22: Study Intersection P.M. Peak Hour Turning Movement Volumes (Adjusted from Counts), 2010 Daily

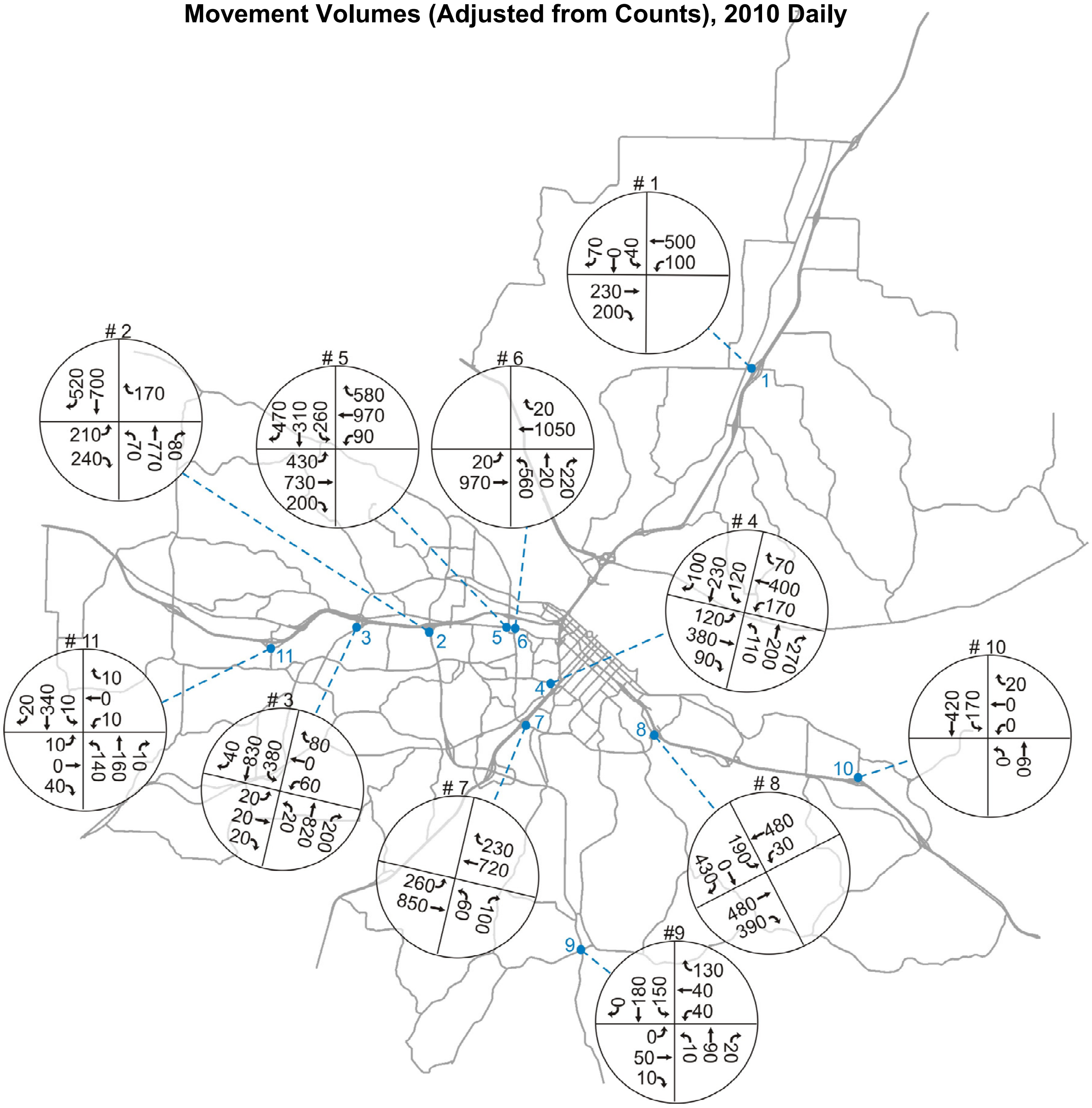


Table 2-16: 2010 P.M. Peak Hour Intersection Analysis

		Sig/Unsig*	Delay	LOS
1.	US-54 SB Ramps & Simon Blvd	U	24.6 (SB)	C
2.	Missouri Blvd EB Ramps & Rte. 179	S	13.9	B
3.	US-50 EB/Horner Rd & Truman Blvd	S	18.3	B
4.	Stadium Blvd & Jefferson St	S	34.0	C ǂ
5.	Missouri Blvd & Dix Rd	S	29.9	C ǂ
6.	Missouri Blvd & Beck St	S	19.3	B
7.	US-54 NB Ramps & Ellis Blvd	S	23.8	C
8.	US-50/63 EB Ramps & Eastland Dr	S	10.7	B
9.	Rte. B/W/M**	U	16.9 (WB)	C
10.	US-50/63 WB Ramps & Militia Dr	U	8.7 (WB)	A
11.	US-50 EB/Horner Rd & Big Horn Dr	U	15.7 (WB)	C

**For unsignalized intersections the delay/LOS reported are for the worst movement at the intersection.*

***Intersection 9 was analyzed as a two-way stop (east-west stop) because Synchro does not allow analysis of the actual configuration (3-way stop at a 4-way intersection).*

ǂ One or more movements operate at LOS E.

2.7: Model Calibration/Validation

Calibration is an iterative process that involves enhancing or adjusting input data, program coefficients or parameters, and assumptions with the goal of replicating observed travel-related data. Each element of the travel demand model, from the network and land-use assumptions to the traffic assignment parameters, is subject to calibration until the model sufficiently represents the base year conditions. Once the travel demand model is calibrated, the resulting outputs are validated and checked for reasonableness. Preferably, this second step would employ new data sets that differ from those used to originally calibrate the model.

The model calibration should ultimately result in traffic volumes that that are within selected tolerances of actual traffic count data. If the calibrated model can replicate the current traffic data and patterns with sufficient accuracy, and if the results are determined to be valid, then it is ready for use in forecasting. Setting the allowable level of variation is an important step in this process. While differences are unavoidable, the acceptable amount will vary by topic, magnitude, and sample size. Once the model has passed the calibration and validation tests, it would be expected to yield reasonable future-year volumes for transportation planning purposes, given a future year socio-economic / land-use scenario.

Two documents that play a central role in the calibration and validation steps are: *NCHRP 716 Travel Demand Forecasting: Parameters and Techniques* (Cambridge Systematics, 2012) and *Travel Model Validation and Reasonableness Checking Manual 2nd Ed.* (Cambridge Systematics, 2010). The remainder of this section will present the model calibration and validation results for each component of the model as well as the model outputs.

Trip Assignment

Several tests were applied to make sure that the 2010 model was calibrated and valid (see box at right). The calibration steps check to see if the model sufficiently represents the traffic volumes and patterns, while the validation step then compares the results to other data sets.

Assignment Performance Measures

Percent Assignment Error
Root Mean Square Error (RMSE)
Coefficient of Determination (R^2)
Screenline Analysis

Percent Assignment Error

The assigned 2010 daily traffic volumes were compared with the counted daily traffic volumes for individual links. **Figure 2-23** shows the predicted vs. actual traffic volumes. The link segments included in the percent error evaluation (i.e. those with counts) are shown in **Figure 2-24**.

Table 2-17 illustrates the percent assignment error, which is the difference between the assigned traffic volumes and the counted traffic volumes divided by the counted traffic volumes. The report *Travel Model Validation and Reasonableness Checking Manual 2nd Ed.* presents the error limits used for various models. This analysis employs the values recommended by the FHWA in their 1990 report: *Calibration and Adjustment of System Planning Models*. The computed percent error is given in **Table 2-17** in comparison to the suggested error limits. The percent error of the traffic assignment for the network as a whole was -4.0 percent, and the errors for the individual functional classifications were within acceptable tolerances.

Figure 2-23: Predicted vs. Actual Volumes

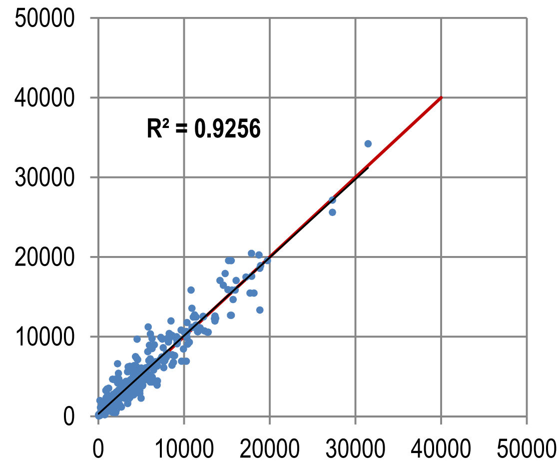


Table 2-17: Percent Assignment Error – 2010 Daily

Functional Class	Percent Error: Computed	Percent Error: Suggested Range*
Freeway	2.3%	±7%
Primary Arterial	-6.8%	±10%
Collector	-14.0%	±25%
Local	0.3%	±25%
Overall	**-4.0%**	±5%

*Source: *Calibration and Adjustment of System Planning Models,* Federal Highway Administration, December 1990. The original published values use a slightly different functional classification system:

Freeways	± 7%
Principal Arterials	± 10%
Minor Arterials	± 15%
Collectors	± 25%
Frontage Roads	± 25%

Figure 2-24: Link Counts for Model Calibration

Coefficient of Determination

Another tool to measure the overall model accuracy is the coefficient of determination or R^2 (see formula at right). The R^2, or "goodness of fit", statistic shows how well the regression line represents the assignment data. The desirable R^2 is 0.88 or higher. A value of 1.00 is perfect, but even if traffic counts were compared against themselves, the daily variation would not allow for a regression coefficient of 1.00. The value of **0.926** achieved illustrates a good fit between the model output and the available counts.

Coefficient of Determination

$$R^2 = \left(\frac{n\sum(x_i y_i) - \left(\sum x_i\right)\left(\sum y_i\right)}{\sqrt{\left[n\sum x_i^2 - \left(\sum x_i\right)^2\right]\left[n\sum y_i^2 - \left(\sum y_i\right)^2\right]}} \right)^2$$

Where:
x = counts
y = model volumes
n = number of counts

Root Mean Square Error

Another measure of the model's ability to assign traffic volumes is the percent RMSE. The RMSE measures the deviation between the assigned traffic volumes and the counted traffic volumes; the calculation is shown at the bottom of **Table 2-18**. A large percent RMSE indicates a large deviation between the assigned and counted traffic volumes; whereas, a small percent RMSE indicates a small deviation between the assigned and counted traffic volumes. The percent RMSE by facility type for the study area is given in **Table 2-18**.

Currently, there are no national standards for model verifications of RMSE. However, a number of DOTs have adopted guidelines by link volume group. The Oregon Department of Transportation values are employed here as a guideline by link volume group along with the Montana Department of Transportation recommendation that a model have an overall RMSE of 30 percent or lower. For all volume ranges, the model values are under the recommended guidelines.

Table 2-18: Percent Root Mean Square Error (RMSE) – 2010 Daily

Volume Ranges	RMSE	Guidelines*
20,000 to 39,999	7.8%	25.4%
10,000 to 19,999	16.2%	28.3%
5,000 to 9,999	23.9%	43.1%
0 to 4,999	45.2%	115.8%
Overall	**26.4%**	**30.0%**

* Source: *Minimum Travel Demand Model Calibration and Validation Guidelines for State Of Tennessee*

$$\%RMSE = \frac{100 * \sqrt{\frac{\sum_j (Model_j - Count_j)^2}{(NumberofCaunts - 1)}}}{\left(\frac{\sum_j Count_j}{NumberofCaunts}\right)}$$

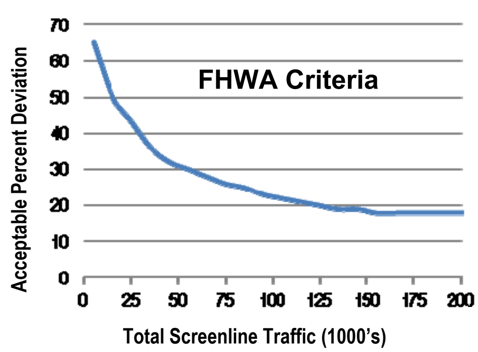
Screenline/Cutline Analysis

A screenline or cutline is an imaginary line crossing all (screenline) or a portion (cutline) of the model area and intersecting a number of network links. Typically, these lines divide the model area into logical regions or cut across major travel routes. A screenline analysis compares the results of a trip assignment with the traffic counts on network links along that screenline. More precisely, the process compares the sum of daily traffic count volumes across a screenline with the sum of assigned daily traffic volumes across the same screenline.

The average of ratios over all the screenlines can be also used to measure the overall accuracy of the model. The screenlines and associated volumes used in this analysis are included in **Table 2-19**. The locations of the screenlines are shown graphically in **Figure 2-25**.

Table 2-19: Screenline Analysis – 2010 Daily

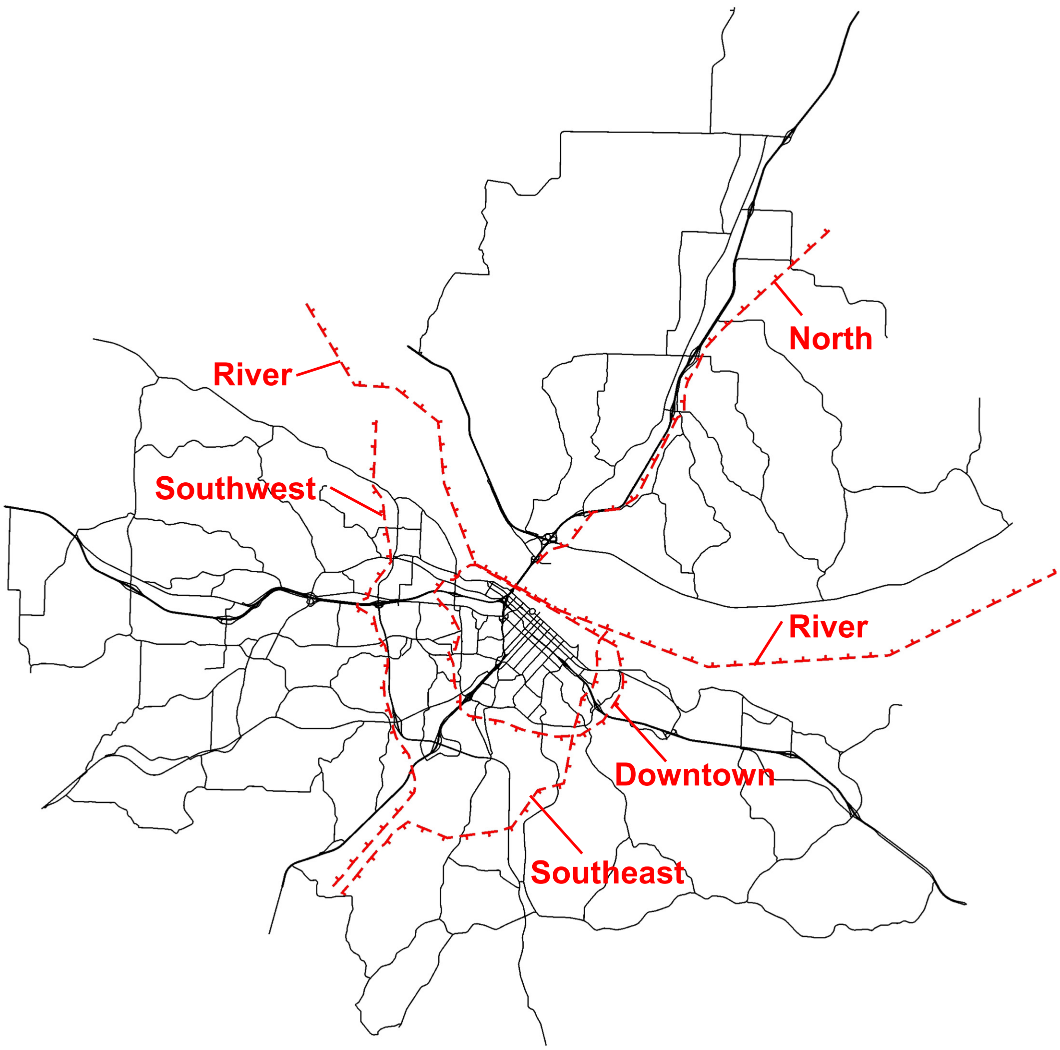
Screenline	Model Volume	Traffic Count	% Diff	FHWA Allowable %
North	18,358	17,052	8%	± 45%
River	54,606	52,757	4%	± 30%
Southeast	57,710	52,445	10%	± 30%
Southwest	98,786	98,398	0%	± 22%
Downtown	214,725	208,758	3%	± 18%
Total	**444,185**	**429,410**	**3%**	



Source: NCHRP 255 p.49 (cited in FHWA, *Calibration and Adjustment of System Planning Models, Dec. 1990)*

At the conclusion of each model run, assigned volumes from the run were compared against the screenline count data. The resulting deviations were compared against acceptable levels of error as outlined in NCHRP 255 report (illustrated in the graph below **Table 2-19**).

Figure 2-25: Screenline Locations

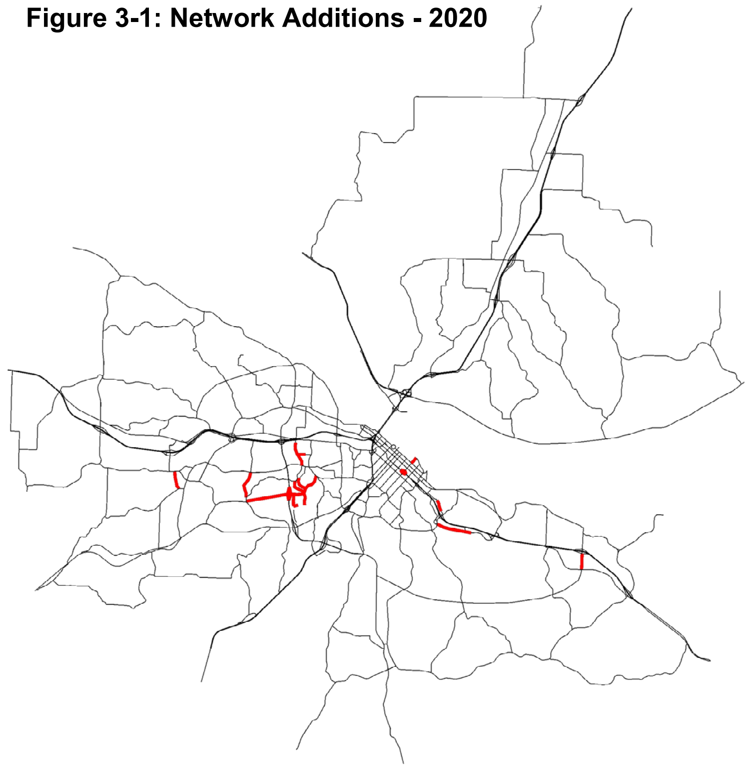


Chapter 3: 2020 Model

3.1: Year 2020 Roadway Network

To create the network for the 2020 model scenario, modifications were made to the 2010 model network to expand to the street system to include the new roadway facilities currently being planned for construction by 2020. The location, type, and characteristics of these facilities were provided by CAMPO staff. **Figure 3-1** highlights the new network links that were added.

Figure 3-1: Network Additions - 2020



In order to maintain one network for all model scenarios, attributes were added to the network to indicate which links are only in the future scenarios. If there is a "1" in the [2020] field, then the model uses the link in the 2020 scenario.

Roadway Link Attributes

No adjustments were made to existing roadways to account for capacity expansions in the 2020 model scenario. Similarly, functional classes, lanes, posted speeds, median type, and directionality remained unchanged for existing links. The attributes for the new links were provided by CAMPO staff and then coded in accordance with the procedures used for the 2010 model network.

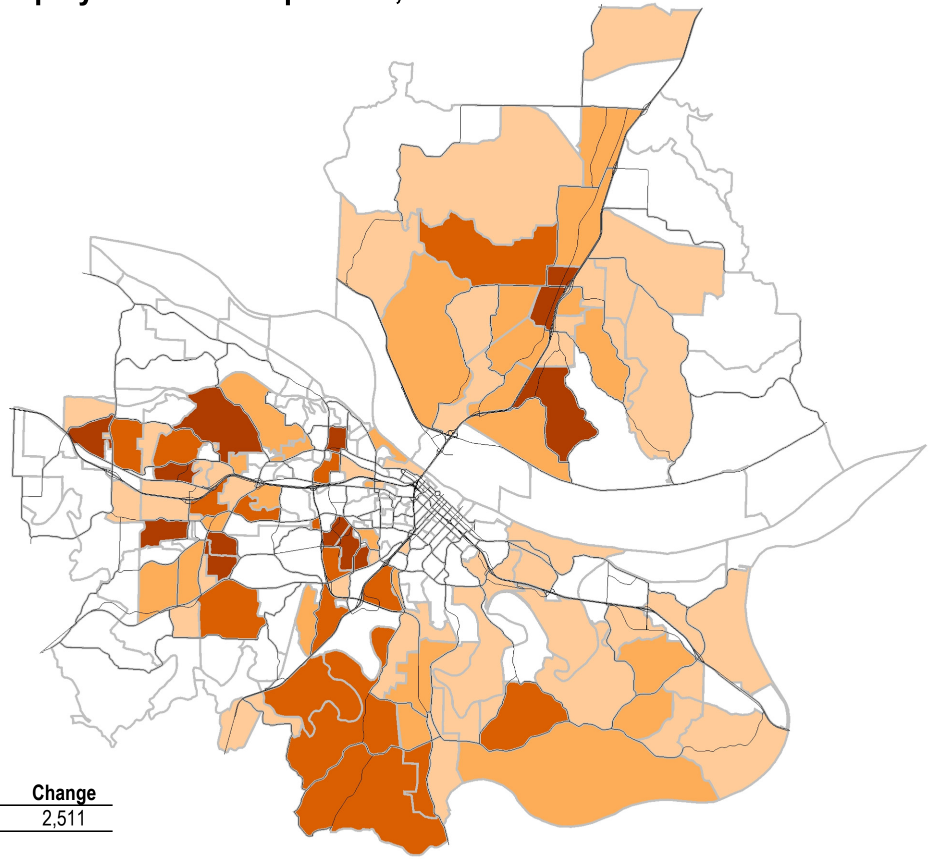
Turn Penalties

Global turn penalties shown previously in Chapter 2 were also used in the 2020 model. No additional turn penalties were added to the model to create the 2020 network.

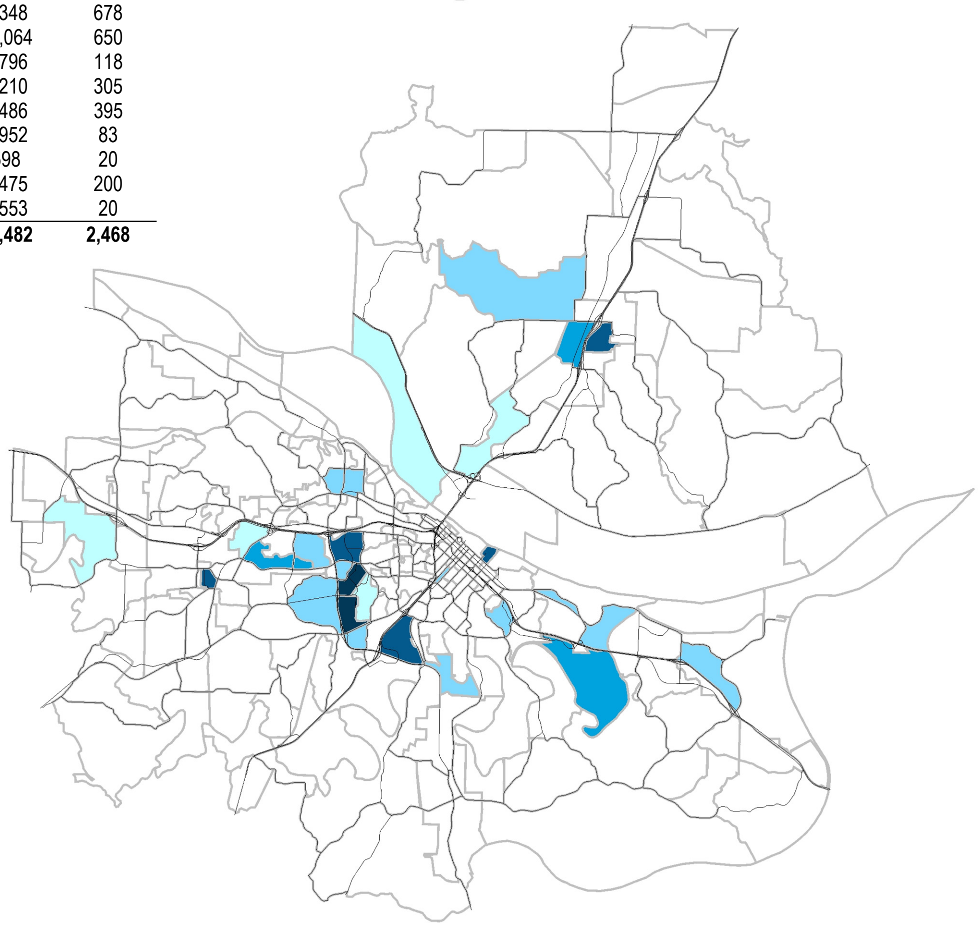
3.2: Year 2020 Land Use/Socioeconomic Data

The TAZ structure created for the 2010 model was left unaltered for the 2020 model. However, the most significant change between the 2010 and 2020 models was assumed growth, translating to more households and employment in various parts of the model. **Figure 3-2** summarizes the 2020 model land-use in comparison to the 2010 model, and maps the projected growth in households and employment per TAZ.

Figure 3-2: Household and Employment Growth per TAZ, 2010 – 2020

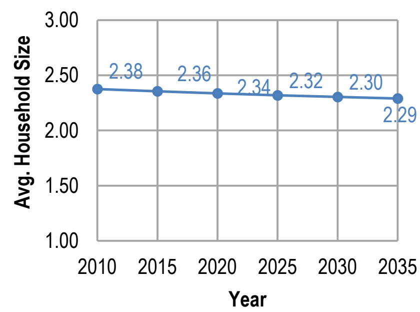


	2010	2020	Change
Households	31,052	33,563	2,511
Employees:			
Retail	4,670	5,348	678
Office/Service	24,414	25,064	650
Education	2,678	2,796	118
Medical	4,905	5,210	305
Industrial	4,091	4,486	395
Warehouse	1,869	1,952	83
Entertain/Recr	578	598	20
Retail – High Density	3,275	3,475	200
Other	3,533	3,553	20
Total Employees	**50,014**	**52,482**	**2,468**



Another change made to the future-year socioeconomic data related to household size. As "the baby boom" population continues to age, average household sizes have begun to decrease. This trend is expected to continue into the future. The model accounted for this by assuming smaller household sizes for all new households in future scenarios (1.90 for households added by 2020; 1.80 for households added between 2020 and 2035). When mixed with the existing housing stock in the CAMPO model area, this assumption resulted in the decreasing trend shown in **Figure 3-3.**

Figure 3-3:
Forecasted Household Size Trends



3.3: Trip Generation

Trip generation for 2020 uses the same procedures used for 2010 conditions (see Chapter 2). The same five trip purposes are used, and the trip production/attraction rates are carried forward.

Trip Productions and Attractions

Table 3-1 summarizes the estimated productions and attractions by trip purpose for the 2020 model, in comparison to the 2010 model. As the table indicates, the 2020 model results in 51,400 additional trips (productions plus attractions) compared to the 2010 model.

Table 3-1: Productions + Attractions by Purpose - 2020

Trip Purpose	2010	2020	New Trips
HBW	155,458	165,935	10,477
HBSCH	55,125	56,948	1,823
HBSHOP	118,907	127,055	8,148
HBO	267,562	283,724	16,162
NHB	224,548	239,359	14,811
Total	**821,600**	**873,021**	**51,421**

External Stations

To develop 2020 external station volumes, historical growth rates were extrapolated forward in a reasonable manner on a location-specific basis. **Table 3-2** includes the 2020 E-E matrix. External stations are forecasted to carry 5,700 more daily vehicles in 2020 than in 2010.

Table 3-2: E-E Matrix – 2020 Daily

	401	402	403	404	405	406	407	408	409	410	411	412	413	414	E-E Sum	Two-way EE	I-E/ E-I Sum	Total External Volume
401	0	1	3	202	6	21	596	11	25	907	40	7	194	7	2,020	4,047	15,919	19,959
402	1	0	0	2	0	0	2	0	0	3	0	0	1	0	10	25	824	844
403	3	0	0	1	0	0	1	0	0	2	0	0	1	0	10	16	508	528
404	202	2	1	0	3	7	253	3	8	404	13	2	269	2	1,170	2,347	9,740	12,080
405	6	0	0	3	0	0	3	0	0	4	1	0	3	0	20	38	340	380
406	21	0	0	7	0	0	8	0	1	14	1	0	7	0	60	123	2,342	2,462
407	596	2	1	253	3	8	0	4	9	399	14	3	266	3	1,560	3,129	12,654	15,774
408	11	0	0	3	0	0	4	0	0	7	0	0	3	0	30	63	2,028	2,088
409	25	0	0	8	0	1	9	0	0	16	1	0	8	0	70	145	2,760	2,900
410	906	3	2	404	4	14	399	7	16	0	25	5	130	5	1,920	3,838	15,178	19,018
411	40	0	0	13	1	1	14	0	1	25	0	0	13	0	110	218	4,130	4,350
412	7	0	0	2	0	0	3	0	0	5	0	0	2	0	20	34	1,106	1,146
413	194	1	1	269	3	7	266	3	8	130	13	2	0	2	900	1,800	7,668	9,468
414	7	0	0	2	0	0	3	0	0	5	0	0	2	0	20	33	625	665
Sum	2,020	10	10	1,170	20	60	1,560	30	70	1,920	110	20	900	20	7,920	15,855	75,822	91,662

3.4: Trip Distribution

The 2020 model used the same trip distribution procedures used for the 2010 model: the gravity formulation, friction factors, and K-factors used for 2010 conditions were retained for 2020 conditions. The total 2020 person-trips by purpose are illustrated in **Table 3-3**.

Table 3-3: 2020 Person Trip Summary

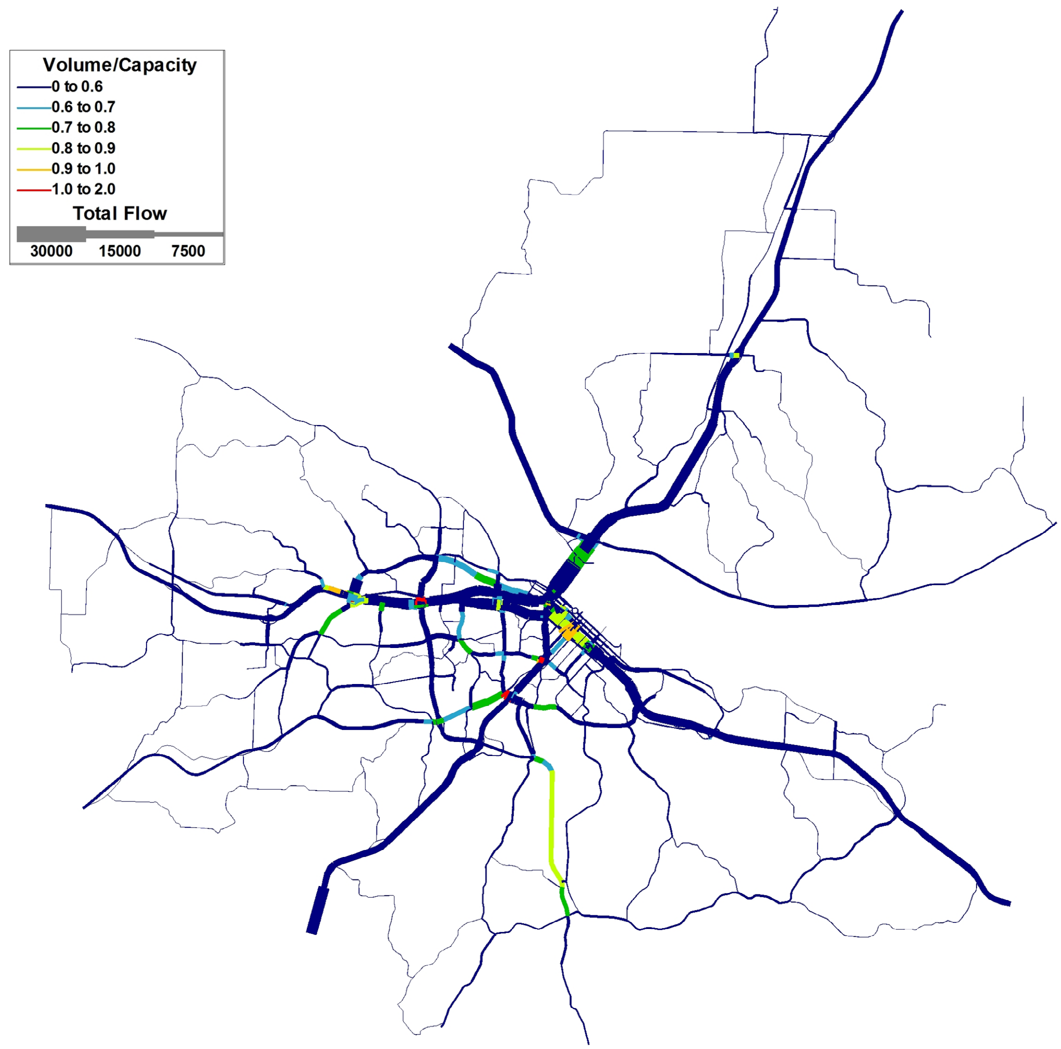
Trip Purpose	Total Trips	Percent Trips
HBW	82,967	19%
HBSCH	28,474	6.5%
HBSHOP	63,527	14.6%
HBO	141,862	32.5%
NHB	119,680	27.4%
Total Trips	**436,510**	**100%**

3.5: Vehicle Trip Assignment

Daily

As with the 2010 model, the 2020 model uses the SUE assignment algorithm. The vehicle occupancies and volume-delay function parameters developed for the 2010 model were also applied to the 2020 model. **Figure 3-5** illustrates the trip assignment and v/c ratios resulting from the 2020 model.

Figure 3-5: Assignment Bandwidth with V/C Ratios, 2020



Peak-Hour

P.M. peak-hour turning-movement volumes were extracted from the model for each of the study intersections, post-processed in accordance with the procedures developed using the base model, and then analyzed using the Synchro software. **Table 3-4** summarizes the results of the intersection operational analysis. Delay increases for all 11 intersections. The southbound off-ramp of US-54 at Simon Boulevard is projected to fall to LOS D. The intersection of Stadium Boulevard and Jefferson Street falls to LOS D. The intersection of the US-50 EB Ramps/Horner Road and Truman Road had one movement fall to LOS E; however, the overall intersection operates at LOS C.

Table 3-4: 2020 P.M. Peak Hour Intersection Analysis

			2010		2020	
	Intersection	**Sig/Unsig***	**Delay**	**LOS**	**Delay**	**LOS**
1.	US-54 SB Ramps & Simon Blvd	U	24.6 (SB)	C	33.1 (SB)	D
2.	Missouri Blvd EB Ramps & Rte. 179	S	13.9	B	14.1	B
3.	US-50 EB/Horner Rd & Truman Blvd	S	18.3	B	20.5	C ǂ
4.	Stadium Blvd & Jefferson St	S	34.0	C ǂ	38.3	D ǂ
5.	Missouri Blvd & Dix Rd	S	29.9	C ǂ	31.3	C ǂ
6.	Missouri Blvd & Beck St	S	19.3	B	19.7	B
7.	US-54 NB Ramps & Ellis Blvd	S	23.8	C	24.1	C
8.	US-50/63 EB Ramps & Eastland Dr	S	10.7	B	11.7	B
9.	Rte. B/W/M**	U	16.9 (WB)	C	20.1 (WB)	C
10.	US-50/63 WB Ramps & Militia Dr	U	8.7 (WB)	A	8.8 (WB)	A
11.	US-50 EB/Horner Rd & Big Horn Dr	U	15.7 (WB)	C	16.5 (WB)	C

**For unsignalized intersections the delay/LOS reported are for the worst movement at the intersection.*

***Intersection 9 was analyzed as a two-way stop (east-west stop) because Synchro does not allow analysis of the actual configuration (3-way stop at 4 way intersection).*

ǂ One or more movements operate at LOS E.

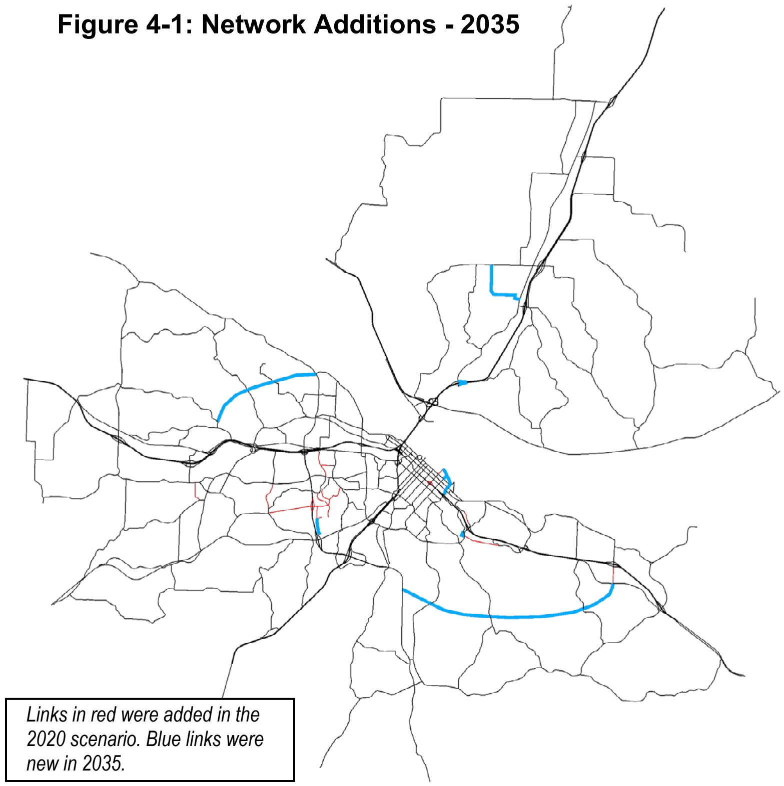
Chapter 4: 2035 Model

4.1: Year 2035 Roadway Network

To create the network for the 2035 model scenario, further modifications were made to the 2020 model network to expand to the street system in accordance with the current regional planning efforts. Again, CAMPO staff provided the proposed 2035 highway improvements including the critical network attributes. These attributes were then coded in accordance with the methods used for the prior model scenarios. In some cases assumptions were required regarding connectivity and changes where new roads connected to existing roads. **Figure 4-1** highlights the new network links that were added.

Again, in order to maintain one network for all model scenarios, attributes were added to the network to indicate which links are only in the future scenarios. If there is a "1" in the [2035] field, then the model uses the link in the 2035 scenario.

Figure 4-1: Network Additions - 2035



Roadway Link Capacity

As with the 2020 model, no adjustments were made to existing roadways to account for capacity expansions to 2035, beyond the addition of capacities for the new roadways shown in **Figure 4-1.** Similarly, functional classes, lanes, posted speeds, median type, and directionality remained unchanged for existing links.

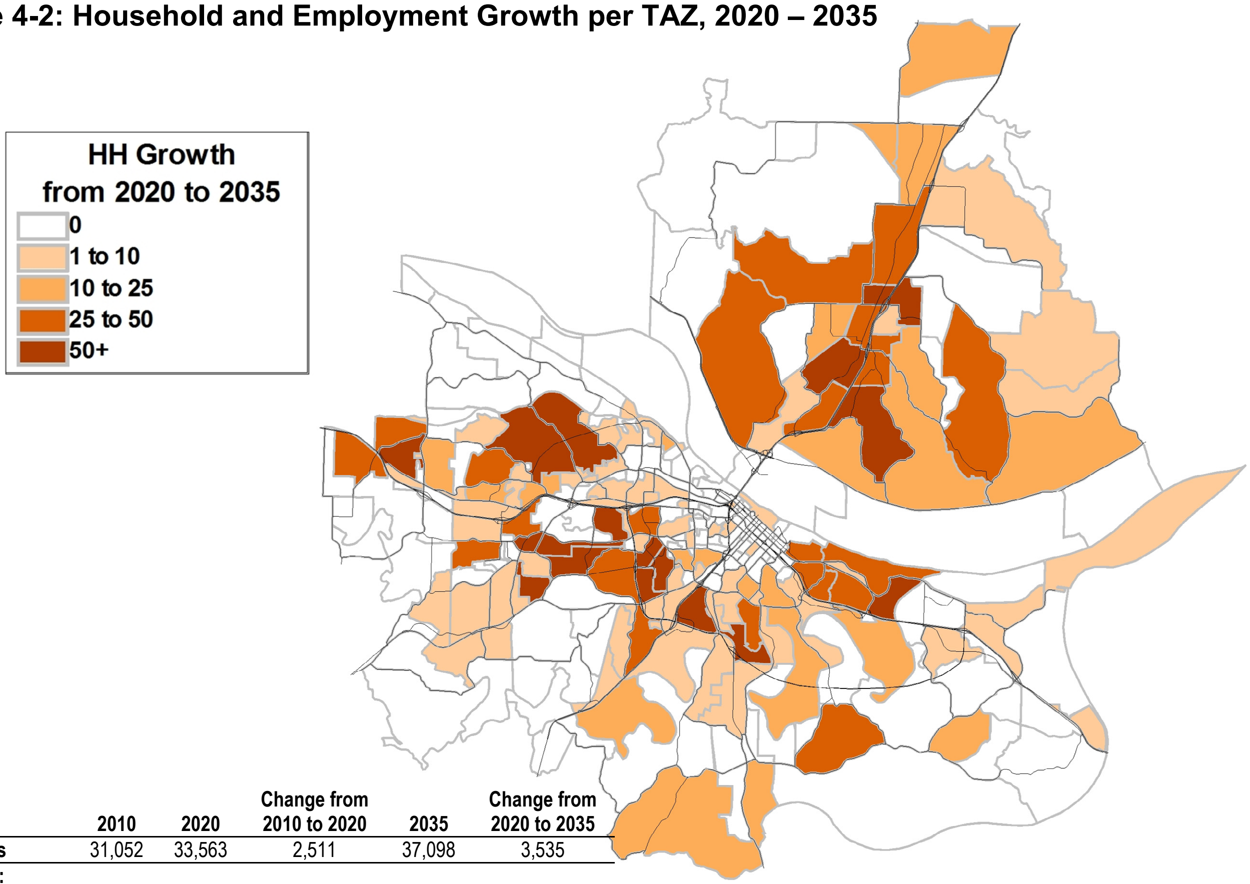
Turn Penalties

Global turn penalties shown previously in Chapter 2 were also used in the 2035 model. No additional turn penalties were added to the model to create the 2035 network.

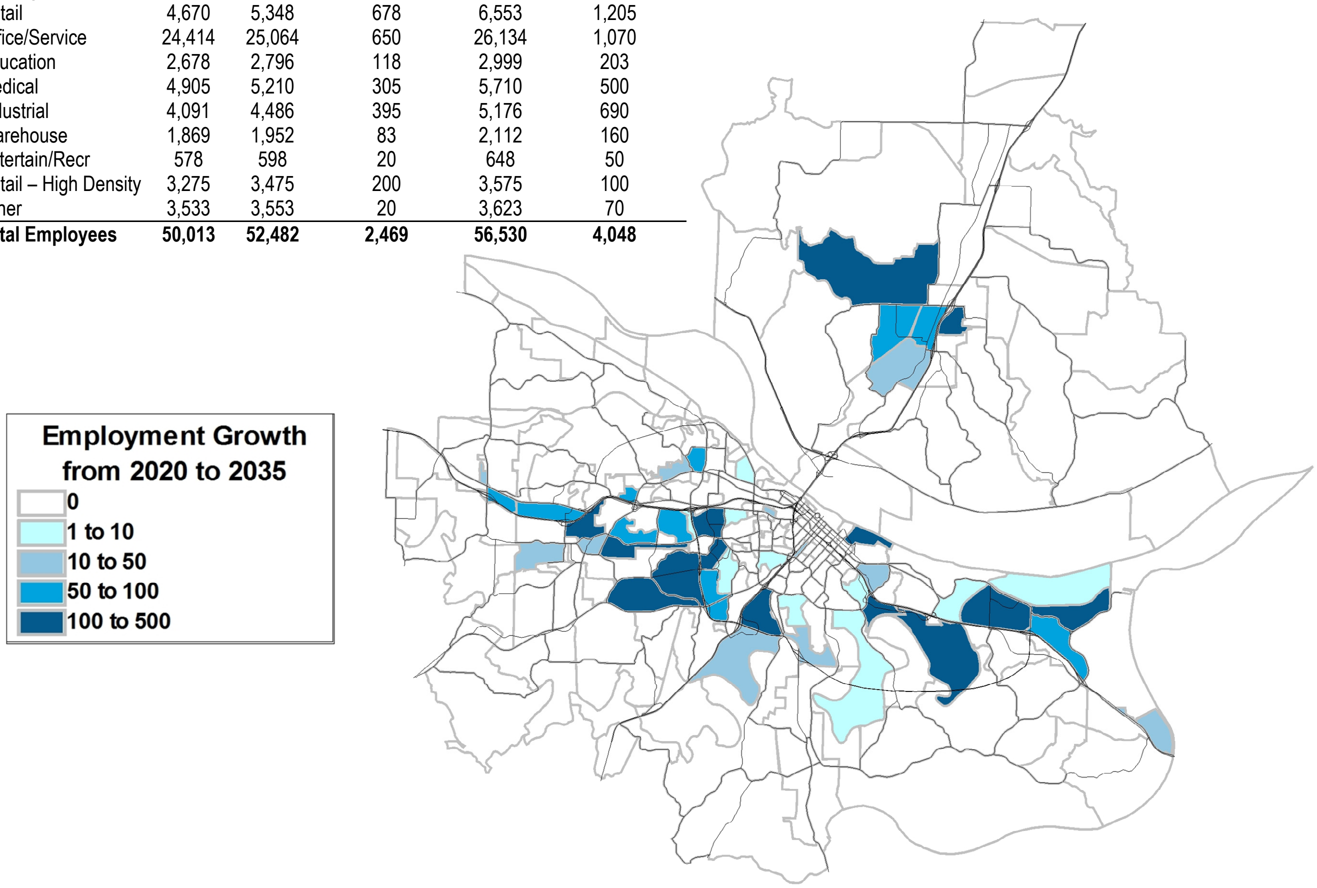
4.2: Year 2035 Land Use/Socioeconomic Data

The TAZ structure created for the 2010 model was left unaltered for the 2035 model. As with the 2020 model, the most significant change between the 2010 and 2035 models was assumed growth, translating to more households and employment in various parts of the model. **Figure 4-2** summarizes the 2035 model land-use in comparison to the 2020 model, and maps the projected growth in households and employment per TAZ.

Figure 4-2: Household and Employment Growth per TAZ, 2020 – 2035

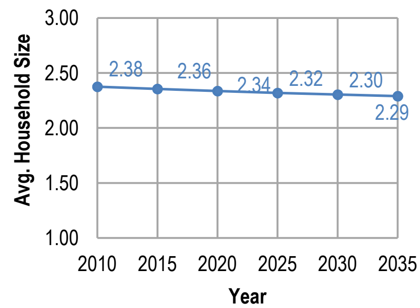


	2010	2020	Change from 2010 to 2020	2035	Change from 2020 to 2035
Households	31,052	33,563	2,511	37,098	3,535
Employees:					
Retail	4,670	5,348	678	6,553	1,205
Office/Service	24,414	25,064	650	26,134	1,070
Education	2,678	2,796	118	2,999	203
Medical	4,905	5,210	305	5,710	500
Industrial	4,091	4,486	395	5,176	690
Warehouse	1,869	1,952	83	2,112	160
Entertain/Recr	578	598	20	648	50
Retail – High Density	3,275	3,475	200	3,575	100
Other	3,533	3,553	20	3,623	70
Total Employees	**50,013**	**52,482**	**2,469**	**56,530**	**4,048**



As with the 2020 model, the 2035 model further adjusted future-year socioeconomic data by assuming smaller household sizes for all new households in future scenarios (1.90 for households added by 2020; 1.80 for households added between 2020 and 2035). When mixed with the existing housing stock in the CAMPO model area, this assumption resulted in the decreasing trend shown in **Figure 4-3.**

Figure 4-3:
Forecasted Household Size Trends



4.3: Trip Generation

Trip generation for 2035 uses the same procedures used for 2010 conditions (see Chapter 2). The same five trip purposes are used, and the trip production/attraction rates are carried forward.

Trip Productions and Attractions

Table 4-1 summarizes the computed productions and attractions by trip purpose for the 2035 model, in comparison to the 2010 and 2020 models. As the table indicates, the 2035 model results in 76,300 additional trips (productions plus attractions) compared to the 2020 model.

Table 4-1: Productions + Attractions by Purpose - 2035

Trip Purpose	2010	2020	New Trips 2010 to 2020	2035	New Trips 2020 to 2035
HBW	155,458	165,935	10,477	181,333	15,398
HBSCH	55,125	56,948	1,823	60,125	3,177
HBSHOP	118,907	127,055	8,148	139,014	11,959
HBO	267,562	283,724	16,162	307,800	24,076
NHB	224,548	239,359	14,811	261,067	21,708
Total	**821,600**	**873,021**	**51,421**	**949,339**	**76,318**

External Stations

To develop 2035 external station volumes, historical growth rates were extrapolated forward in a reasonable manner on a location-specific basis. **Table 4-2** includes the 2035 E-E matrix. External stations are forecasted to carry 8,550 more daily vehicles in 2035 than in 2020.

Table 4-2: E-E Matrix – 2035 Daily

	401	402	403	404	405	406	407	408	409	410	411	412	413	414	E-E Sum	E-E 2-Way Sum	I-E/ E-I Sum	Total External Volume
401	0	1	4	280	9	28	719	16	31	946	44	8	205	8	2,300	4,598	17,759	22,359
402	1	0	0	2	0	0	2	0	0	3	0	0	1	0	10	30	974	994
403	4	0	0	1	0	0	1	0	0	2	0	0	1	0	10	20	658	678
404	280	2	1	0	5	10	316	5	11	432	15	3	297	3	1,380	2,758	11,270	14,030
405	9	0	0	5	0	1	4	0	1	6	1	0	3	0	30	53	470	530
406	28	0	0	10	1	0	9	0	1	13	1	0	7	0	70	146	2,772	2,912
407	719	2	1	316	4	9	0	5	10	381	14	3	262	3	1,730	3,458	13,814	17,274
408	16	0	0	5	0	0	5	0	0	8	1	0	4	0	40	90	2,908	2,988
409	31	0	0	11	1	1	10	0	0	15	1	0	8	0	80	153	2,890	3,050
410	946	3	2	431	6	13	381	8	15	0	21	4	106	4	1,940	3,872	15,288	19,168
411	44	0	0	15	1	1	14	1	1	21	0	0	11	0	110	225	4,280	4,500
412	8	0	0	3	0	0	3	0	0	4	0	0	2	0	20	39	1,256	1,296
413	205	1	1	297	3	7	262	4	8	106	11	2	0	2	910	1,830	7,798	9,618
414	8	0	0	3	0	0	3	0	0	4	0	0	2	0	20	41	775	815
Sum	2300	10	10	1380	30	70	1730	40	80	1940	110	20	910	20	8650	17,311	82,912	100,212

4.4: Trip Distribution

The 2035 model used the same trip distribution procedures used for the 2010 and 2020 models: the gravity formulation, friction factors, and K-factors used for those models retained for 2035 conditions. The total 2035 person-trips by purpose are illustrated in **Table 4-3**.

Table 4-3: 2035 Person Trip Summary

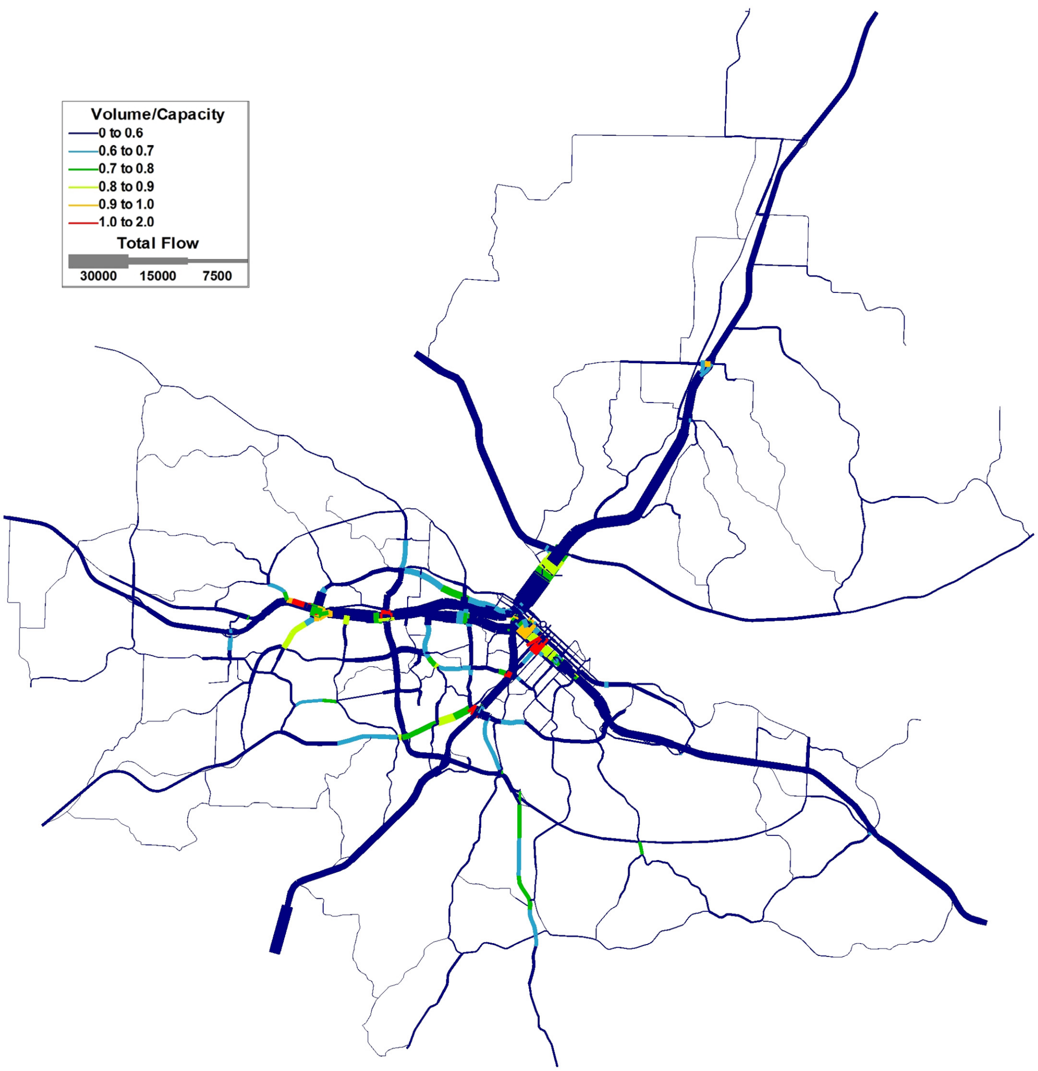
Trip Purpose	Total Trips	Percent Trips
HBW	90,667	19.1%
HBSCH	30,062	6.3%
HBSHOP	69,507	14.6%
HBO	153,900	32.4%
NHB	130,534	27.5%
Total Trips	**474,670**	

4.5: Vehicle Trip Assignment

Daily

As with the 2010 and 2020 models, the 2035 model uses the SUE assignment algorithm. The vehicle occupancies and volume-delay function parameters developed for the 2010 and 2020 models were also applied to the 2035 model. **Figure 4-5** illustrates the trip assignment and v/c ratios resulting from the 2020 model.

Figure 4-5: Assignment Bandwidth with V/C Ratios, 2035



Peak Hour

P.M. peak-hour turning-movement volumes were extracted from the model for each of the study intersections, and analyzed using the Synchro software. **Figure 4-6** illustrates the 2035 p.m. peak-hour turning-movement volumes. **Table 4-4** summarizes the results of the intersection operational analysis. The Southbound Ramps of US-54 at Simon Boulevard is forecasted to degrade to LOS F under this scenario.

One possible reason why projected levels of service remain similar in 2035 (compared to 2020) could be because added development was dispersed throughout the region and some traffic was redistributed to the new roads included in this scenario.

Table 4-4: 2035 P.M. Peak Hour Intersection Analysis

			2010		2020		2035	
	Intersection	**Sig/Unsig***	**Delay**	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**
1.	US-54 SB Ramps & Simon Blvd	U	24.6 (SB)	C	33.1 (SB)	D	92.2 (SB)	F
2.	Missouri Blvd EB Ramps & Rte. 179	S	13.9	B	14.1	B	14.2	B
3.	US-50 EB/Horner Rd & Truman Blvd	S	18.3	B	20.5	C ǂ	22.3	C ǂ
4.	Stadium Blvd & Jefferson St	S	34.0	C ǂ	38.3	D ǂ	38.6	D ǂ
5.	Missouri Blvd & Dix Rd	S	29.9	C ǂ	31.3	C ǂ	31.9	C ǂ
6.	Missouri Blvd & Beck St	S	19.3	B	19.7	B	19.9	B
7.	US-54 NB Ramps & Ellis Blvd	S	23.8	C	24.1	C	27.8	C
8.	US-50/63 EB Ramps & Eastland Dr	S	10.7	B	11.7	B	11.8	B
9.	Rte. B/W/M**	U	16.9 (WB)	C	20.1 (WB)	C	20.0 (WB)	C
10.	US-50/63 WB Ramps & Militia Dr	U	8.7 (WB)	A	8.8 (WB)	A	9.2 (WB)	A
11.	US-50 EB/Horner Rd & Big Horn Dr	U	15.7 (WB)	C	16.5 (WB)	C	18.9 (WB)	C

**For unsignalized intersections the delay/LOS reported are for the worst movement at the intersection.*

***Intersection 9 was analyzed as a two-way stop (east-west stop) because Synchro does not allow analysis of the actual configuration (3-way stop at a four-way intersection).*

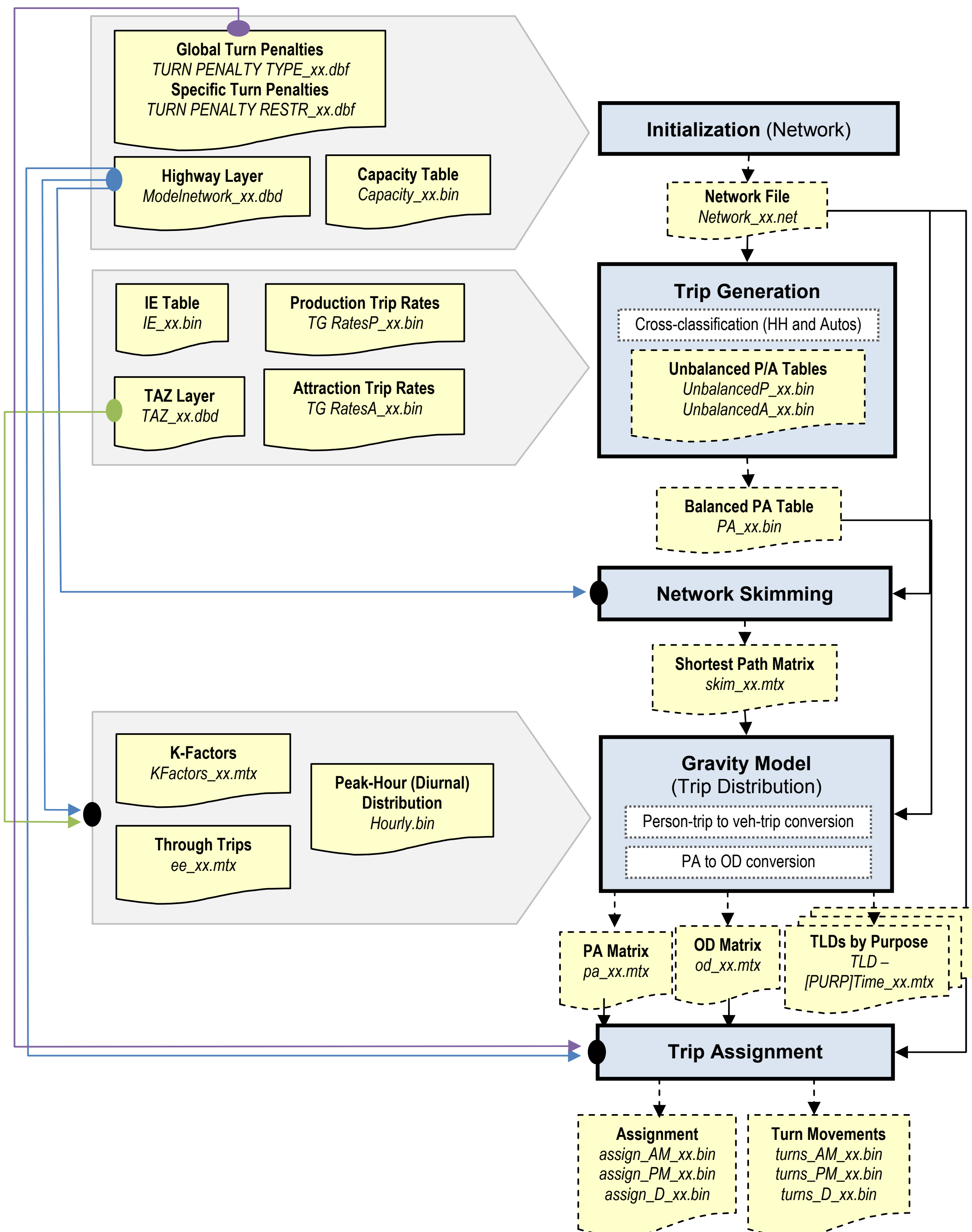
ǂ One or more movements operate at LOS E.

Chapter 5: Model Procedures

5.1: General Model Flowchart

Figure 5-1 summarizes the CAMPO model process. Filenames not mentioned in this figure are not active in the model and may serve as placeholders for future implementation.

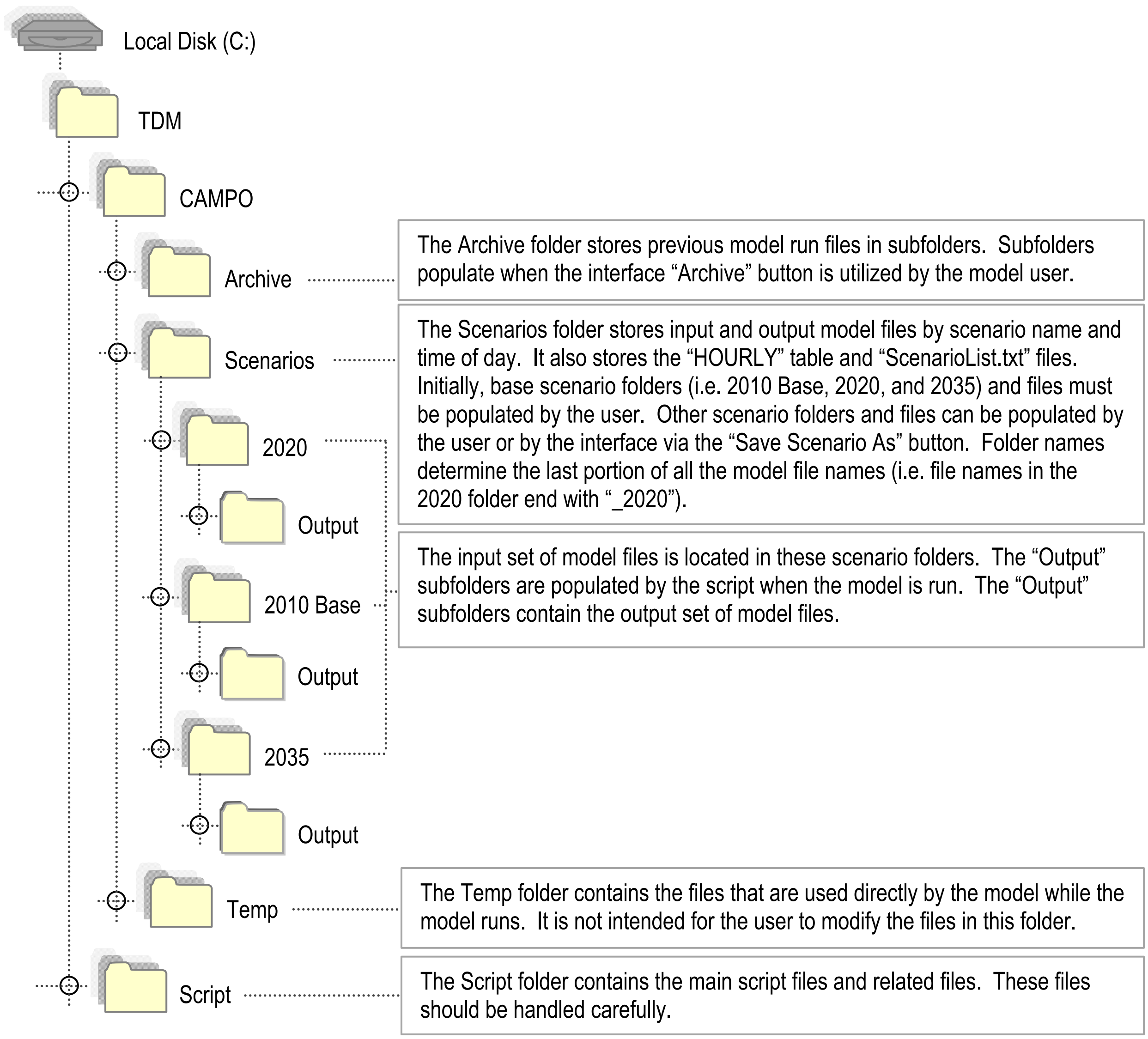
Figure 5-1: CAMPO Model Process



5.2: File/Folder Structure

Figure 5-2 summarizes the CAMPO model files and folder structure. The fundamental folder and file structure must remain as described in the figure. Any changes to directories or file names will result in model run errors. This structure also facilitates file maintenance amongst users.

Figure 5-2: CAMPO File/Folder Structure



5.3: Basic Setup

Please complete these steps before attempting your first model run.

1. Create the folders listed below:

Folder Directory	Can User Modify Contents?	Folder Description
C:\TDM\Script	No	All custom and standard script files. Please consult with the HDR team if changes need to be made.
C:\TDM\CAMPO	--	The main directory for this TransCAD model.
C:\TDM\CAMPO\Archive	Yes	In the TransCAD dialog box, there will be an option to auto-Archive model run files and an Archive button. This is where the files will be stored. Each set of files will have a folder name with its archival date.
C:\TDM\CAMPO\Scenarios	Scenario folder contents – Yes File names – No (these are dependent on the scenario folder name)	All scenario folders and files will reside here. You can manage your own scenario folders/files or use the scenario manager buttons in the dialog box.
C:\TDM\CAMPO\Temp	No	These are temporary files that TransCAD uses during the runs.
C:\TDM\CAMPO\Scenarios\2010 Base	Scenario folder contents – Yes File names – No (these are dependent on the scenario folder name)	All input Existing Conditions files. An "Output" subfolder will be created by the script for the output files.
C:\TDM\CAMPO\Scenarios\2020	Scenario folder contents – Yes File names – No (these are dependent on the scenario folder name)	All input 2020 files. A subfolder will be created by the script for the output files.
C:\TDM\CAMPO\Scenarios\2035	Scenario folder contents – Yes File names – No	All input 2035 files. A subfolder will be created by the script for the output files.

2. Note the path and folder name for your TransCAD folder.

Folder Directory	Can User Modify Contents?	Folder Description
C:\Program Files*-enter your TransCAD folder name here-*	Folder contents – Yes File names – No	This folder is where the TransCAD software is installed; the directory name varies depending on what the user named the folder upon installation. It is where TransCAD looks for essential behind-the-scenes files.

3. Place all files in zip file "Script" under: **C:\TDM\Script**. Delete or archive old files in this folder if any exist.

4. Place "ScenarioList.txt", "HOURLY.BIN", and "HOURLY.DCB" in **C:\TDM\CAMPO\Scenarios**.

5. Place "campo.ini" in your TransCAD folder: **C:\Program Files*-enter your TransCAD folder name here-***

6. Place all files in the zip file “2010 Base” in **C:\TDM\CAMPO\Scenarios\2010 Base**. Delete or archive any old files in this folder if any exist.

7. Place all files in the zip file “2020” in **C:\TDM\CAMPO\Scenarios\2020**. Delete or archive any old files in this folder if any exist.

8. Place all files in the zip file “2035” in **C:\TDM\CAMPO\Scenarios\2035**. Delete or archive any old files in this folder if any exist.

9. If your TransCAD folder is not named “TRANSCAD FULL”, you have two choices:
   1. Rename it to “TRANSCAD FULL”.
   2. Open your TransCAD folder and find “campo.ini” (you placed it there in step 5). Open “campo.ini”. It should open up with Notepad or any other text editor. Change the directory listed under “[UI File]” to “C:\Program Files*-enter your TransCAD folder name here-*\campo.dbd”. If you do not yet have a campo.dbd file in your TransCAD folder, do not be alarmed. We will create it in the next section.

Compilation
From this point forward you will need a TransCAD Standard Key (USB device). If you have not run a TransCAD model via script files, this section will be helpful. Please follow these steps in order. You should only need to do this setup once. These steps only need to be repeated if script files are changed.

1. Open TransCAD. Go to Tools > GIS Developer’s Kit. The kit will appear as a dialog box or docked on the taskbar.

Dialog Box

Docked on the taskbar

2. Click the “Compile to UI” button, which is the third button from the left.
3. Browse to “C:\TDM\Script\” and select “campo_compile_list.lst”. Click the “Open” button.
4. In the next dialog box, browse to “C:\Program Files*-enter your TransCAD folder name here-*”. Type in “campo.dbd” and click “Save”. Click “Yes”/“OK” at the prompt.

If you encounter any errors or questionable pop-up messages during this process, please make sure you have followed all the steps in this section correctly. If the errors persist, please notify the HDR team and we will assist you.

Add-in
This subsection outlines steps to setup access to the Dialog Box (also known as “Graphical User Interface”) from which you can do a model run.

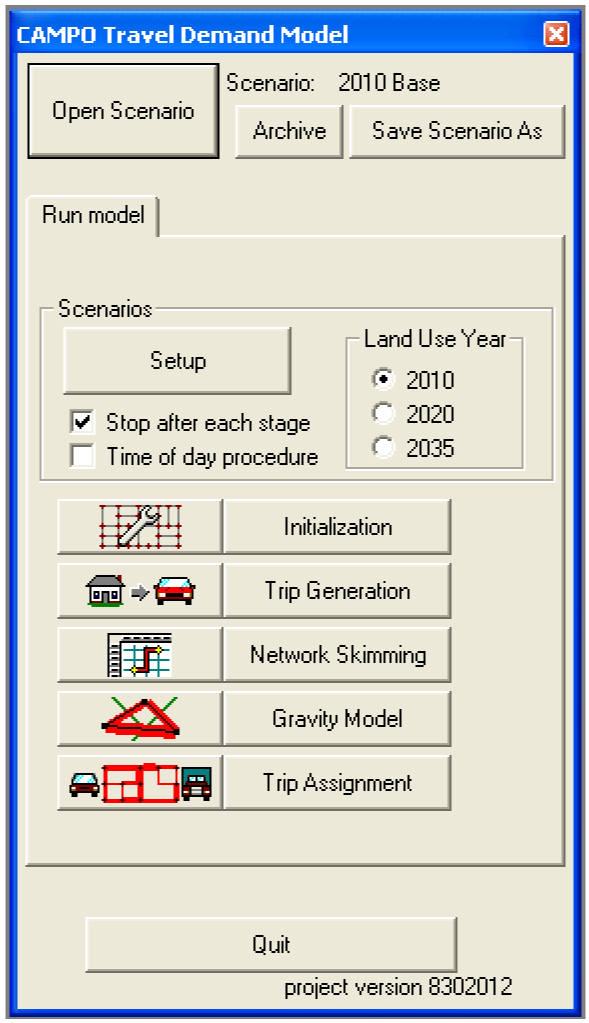
1. Go to Tools > Setup Add-ins…
2. Click the “Add” button.
3. Settings:
   1. Type: Dialog Box
   2. Description: CAMPO
   3. Name: CAMPO Model

4. UI Database:
C:\Program Files\C:\Program Files\-*enter your TransCAD folder name here*-\campo.dbd
5. In Folder: None

4. Click "OK".

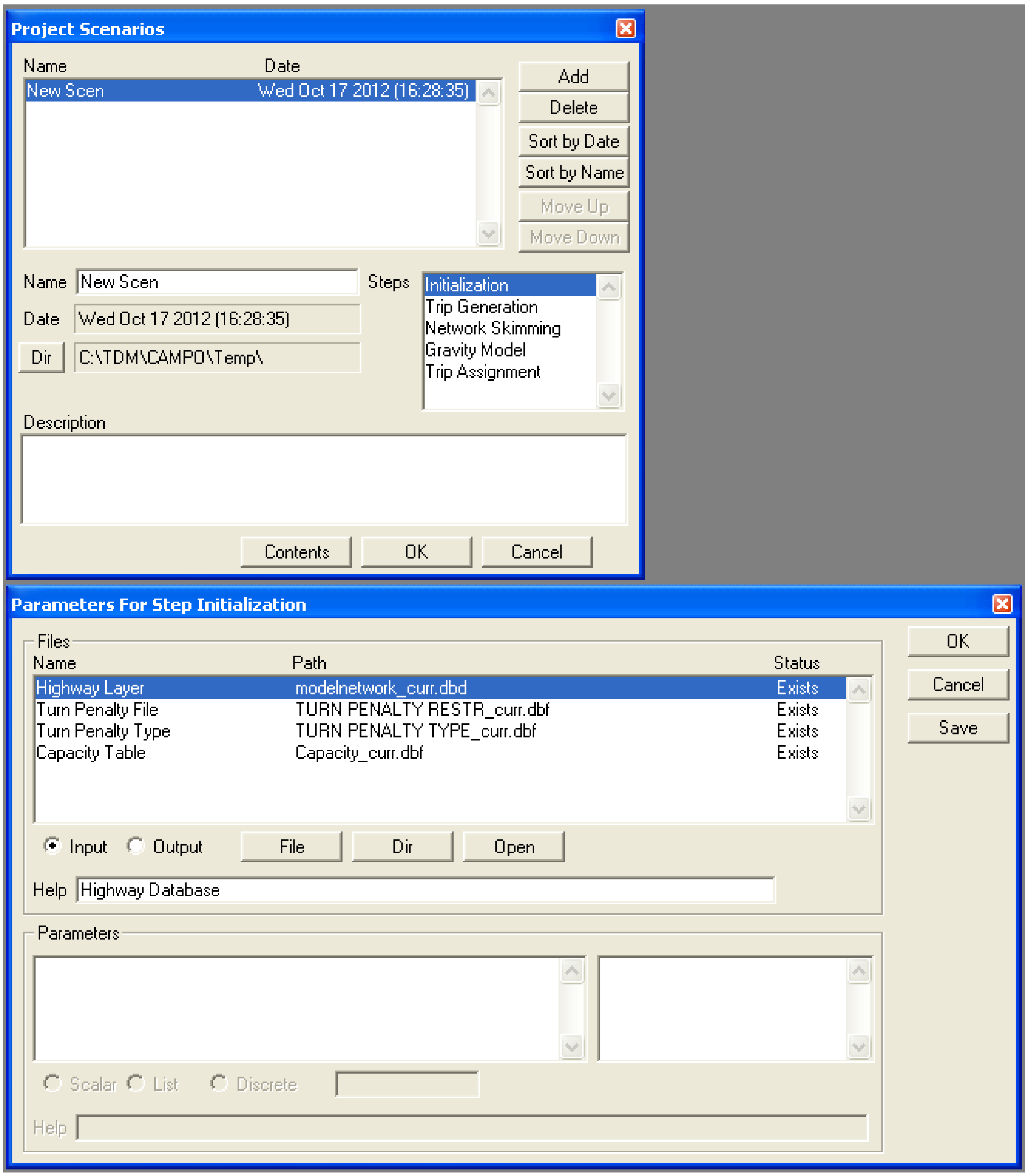
5.4: Basic Setup

To complete a model run using our custom Dialog Box (shown below), please follow these instructions.



1. In TransCAD, go to Tools > Add-ins > CAMPO (After a few uses, TransCAD will create a shortcut directly under the Tools drop down menu called "CAMPO"). The Dialog Box should appear.
2. Click the "Open Scenario" button. Select the desired scenario (i.e. "2010 Base", "2020", or "2035"). Click "OK". A status bar should appear.
3. The text at the top of the CAMPO Travel Demand Model dialog box should read: "Scenario: 2010 Base"

4. ***This step is only a check that the directories and file names have loaded properly.*** Click the "Setup" button. The "Project Scenarios" box should appear. An image of the "Project Scenarios" box is shown below.
    a. On the left, the text to the right of the "Dir" button should be "C:\TDM\CAMPO\Temp".
    b. Double click on each of the "Steps" listed in the right scroll box. Select both "Input" and "Output" radio buttons and check that all the files have status "Exists".
    c. If any files have status "Missing", then please make sure you have followed previous steps to load the files into the correct directories.
    d. Exit the "Project Scenarios" box by clicking "OK".



5. Interface and Checkboxes:

    a. **Stop after each stage.** A "stage" is a model step (i.e. "Initialization", "Trip Generation", etc.). If this box is checked, only the model step selected by the user is run. If this box is unchecked, the model step selected by the user as well as subsequent model steps are run continuously.
    b. **Time of day procedure.** By selecting this checkbox, the model steps "Gravity Model" and "Trip Assignment" will include appropriate procedures to output peak hour results.
6. Run the model by clicking "Initialization" then "Trip Generation" then "Network Skimming" etc.
7. Additional buttons not yet mentioned:
    a. **Archive.** This button will archive the latest model output files for the scenario listed shown at the top of the Dialog Box. Those files are copied into a subfolder in "C:\TDM\CAMPO\Archive". The subfolder is named with the archival time and date.
    b. **Save Scenario As.** This button will allow you to create a new scenario. When you use "Save Scenario As", a window will prompt you to manually create a new scenario folder. The new scenario folder needs to be located under the directory "C:\TDM\CAMPO\Scenarios\". Then the script will auto rename and save your files in the new folder based on the new folder's name. The button is also helpful to start a whole new set of files, which you can edit for your new scenario.

5.5: Network Changes: Modifying/Adding Links

To make changes to the network, open and modify the file "modelnetwork_(scenario name).dbd". If making any changes to existing base conditions, make sure to make the same changes to the future years' base scenarios networks as well. When editing link attributes, please make sure all of the attributes in the table below are updated. When adding a link, use the TransCAD Map Editing tool and populate all fields below. The Fields in the network file not mentioned below were referenced by HDR during model development.

Attribute (Field Name)	Description	Notes
Dir*	One-way (1, -1) or Two-way (0)	To define a one way link, change your link layer attributes to show "Topology". Dir = 1 agrees with the topology arrows. Dir = -1 opposes the topology. The link layer attributes "Direction of flow" arrow is based on the "Dir" value.
Street Name	Street Name	--
FunClass	1 = Freeways 3 = Arterials 5 = Collectors 6 = Local 7 = Ramps 8 = System Ramps 9 = Centroid Connectors	Roadway Functional Classification Numbers. Numbers 2 and 4 are typically used for expressways and minor arterials respectively. They are not currently used by the model, but the numbers are reserved for future implementation. When the minor arterials classification is used, functional class 3 represents major arterials.
Area Type	1 = CBD 2 = Non-CBD	To determine the Area Type, refer to the Area Type figure in Chapter 2.
Median Type	1 = Undivided 2 = Undivided with turn lanes at intersections 3 = TWLTL (two-way left-turn lane) 4 = Raised Median – No turn lanes 5 = Raised Median – With turn lanes	The type of median located on the link.
AB_Lane** BA_Lane**	Number of Lanes	The number of lanes in the AB or BA direction.
AB_Speed** BA_Speed**	Posted Speed and/or Free-Flow Travel Speed	The posted and/or free-flow travel speed in the AB or BA direction.
ADT *(Only modify for new links)*	2005-2012 Daily Traffic Count	Used for calibration. Please do not modify for existing links.
2020	"1" indicates the link is in 2020 and 2035	Used for making base network changes.
2035	"1" indicates the link is in 2035	Used for making base network changes.
Not in 2020	"1" indicates the link is not in 2020	Used for making base network changes.
Not in 2035	"1" indicates the link is not in 2035	Used for making base network changes.

* The topology is determined by the way the link was originally drawn when the link was created.
**AB_ indicates traffic flow that is consistent with the link's topology. BA_ indicates traffic flow opposite the link's topology.

Be sure to check loading onto new links and add new centroid connectors if applicable. Be aware that the properties of existing centroid connectors are tied to the calibrated existing conditions model. Also note that centroid connector lengths affect the amount of traffic distributed amongst centroid connectors. Generally, for a TAZ, more traffic will be attracted to the TAZ's shorter centroid connector compared to its longer centroid connector. However, there are other variables that affect the resulting volumes on these connectors.

For changes applicable to one or more of the three base scenario networks, it is advised to modify an "all base scenarios" network. This network will be provided along with the model files used for running the model. It is named "modelnetwork_2010 Base.dbd", but it contains all existing and future base scenario links. After making the appropriate changes in this "all base scenarios" network, follow the steps below:

1. Make three copies of the "all base scenarios" network that was just modified. Each of these three files will need to be modified further to apply to the three base years accordingly.
2. In the network that will be used as the 2010 Base network, delete links that have a "1" in the [2020] and [2035] fields.
3. In the network that will be used as the 2020 network, delete links that have a "1" in the [2035] and [Not in 2020] fields.
4. In the network that will be used as the 2035 network, delete links that have a "1" in the [Not in 2035] field.
5. Since these three networks have the same name "modelnetwork_2010 Base.dbd", the model Dialog Box is used to rename them. There are other simpler methods of renaming these files (i.e. exporting, renaming in Windows, etc.), but they have been known to yield model errors.
6. 2010 Base
    a. Copy the model network from step 2 and use it to replace the model network file in "C:\TDM\CAMPO\Scenarios\2010 Base".
    b. The 2010 Base scenario is now ready to be run with the latest changes.
7. 2020
    a. Go to the "C:\TDM\CAMPO\Scenarios\2020" folder and make copies of following files:
        i. ee_2020.mtx
        ii. IE_2020.bin
        iii. IE_2020.dcb
    b. Copy the model network from step 3 and use it to replace the model network file in "C:\TDM\CAMPO\Scenarios\2010 Base".
    c. Open the Dialog Box.
    d. Click on "Open Scenario", select "2010 Base", and click "OK". A progress bar will appear briefly.
    e. Click "Save Scenario As" and select the "C:\TDM\CAMPO\Scenarios\2020" folder.
    f. Copy the files created in part (a) and use it to replace those same three files in the "C:\TDM\CAMPO\Scenarios\2020" folder.
    g. The 2020 scenario is now ready to be run with the latest changes.
8. 2035
    a. Go to the "C:\TDM\CAMPO\Scenarios\2035" folder and make copies of following files:
        i. ee_2035.mtx
        ii. IE_2035.bin
        iii. IE_2035.dcb
    b. Copy the model network from step 4 and replace the model network file in "C:\TDM\CAMPO\Scenarios\2010 Base".
    c. Open the Dialog Box.
    d. Click on "Open Scenario", select "2010 Base", and click "OK". A progress bar will appear briefly.
    e. Click "Save Scenario As" and select the "C:\TDM\CAMPO\Scenarios\2035" folder.
    f. Copy the files created in part (a) and use it to replace those same three files in the "C:\TDM\CAMPO\Scenarios\2035" folder.
    g. The 2035 scenario is now ready to be run with the latest changes.

5.6: TAZ Changes: Modifying a TAZ

To make changes to the TAZ structure, modify "taz_(scenario name).dbd". Note the provided "taz_2010 Base.dbd", "taz_2020.dbd", and "taz_2035.dbd" are the same file with different names. When editing TAZ attributes, please refer to the table below. Fields in the TAZ file not mentioned below were referenced by HDR during model development.

Attribute (Field Name)	Description	Notes
External	External TAZs are marked with "1"	External TAZs are a fixed part of the model due to their importance in the calibration process. Updating future year external information can be helpful to improve future year forecasts.
Extra TAZ	Extra TAZs marked with "1"	Blank TAZs. Once a TAZ is converted to a TAZ in use, please delete the "1".
[Year] Households	Households (for appropriate analysis year)	--
[Year] HHsize_1	Number of Households with a household size of 1 person (for appropriate analysis year)	--
[Year] HHsize_2	Number of Households with a household size of 2 person (for appropriate analysis year)	--
[Year] HHsize_3	Number of Households with a household size of 3 person (for appropriate analysis year)	--
[Year] HHsize_4	Number of Households with a household size of 4 person (for appropriate analysis year)	--
[Year] HHsize_5+	Number of Households with a household size of 5+ person (for appropriate analysis year)	--
[Year] Retail, Office/Service, Education, Medical, Industrial, Warehouse, Entertain/Recr, Other, Retail-High	Land Use Data used by the model script	Entertain/Recr: Entertainment/Recreation Retail-High: dense retail or retail with higher trip attraction rates compared to the regular Retail category

5.7: TAZ Changes: Adding a TAZ

When adding a TAZ, use the Extra TAZs with the number "1" in the "Extras" field. Then, be sure to populate the fields in the table above. After using the TransCAD Map Editing tool to change the location and shape of the TAZ, you need to move the centroid and centroid connector(s) in the model network. You will also need to modify the k factors matrix.

File	Layer/Matrix Currency	To Do
modelnetwork_(scenario name).dbd	CAMPO_Link	Use the TransCAD Map Editing tool to draw in your centroid connectors. When splitting existing links with the centroid connector, be aware of any auto changes to the links. Fill in the new centroid connector's attributes by copying an existing centroid connector's attributes.
modelnetwork_(scenario name).dbd	Node	For the centroid of the TAZ, fill in field [TAZ] with the appropriate TAZ [ID] number.
kfactors_(scenario name).mtx	Modify 'HBSCH' and 'HBSHOP'	Section 2.4 includes a description on the use of K-factors in this model. There is also a spreadsheet available that can be provided if needed.

GLOSSARY

ADT: Average Daily Traffic - average daily traffic volume as measured over a certain number of days.

Area Type: A link-level variable used to define terminal time based on the area the link is in. The CAMPO model defines two types: downtown and non-downtown.

Balancing (or "Trip Balancing"): A procedure that takes trip productions and trip attractions model-wide and rectifies them by purpose so that distribution can match productions with attractions one-for-one.

Calibration: The process of defining and adjusting model parameters until the model replicates the travel patterns exhibited in the study area.

Capacity: The maximum number of vehicles or persons that can be carried past a point on a transportation system in a specified time.

Capacity Restraint: The limiting of traffic movement on a link by applying a volume-to-capacity ratio (which measures congestion) based traffic assignment.

Centroid: A representative node in the transportation network that is assumed to be the location of all trips generated to and from a zone.

E-E Trips: Trips that travel directly from one external station to another without an origin or destination at any internal TAZ.

External Station: A traffic analysis zone (see TAZ) that lies outside the model area boundary, and is used to generate trips with origins and/or destinations out of the model area.

Free-flow Time: Non-congested travel time in units of minutes defined by link speed over length.

Frequency Distribution: A table or graphical representation that shows the percentage of total trips within each travel time increment.

Functional Class: A system of categorizing roadways and highways by their function in a network hierarchy. The CAMPO model uses eight functional classes: Freeway, Arterials, Collector, Local, Ramp, and System-to-System Ramp.

Friction Factor: In a gravity model calculation, friction factors are a function of the travel time (or cost) between TAZs; the larger the friction factor, the more mutually attractive the TAZs are for distribution purposes.

Gravity Model: A method of distributing trips between TAZs in which the amount of trips assigned is proportional to the trips generated/attracted by the TAZs, and inversely proportional to the travel time between the TAZs.

Ground Count: An actual traffic volume count.

Intra-zonal Trips: Those trips occurring totally within a TAZ.

Link: An element in a transportation network representing a street section that connects two nodes.

Median Type: A link-level variable used to adjust capacity based on the median configuration of the link. The CAMPO model defines five types: Undivided, Undivided with Turn Lanes, TWTL (Two-Way Left-Turn Lane), Raised Median – No Turn Lanes, and Raised Median – With Turn Lanes.

Minimum Path: The travel route between two points which yields the minimum travel time. This data is displayed in a matrix.

Network: A system of links and nodes that describes a transportation system.

Network Coding: The process of representing a real transportation system in terms of a network "model" used for computer processing.

Node: A point on a highway network where links intersect, end or change direction.

Occupancy (or "Average Vehicle Occupancy"): A ratio indicating how many occupants are typically in a vehicle, used to convert person-trips to vehicle-trips. In the CAMPO model, occupancies vary by time period (daily, a.m., p.m.) and trip purpose.

Peak Hour: The heaviest one-hour period in each of the morning and evening commute periods. The CAMPO model uses 7-8 a.m. and 5-6 p.m.

Person Trip: A trip made by an individual person between two points. Multiple people can be in one vehicle, so a model generates fewer vehicle trips than person trips. Person-trips are converted to vehicle trips during the CAMPO modeling process, using vehicle occupancy factors.

R^2: Coefficient of Determination – a goodness-of-fit statistic that measures how well a regression line correlating model-assigned and field-counted volumes represents the assignment data. (Used in calibration.)

RMSE: Root Mean Square Error – a measure of the deviation between model-assigned and field-counted traffic volumes. Larger RMSE values indicate greater deviation. (Used in calibration.)

Screenline: A screenline is an imaginary line of one of more line segments crossing a number of network links. Screenline analyses are used for calibration purposes.

SUE: Stochastic User Equilibrium – a trip assignment method used by the CAMPO model that iteratively assigns traffic to links based on link cost functions until a convergence is reached (equilibrium) in which a trip in the system cannot be made by an alternate path without increasing the total travel time of all trips in the network. The stochastic element allows use of less attractive routes as well as the most attractive route.

TAZ: Traffic Analysis Zone - a geographical area used as a basis for estimating socioeconomic variables and trip generation.

Terminal Time: Time added to free-flow time to account for the time at the beginning and end of a trip out-of-vehicle travel times (i.e. time to walk from a downtown parking lot to an office building). The terminal time is designated by area type.

TLD: Trip-Length Distribution – a statistical distribution that indicates the frequency of various trip lengths for each purpose type. For example, home-based work trips may tend to be longer than home-based shopping trips. (Used in calibration.)

Travel Time: The amount of time needed to travel between two points or places.

Trip Assignment: A process that assigns trips to various paths or routes in a network.

Trip Attractions: Vehicle-trips or person-trips (pre-balancing) to an “attractor” – generally non-residential, employment-type land-uses.

Trip Distribution: The process that estimates the number of trips traveling between geographical zones in a transportation network.

Trip Generation: The process that estimates the number of trips generated by land use within each zone.

Trip Productions: Vehicle-trips or person-trips (pre-balancing) from a “producer” – generally residential land-uses.

Trip Purpose: A method of subcategorizing vehicle trips and person trips, defined in the trip generation stage, that allows more refined distribution of trips during the trip distribution stage. The CAMPO model defines five trip purposes: Home-Based Work (HBW), Home-Based School (HBSCH), Home-Based Shopping (HBSHOP), Home-Based Other (HBO), and Non-Home-Based (NHB).

Trip Table: A table (matrix) illustrating the number of trips from each zone to every other zone in the study area.

Turn Penalty: Travel time added by a model to certain traffic movements to replicate physical or legal turn restrictions, or to indicate other factors that reduce a link’s attractiveness.

Validation: Running the calibrated model(s) with the current socioeconomic data and comparing to the ground traffic counts.

Vehicle Trip: An auto/truck trip made between two points, converted from a person-trip during the CAMPO modeling process.

VDF: Volume-Delay Function – a mathematical function that predicts the congested travel cost on a link as a function of the link’s capacity, and the volume carried by the link.

VHT: Vehicle hours of travel - the number of vehicles on a link, generally for a daily period, multiplied by the length of the time traveled, in hours. The VHT for a study area is the sum of the VHTs for each link.

VMT: Vehicle miles of travel - the number of vehicles on a link, generally for a daily period, multiplied by the length of the link, in miles. The VMT for a study area is the sum of the VMTs for each link.