GENESEE COUNTY URBAN TRAVEL DEMAND MODEL IMPROVMENTS

Model Development and Validation Report

Prepared for the
Genesee County Metropolitan Planning Commission

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I. OVERVIEW

This report presents model development procedures used to develop the Genesee County Travel Demand Model. The Genesee County model utilizes a GIS-based travel demand modeling software, TransCAD. Using TransCAD's GIS techniques, the model incorporates extensive geographic and traffic operational databases into the highway network and the traffic analysis zone (TAZ) GIS layer for use in the modeling process. Peak-period modeling capabilities are also embedded in this model through time-of-day (TOD) models. The "MI Travel Counts" household survey together with the 2007 transit on-board survey was fully analyzed to derive key modeling components such as trip generation rates, trip length frequency distributions, mode shares, time-of-day distributions and vehicle occupancy rates.

The Genesee County model is structured to implement "four-step" processes with travel time feedback loop. Four steps are trip generation, trip distribution, mode choice and trip assignment. Based on this structure, the model runs four steps assignment initially, and then "feedback" the congested travel time from assignments back to trip distribution and starts subsequent model runs. With the feedback routine, trips are distributed and assigned on the network in a more effective and realistic manner since trip destination and route choices are determined based on congested network condition. In addition, the transit trip assignment is based on the congested travel time from the last iteration of model runs.

Major features of the Genesee TransCAD model are summarized as follows:

- **Study Area.** The model fully covers Genesee County. Trips external to this study area (i.e., external-internal or external-external trips) are captured by 37 external stations.

- **TAZ Development.** TAZs were appropriately defined throughout the study area to be bounded by the modeled roadway network with a minimum of network passing through any zone. Each TAZ is filled by demographics and employment attributes not only for the 2005 base year but also for the future years.

- **Network Update and Transit Route Development.** The Genesee County highway network was updated with more roadway data sources and the current traffic count data. The network includes extensive geometric and operational link attributes. Traffic signals were also coded in the network to estimate delays associated with this control device. Consistent with the new TAZs, network details with proper centroid connectors were appropriately added throughout the study area. The transit route component has been developed concurrently with the development of the roadway network and traffic analysis zones (TAZ), so that any special considerations needed for transit modeling are accommodated in the design of the new TAZ structure and/or road network. The development is done for all fixed bus service routes.

- **Improved Estimation of Free-Flow Speeds and Link Capacity.** Instead of using posted speed limits as a surrogate for free-flow speeds, free-flow speeds were estimated based on a tool developed by Bernardin Lochmuller and Associates. The new tool was developed from GPS and other speed surveys conducted in the Genesee County and other areas. Based on the speed surveys, the relationship between free-flow speeds and several determining factors such as posted speed, access control and area type was identified for each facility type. This relationship was expressed in various forms of nonlinear regression models. Geometric and operational link data were utilized for improved estimation of link capacities. It calculates the speed and capacities based on the concepts presented in the HCM2000. This methodology derives various capacity adjustment factors from a series of bi-factor nonlinear regression formulas. The estimated peak-hour capacities were then converted to peak and off-peak period capacities.

- **Intersection Delays.** Delays associated with traffic signals were estimated to adjust directional link free-flow speeds and capacities. The HCM 2000 method of calculating vehicle delay that takes into consideration green time and progression effect was adopted.

- **External Trip Estimation.** TransCAD's subarea analysis method was used in the Michigan statewide travel demand model to generate preliminary auto vehicle and truck external trip tables for Genesee County. Then these external trip tables of 2005 were adjusted to match the base year traffic counts at all external stations, and the 2005 adjustment amounts were applied to the 2030 preliminary tables to form the final 2030 external trip tables. The annual growth rates of auto and truck external trips were calculated using the number of trips in the 2005 and 2030 external trip tables. Finally the 2035 external trips were obtained by applying these growth rates to the 2005 external trips.

- **Trip Generation Model.** Simply speaking, travel demand modeling is the process of translating different types of trips into vehicular traffic on the network. Trip production and attraction models were developed for each of these trip purposes through various statistical analyses using trip data from the *MI Travel Counts Household Travel Survey data.*

- **Trip Distribution Model.** During the development of the Genesee County model, unique friction factor tables were calibrated to survey data for each of the trip purposes, including truck trips.

- **Mode Choice Model.** The Genesee County model takes account of auto, transit, bike and pedestrian. This mode choice model has the factors for daily only and are derived from the *Travel Counts Household Travel Survey data and the bus on-board survey.*

- **Time-of-Day Models.** The Genesee County model consists of four time-of-day (TOD) models: morning peak, midday, evening peak and night. Most modeling factors that are unique to each time period were derived from the *MI Travel Counts Household Travel Survey data*. Compared to a single daily model, the TOD modeling generates a more accurate travel model by treating each period uniquely.

- **Truck Model.** Travel patterns of trucks are different from those of passenger cars, thus it is desirable to have a separate truck mode in the model. In each of the four step processes, the Genesee County model maintains a separate truck model to address the unique travel characteristics of trucks. Truck trips are separately generated and distributed. Then, they are assigned to the network for each TOD simultaneously with the corresponding passenger car assignments.

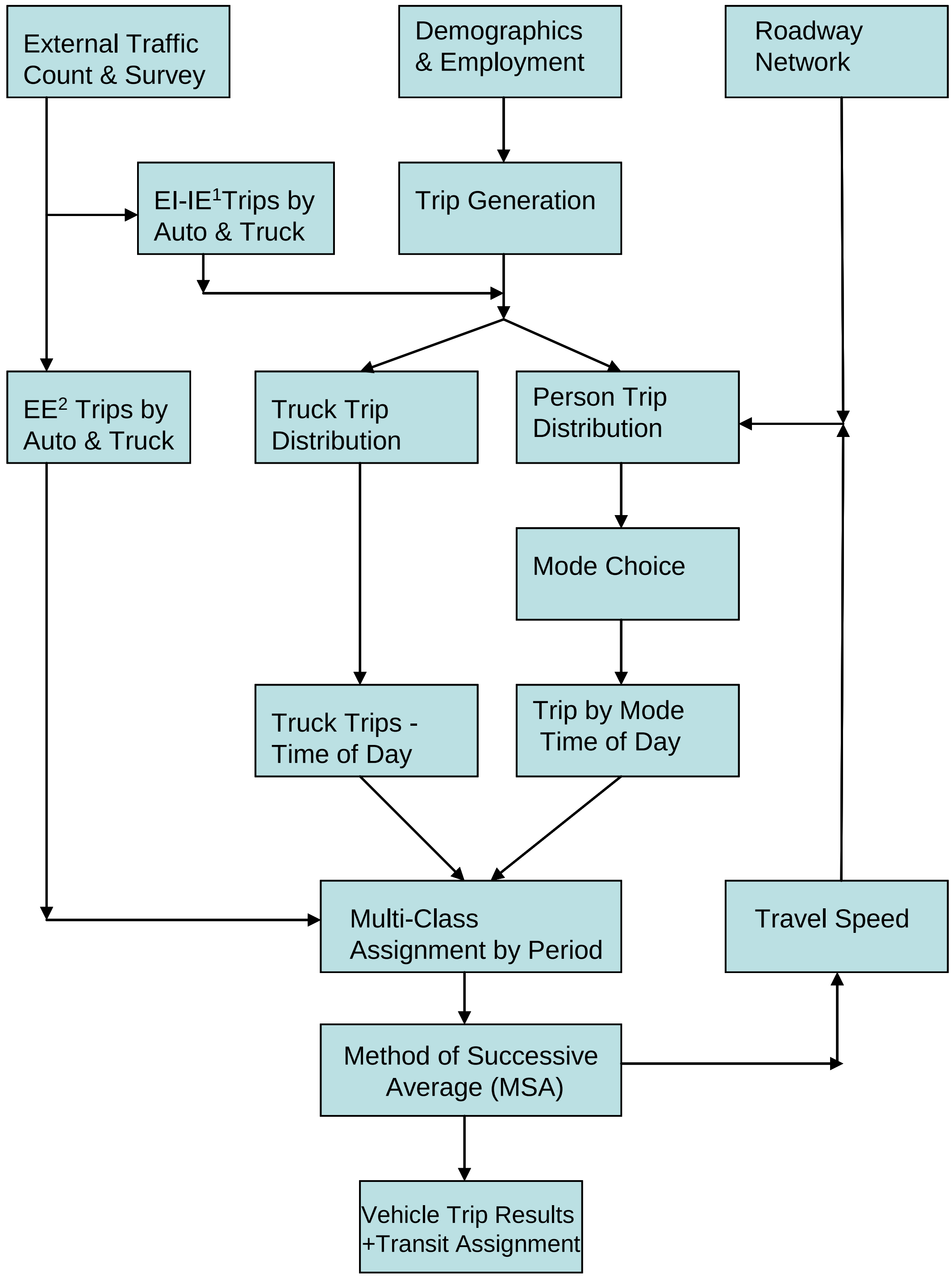
- **Vehicle Trip Assignment and Feedback Loop.** Link free-flow speeds derive the first phase of the model run, or initial assignment. It is used for network skimming, trip distribution and route choice. Following the first phase, link congested-speeds are estimated and used to redistribute trips in subsequent model runs, or feedback assignments. The final assignment results are obtained from the feedback assignment.

- **Transit Trip Assignment.** The link congested-speeds and travel time are used to assign the transit passengers onto the transit routes. The assignment rule is to find the shortest path of the general cost for passengers. The general cost is a combination of travel time, cost and other factors.

- **Post-processors.** The Genesee County model is equipped with several post-processors. These post-processors report (1) calibration statistics through a program "CAL_REP", (2) a variety of performance measures of the model through a program "POST_ALT". These post-processors are embedded in the model user interface.

- **User-friendly Travel Model Geographic User Interface (GUI).** Using TransCAD's programming capability, GISDK script a user friendly model interface was designed to run the model by automating the entire modeling and post-processing procedures. The first part of the interface elicits from the user all necessary inputs to the model, including the highway network, the TAZ database and the location of model component files. The second part is the selection of type of model runs. The remaining part is post-processing. Detailed descriptions of the model GUI are provided in the *Model Users Guide*.

The first part of this report is devoted to describing the model coverage area and the model input GIS databases. Then, the new speed and capacity estimation procedures are explained in detail. Modeling components of the Genesee County model are described with associated tables and figures. Later, model validation results are presented with key performance measures such as loading error, VMT error, and percent root mean square error. Post-processors developed for the model are also described.



Note [1] EI-IE: External-to-Internal/Internal-to-External

[2] EE: External-to-External

Figure 1. Flow Chart of Model Process

II. MODEL AREA

The model study area fully covers Genesee County. All roadway classes which include Interstates, major and minor arterials, major and minor collectors, and some local roads are represented in the model's coverage area. The zone structure of the county are detailed to address diverse and intense socioeconomic activities in the county.

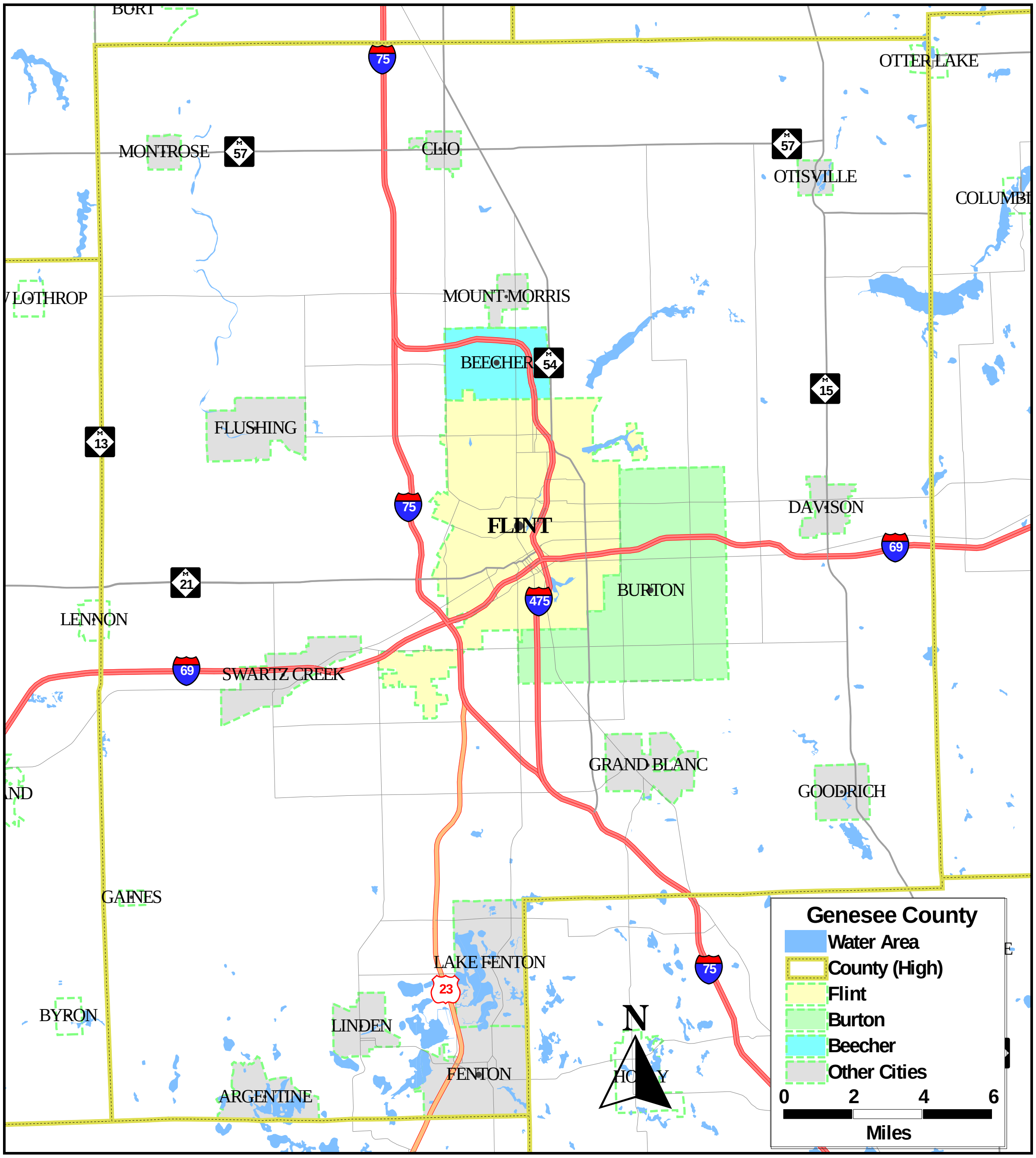


Figure 2. Genesee County Travel Model Study Area

III. TAZ DEVELOPMENT

The study area of the Genesee county model was disaggregated into 639 traffic analysis zones (Shown in Figure 3). There are 37 external zones and the TAZ layer consists of a total of 676 zones. The internal-zone attributes include land area, county name/number, TAZ number and detailed categorization of population, households, vehicle ownership, mean household income, school enrollment, university enrollment and employment by economic sector. These demographic and employment features are the inputs for trip generation. The TAZ layer contains the multi-year attribute data, including the data not only for the 2005 base year but also for the future years. For details about TAZ attributes, refer to the *Model Users Guide*.

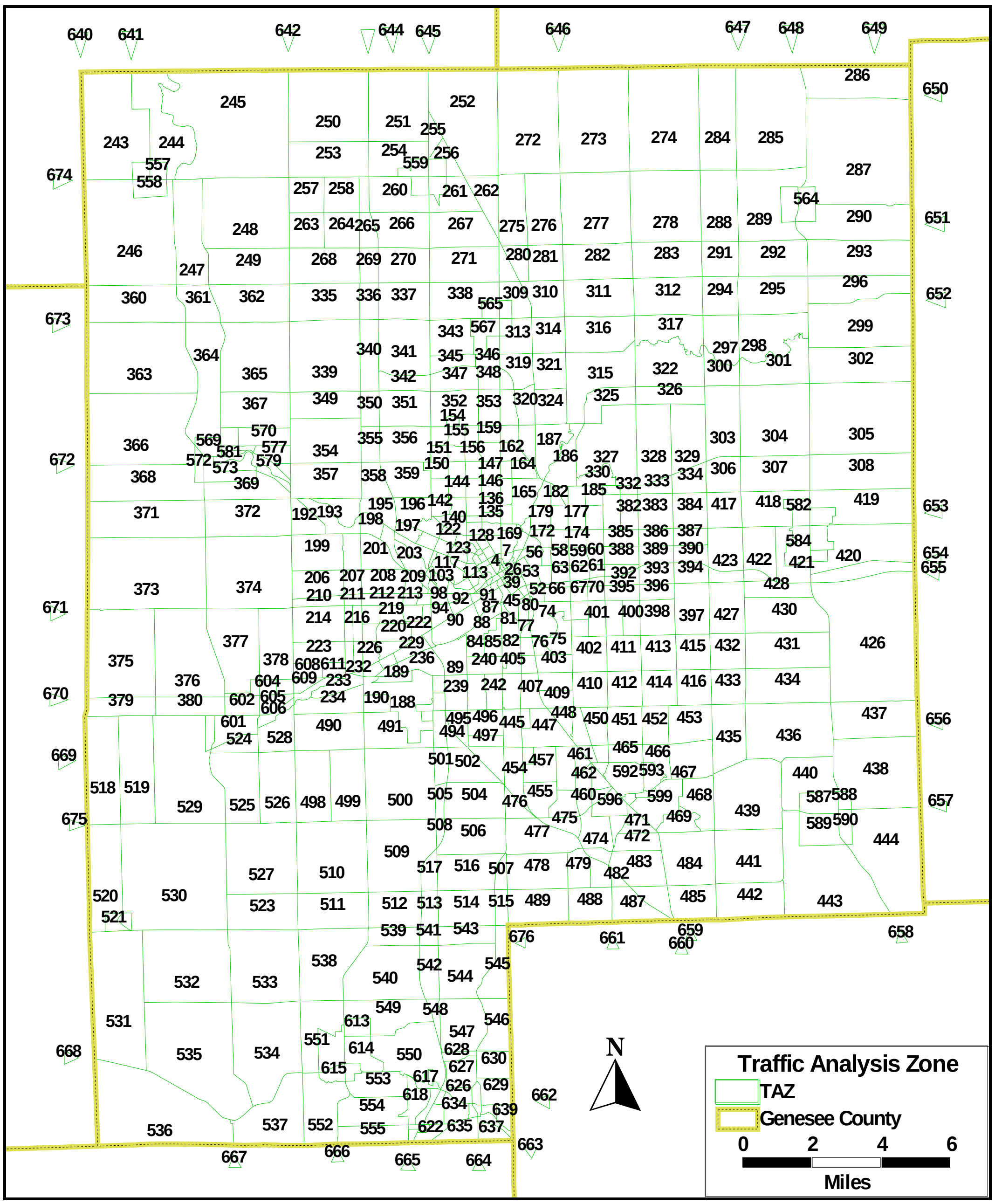


Figure 3. Genesee County TAZ

IV. NETWORK UPDATE AND TRANSIT ROUTE DEVELOPMENT

Network Update

A substantial effort was undertaken on the Genesee county model network to update a TransCAD-based network that included all necessary highways (freeway, arterials, and collectors) to be analyzed along with the highway attributes. There are 4,330 links serving the 676 zones in the Genesee County travel model. Over 1,413 centroid connectors are used to link the centroids to the greater network. There are thirty-seven external stations in the network. **Figure 4** shows the final Genesee County Travel Model network.

The updated Genesee model network, developed using TransCAD software, includes the following fundamental elements of travel model networks:

- Nodes are elements that describe the position of intersections, junctions or switches in roadway or railway networks. Centroids are nodes that lie at the center of a Traffic Analysis Zone (TAZ).
- Signalized intersections are marked in the network for the accurate estimation of link speed and capacity.
- Links are network model elements that connect the nodes and have attributes including direction, speed, capacity, functional classification, and observed traffic. They represent the street grid.
- Centroid connectors link the zones to the network. They represent the distance to be covered between a zone's center of gravity and the highway nodes or transit stops in the region.
- 2005 base year traffic count data is inputted by using the data resource from MDOT, MPO and cities.

The following rules were used in the network update:

- The Michigan Geographic Framework Version 6C was used to edit or confirm the location of roads with respect to cities, villages, townships and the roadway system itself. Transit service lines were respected so that a transit network could be built on the highway network.
- Centroid connectors were given a thorough review using Genesee County digital aerials. The roadway network was used to align connectors where feasible. Each centroid ID was coded onto the centroid connectors so that it could be referenced by the travel model if needed. Wherever logical access points exist, a centroid connector was added.
- External stations were given a thorough review by Genesee County. As a result of this analysis, a small set of very low traffic external points was removed. The TAZ, connector and network were edited to reflect this change.
- Geometry and grade separation were reviewed on major roads and interchanges.
- A list of network validation tests was established and begun. These include the testing of the network with an artificial "matrix of ones" that shows which segments and connectors have zero volumes.

The incorporation of geometric and operational data was one of the major improvements made in the Genesee County model. These detailed data on the roadway characteristics provided valuable information for estimating various inputs (such as capacities and speeds) to the subsequent modeling processes. Tables of the link attributes can be found in the *Model Users Guide*.

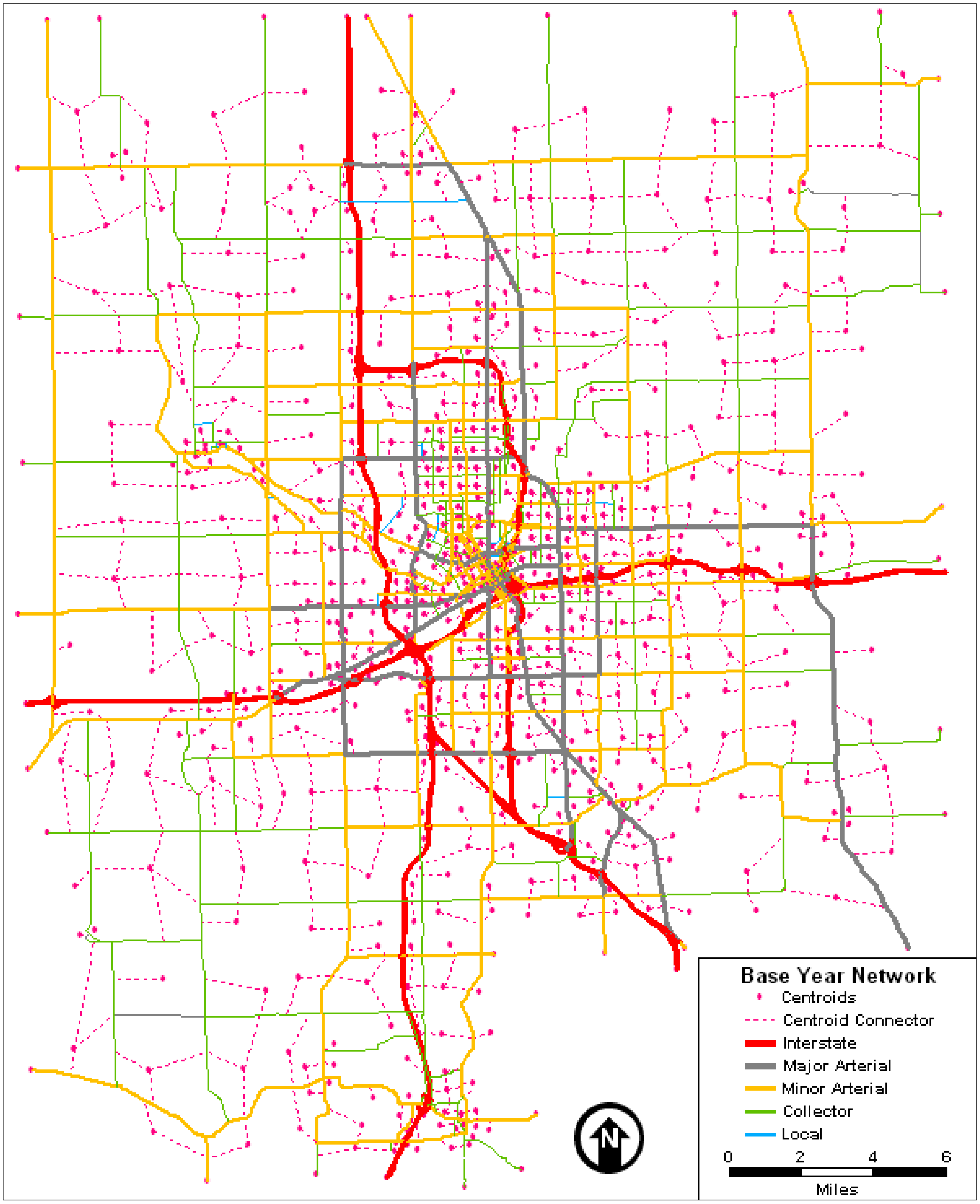


Figure 4. Genesee County Highway Network

Transit Route System

The transit network component has been developed concurrently with the development of the roadway network and traffic analysis zones (TAZ), so that any special considerations needed for transit modeling are accommodated in the design of the new TAZ structure and/or road network.

- Route service information was collected from MTA
- GIS files related to MTA routes and bus stops were assembled
- GIS files from the MTA on-board survey were used to identify active stops
- MTA fixed route system was coded as TransCAD route system

The Flint MTA system, operates both fixed route and curb-to-curb "Your Ride" service. Only the fixed route portion of the system was represented in the TransCAD model. The fixed-route bus system structure is a classic hub and spoke system centered on the downtown Flint transit center. The Flint MTA operates 14 distinct routes during a typical weekday. Route alignments and headways vary by time of day.

The developed transit route system is displayed in **Figure 5**. Tables of the route attributes, such as headway, seat capacity and so on, can be found in the *Model Users Guide*. The following fundamental elements are included in the transit route development:

- The transit network was created using the new 2005 base year road network geographic file which was originally developed from the MGF version 6, but has been significantly edited and modified to become the new Genesee County model network.

- Transit routes in the model are represented via TransCAD's special data structure called a route system. Each of the bus routes were coded by hand using the TransCAD route system editing toolkit. Future edits to the route system must use the same method. Also, because of the desire to use a master network, which keeps all future network scenarios in one file, the transit route system scenarios is kept in a single TransCAD routing system file with attributes to identify which routes belong to each unique scenario.

- During development and coding of the transit system in TransCAD, some additional roadway network links were added to accommodate the bus routes. However, this was only done in cases where the transit route uses significant public roadways. In several cases, the transit routes go onto private property (shopping centers, commercial complexes, etc.) or on minor non-functionally classed roadway, and the decision was made to not code those into the road and transit network system in TransCAD.

- The MTA route structure varies by time of day, and the model has 4 time periods. The model's time periods are AM and PM 3 hour peak periods, a 6 hour mid-day period, and a 12 hour off-peak period. The route system was coded to accommodate these needs. For the off-peak period, headways were coded such that they reflect only the times when the transit service is operating.

- Transit stops were added based on several datasets.

    1. GCMPC supplied GIS layer of route alignments and stop points
    2. MTA 2007 on-board survey, geocoded "on/off stop" locations
    3. MTA 2008 route sheets, public information brochures and website (see appendix)

- The final base year model transit routes as they are represented in the TransCAD route system are shown in the following figure.

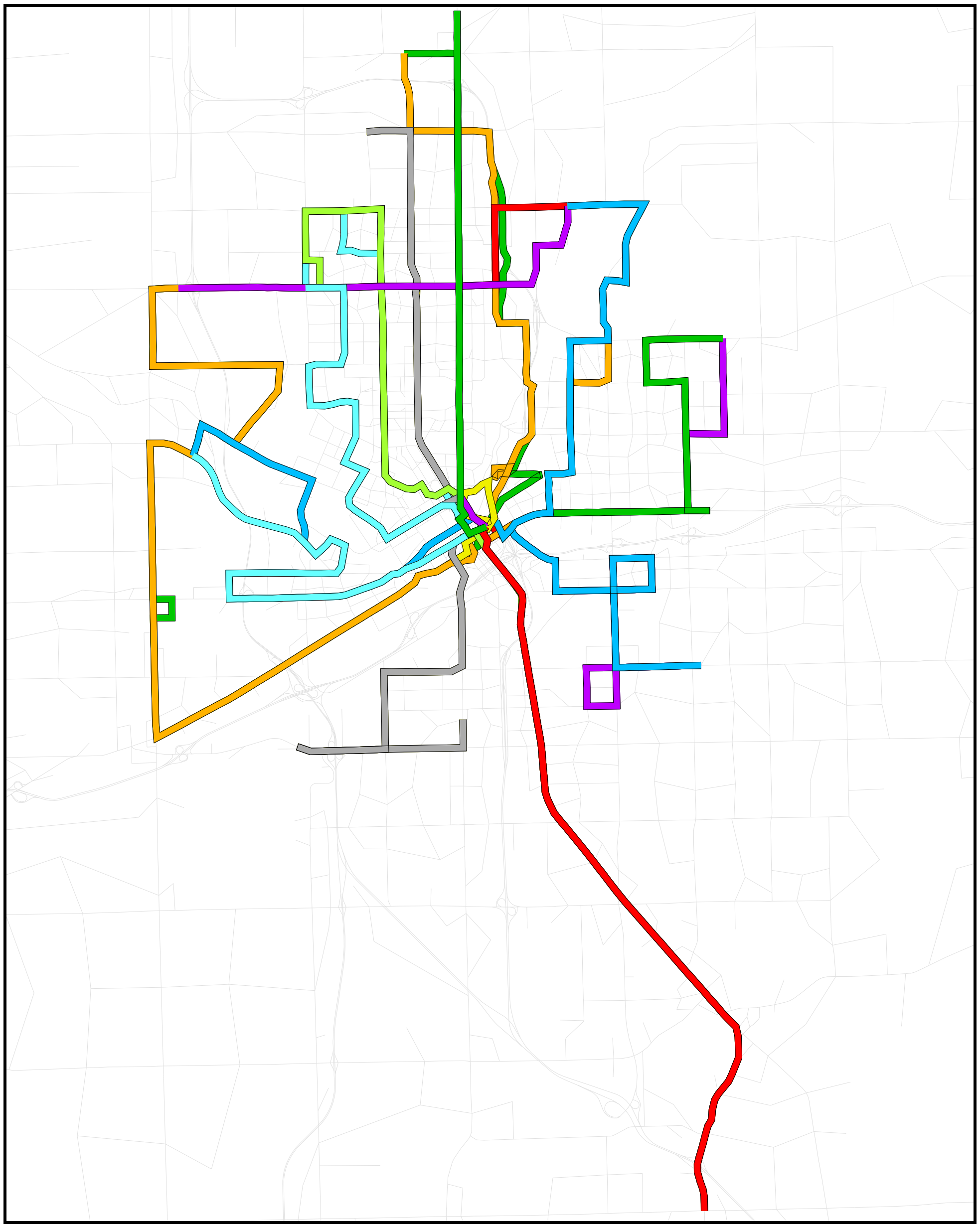


Figure 5. Flint MTA Bus Routes

V. FREE-FLOW SPEED AND CAPACITY ESTIMATION

Free-flow Speed Estimation

By definition, "free-flow" speed is the speed that occurs when traffic density (vehicles per lane mile) and traffic flow (vehicles per hour) are zero. Thus, factors determining free-flow speed only include the geometrics of the road and the posted speed without any influences by traffic, weather or accidents. Free-flow link speeds are used in most elements of the assignment procedures including network skim, trip distribution and trip assignment. The importance of using correct free-flow speeds cannot be overstated.

Most travel models use posted speed limits as a surrogate for free-flow speeds. The previous Genesee County Urban Travel Demand Model falls in this category. This common practice does not provide true free-flow inputs to the travel model, and raises the risk of a significant mis-estimation of travel times.

Another widely used method relies on a detailed speed table that determines free-flow speeds based on the roadway's area type, functional class, posted speed and number of lanes. This table is constructed from various statistical analyses on field data collected from an extensive speed survey. Using the speed table, more realistic free-flow speeds can be input to the above mentioned models.

Bernardin Lochmueller and Associates has developed a tool which calculates the free-flow speeds based on the methodologies presented in the *Highway Capacity Manual 2000* (HCM 2000). This new speed estimation procedure further improves the previous method. The previous method is heavily dependent on the roadway's functional class definition. However, definition of the functional class is somewhat judgmental and can lead to incorrect interpretation of actual geometric and functional roadway conditions. On this ground, the new procedure utilizes roadway's facility type instead of relying on its functional class.

The tool was originally developed for the Indiana Statewide Travel demand model, and has been refined for several subsequent urban model applications around the nation. For the original work, a speed survey was conducted in an area of 26 counties and relationships between facility type and free-flow speed was investigated. The facility type was determined based on area type, total number of lanes, median type (divided vs. undivided), directionality (one-way vs. bi-directional), and access control type (full, partial or none). For each unique facility type, observed speeds that represent free-flow conditions were compared with their respective posted speed limits. The relationship between the observed free-flow speeds and the posted speeds was then formulated by curve fitting these two data items using nonlinear regressions. **Table 1** lists the nonlinear formula developed for major facility types. The speeds for other minor variations in facility type such as one-way streets were derived from these formula based on similarity in geometric and functional characteristics of the roadway.

Table 1. Free-Flow Speed Estimation Formula

Area Type	**Free-Flow Speed [1, 2]**	**Condition**	**Note**
2-lane 2-way undivided highways			
Rural	$0.009751 \cdot PSPD^2 + 30.03397$	25 ≤ PSPD ≤ 55	No or Partial Access Control
	25	PSPD < 25	
Suburban	$117.640917 \cdot PSPD^{0.0015+0.001279PSPD} - 98.065483$	25 ≤ PSPD ≤ 55	
	25	PSPD < 25	
Urban	$6.189 + 0.9437 \cdot PSPD$	25 ≤ PSPD ≤ 55	
	25	PSPD < 25	
2-lane 2-way divided highways			
Rural	$\left(0.000017 \cdot (PSPD - 72.323105)^2 + 0.019702\right)^{-1} + 19.835323$	25 ≤ PSPD ≤ 55	No Access Control
	25	PSPD < 25	
Suburban	$3.180682 \cdot PSPD^{0.857638} - 84.105587 \cdot e^{-41.803252/PSPD}$	25 ≤ PSPD ≤ 55	
	25	PSPD < 25	
Urban	$\left(0.119687 - 0.023365 \cdot \ln(PSPD)\right)^{-1} + 0.373821 \cdot PSPD$	25 ≤ PSPD ≤ 55	
	25	PSPD < 25	
Multilane undivided highways			
Rural	$\left(0.000017 \cdot (PSPD - 72.323105)^2 + 0.019702\right)^{-1} + 19.835323$	25 ≤ PSPD ≤ 65	
	25	PSPD < 25	
Suburban	$3.180682 \cdot PSPD^{0.857638} - 84.105587 \cdot e^{-41.803252/PSPD}$	25 ≤ PSPD ≤ 55	
	25	PSPD < 25	
Urban	$\left(0.119687 - 0.023365 \cdot \ln(PSPD)\right)^{-1} + 0.373821 \cdot PSPD$	25 ≤ PSPD ≤ 55	
	25	PSPD < 25	
Multilane divided highways			
Rural	$2.836165 \cdot PSPD - 0.071256 \cdot PSPD^2 + 0.000744 \cdot PSPD^3$	25 ≤ PSPD ≤ 50	No or Partial Access Control
	$16.0359 + 0.8223 \cdot PSPD$	50 < PSPD ≤ 65	
	25	PSPD < 25	
Suburban	$\left(0.000071 \cdot (PSPD - 64.166165)^2 + 0.035258\right)^{-1} + 9.061039 \cdot \ln(PSPD)$	25 ≤ PSPD ≤ 55	
	25	PSPD < 25	
Urban	$\left(0.081714 - 0.016217 \cdot \ln(PSPD)\right)^{-1}$	25 ≤ PSPD ≤ 55	
	25	PSPD < 25	
Full access controlled highways			
	55.00	PSPD = 55	
	58.00	PSPD = 60	
	62.00	PSPD = 65	
	65.00	PSPD = 70	

Note: [1] Free-flow speeds in mph, [2] PSPD: Posted speeds in mph

For the speed calculations, links on the Genesee County road network was categorized into facility types. The facility types are defined differently from what is coded in the network in the fields “LINK_TYPE_CD” or “FACILITY_TYPE_CD”. Instead, the new categories are defined from the following attributes: number of lanes, divided/undivided and area type. The naming convention is: <lanes> + <divided/undivided> + <area type>. An example of new facility type categories is "2xd_rur" which means, 2 lane highway, undivided, rural area. The following fields from the network were used to obtain the needed information:

1- *Directionality of the links:* Field “Dir”
2- *Number of Lanes:* Filed “NUM_LANES” gives total number of lanes. Also the line layer has “THRU_LANES” coded. “NUM_LANES” includes the Left Turn Only Center Lanes and Left Turn Bays at intersections. For Speed Calculations “THRU_LANES” is used.
3- *Divided/Undivided*: Filed FACILITY_TYPE_CD defines Freeways when its value is 1 and Divided Arterials when its value is 2. These two type roads are the undivided roads. DIV_UNDIV was created as a new data field based on the information from FACILITY_TYPE_CD.
4- *Area Type:* Filed “AREA_TYPE_CD” defines 5 area types.
5- *Access Control:* Filed TRFC_OP_CD gives the information about the access control. TRFC_OP_CD = 1 implies the full access control while TRFC_OP_CD = 2 implies the partial access control. It is the variable used for the speed and capacity calculations.
6- *Posted Speeds*: Field “POSTED_SPEED”

GPS Speed Survey

A GPS speed survey for Genesee County was conducted in 2007-2008 by planning commission staff. The survey covers large portions of Genesee County and provides a sufficient sampling of the higher functional class road system with coverage that includes the full range of area types and varying types of roadways (median divided, center turn lane, signalized, freeway, etc.). The survey data was processed and the used to update the equations for model links such that they reflect the road specifics and drivers behavior in the area. The posted speed breakpoints for each functional type were revised. **Figure 6** shows the location of the speed survey coverage.

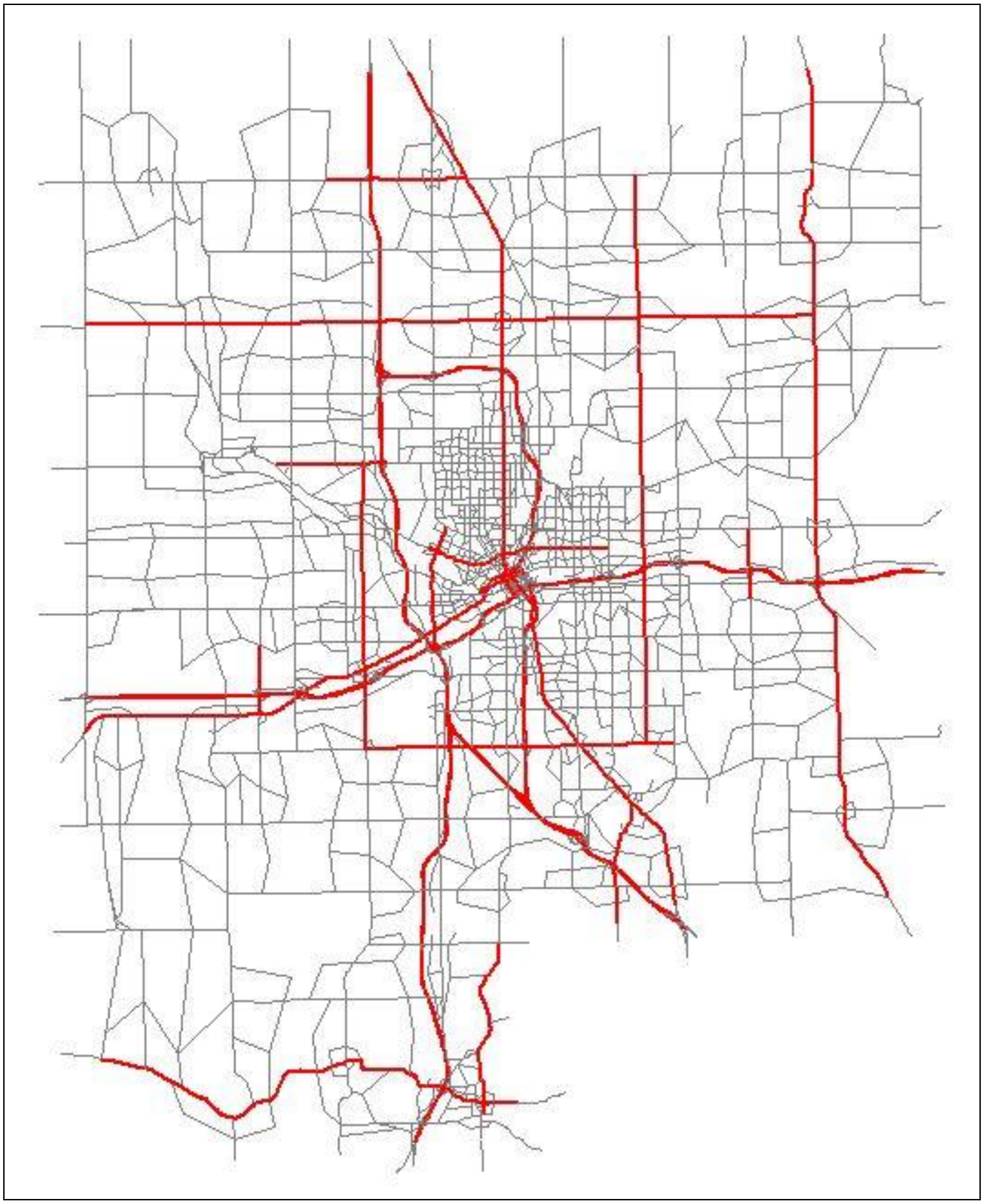


Figure 6. GPS Speed Survey Coverage

Capacity Estimation

The common practice applied in most travel models ascribes a roadway capacity based on a simplified link-capacity system that in many cases over or underestimates the true capacity of the roadway. Generally, they use several inputs factors in the capacity calculators. The most common used factors are: facility type, area type and number of lanes. The capacity calculator used in the 2002 previous Genesee County Travel Demand Model falls in this category too. Although these calculators are easy to understand and practical to use, they ignore the effect on capacity of other factors such as lane width, shoulder width, signal spacing, and other elements. For the 2005 model, peak-hour roadway capacities of the Genesee County regional network were estimated based on the *Highway Capacity Manual 2000* (HCM 2000) procedure. In this new procedure, detailed link data on geometric and operational characteristics incorporated in the network link attributes were used for improved estimates of link capacities. First, all links in the model area were set to “maximum hourly service flows” as specified in HCM with respect to their functional class. Then, the maximum service flows were adjusted to “hourly service flows” based on several of limiting factors. These capacity reduction factors include: right-shoulder lateral clearance, heavy vehicles, driver population, lane width, number of lanes, interchange density, median type, access points, and directional distribution.

A significant effort was given to develop these limiting factors from HCM 2000. For each of these factors, the manual provides adjustments (or reductions) in free-flow speeds that reflect negative effect of the factor. The reductions are determined based on geometric features of the roadway. For instance, for adjustments for lateral clearance for freeways, two geometric variables (right-shoulder lateral clearance and number of lanes) are cross-referenced to estimate the reduction in free-flow speed. These adjustments are then applied to base free-flow speed to obtain *actual* free-flow speed that takes into consideration unique physical conditions of the roadway. For example, reductions in free-flow speed for varying right-shoulder lateral clearance for basic freeway segments are shown **Figure 7**.

As the first step to derive the capacity reduction factors, a possible range of free-flow speed is set based on facility type. In the above example for freeways, free-flow speeds from 55 mph to 75 mph in an increment of 2.5 mph are used. For each combination of these preset free-flow speeds and the geometric variables, a ratio of the reduced free-flow speed to the original free-flow speed is calculated. This process resulted in a two-dimensional table (i.e., one dimension containing a range of free-flow speed and the other containing the geometric variables), which is populated with the ratios, or free-flow speed reduction factors. Under the assumption that the maximum service flow can be adjusted to the service flow with the same reduction percentage as the speed reduction factor, these free-flow speed reduction factors are used to estimate hourly service flows.

The two-dimensional table can be represented in a 3-dimension space as exemplified in **Figure 7**. The factors in this space were then generalized by curve fitting the factors using bi-factor nonlinear regression technique. As an example, **Table 2** lists curve-fitted formula for capacity reduction factors for lateral clearance. This procedure was applied to other capacity limiting factors such as adjustments for access point densities, lane widths, and other.

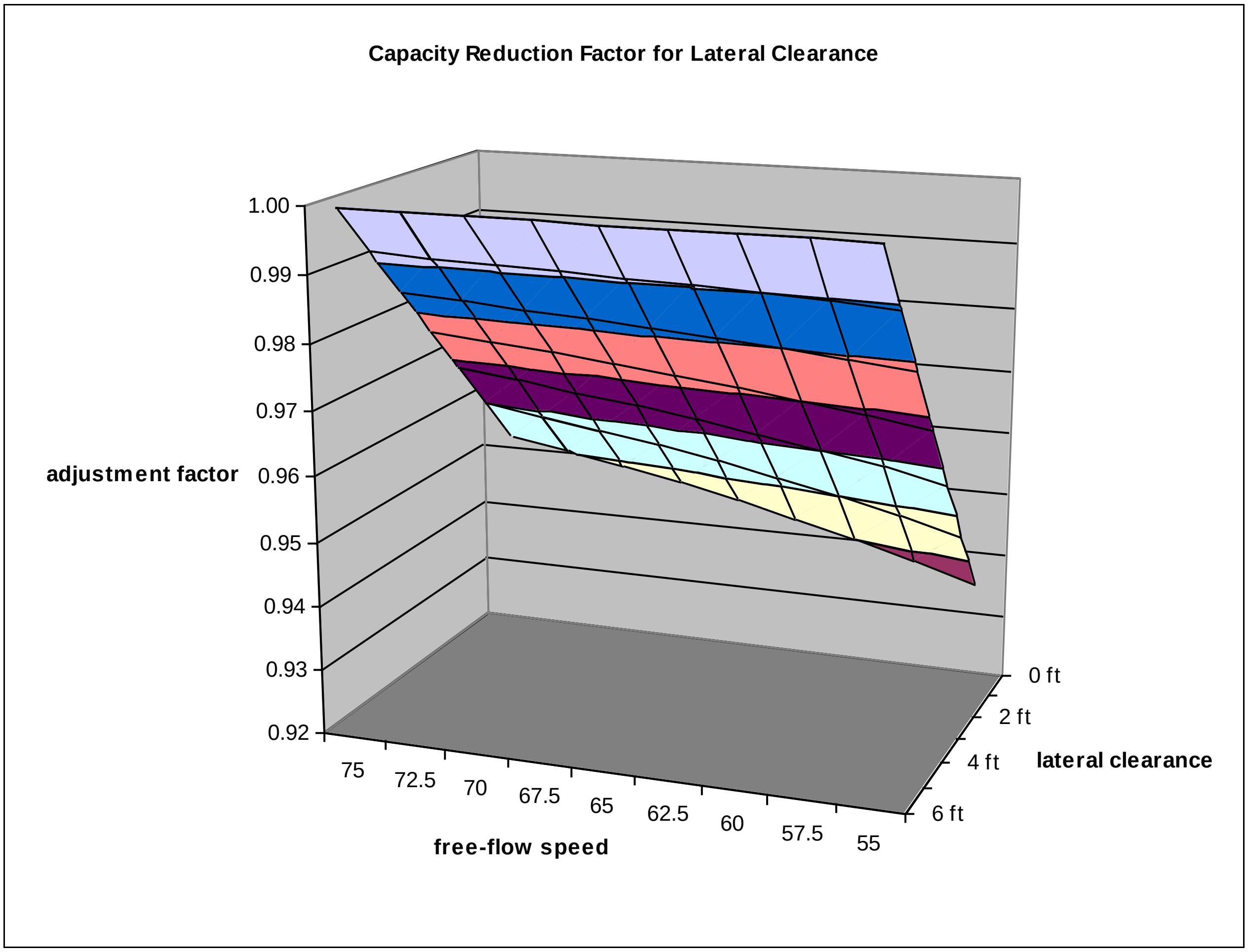


Figure 7. Capacity Reduction Factors for Lateral Clearance (Basic Freeway Segments)

In the Genesee County line layer:

1- Lane width is given in field: “LANE_WIDTH”
2- Right Shoulder Width is given in filed: “SHOULDER_WIDTH” –this field is filled only for trunk lines. This information of non-trunk line is not available.
3- Federal Highway Functional Classes are given in field: “FUNCLASS”
4- *Number of Lanes:* Filed “NUM_LANES” gives total number of lanes. Also the line layer has “THRU_LANES” coded. “NUM_LANES” includes the Left Turn Only Center Lanes and Left Turn Bays at intersections. Capacity calculations is based on the “THRU_LANES”.

Table 2: Capacity Reduction Factors for Lateral Clearance

Class	Reduction Factor [1]	Note
Interstates and Freeways		
2 lanes in one direction	$\frac{-6.00001+\text{RSLC}}{0.0001+1.66667\cdot\text{FSPD}}+1$	Min. 0.9345
3 lanes in one direction	$\frac{-5.99999+\text{RSLC}}{-0.00084+2.50001\cdot\text{FSPD}}+1$	Min. 0.9564
4 lanes in one direction	$\frac{-6.00001+\text{RSLC}}{-0.00002+5\cdot\text{FSPD}}+1$	Min. 0.9782
≥5 lanes in one direction	$\frac{-6.00002+\text{RSLC}}{0.00371+9.99994\cdot\text{FSPD}}+1$	Min. 0.9891
Multilane Highways		
4 total lanes	$\frac{1095.74797+\text{FSPD}}{1280.33942+6.53454\cdot\text{RSLC}^2}+0.03975\cdot\text{RSLC}$	Min. 0.8800
6 total lanes	$\frac{1485.4381+\text{FSPD}}{1660.34815+3.0981\cdot\text{RSLC}^2}+0.02166\cdot\text{RSLC}$	Min. 0.9133
Two-Lane Highways		
Shoulder width < 2 ft	$1.20306\cdot\text{FSPD}^{(0.27207-0.08633\cdot\ln(\text{LW}))}-\frac{7.09882}{\text{LW}}$	Min. 0.8400
Shoulder width < 4 ft	$1.43621\cdot\text{FSPD}^{(0.26354-0.09366\cdot\ln(\text{LW}))}-\frac{8.06484}{\text{LW}}$	Min. 0.8800
Shoulder width < 6 ft	$1.58362\cdot\text{FSPD}^{(0.24881-0.09472\cdot\ln(\text{LW}))}-\frac{8.34158}{\text{LW}}$	Min. 0.9125

Note: [1] RSLC: right-shoulder lateral clearance (ft), FSPD: free-flow speed (mph), LW: lane width (ft)

The 2005 Genesee County model consists of four different time-of-day models; thus, each of the time periods is analyzed with roadway capacities that are specific to the respective time period. The peak hour capacity obtained using the nonlinear curve fitting methods is then converted to period capacities by multiplying appropriate number of hours in each time period. In this model, morning and evening peak periods is defined as three hour spans, and midday is from 9AM to 3PM. The remaining hours are defined as an off-peak period.

The peak-period capacity is then converted to directional capacities. Changes in directional capacities by time period are estimated according to changes in lane usage by time-of-day. The capacity for the off-peak period is obtained by applying K-factors to the directional peak-hour capacity. The K-factors are used by area type based on the recommendation in the *Florida's Level of Service Standards and Guidelines Manual for Planning, FDOT, 1995.*

VI. DELAYS ON INTERRUPTED FACILITIES

Free-flow speeds and roadway capacities estimated in the previous steps needed to be adjusted to account for delays associated with traffic signals. The adjustment was made directionally according to the methodology described below.

Traffic signals were entered in the network as link attributes with designations of approach prioritization and multiple signals. If the approach to the signalized intersection was a higher functional class than crossroad, it was coded as "high" priority. If it was on par with the crossroad, it was assumed to have "equal" priority. If it was a lower functional class than the crossroad, it was given "low" priority. The number of multiple upstream signals was coded to account for progression effect as a result of signal coordination.

The speed and capacity adjustment for traffic signal delay followed a HCM methodology that uses the following equation:

$$d = 0.5C\left(1 - \frac{g}{C}\right)^2 \cdot PF$$

where, d = delay per vehicle,
g = effective green time,
C = cycle length, and
PF = progression adjustment factor.

Delay estimated from the above equation is added to the free-flow speed-based link travel-time to come up with an "adjusted" free-flow travel time. Based on the fact that the mainline road is given a higher priority than the lower-class crossroad, varying green time ratios (g/C) were assumed by the priority code of the signal approach. HCM provides the progression adjustment factor as a function of the green time ratio and the arrival type. The arrival type for the signal approach is assumed based on multiple signals coded in the network. With the assumed green time ratio and the arrival type, an appropriate progression factor in HCM is sought and used to estimate signal delay of the approach.

The capacity reduction methodology is based on travel-speed reductions resulting from delays on the flow-interrupted facilities. The service flow rate is a function of the travel time along a road segment. Increasing signal densities effectively reduces travel speeds, and, in turn, reduces the amount of traffic flow that is possible. The reduction in service flow is calculated by dividing the maximum service flow approximate based on free-flow speed by the maximum service flow approximates based on speeds with traffic signal delays.

These speed and capacity adjustments due to traffic signals are made directionally. Thus, signal approach lane(s) and lane(s) in the other direction are estimated with different speed and capacity values. In the 2005 Genesee County node layer, signal information is stored in the field: "TRAFFIC SIGNAL". The presence of a signal is indicated by filling this filed with "Y". For the 2005 model, a new convention was developed for filling this field to consider the presence of left turn lanes by approach in the capacity calculations.

VII. GENESEE TRAVEL MODEL COMPONENTS

The Genesee County Travel Demand Model is built upon a model of the population of Genesee County. Fundamentally, it is people that make trips, and within a travel demand model, trip making and ultimately traffic volumes on roadway segments and VMT in a region are driven by the people who live and work there. All travel demand models in the U.S. are based on Census data about the population of the model area.

The way in which Census data is used in various models differs widely. In some of the oldest and simplest models, trip making and other aspects of travel demand like mode choice are based on the number of people or households in each traffic analysis zone and their aggregate or average characteristics (average automobiles owned per household, etc.). However, this very simple approach inevitably results in a variety of errors because it is not able to capture the complexities of the people and behaviors involved. Many of the behaviors involved, such as trip-making, are not linearly related to the variables used to predict them. Although trip making can be represented simply by an average trip rate, for instance 0.48 home-based shop/personal business trips per person from the *MI Travel Counts Household Travel Survey*, a household with one person produces 0.92 trips on average while a household with four or more people produces an average of only 1.71 such trips. There are a number of reasons for these sort of nonlinearity, but for instance, it stands to reason that just because a household had more people does not necessarily mean that it needs to make more trips to buy groceries each week; they may simply buy more groceries in a single trip.

The traditional way of dealing with these nonlinearities in travel behavior is to segment the population and use averages specific to each segment. So, for instance, based on the average number of persons per household, predict the number of one person households, two person households, etc., and apply a trip rate specific to each type of household. Typically this is done using two variables, such as number of persons per household and number of vehicles per household. This approach is called cross-classification. There are several difficulties with this approach. The most notable is that it severely limits the number of variables that can be used to explain trip making, mode choice and other aspects of travel behavior. The limitations of the traditional approach have motivated the development of alternative approaches.

The common alternative to the traditional approach which has been experimented with in research and practice is activity-based modeling. In activity-based modeling, average characteristics of the population from Census data are used to build a simulated population which has the same average attributes as the real population. Then, each simulated person or household makes choices hopefully similar to the real choices people make about what to do, where to do it and how to get there. The two main drawbacks of activity-based modeling are that they are simulation based or probabilistic models rather than deterministic models (which complicates the comparison of results for different alternatives) and that they require many more component models which in turn require more data to estimate and considerably more computer power and time to run.

The Genesee County model takes an intermediate approach. It begins by building a synthetic population of simulated households, very much like an activity based model, but then uses a more traditional, trip-based rather than activity-based framework for modeling people’s travel. Using a synthetic population, however, allows even trip-based models to incorporate many more variables and capture many of the advantages, increased realism and increased sensitivity to more policy variables, offered by activity-based models without the disadvantages of the complexities of simulation modeling or long run times. For instance, the Genesee County model responds to an increase in households with seniors (age 65+) and predict less work trips, but more shop trips, less trips by foot or bike, and more trips during the middle of the day and less during the peak hours. Traditional models do not offer this kind of sensitivity. Activity-based models offer this and more, but at much greater cost in run time and development cost. The Genesee County disaggregate deterministic approach offers this sort of additional sensitivity at no greater cost than a simpler traditional model.

A. EXTERNAL MODELS

One trip has two ends, one is origin and the other is destination. The trips with one end in the study area are referred to as External-Internal (EI) or Internal-External (IE) trips while the trips with no ends in the study area are referred to as through or External-External (EE) trips. The end point on the roadway outside the study area or on the roadway where the study area bound line is crossed is referred to as an external station/zone.

Three vehicle classes, bus, truck and auto vehicle, are considered in the Genesee travel demand model. A commercial vehicle with six tires or above belongs to the truck class while a motorcycle, a passage car or a commercial vehicle with four tires belongs to the auto vehicle class. Only truck and auto vehicle classes are taken into account in the external trip estimation.

Considering that there is no external travel survey for Genesee County and the external trip estimation method introduced in NCHRP Report 365 is not applicable for a study area with a population over 100,000, an alternative method was proposed to use the TransCAD's subarea analysis in the Michigan statewide travel demand model to generate two preliminary external trip tables for Genesee County. One external trip table is for auto vehicle class and the other is for truck. Then these external trip tables were adjusted to match the base year traffic counts at all external stations. The Michigan statewide model covers only major roads in Genesee County. The general assumption of the alternative method is the external-external trips exist from one external station to another only if there are trips between these two locations in the Michigan statewide model.

The 2035 external trip estimation is required for the Genesee model update. The 2030 preliminary external trip tables were generated by the subarea analysis in the 2030 Michigan statewide model. The 2030 preliminary external trip tables were adjusted by the 2005 adjustment amounts, and then the annual growth rates of auto vehicle and truck trips were calculate using the number of trips in the 2005 and 2030 external trip tables. The annual growth rates were used to calculate the 2035 total external trips and external-external trips, and the Fratar model was used to compute the 2035 external-external trip matrices for auto vehicle and truck. The Michigan statewide model covers only twenty-five external stations of the Genesee County model. For the other ten external stations not in the statewide model, the annual growth rates were assumed, and the general assumption is there are no external-external trips of these ten external stations. In other words, the external trips of those ten external stations that are not in the Michigan statewide model network are all EI-IE trips. In addition, this approach can also be used to estimate the external trip tables of any year in between 2005 and 2035.

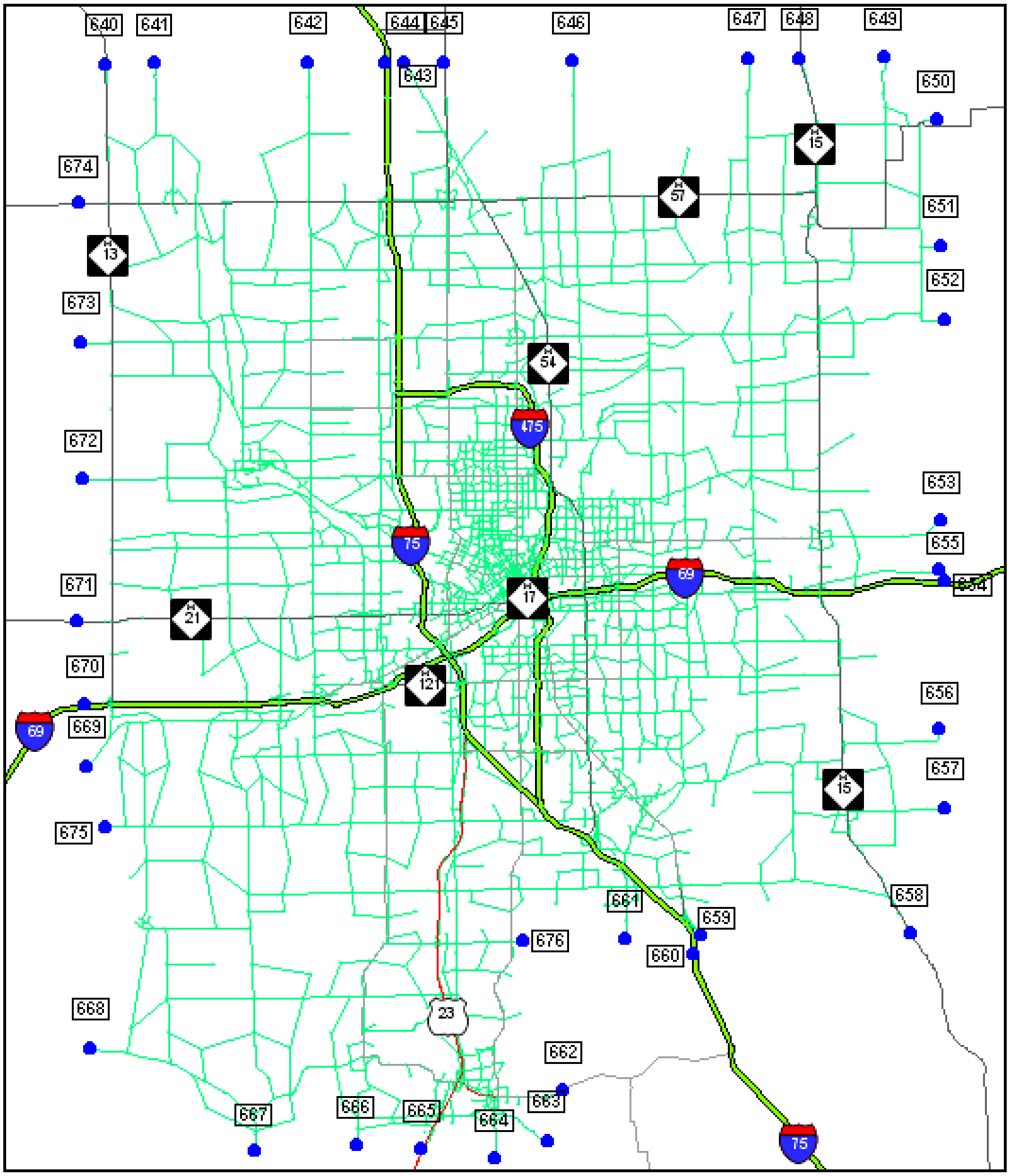


Figure 8. External Station Locations and IDs

Base Year External Station Summary

The detail information of these thirty-seven external stations shown in **Figure 8** is given in **Table 3**. It includes the name, location, functional class, daily traffic count, daily truck count and truck percent of each external station. **Table 3** also summarizes the daily traffic count, daily truck count and truck percent for all external stations. Among those thirty-seven external stations, thirty are in rural areas and seven are in urban areas. Six major external stations are on interstate, expressway and principal arterial, and ID numbers are 643, 655, 658, 660, 665 and 670. The Average Daily Traffic (ADT) counts very from 662 to 52,222 and the ADT truck counts vary from 50 to 6,788. The highest truck percent is 18.03%, the lowest truck percent is 2.98% and the average truck percent is 9.7% for all external stations.

Table 3. External Station Summary

External Station				ADT Traffic	ADT Truck	Truck
ID	**Name**	**Location**	**Functional Class**	**Count**	**Count**	**Percent**
640	Sheridan Ave	North of Study Area	Rural Minor Arterial	5,068	506	9.98%
641	Nichols Rd	North of Study Area	Rural Major Collector	662	70	10.57%
642	Elms Rd	North of Study Area	Rural Major Collector	2,302	262	11.38%
643	**I 75 North**	North of Study Area	Rural Interstate	52,222	6,788	13.00%
644	Saginaw Rd	North of Study Area	Rural Minor Arterial	5,790	330	5.70%
645	Clio Rd	North of Study Area	Urban Minor Arterial	4,558	152	3.33%
646	Bray Rd	North of Study Area	Rural Major Collector	2,650	284	10.72%
647	Irish Rd	North of Study Area	Rural Major Collector	1,206	58	4.81%
648	State Rd	North of Study Area	Rural Minor Arterial	8,262	246	2.98%
649	Henderson Rd	North of Study Area	Rural Major Collector	924	158	17.10%
650	Lake Rd	East of Study Area	Rural Minor Arterial	2,666	152	5.70%
651	Columbiaville Rd	East of Study Area	Rural Major Collector	2,932	168	5.73%
652	E Mount Morris Rd	East of Study Area	Rural Major Collector	4,120	234	5.68%
653	Davison Rd	East of Study Area	Rural Minor Arterial	5,854	400	6.83%
654	Lapeer Rd	East of Study Area	Rural Major Collector	2,138	122	5.71%
655	**I 69 East**	East of Study Area	Rural Interstate	36,928	4,800	13.00%
656	Hill Rd	East of Study Area	Rural Major Collector	2,256	128	5.67%
657	Hegel Rd	East of Study Area	Rural Major Collector	1,570	90	5.73%
658	**Ortonville Rd**	South of Study Area	Rural Principal Arterial	14,538	436	3.00%
659	Dixie Hwy	South of Study Area	Urban Minor Arterial	13,918	514	3.69%
660	**I 75 South**	South of Study Area	Rural Interstate	43,874	5,046	11.50%
661	N Holly Rd	South of Study Area	Rural Minor Arterial	9,298	530	5.70%
662	Main St	South of Study Area	Rural Minor Arterial	13,042	812	6.23%
663	S Holly Rd	South of Study Area	Urban Collector	6,684	248	3.71%
664	Adelaide St	SW of Study Area	Urban Collector	3,420	254	7.43%
665	**S US 23**	SW of Study Area	Urban Expressway	43,394	4,338	10.00%
666	Linden Rd	South of Study Area	Urban Collector	6,122	294	4.80%
667	Seymour Rd	SW of Study Area	Rural Minor Arterial	4,276	244	5.71%
668	Silver Lake Rd	West of Study Area	Rural Minor Arterial	4,054	228	5.62%
669	Lansing Rd	West of Study Area	Rural Minor Arterial	3,682	210	5.70%
670	**I 69 West**	West of Study Area	Rural Interstate	29,400	5,300	18.03%
671	M 21	West of Study Area	Rural Minor Arterial	9,016	450	4.99%
672	Pierson Rd	West of Study Area	Rural Major Collector	1,224	70	5.72%
673	W Mount Morris Rd	West of Study Area	Rural Major Collector	2,166	124	5.72%
674	Vienna Rd	West of Study Area	Rural Minor Arterial	4,656	512	11.00%
675	Grand Blanc Rd	West of Study Area	Rural Collector	3,800	300	7.89%
676	Thompson Rd	South of Study Area	Urban Minor Arterial	700	50	7.14%
Total				359,372	34,908	9.71%

Base Year External Trip Estimation

The base year external trip estimation has three steps, i.e. subarea analysis, trip table adjustment and EI-IE trip calculation by trip purpose. Genesee County was selected as the subarea in the Michigan statewide travel demand model, and the subarea analysis was performed to generate two preliminary external trip tables. One external trip table is for auto vehicle class and the other is for truck. These external trip tables were adjusted to match the base year traffic counts at all external stations. Finally the EI-IE trips were calculated by three trip purposes, i.e. non-work, EI and IE work purposes. This calculation used the split ratios obtained from the "MI Travel Counts" household travel survey and the 2000 Census Transportation Planning Package (CTPP). The Michigan statewide model covers only major roads in Genesee County. The general assumption of the alternative method is the external-external trips exist from one external station to another only if there are trips between these two locations in the Michigan statewide model. In other words, the external trips of external stations on some roadways that are not in the Michigan statewide model network are all EI-IE trips. The following section introduces the Michigan statewide travel demand model.

The 2005 and 2030 trip tables along with the network of the Michigan statewide travel demand model were obtained for this project. The statewide model has no breakout between autos, trucks, or transit. The trip tables include the following trip purposes: Home Based Work Business (HBWB), Home Based Social Recreation (HBSR), Home Based Other (HBO), Non-Home Based Work Business (NHBWB), and Non-Home Based Other (NHBO). In the statewide model, a trip table (matrix) of all trips - all purposes combined is generated for the trip assignment. The assignment method is the all-or-nothing traffic assignment.

With the network and trip tables a subarea analysis can be performed to get a smaller version of the statewide model just for Genesee County. Genesee County is defined as a subarea in the Michigan statewide model. **Figure 9** displays the selected subarea and twenty-seven gates (points), i.e. external stations for the Genesee county model. The trips in the statewide model go into or leave Genesee County through those gates. Two external stations on Grand Blanc Road (west of the study area) and Flint Street (east of study area) do not exist in the Genesee county model, and its ID numbers are zero. Ten external stations in the Genesee model are on lower-function roadways and do not exit in the statewide model. It is assumed that there are no external-external trips for those ten external stations.

The subarea analysis of Multi-Modal Multi-Class Assignment (MMA) was performed in TransCAD to get the subarea trip table for each trip purpose mentioned above for estimating the truck external trip table. A preliminary truck trip table was estimated by adding 20% NHBO and 10% NHBWB trips together, and the preliminary auto trip table is equal to the difference between all-vehicle trip table and the truck trip table. Since the all-or-nothing method was used in the assignment, the inbound and outbound traffic volumes are unbalanced. The symmetric matrix processing is necessary to get the balance inbound and outbound volumes.

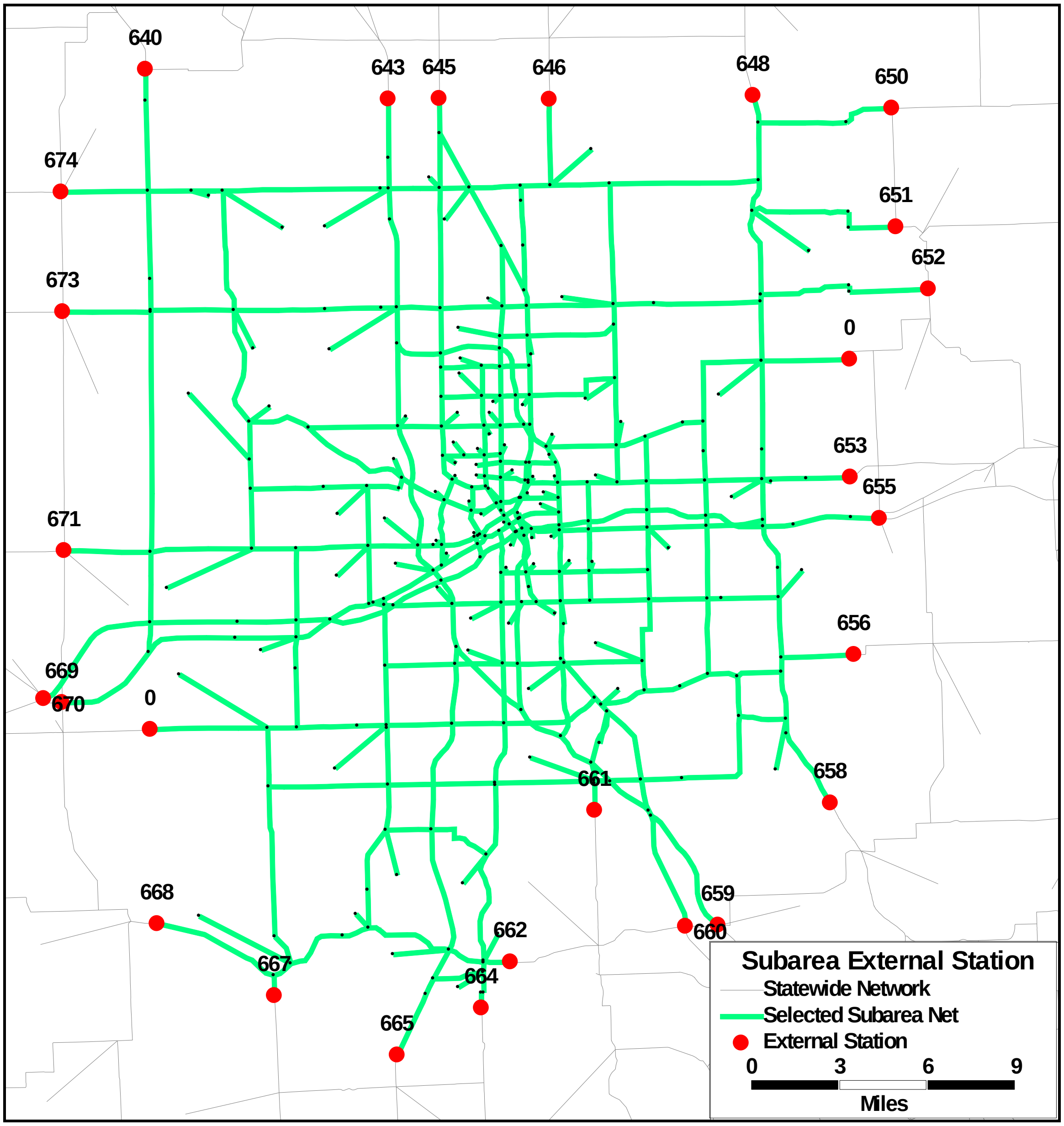


Figure 9. Subarea Model External Stations

The preliminary external trip tables from the subarea analysis need to be adjusted to match the Average Daily Traffic (ADT) counts. The following steps are proposed for the external trip table adjustment,

(1) Determining daily Origin (O) and Destination (D) trips by auto vehicle and truck for each external station from ADT counts
(2) Generating the symmetric trip matrices (tables) if these matrices are asymmetric
(3) Splitting EI-IE and EE trips and computing the final EE O-D matrices for auto vehicle and truck
(4) Calculating EI-IE O and D trips by auto vehicle and truck.

Fratar Model

The doubly-constrained growth factor method is also known as Fratar model that keeps the total balance to both origins and destinations, or productions and attractions. The final O-D matrix should be such that the sum of each row (i.e., origin trips per zone) is within a given convergence criterion of the corresponding forecast origin trips for that zone, and the sum of each column (i.e., destination trips per zone) is within a given convergence criterion of the corresponding forecast destination trips. The goal is to solve the following equation:

$$T_{ij} = t_{ij} * oi * dj$$

$$\text{subject to: } \sum_j T_{ij} = Oi, \quad \sum_i T_{ij} = Dj \qquad (1)$$

where T_{ij}= Output trips from zone *i* to zone *j*

t_{ij}= Original trips from zone *i* to zone *j*

o_i = Balancing factor for row

d_j = Balancing factor for column

O_i= Origin trips of zone *i*

D_j= Destination trips of zone *j*

The following steps are proposed for applying the Fratar Model in the external trip adjustment of each vehicle class,

(i) Splitting the EE and EI-IE trips in the subarea trip table from the statewide model

(ii) Factoring the preliminary EE and EI-IE O & D trips to match the base year traffic counts at each external station

(iii) Balancing the factored EE O & D trips by the *Weighted Sum* (50% O to 50% D) *method in TransCAD.* Balance process makes total EE O trips are equal to total EE D trips of all external stations

(iv) Obtaining the final EE O-D table by applying the balanced EE O & D to the preliminary EE O-D table using the Fratar model. This is the process to adjust the preliminary EE O-D matrix obtained from the statewide model to replicate the current local traffic conditions

(v) Obtaining the EI-IE (O +D) by (O+D) minus EE (O+D).

Tables 4 and 5 show 2005 ADT counts, 2005 statewide model volumes, 2005 final EE O & D, and 2005 final EI-IE (O+D) for auto vehicle and truck trips. **Tables 6 and 7** display the EE O-D trip tables for auto vehicle and truck.

Table 4. 2005 External Auto Trip Estimation

ID	NAME	2005 Auto ADT Count	2005 SW Model Auto Volume	2005 Auto External Trip Results				
				O	D	EE O	EE D	EI-IE O+D
640	Sheridan Ave	4,562	6,358	2,281	2,281	1,549	1,549	1,464
641	Nichols Rd	592	0	296	296	0	0	592
642	Elms Rd	2,042	0	1,021	1,021	0	0	2,042
643	I 75 North	45,434	53,596	22,717	22,717	13,468	13,468	18,498
644	Saginaw Rd	5,460	0	2,730	2,730	0	0	5,460
645	Clio Rd	3,676	6,238	1,838	1,838	556	556	2,564
646	Bray Rd	2,644	3,272	1,322	1,322	13	13	2,618
647	Irish Rd	964	0	482	482	0	0	964
648	State Rd	8,016	7,376	4,008	4,008	1,186	1,186	5,644
649	Henderson Rd	766	0	383	383	0	0	766
650	Lake Rd	2,514	2,122	1,257	1,257	526	526	1,462
651	Columbiaville Rd	2,764	2,226	1,382	1,382	1,051	1,051	662
652	E Mount Morris Rd	3,886	1,038	1,943	1,943	18	18	3,850
653	Davison Rd	3,856	0	1,928	1,928	0	0	3,856
654	Lapeer Rd	2,016	0	1,008	1,008	0	0	2,016
655	I 69 East	32,128	44,798	16,064	16,064	7,914	7,914	16,300
656	Hill Rd	2,128	3,686	1,064	1,064	94	94	1,940
657	Hegel Rd	1,680	0	840	840	0	0	1,680
658	Ortonville RD	14,102	11,328	7,051	7,051	613	613	12,876
659	Dixie Hwy	13,404	0	6,702	6,702	0	0	13,404
660	I 75 South	38,828	55,428	19,414	19,414	3,865	3,865	31,098
661	N Holly Rd	8,768	826	4,384	4,384	2,388	2,388	3,992
662	Main St	12,230	162	6,115	6,115	3,170	3,170	5,890
663	S Holly Rd	6,436	0	3,218	3,218	0	0	6,436
664	Adelaide St	3,168	0	1,584	1,584	0	0	3,168
665	S US 23	39,056	50,618	19,528	19,528	5,865	5,865	27,326
666	Linden Rd	7,634	0	3,817	3,817	0	0	7,634
667	Seymour Rd	4,032	2,028	2,016	2,016	96	96	3,840
668	Silver Lake Rd	3,762	4,148	1,881	1,881	96	96	3,570
669	Lansing Rd	3,472	0	1,736	1,736	0	0	3,472
670	I 69 West	24,100	33,442	12,050	12,050	6,346	6,346	11,408
671	M 21	8,566	8,268	4,283	4,283	831	831	6,904
672	Pierson Rd	1,154	0	577	577	0	0	1,154
673	W Mount Morris Rd	2,042	1,970	1,021	1,021	208	208	1,626
674	Vienna Rd	4,144	7,200	2,072	2,072	981	981	2,182
675	Grand Blanc Rd	3,500	0	1,750	1,750	0	0	3,500
676	Thompson Rd	650	0	325	325	0	0	650
	Total	324,176	306,128	162,088	162,088	50,834	50,834	222,508

Table 5. 2005 External Truck Trip Estimation

ID	NAME	2005 Truck ADT Count	2005 SW Model Truck Volume	2005 External Truck Trip Results				
				O	D	EE O	EE D	EI-IE O+D
640	Sheridan Ave	506	694	253	253	176	176	154
641	Nichols Rd	70	0	35	35	0	0	70
642	Elms Rd	262	0	131	131	0	0	262
643	I 75 North	6,788	5,626	3,394	3,394	2,140	2,140	2,508
644	Saginaw Rd	330	0	165	165	0	0	330
645	Clio Rd	152	570	76	76	15	15	122
646	Bray Rd	284	272	142	142	2	2	280
647	Irish Rd	58	0	29	29	0	0	58
648	State Rd	246	690	123	123	41	41	164
649	Henderson Rd	158	0	79	79	0	0	158
650	Lake Rd	152	214	76	76	26	26	100
651	Columbiaville Rd	168	144	84	84	63	63	42
652	E Mount Morris Rd	234	88	117	117	0	0	234
653	Davison Rd	400	0	200	200	0	0	400
654	Lapeer Rd	122	0	61	61	0	0	122
655	I 69 East	4,800	3,618	2,400	2,400	1,542	1,542	1,716
656	Hill Rd	128	254	64	64	11	11	106
657	Hegel Rd	90	0	45	45	0	0	90
658	Ortonville RD	436	838	218	218	24	24	388
659	Dixie Hwy	514	0	257	257	0	0	514
660	I 75 South	5,046	7,234	2,523	2,523	489	489	4,068
661	N Holly Rd	530	72	265	265	176	176	178
662	Main St	812	14	406	406	232	232	348
663	S Holly Rd	248	0	124	124	0	0	248
664	Adelaide St	254	0	127	127	0	0	254
665	S US 23	4,338	5,538	2,169	2,169	717	717	2,904
666	Linden Rd	294	0	147	147	0	0	294
667	Seymour Rd	244	156	122	122	7	7	230
668	Silver Lake Rd	228	300	114	114	7	7	214
669	Lansing Rd	210	0	105	105	0	0	210
670	I 69 West	5,300	3,732	2,650	2,650	1,454	1,454	2,392
671	M 21	450	676	225	225	69	69	312
672	Pierson Rd	70	0	35	35	0	0	70
673	W Mount Morris Rd	124	188	62	62	13	13	98
674	Vienna Rd	512	680	256	256	126	126	260
675	Grand Blanc Rd	300	0	150	150	0	0	300
676	Thompson Rd	50	0	25	25	0	0	50
	Total	34,908	31,598	17,454	17,454	7,330	7,330	20,248

Table 6. 2005 External-to-External Auto Trips

	640	643	645	646	648	650	651	652	655	656	658	660	661	662	665	667	668	670	671	673	674	Sum
640	--	--	--	--	--	1.9	0.7	--	11.1	0.1	0.0	19.5	1.0	--	16.0	--	--	879.6	311.5	106.2	201.4	1549.0
643	--	--	--	--	--	--	--	--	3718.5	56.9	16.7	3293.4	1315.3	--	2261.2	--	--	2348.0	250.4	36.5	171.2	13468.0
645	--	--	--	--	--	--	511.9	--	31.2	0.8	12.1	--	--	--	--	--	--	--	--	--	--	556.0
646	--	--	--	--	--	--	--	--	--	--	--	10.7	2.3	--	--	--	--	--	--	--	--	13.0
648	--	--	--	--	--	459.0	449.3	--	79.4	10.7	46.1	0.4	16.7	--	10.9	--	--	88.9	2.3	0.7	21.5	1186.0
650	1.9	--	--	--	459.0	--	--	--	--	--	--	--	--	--	--	--	--	--	0.5	2.7	61.8	526.0
651	0.7	--	511.9	--	449.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.0	89.0	1051.0
652	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	18.0	--	18.0
655	11.1	3718.5	31.2	--	79.4	--	--	--	--	--	515.7	13.7	722.1	--	236.1	--	--	2298.6	68.8	16.4	203.5	7915.0
656	0.1	56.9	0.8	--	10.7	--	--	--	--	--	--	--	--	--	4.4	--	0.0	17.4	0.6	0.1	3.0	94.0
658	0.0	16.7	12.1	--	46.1	--	--	--	515.7	--	--	--	--	--	--	--	--	22.1	0.0	0.0	0.2	613.0
660	19.5	3293.4	--	10.7	0.4	--	--	--	13.7	--	--	--	--	--	--	--	--	322.4	108.2	12.2	84.6	3865.0
661	1.0	1315.3	--	2.3	16.7	--	--	--	722.1	--	--	--	--	--	--	--	--	268.6	11.6	1.1	49.4	2388.0
662	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3170.0	--	0.0	--	--	--	--	3170.0
665	16.0	2261.2	--	--	10.9	--	--	--	236.1	4.4	--	--	--	3170.0	--	--	--	40.7	77.0	14.2	34.7	5865.0
667	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	96.0	--	--	--	--	96.0
668	--	--	--	--	--	--	--	--	--	0.0	--	--	--	0.0	--	96.0	--	--	--	--	--	96.0
670	879.6	2348.0	--	--	88.9	--	--	--	2298.6	17.4	22.1	322.4	268.6	--	40.7	--	--	--	--	--	60.7	6347.0
671	311.5	250.4	--	--	2.3	0.5	--	--	68.8	0.6	0.0	108.2	11.6	--	77.0	--	--	--	--	--	--	831.0
673	106.2	36.5	--	--	0.7	2.7	0.0	18.0	16.4	0.1	0.0	12.2	1.1	--	14.2	--	--	--	--	--	--	208.0
674	201.4	171.2	--	--	21.5	61.8	89.0	--	203.5	3.0	0.2	84.6	49.4	--	34.7	--	--	60.7	--	--	--	981.0
Sum	1549.0	13468.0	556.0	13.0	1186.0	526.0	1051.0	18.0	7915.0	94.0	613.0	3865.0	2388.0	3170.0	5865.0	96.0	96.0	6347.0	831.0	208.0	981.0	50836.0

Table 7. 2005 External-to-External Truck Trips

	640	643	645	646	648	650	651	652	655	656	658	660	661	662	665	667	668	670	671	673	674	Sum
640	--	--	--	--	--	0.5	0.3	--	2.2	0.0	0.0	2.0	0.1	--	2.1	--	--	133.6	16.9	5.5	12.9	176.0
643	--	--	--	--	--	--	--	--	681.7	6.9	0.5	402.9	82.0	--	400.8	--	--	531.8	19.1	2.2	12.0	2140.0
645	--	--	--	--	--	--	14.2	--	0.7	0.0	0.1	--	--	--	--	--	--	--	--	--	--	15.0
646	--	--	--	--	--	--	--	--	--	--	--	1.7	0.3	--	--	--	--	--	--	--	--	2.0
648	--	--	--	--	--	12.6	20.0	--	2.7	0.2	0.3	0.0	0.2	--	0.4	--	--	4.2	0.1	0.0	0.3	41.0
650	0.5	--	--	--	12.6	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.5	12.3	26.0
651	0.3	--	14.2	--	20.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.0	28.5	63.0
652	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.0	--	0.0
655	2.2	681.7	0.7	--	2.7	--	--	--	--	--	22.6	1.8	64.5	--	50.4	--	--	671.2	11.1	2.0	31.1	1542.0
656	0.0	6.9	0.0	--	0.2	--	--	--	--	--	--	--	--	--	0.6	--	0.0	2.9	0.0	0.0	0.3	11.0
658	0.0	0.5	0.1	--	0.3	--	--	--	22.6	--	--	--	--	--	--	--	--	0.5	0.0	0.0	0.0	24.0
660	2.0	402.9	--	1.7	0.0	--	--	--	1.8	--	--	--	--	--	--	--	--	59.5	10.7	1.2	9.1	489.0
661	0.1	82.0	--	0.3	0.2	--	--	--	64.5	--	--	--	--	--	--	--	--	25.5	0.6	0.1	2.7	176.0
662	--	--	--	--	--	--	--	--	--	--	--	--	--	--	232.0	--	0.0	--	--	--	--	232.0
665	2.1	400.8	--	--	0.4	--	--	--	50.4	0.6	--	--	--	232.0	--	--	--	13.5	10.3	1.5	5.4	717.0
667	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.0	--	--	--	--	7.0
668	--	--	--	--	--	--	--	--	--	0.0	--	--	--	0.0	--	7.0	--	--	--	--	--	7.0
670	133.6	531.8	--	--	4.2	--	--	--	671.2	2.9	0.5	59.5	25.5	--	13.5	--	--	--	--	--	11.5	1454.0
671	16.9	19.1	--	--	0.1	0.1	--	--	11.1	0.0	0.0	10.7	0.6	--	10.3	--	--	--	--	--	--	69.0
673	5.5	2.2	--	--	0.0	0.5	0.0	0.0	2.0	0.0	0.0	1.2	0.1	--	1.5	--	--	--	--	--	--	13.0
674	12.9	12.0	--	--	0.3	12.3	28.5	--	31.1	0.3	0.0	9.1	2.7	--	5.4	--	--	11.5	--	--	--	126.0
Sum	176.0	2140.0	15.0	2.0	41.0	26.0	63.0	0.0	1542.0	11.0	24.0	489.0	176.0	232.0	717.0	7.0	7.0	1454.0	69.0	13.0	126.0	7330.0

Genesee County not only serves as a bedroom community to several neighboring counties, but also attracts trips into the region for other purposes, including working. For this reason, three separate purposes of EI-IE auto trips were defined:

- EI_Work (EI_W). The EI_W trips represent the inbound commute to work and return from work made by residents outside of Genesee County. Trip Productions (P) are assigned at external stations as a percent of total volumes based on MI Travel Counts and CTPP JTW and trip attractions are estimated at internal zones as function of HBW attractions
- IE_Work (IE_W). The IE_W trips represent the outbound work commute and return from work made by residents inside Genesee County. Trip productions estimated to internal TAZs as a function of HBW and trip attractions using MI Travel Count data and attractions are assigned to external stations as a percentage of total outbound traffic
- External NonWork (E_NW). The E_NW trips represent other external trips that are not related to work. Trip productions are assigned at external station as a percent of total volume, and trip attractions estimated at internal zones as function of HBO and HBSH attractions.

In Technical Memorandum 5.2 – Trip Generation, a table was made to report the number of records in the survey database disaggregated based on EI_work, IE_work, External NonWork by region. The table is copied in the following and the distribution percents by purpose were calculated based on the number of records of each trip purpose.

Table 8. EI-IE Trip Percent by Purpose

Entry Region	EI_W Trips	IE_W Trips	E_NW Trips	Total	EI_W Percent	IE_W Percent	E_NW Percent	Total
North	100	44	362	506	20%	9%	72%	100%
East	59	26	212	297	20%	9%	71%	100%
West	94	37	217	348	27%	11%	62%	100%
South	43	230	154	427	10%	54%	36%	100%
Southwest	64	114	170	348	18%	33%	49%	100%
Total	360	451	1,115	1,926	19%	23%	58%	100%

Table 8 reports the external station locations, 2005 auto EI-IE trip production & attraction, distribution percent by purpose, EI_Work trip production, IE_Work trip attraction and External NonWork trip production. The 2005 auto EI-IE trip productions and attractions are equal to the 2005 auto EI-IE trip origins and destinations in **Table 9**.

Table 9. 2005 EI-IE Trips by Purpose

ID	NAME	Location	2005 AUTO EI-IE P+A	Percent EI_W P	IE_W A	E_NW P	EI_W Production	IE_W Attraction	E_NW Production
640	Sheridan Ave	North of Study Area	1,464	20%	9%	71%	293	132	1,039
641	Nichols Rd	North of Study Area	592	20%	9%	71%	118	53	420
642	Elms Rd	North of Study Area	2,042	20%	9%	71%	408	184	1,450
643	I 75 North	North of Study Area	18,498	20%	9%	71%	3,700	1,665	13,134
644	Saginaw Rd	North of Study Area	5,460	20%	9%	71%	1,092	491	3,877
645	Clio Rd	North of Study Area	2,564	20%	9%	71%	513	231	1,820
646	Bray Rd	North of Study Area	2,618	20%	9%	71%	524	236	1,859
647	Irish Rd	North of Study Area	964	20%	9%	71%	193	87	684
648	State Rd	North of Study Area	5,644	20%	9%	71%	1,129	508	4,007
649	Henderson Rd	North of Study Area	766	20%	9%	71%	153	69	544
650	Lake Rd	East of Study Area	1,462	20%	9%	71%	292	132	1,038
651	Columbiaville Rd	East of Study Area	662	20%	9%	71%	132	60	470
652	E Mount Morris Rd	East of Study Area	3,850	20%	9%	71%	770	347	2,734
653	Davison Rd	East of Study Area	3,856	20%	9%	71%	771	347	2,738
654	Lapeer Rd	East of Study Area	2,016	20%	9%	71%	403	181	1,431
655	I 69 East	East of Study Area	16,300	20%	9%	71%	3,260	1,467	11,573
656	Hill Rd	East of Study Area	1,940	20%	9%	71%	388	175	1,377
657	Hegel Rd	East of Study Area	1,680	20%	9%	71%	336	151	1,193
658	Ortonville RD	South of Study Area	12,876	10%	54%	36%	1,288	6,953	4,635
659	Dixie Hwy	South of Study Area	13,404	10%	54%	36%	1,340	7,238	4,825
660	I 75 South	South of Study Area	31,098	10%	54%	36%	3,110	16,793	11,195
661	N Holly Rd	South of Study Area	3,992	10%	54%	36%	399	2,156	1,437
662	Main St	South of Study Area	5,890	10%	54%	36%	589	3,181	2,120
663	S Holly Rd	South of Study Area	6,436	10%	54%	36%	644	3,475	2,317
664	Adelaide St	SW of Study Area	3,167	18%	33%	49%	570	1,045	1,552
665	S US 23	SW of Study Area	27,326	18%	33%	49%	4,919	9,018	13,390
666	Linden Rd	South of Study Area	7,634	10%	54%	36%	763	4,122	2,748
667	Seymour Rd	SW of Study Area	3,840	18%	33%	49%	691	1,267	1,882
668	Silver Lake Rd	West of Study Area	3,570	27%	11%	62%	964	393	2,213
669	Lansing Rd	West of Study Area	3,472	27%	11%	62%	937	382	2,153
670	I 69 West	West of Study Area	11,408	27%	11%	62%	3,080	1,255	7,073
671	M 21	West of Study Area	6,904	27%	11%	62%	1,864	759	4,280
672	Pierson Rd	West of Study Area	1,154	27%	11%	62%	312	127	715
673	W Mount Morris Rd	West of Study Area	1,626	27%	11%	62%	439	179	1,008
674	Vienna Rd	West of Study Area	2,182	27%	11%	62%	589	240	1,353
675	Grand Blanc Rd	West of Study Area	3,500	27%	11%	62%	945	385	2,170
676	Thompson Rd	South of Study Area	650	10%	54%	36%	65	351	234
	Total		222,507				37,984	65,833	118,690

Future Year External Trip Estimation

The 2035 external trip table estimation is required for the Genesee model update. The Michigan statewide travel demand model has two horizontal years, i.e. 2005 and 2030. The 2030 preliminary external trip tables were generated by the subarea analysis in the 2030 Michigan statewide model. The 2030 preliminary external trip tables were adjusted by the 2005 adjustment amounts, and then the annual growth rates of auto vehicle and truck trips were calculated using the number of trips in the 2005 and 2030 external trip tables. The annual growth rates were used to calculate the 2035 total external trips and external-external trips, and the Fratar model was used to compute the 2035 external-external trip matrices for auto vehicle and Truck. The Michigan statewide model covers only twenty-five external stations of the Genesee county model. For other ten external stations not in the statewide model, the annual growth rates were assumed, and the general assumption is there are no external-external trips of these ten external stations. In other words, the external trips of those ten external stations that are not in the Michigan statewide model network are all EI-IE trips. In addition, this approach was coded in the Genesee model and can be used to calculate the external trip table of any year in between 2005 and 2035. Finally the EI-IE trips were calculated by three trip purposes, i.e. non-work, EI and IE work purposes.

The subarea analysis of Multi-Modal Multi-Class Assignment (MMA) was performed in TransCAD to get the external trip tables (matrix) for each trip purpose defined in the statewide model. The preliminary external truck trip table is estimated by adding 20% NHBO and 10% NHBWB matrices together, and the preliminary auto external trip matrix is equal to the difference between all-vehicle trip matrix and the truck external trip matrix. There were adjustments to the statewide model results in the 2005 external trip estimation, and those adjustments were applied to the 2030 statewide model results as well. The final 2030 external trip calculation of each vehicle class can be explained by the following equation:

2030 External Trips = 2030 SW Model Trips + (2005 ADT Count – 2005 SW Model Trips)   (2)

The final 2035 external traffic volumes of auto vehicle and truck are listed in **Table 11**. The trip growth calculation equation is given below,

$$Vol_{2035} = Vol_{2005} * (1+r)^{(2035-2005)} \quad (3)$$

Where Vol_{2035} is the 2035 external traffic volumes, i.e. total trip origins and destinations
Vol_{2005} is the 2005 external traffic volumes
r is the annual growth rate

Table 10 shows the calculated growth rates of twenty-five external stations for auto vehicle and truck. These rates were calculated based on the equation below,

$$r = \exp\{[\mathrm{Ln}(Vol_{2035}) - \mathrm{Ln}(Vol_{2005})]/25\} - 1 \quad (4)$$

where exp() is the function returning the value of the constant *e* raised to a power
Ln() is the function returning the natural logarithm of a number

Table 10. Annual Growth Rate of Auto and Truck Trips

ID	NAME	Rate Type	Annual Auto Growth Rate	Annual Truck Growth Rate
640	Sheridan Ave	**calculated**	2.5%	0.6%
641	Nichols Rd	assumed	0.8%	0.5%
642	Elms Rd	assumed	0.8%	0.5%
643	I 75 North	**calculated**	1.3%	0.4%
644	Saginaw Rd	assumed	0.8%	0.5%
645	Clio Rd	**calculated**	3.0%	1.6%
646	Bray Rd	**calculated**	0.8%	0.1%
647	Irish Rd	assumed	0.8%	0.5%
648	State Rd	**calculated**	0.8%	0.8%
649	Henderson Rd	assumed	0.8%	0.5%
650	Lake Rd	**calculated**	1.2%	0.3%
651	Columbiaville Rd	**calculated**	3.2%	0.5%
652	E Mount Morris Rd	**calculated**	0.3%	0.1%
653	Davison Rd	assumed	0.8%	0.5%
654	Lapeer Rd	assumed	0.8%	0.5%
655	I 69 East	**calculated**	2.4%	0.6%
656	Hill Rd	**calculated**	1.0%	0.1%
657	Hegel Rd	assumed	0.8%	0.5%
658	Ortonville RD	**calculated**	1.1%	0.9%
659	Dixie Hwy	assumed	0.8%	0.5%
660	I 75 South	**calculated**	1.9%	0.5%
661	N Holly Rd	**calculated**	0.4%	0.2%
662	Main St	**calculated**	0.1%	0.1%
663	S Holly Rd	assumed	0.8%	0.5%
664	Adelaide St	assumed	0.8%	0.5%
665	S US 23	**calculated**	2.3%	0.9%
666	Linden Rd	assumed	0.8%	0.5%
667	Seymour Rd	**calculated**	1.0%	0.4%
668	Silver Lake Rd	**calculated**	1.0%	0.6%
669	Lansing Rd	assumed	0.8%	0.5%
670	I 69 West	**calculated**	2.2%	0.4%
671	M 21	**calculated**	0.9%	0.3%
672	Pierson Rd	assumed	0.8%	0.5%
673	W Mount Morris Rd	**calculated**	0.7%	0.4%
674	Vienna Rd	**calculated**	2.1%	0.5%
675	Grand Blanc Rd	assumed	0.8%	0.5%
676	Thompson Rd	assumed	0.4%	0.2%

If a rate is less than 0.1%, this rate is assigned with 0.1%. Ten external stations that are not in the Michigan statewide model are on low functional classification roadway, such as collector and minor arterial. Its annual growth rates were assumed as 0.8% for auto vehicle trips and 0.5% for truck trips. However, the annual growth rates of external station 676 were assumed as 0.4% for auto trips and 0.2% for truck trips in consideration of the development conditions in the areas around this external station.

Based on the annual growth rates in **Table 10** and the 2005 external trips in **Table 3**, the number of 2035 External-Internal and Internal-External (EI-IE) trips can be calculated by use of Equation (3). Then 2035 EI-IE trips can be further disaggregated into the 2035 External-Internal Work (EI_W) trip productions, Internal-External Work (IE_W) trip attractions and External NonWork (E_NW) trip productions by use of the distribution percent in **Table 8**.

The number of 2035 external-external (EE) trips can be calculated using Equation (3) in a similar way. For each vehicle class, the 2035 external trips are the EE trips plus the EI-IE trips. **Table 11** reports the results of the 2035 external trip estimation. The 2005 external trip numbers were added in the table for comparison reason. Overall the number of truck trips increases 17.1% from 2005 to 2035 while the number of auto trips increases 59.6%.

Table 11. 2035 External Trips

ID	NAME	2005 Truck ADT Count	2035 Truck	Increase (%)	2005 Auto ADT Count	2035 Auto O+D	Increase (%)	2035 AUTO EI-IE P+A	2035 EI_W Production	2035 IE_W Attraction	2035 E_NW Production
640	Sheridan Ave	506	600	18.6%	4,562	9,460	107.4%	3,036	607	273	2,156
641	Nichols Rd	70	81	15.7%	592	751	26.9%	751	150	68	533
642	Elms Rd	262	304	16.0%	2,042	2,593	27.0%	2,593	519	233	1,841
643	I 75 North	6,788	7,736	14.0%	45,434	66,266	45.9%	26,980	5,396	2,428	19,156
644	Saginaw Rd	330	383	16.1%	5,460	6,934	27.0%	6,934	1,387	624	4,923
645	Clio Rd	152	244	60.5%	3,676	8,850	140.8%	6,174	1,235	556	4,384
646	Bray Rd	284	291	2.5%	2,644	3,400	28.6%	3,368	674	303	2,391
647	Irish Rd	58	67	15.5%	964	1,224	27.0%	1,224	245	110	869
648	State Rd	246	308	25.2%	8,016	10,182	27.0%	7,170	1,434	645	5,091
649	Henderson Rd	158	183	15.8%	766	972	26.9%	972	194	87	690
650	Lake Rd	152	163	7.2%	2,514	3,591	42.8%	2,089	418	188	1,483
651	Columbiaville Rd	168	195	16.1%	2,764	7,116	157.5%	1,704	341	153	1,210
652	E Mount Morris	234	241	3.0%	3,886	4,223	8.7%	4,185	837	377	2,971
653	Davison Rd	400	464	16.0%	3,856	4,897	27.0%	4,897	979	441	3,477
654	Lapeer Rd	122	141	15.6%	2,016	2,560	27.0%	2,560	512	230	1,818
655	I 69 East	4,800	5,734	19.5%	32,128	65,069	102.5%	33,013	6,603	2,971	23,439
656	Hill Rd	128	129	0.8%	2,128	2,861	34.4%	2,609	522	235	1,852
657	Hegel Rd	90	104	15.6%	1,680	2,133	27.0%	2,133	427	192	1,514
658	Ortonville RD	436	565	29.6%	14,102	19,504	38.3%	17,810	1,781	9,617	6,412
659	Dixie Hwy	514	596	16.0%	13,404	17,023	27.0%	17,023	1,702	9,192	6,128
660	I 75 South	5,046	5,874	16.4%	38,828	67,711	74.4%	54,231	5,423	29,285	19,523
661	N Holly Rd	530	563	6.2%	8,768	9,815	11.9%	4,469	447	2,413	1,609
662	Main St	812	836	3.0%	12,230	12,601	3.0%	6,069	607	3,277	2,185
663	S Holly Rd	248	288	16.1%	6,436	8,173	27.0%	8,173	817	4,413	2,942
664	Adelaide St	254	294	15.7%	3,168	4,022	27.0%	4,022	724	1,327	1,971
665	S US 23	4,338	5,626	29.7%	39,056	76,600	96.1%	53,594	9,647	17,686	26,261
666	Linden Rd	294	341	16.0%	7,634	9,695	27.0%	9,695	970	5,235	3,490
667	Seymour Rd	244	271	11.1%	4,032	5,418	34.4%	5,160	929	1,703	2,528
668	Silver Lake Rd	228	273	19.7%	3,762	5,059	34.5%	4,801	1,296	528	2,977
669	Lansing Rd	210	243	15.7%	3,472	4,409	27.0%	4,409	1,190	485	2,734
670	I 69 West	5,300	6,048	14.1%	24,100	46,560	93.2%	22,040	5,951	2,424	13,665
671	M 21	450	486	8.0%	8,566	11,051	29.0%	8,907	2,405	980	5,522
672	Pierson Rd	70	81	15.7%	1,154	1,465	26.9%	1,465	396	161	908
673	W Mount Morris	124	137	10.5%	2,042	2,499	22.4%	1,991	538	219	1,234
674	Vienna Rd	512	589	15.0%	4,144	7,671	85.1%	4,039	1,091	444	2,504
675	Grand Blac Rd	300	348	16.0%	3,500	4,445	27.0%	4,445	845	845	2,756
676	Thompson Rd	50	53	6.0%	650	732	12.6%	732	146	66	520
	Total	34,908	40,880	17.1%	324,176	517,535	59.6%	345,467	59,382	100,417	185,668

B. TRIP GENERATION MODEL

The trip generation component of the Genesee County model consists of trip production models for several trip purposes. The models were estimated using multiple regression techniques based on the *MI Travel Counts Household Travel Survey*.

For the Genesee County model, trip purposes were categorized as follows:

- Home Based Work Low Income (HBWLo)
- Home Based Work High Income (HBWHi)
- Home Based Shopping (HBS)
- Home Based Other (HBO)
- Home Based School – K12 (HBSCH)
- Home Based School – Univ / College (HBU)
- Non Home Based Other (NHBO)
- Non Home Based Work (NHBW)

Household Stratification

Based on the selection of trip purposes and cross classification variables, it is necessary to disaggregate the zonal households into the following categories:

- Household Size: 1, 2, 3 and 4+ Persons
- Household Workers: 0, 1, 2, and 3+ Workers per Household
- Vehicles per Household: 0, 1, 2 and 3+ Vehicles per Household
- Household Income: Low and High.

Households with an annual income less than $42,500 are categorized as the lower income group and all others are in the high income group. The cross classification of households necessary for trip production estimation is based on a cross multiplication of the necessary single dimension distributions to develop the two or three dimensional distribution of households. The single distributions were calibrated for Genesee County using Census for Transportation Planning Package (CTPP) Part 1 Data Tables at the CTPP TAZ level of geography. The specific tables used are shown in the following table.

Table 12. Household Stratification Calibration CTPP Data Sources

Variable	CTPP Table
Household Size	Table 62: Household Size by Number of Workers in Household Table 47: Total Number of Persons
Household Workers	Table 62: Household Size by Number of Workers in Household Table 17: Industry by Time Leaving Home to Go to Work
Vehicles per Household	Table 63: Household Size by Vehicles Available
Household Income	Table 66: Number of Workers in Household by Household Income

Using the CTPP TAZ Geography and corresponding data from the above tables, the distribution of households into each category was calculated from the CTPP data. In addition the independent variables were estimated for each CTPP TAZ. The independent variables used include:

- Household Size: Average Household Size
- Workers per Household: Average Number of Workers per Household
- Vehicles per Household: Average Number of Vehicles per Household
- Income: Zonal Average Income / Regional Average Income

Using SPSS, regression models were estimated for each size bin of the four dimensions using linear, quadratic and cubic functions. The resulting R squared, constant and coefficients for each model are presented in Table 2. In the application, a model must be chosen for each size category and applied using the zonal independent variable. A second consideration is how to "normalize" the resulting percentages to 1.0 or 100%. One approach proposed is to consider one size category as a residual. Thus the other size categories are estimated and the fourth category is then 1 minus the sum of the other categories. A final consideration in application is the treatment of values at the extreme ends of the curves. The predictive value of the models does not hold at the extremes, for example household size = 1. Thus the curves must be normalized to provide the correct result at the extreme minimum and maximum values of the independent variable.

Following is a series of figures that show the relationship between the zonal independent variable and observed percentages in each size category along with the calibrated models.

Table 13. Household Stratification Curve Estimation

Dependent	Model	R Square	Constant	b1	b2	b3
HH1	Linear	0.43108	0.771676	-0.20003		
	Quadratic	0.515363	1.350802	-0.65898	0.087752	
	Cubic	0.517791	1.556084	-0.91045	0.18395	-0.01156
HH2	Linear	0.042613	0.46252	-0.05072		
	Quadratic	0.076601	0.165912	0.184336	-0.04494	
	Cubic	0.080061	-0.03174	0.426456	-0.13757	0.01113
HH3	Linear	0.098116	-0.01445	0.072559		
	Quadratic	0.106726	-0.15519	0.184096	-0.02133	
	Cubic	0.109656	-0.32666	0.394147	-0.10168	0.009656
HH4	Linear	0.531357	-0.21975	0.178194		
	Quadratic	0.539203	-0.36153	0.29055	-0.02148	
	Cubic	0.541605	-0.19768	0.089848	0.055295	-0.00923

Independent: Average Household Size

Dependent	Model	R Square	Constant	b1	b2	b3
W0	Linear	0.634243	0.679496	-0.34407		
	Quadratic	0.717014	0.93788	-0.79967	0.184965	
	Cubic	0.719771	1.010131	-1.01074	0.364115	-0.04495
W1	Linear	0.025984	0.447983	-0.06093		
	Quadratic	0.074507	0.274906	0.244248	-0.1239	
	Cubic	0.148535	-0.05264	1.201123	-0.93606	0.203758
W2	Linear	0.478866	-0.05584	0.290012		
	Quadratic	0.502828	-0.1907	0.527793	-0.09654	
	Cubic	0.525725	0.011283	-0.06226	0.404278	-0.12565
W3	Linear	0.391397	-0.07164	0.114991		
	Quadratic	0.408214	-0.02209	0.027625	0.035469	
	Cubic	0.416509	0.031226	-0.12813	0.167666	-0.03317

Independent: Average Workers per Household

Dependent	Model	R Square	Constant	b1	b2	b3
V0	Linear	0.241045	0.198656	-0.06944		
	Quadratic	0.312985	0.339316	-0.22679	0.038314	
	Cubic	0.316623	0.397091	-0.33226	0.094188	-0.00875
V1	Linear	0.234151	0.525783	-0.11049		
	Quadratic	0.285691	0.71801	-0.32553	0.05236	
	Cubic	0.314217	0.456779	0.15138	-0.20028	0.03955
V2	Linear	0.216445	0.22872	0.100784		
	Quadratic	0.253326	0.074451	0.273361	-0.04202	
	Cubic	0.253496	0.055315	0.308297	-0.06053	0.002897
V3	Linear	0.21816	0.046842	0.079143		
	Quadratic	0.298975	-0.13178	0.27896	-0.04865	
	Cubic	0.336587	0.090814	-0.12741	0.166616	-0.0337

Independent: Average Vehicles per Household

Dependent	Model	R Square	Constant	b1	b2	b3
LOW	Linear	0.575313	0.902518	-0.41562		
	Quadratic	0.616462	1.116436	-0.86429	0.203395	
	Cubic	0.627002	0.927256	-0.22615	-0.40785	0.172674
HIGH	Linear	0.575313	0.097482	0.415616		
	Quadratic	0.616462	-0.11644	0.864292	-0.2034	
	Cubic	0.627002	0.072744	0.226147	0.407847	-0.17267

Independent: Zonal Average Income / Regional Average Income

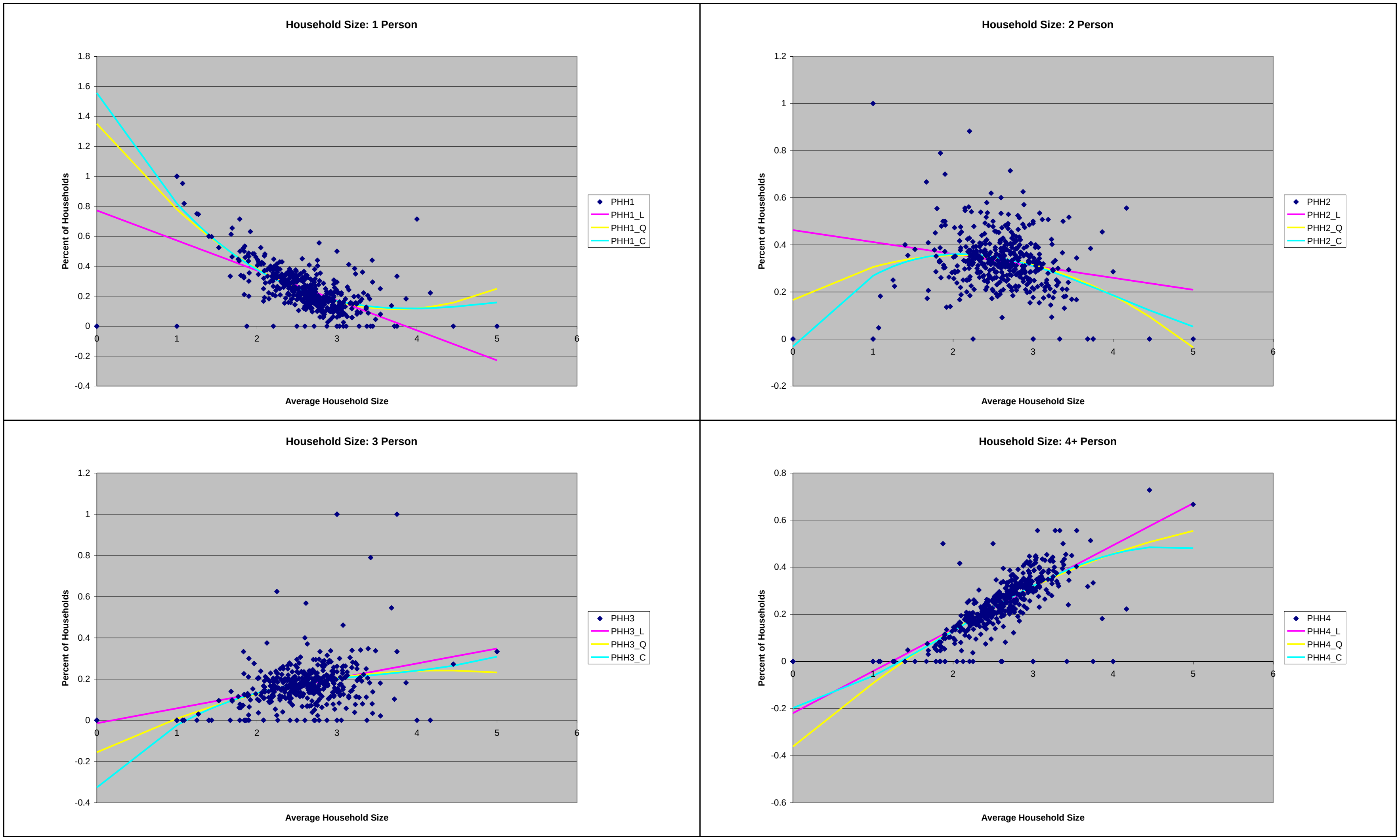


Figure 10. Household Size Stratification Models

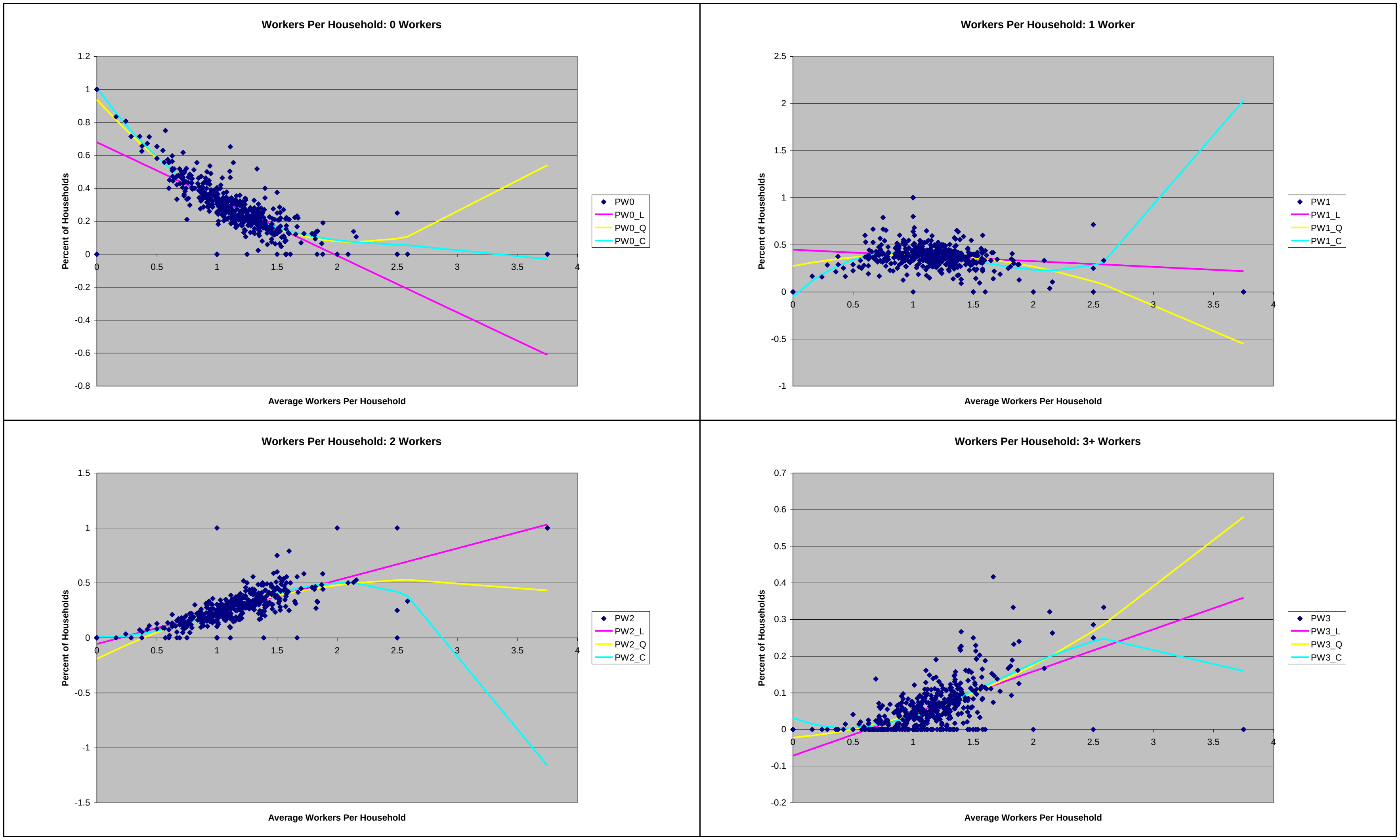


Figure 11. Workers per Household Stratification Models

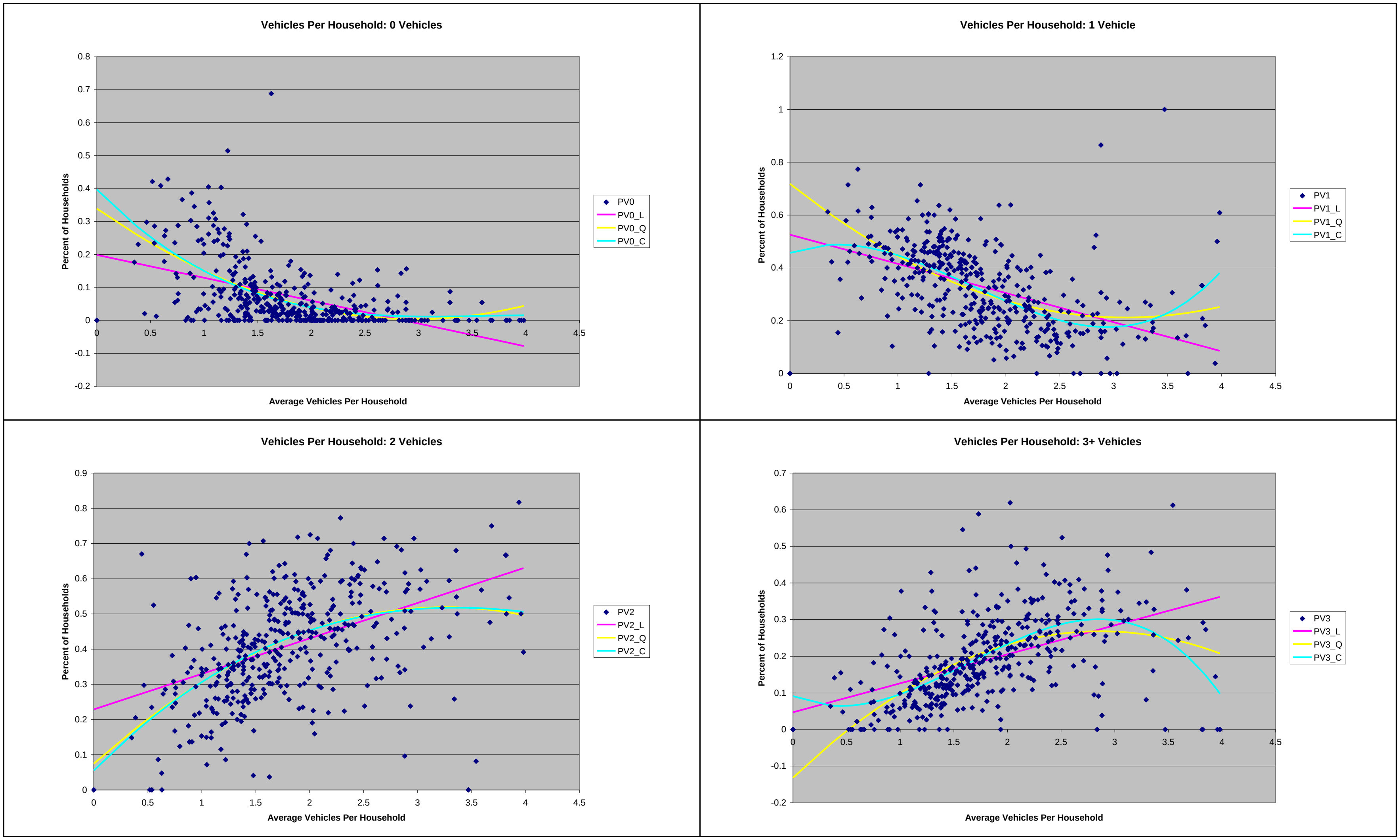


Figure 12. Vehicles per Household Stratification Models

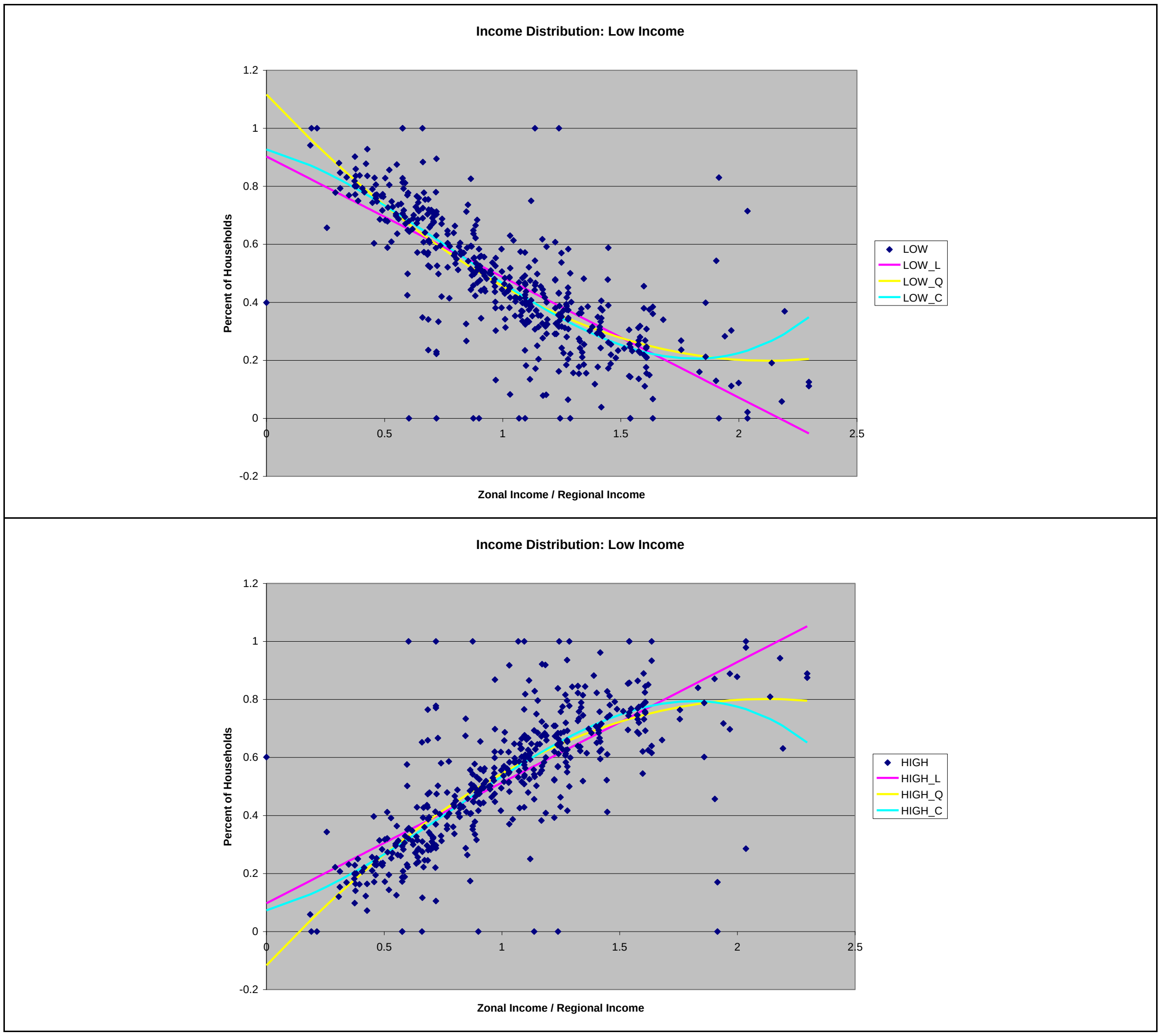


Figure 13. Income Stratification Models

In application, it is important to compare the resulting distribution of households to the CTPP distributions used to calibrate the stratification models. Following is a series of household distributions based on the CTPP data for Genesee County.

Table 14. Household Distribution by Vehicles, Workers and Income

		Household Size			
		1	2	3	4
Vehicles per Household	0	4.1%	1.5%	1.0%	1.1%
	1	18.2%	9.2%	4.0%	4.3%
	2	3.4%	17.6%	7.3%	11.4%
	3	0.8%	3.9%	4.9%	7.3%

		Workers per Household			
		0	1	2	3
Vehicles per Household	0	2.3%	3.0%	2.1%	0.4%
	1	10.5%	13.6%	9.5%	2.0%
	2	11.7%	15.1%	10.6%	2.2%
	3	5.1%	6.6%	4.6%	0.9%

		Workers per Household			
		0	1	2	3
Income	Low	23.7%	20.7%	5.7%	0.4%
	High	5.7%	17.6%	21.0%	5.1%

Trip Production Model

From the standpoint of trip generation, the vast majority of trips are generated by households within the study area. The *MI Travel Counts survey* was used to develop cross-classification models of daily number of household trips (broken down by trip purpose) based on various characteristics of the household and its accessibility to employment of various types. The following series of tables present the calibrated trip production rates using the cell compression and income stratifications described above. The trip production rates were calibrated using the combined TMA samples from the *MI Travel Counts* and were weighted by the expansion factors. Because the *MI Travel Counts survey* covered a two day period, trip rates were calculated based on the two day period and then multiplied by 0.50 to create an average trip rate for each day.

Table 15. Work Related Trip Production Rates

HBW Low Income Trips		Workers per Household				
		0	1	2	3	
Vehicles per Household	0		1.188			
	1		0.852	1.791		
	2		0.726	1.971	2.250	
	3		0.792	2.387	1.000	
					Total	0.350

HBW High Income Trips		Workers per Household				
		0	1	2	3	
Vehicles per Household	0		0.000			
	1		0.554	0.000		
	2		0.644	1.846	3.000	
	3		0.737	1.622	2.524	
					Total	0.594

NHBW Trips		Workers per Household				
		0	1	2	3	
Vehicles per Household	0		0.067			
	1		0.507	0.409		
	2		0.304	1.271	0.400	
	3		0.330	1.022	1.195	
					Total	0.483

Table 2. Non Work Related Trip Production Rates

HBO Trips

Vehicles per Household	Household Size: 1	2	3	4
0	0.569	1.907		
1	1.046	1.727	1.752	
2		1.904	2.694	3.724
3			2.465	3.096
			Total	1.947

HBSH Trips

Vehicles per Household	Household Size: 1	2	3	4
0	0.351	0.771		
1	0.431	0.740	0.570	
2		0.788	0.872	1.127
3			0.261	0.311
			Total	0.708

NHBO Trips

Vehicles per Household	Household Size: 1	2	3	4
0	0.130	1.612		
1	0.578	1.564	1.928	
2		1.838	2.452	3.945
3			1.732	2.734
			Total	1.744

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Table 3. School Trips Production Rates

HBSC (K-12) Trips

Vehicles per Household	Household Size: 1	2	3	4
0	0.000	1.715		
1	0.028	0.397	3.180	
2		0.131	1.373	3.534
3			0.838	2.951
			Total	1.169

HBU (College - Univ.)

Vehicles per Household	Household Size: 1	2	3	4
0	0.000	0.111		
1	0.000	0.000	0.042	
2		0.020	0.011	0.097
3			0.218	0.244
			Total	0.050

Some variables have been included, despite marginal statistical significance, based on the plausibility of their influence on the dependent variable and the reasonableness of their parameter.

The following series of tables represent a combined average trip rate for all purposes.

Table 18. Aggregated Average Daily Production Rate

HHVH	HBW	HBO	HBSH	NHBO	NHBW	HBSC(K12)	HBSC(U)	HH
0	4,901	18,511	8,635	12,299	333	11,771	762	16,387
1	31,045	76,454	29,835	65,073	15,724	53,982	632	53,548
2	54,426	123,807	42,966	124,593	33,124	68,109	1,808	48,115
3	42,463	67,228	22,548	54,246	22,062	37,871	4,179	28,854
Total	132,835	285,999	103,984	256,211	71,243	171,732	7,382	146,904

HHVH	HBW	HBO	HBSH	NHBO	NHBW	HBSC(K12)	HBSC(U)	Total
0	0.03	0.13	0.06	0.08	0.00	0.08	0.01	0.39
1	0.21	0.52	0.20	0.44	0.11	0.37	0.00	1.86
2	0.37	0.84	0.29	0.85	0.23	0.46	0.01	3.06
3	0.29	0.46	0.15	0.37	0.15	0.26	0.03	1.71
Total	0.90	1.95	0.71	1.74	0.48	1.17	0.05	7.01

Trip Attraction Model

In terms of a travel demand model, the demand for trips is partly determined by the attractiveness of each zone. Attractions can be places of work, shopping locations, service locations, recreation areas, etc. Strictly speaking, attractions do not produce any trips – they attract trips (households are where trips are produced).

Productions and attractions are often confused with origins and destinations. Certainly when a person is leaving home to go to work, that trip is traveling from an origin which is a production to a destination which is an attraction. However, when that person makes the return trip home, that trip leaves from an origin (the workplace) which is an attraction to go to a destination (the household) which is a production. A location that is an attraction is labeled as an attraction irrespective of the direction of travel. The trip attraction model is not based merely on the number of attractions, or the size of the attractions, in a given area, such as a TAZ. The important element is the number of trip ends associated with the attractions in a TAZ, whatever the number of possible attractions. The trip attraction model defines the attractiveness of each area.

The attractions for each trip purpose are calculated using a linear regression model that was calibrated using the MI Travel Counts database with records specific to internal trips made within Genesee County. The following logical steps were taken to come up with attraction equations:

1. Correlation between surveyed attractions and available socioeconomic variables was investigated. The investigation involves main examination of Pearson Correlation and the 2-Tailed Level of Significance. Supplemental to these statistics, nonparametric correlations such as Kendall's tau_b and Spearman's rho were also compared. From this analysis, significantly correlated variables with attractions were selected as a pool of candidates for independent variables.

2. Since the analysis involves numerous combinations of many socioeconomic variables, to be efficient, stepwise regression technique was employed. The stepwise technique is appropriate to

deal with multiple explanatory variables and is superior to one-step multiple regression, forward and backward selection technique. In implementing the stepwise technique, no constants were forced during the analysis since the model without a constant produced better results in most cases.

3. Regression results were analyzed for the following main statistics:
    a. Adjusted R Square
    b. Overall model F-statistics and its significance level
    c. Model coefficients (magnitude and signs)
    d. t-statistics for each of entered variables and its significance level
    e. Multicollinearity among entered variables
4. The model selection process was not solely dependent on one statistic such as Adjusted R Square. Rather the process was based on combinational effects of the above statistics. For example, a model's R Square would increase as more independent variables are added, but it does not necessarily imply that the model is getting better. The performance of each of the entered variables need to be checked.
5. Besides the above statistics, logical judgments were made for appropriateness of each variable. For example, one shows statistically significant, thus it is natural to include the variable in the model since it improves the model. However, the variable may not make a logical connection to trip attractions for a specific trip purpose. In this case, it was decided that the variable does not have reasonable explanatory power and the variable was subsequently removed from the model even though it sacrificed the model performance.

As described above, SPSS was used to calculate the correlation between the attractions for each trip purpose to the socioeconomic variables in each district. The detailed employment variables, as well as the total employment were used. In addition, total household was tested as a variable. For the home based school purpose, k-12 enrollment was not tested but was used as the independent variable in the regression analysis. The results of the correlation analysis are shown below. The pool of potential variables used in the Step-Wise Regression Analysis was based on these results.

Table 19. Correlation Analysis of Observed Trip Ends

	HBW_Z		HBO_Z		HBSH_Z	
Variable	Pearson Correlation	Sig. (2-tailed)	Pearson Correlation	Sig. (2-tailed)	Pearson Correlation	Sig. (2-tailed)
TOTAL	0.825	9.83063E-22	0.830	3.32349E-22	0.681	1.34745E-12
MANUF	0.349	0.001206609	0.392	0.000248532	0.304	0.005162387
OTHER	0.534	1.97513E-07	0.677	2.17671E-12	0.528	2.96917E-07
TRANSP	0.390	0.00027187	0.223	0.04285578	0.235	0.032758661
FINC	0.492	2.25871E-06	0.495	1.99994E-06	0.378	0.000428053
RETAIL	0.707	8.28991E-14	0.779	4.48302E-18	0.835	1.06834E-22
WHOLES	0.443	2.6906E-05	0.469	7.80357E-06	0.406	0.000142811
SERV	0.819	2.83839E-21	0.821	2.16369E-21	0.652	2.42493E-11
GOV	0.291	0.007639842	0.188	0.087967695	0.091	0.412728639
HH	0.642	6.3666E-11	0.801	1.0335E-19	0.651	2.7962E-11

	NHBO		NHBW_W		NHBW_O	
Variable	Pearson Correlation	Sig. (2-tailed)	Pearson Correlation	Sig. (2-tailed)	Pearson Correlation	Sig. (2-tailed)
TOTAL	0.836	8.09512E-23	0.779	4.22651E-18	0.804	6.12084E-20

MANUF	0.400	0.000178715	0.323	0.002906852	0.381	0.000386895
OTHER	0.680	1.57424E-12	0.621	3.74632E-10	0.672	3.37598E-12
TRANSP	0.270	0.013603047	0.442	2.91837E-05	0.332	0.002170822
FINC	0.469	7.84888E-06	0.447	2.2494E-05	0.421	7.31097E-05
RETAIL	0.822	1.70307E-21	0.717	2.56601E-14	0.699	2.00946E-13
WHOLES	0.491	2.4492E-06	0.472	6.53312E-06	0.484	3.46734E-06
SERV	0.829	3.91063E-22	0.776	6.90774E-18	0.799	1.29755E-19
GOV	0.153	0.168352035	0.195	0.077496333	0.201	0.068466087
HH	0.794	3.71824E-19	0.651	2.78481E-11	0.779	4.40691E-18

Once the variables for use in Regression Analysis were selected based on the correlation analysis, Step-Wise Regression was used to determine the best model for each trip purpose. As discussed above, R squared was used as one selection variable. The final model was selected based on a combination of R squared, logical variables and reasonableness of the coefficients.

Table 4. Trip Attraction Step-Wise Regression Results

	HBW	HBO	HBSH	NHBO	NHBW_W	NHBW_O	HBSC1	HBSCU
TOTAL	0.590	0.000	0.000	0.000	0.309	0.000	0.000	0.000
MANUF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
OTHER	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TRANSP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FINC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RETAIL	0.000	3.069	3.403	7.567	0.000	0.504	0.000	0.000
WHOLES	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SERV	0.000	0.961	0.000	1.499	0.000	0.336	0.000	0.000
GOV	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HH	0.000	0.624	0.000	0.797	0.000	0.171	0.000	0.000
K12	0.000	0.000	0.000	0.505	0.000	0.000	1.838	0.000
U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.209
R-squared	0.898	0.931	0.887	0.938	0.869	0.893	0.887	0.900

In the above table, the NHBO Coefficients are scaled to estimate the total number of trips ends which includes both the production and attraction ends of the trip. In application, the NHBO attraction model is used to estimate only the attraction end of the trip. Thus in application, the coefficients for the Genesee County model should be reduced by 0.50.

The model was then applied to the aggregated data. The comparison between the survey expanded trip ends by purpose follows.

Table 5. Observed vs. Modeled Attractions by Purpose

Purpose	Observed	Modeled
HBW	132,692	124,881
HBO	285,570	285,688
HBSH	103,984	95,216
NHBO	511,766	541,155
NHBW_W	70,706	65,404
NHBW_O	70,706	75,592
HBSC K12	171,732	178,580
HBSC U	7,382	7,073

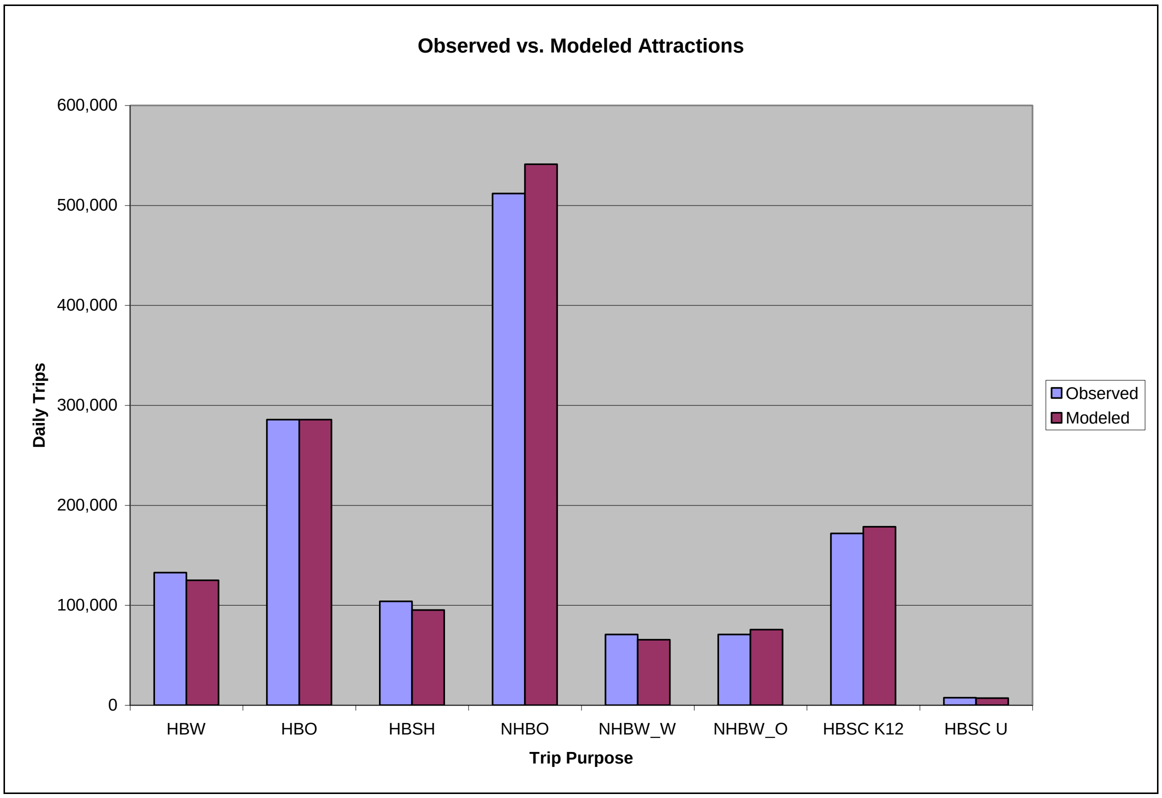

Figure 14. Comparison of Survey and Model Attraction Trip Ends

The coefficients to be applied by income group for the zonal employment categories are presented below.

Table 6. Percent Distribution of Employment Type

	Employment							
Income	MANUF	OTHER	TRANSP	FINC	RETAIL	WHOLES	SERV	GOV
Low	0.247	0.238	0.23	0.29	0.41	0.23	0.355	0.19
High	0.753	0.762	0.77	0.71	0.59	0.77	0.645	0.81

Under-Report and Area Adjustment Factor

After trip distribution and assignment, the assigned trips are checked against the ground traffic counts to verify if the trip production and attraction rates are under-reported in the household survey. For the Genesee County model, the following area factors are introduced to solve the under-report problem. These factors are multiplied with the trips estimated from the above mentioned method.

- CBD area, factor =1.1
- Urban area, factor=1.4
- Suburban area, factor =1.48
- Rural area, factor= 1.3

The under-report problems occur at the parts of Grand Blanc Road and Hill Road corridors. The under report factors for the 15-TAZ area around these parts of the two corridors are saved in SG000.dbf under the file directory \tg\ .

Special Generator

The airport (TAZ 188) is defined as the only special trip generator in the model. The following equations are used to calculate the trips

Number of person trips (tot_trip) = Employment*13.4*1.65*1.59
NHBO_Prod = tot_trip*34%/2
NHBO_Attr = tot_trip*34%/2
HBO_Attr = tot_trip*38%
ENW_Attr = tot_trip*28%

Trip Balance

When trip productions and attractions are calculated by purpose, it is necessary for their total sum of each trip purpose to be balanced as inputs to the trip distribution (gravity) model. The balancing procedure for trip productions and attractions of the Genesee County model uses three different methods in TransCAD. For NHBO trips, the weighted average of production and attraction is used, and for IE work trips, the balance method is to hold attractions constant. For other purpose trips, the balance method is to hold production constant. Since all trips of external stations are actual traffic count numbers, these trips were withheld with no changes in balance processes.

C. TRIP DISTRIBUTION MODEL

The Genesee travel demand model uses a four-step modeling process with a travel time feedback loop. These four steps are trip generation, trip distribution, mode choice, and traffic assignment. Trip distribution links the trip productions and attractions for each pair of Traffic Analysis Zones (TAZs) in Genesee County. The gravity model is the most widely used model for trip distribution. This model estimates the relative number of trips of each trip purpose, proportional to the number of productions and attractions, made between two geographical areas (TAZs), and inversely proportional to a function of travel time between the TAZs.

The gravity model is the most widely used model for trip distribution. Based on Newton's law of gravitation, it assumes that the trips (i.e. trip productions) from a Traffic Analysis Zone (TAZ) are distributed to any TAZ (i.e., trip attractions) in direct proportion to the number of trip attraction and in inverse proportion to the spatial separation between adjacent TAZs. In general, the number of trips attracted to a TAZ reflects the size of the attraction TAZ and the interzonal travel time of the spatial separation between the TAZs. The gravity model with friction factor is employed for trip distribution.

The gravity model is sensitive to changes in the transportation network such as travel speed of roadway, and incorporation of a new facility, etc. In accordance with these changes, the gravity model re-estimates the trip interchange of person trips based on changes in the network link impedance.

The form of the gravity model is expressed as:

$$\mathrm{T_{ij}} = P_i \left(\frac{A_j F_{ij} K_{ij}}{\sum_{k=1}^{zones} A_k F_{ik} K_{ik}} \right)$$

Where,

$\mathbf{T_{ij}}$ = O-D trips between TAZ i and TAZ j,
$\mathbf{P_i}$ = total trip productions of TAZ i,
$\mathbf{D_j}$ = total trips attractions of TAZ j,
$\mathbf{F_{ij}}$ = friction factor between TAZ i and TAZ j, and
$\mathbf{K_{ij}}$ = socioeconomic factor between TAZ i and TAZ j.

In the Genesee model, all Ks are equal to 1. The trip distribution modeling process incorporated the following data inputs and modeling elements:

- Production (P) and Attraction (A) trip ends by trip purpose from the trip generation model, and for each trip purpose the total P must be equal to the total A,
- Interzonal and intrazonal travel times computed using the Genesee County roadway network,
- Friction factors calibrated for each trip purpose using gravity model procedures,
- Socioeconomic adjustment factors, or K-factors, developed as part of the overall model validation process, and
- Gravity model applications by trip purpose using TransCAD procedures.

Shortest path travel time is used as travel impedance between Traffic Analysis Zones (TAZs). The time impedance between TAZs includes the travel time on roadway and terminal time. The terminal time is the time using to walk to/from vehicle and start or park the vehicle. It is defined as below,

- 3 minutes for the CBD and urban area
- 2 minutes for the suburban and rural area
- 5 minutes for the external station

Gravity Model Calibration and Evaluation

The calibration process is to adjust friction factor in the gravity model to replicate the actual Trip Length Frequency Distribution (TLFD) and average travel time. This process is similar to what is introduced in NCHRP report 365, but it uses the friction factor table instead of the gamma function. For each trip purpose, it starts with the standard friction factors from NCHRP report 365 and then adjusts it to generate the trip length frequency distribution and average travel time close to those from the MI Travel Counts. **Table 23** reports the average travel time for external-internal and internal-external (EI-IE) trips, and **Table 24** and **Figure 15** displays the trip length frequency distribution data from the MI Travel Counts. The calibration of friction factors involves iterative procedures as follows:

1. Gravity model is evaluated with initial set of friction factors from NCHRP report 365.
2. TLFD's and average trip lengths from the Gravity model run are estimated.
3. The trip length estimates are compared with the observed trip lengths patterns.
4. Revise the initial set of friction factors based on the comparison in Step 3.
5. Run Gravity model with the revised friction factors and return to Step 2.
6. Repeat Steps 2 to 5 until the following conditions are met,
   (a) the observed TLFD's and model TLFD's are relatively close to one another, and
   (b) average trip lengths become stable.

Using the Genesee County specific trip records, the average trip length and trip length frequency distribution were calculated for each trip purpose. For each record in the MI Travel Counts database, a TAZ was assigned for the origin and destination based on the geocoded coordinates provided by MORPACE. The origin and destination TAZs were then used to assign a skimmed travel time from the model network with free-flow travel time and terminal time. Then the skimmed travel time was aggregated and averaged to represent the actual (survey) trip length frequency distribution and average travel time.

Table 23 shows the average travel time from the calibrated model as well. This average travel time was calculated based on the congested travel time, and the congested travel time was calculated from the model runs with time feedback loop. The calibrated fraction factors are shown in **Table 25**.

Table 23. Average Trip Length (Travel +Terminal Time)

	Average Travel Time by Purpose (Minutes)									
	HBW	HBO	HBSCH	HBS	HBU	NHBW	NHBO	EIW	IEW	ENW
Actual	17.73	14.17	12.29	13.15	17.39	14.46	12.8	16.74	18.35	16.65
Model	18.31	14.1	14.04	13.95	18.56	11.6	15.08	18.69	22.2	17.37

The friction factor in the Gravity model is a key component that represents the magnitude of frictions (or impedances) in traffic flows between pairs of TAZs. Friction factors are derived by trip purpose through trip-length frequency distributions and average trip lengths from a base year origin-destination travel survey.

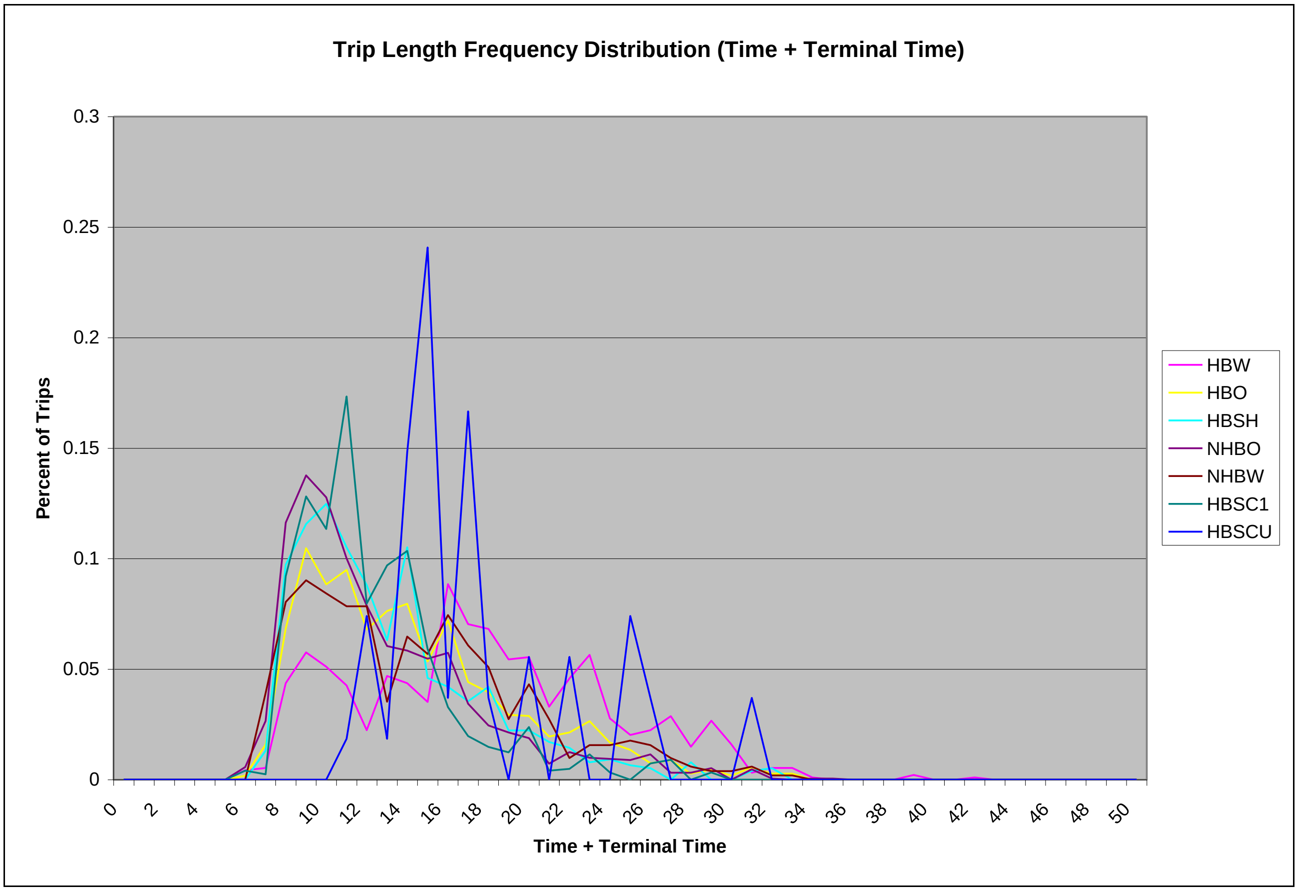

Figure 15. Trip Length Frequency Distribution (Travel Time+ Terminal Time)

Table 24. Trip Length Frequency: Average Travel Time + Terminal Time

Time_TT	HBW	HBO	HBSH	NHBO	NHBW	HBSC1	HBSCU
0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
6	0.004264	0.001861	0	0.005735	0	0.004108	0
7	0.00533	0.015821	0.013141	0.02659	0.039216	0.002465	0
8	0.04371	0.068404	0.09724	0.116267	0.080392	0.09203	0
9	0.057569	0.1047	0.115637	0.137643	0.090196	0.128184	0
10	0.051173	0.088413	0.124836	0.127737	0.084314	0.113394	0
11	0.042644	0.094928	0.105125	0.100104	0.078431	0.173377	0.018519
12	0.022388	0.067939	0.088042	0.078728	0.078431	0.079704	0.074074
13	0.046908	0.076315	0.063075	0.06048	0.035294	0.09696	0.018519
14	0.04371	0.079572	0.105125	0.058394	0.064706	0.103533	0.148148
15	0.035181	0.053513	0.045992	0.054745	0.056863	0.059162	0.240741
16	0.088486	0.072127	0.04205	0.057351	0.07451	0.032868	0.037037
17	0.070362	0.044207	0.03548	0.034411	0.060784	0.019721	0.166667
18	0.06823	0.039553	0.04205	0.024505	0.05098	0.01479	0.037037
19	0.054371	0.029316	0.022339	0.021376	0.027451	0.012325	0
20	0.055437	0.028851	0.022339	0.01877	0.043137	0.023829	0.055556
21	0.033049	0.019544	0.017083	0.007299	0.027451	0.004108	0
22	0.045842	0.021405	0.014455	0.012513	0.009804	0.00493	0.055556
23	0.056503	0.026524	0.007884	0.009906	0.015686	0.011504	0
24	0.027719	0.016752	0.009198	0.009385	0.015686	0.003287	0
25	0.020256	0.013495	0.00657	0.008863	0.017647	0	0.074074
26	0.022388	0.007445	0.005256	0.01147	0.015686	0.007395	0.037037
27	0.028785	0.008841	0	0.003128	0.009804	0.009039	0
28	0.014925	0.002792	0.007884	0.003128	0.005882	0	0
29	0.026652	0.004653	0	0.005214	0.003922	0.003287	0
30	0.015991	0.001861	0	0	0.003922	0	0
31	0.003198	0.005584	0.003942	0.004692	0.005882	0	0.037037
32	0.00533	0.002792	0.005256	0.000521	0.001961	0	0
33	0.00533	0.002792	0	0	0.001961	0	0
34	0.001066	0	0	0.000521	0	0	0
35	0	0	0	0.000521	0	0	0
36	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0
39	0.002132	0	0	0	0	0	0
40	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0
42	0.001066	0	0	0	0	0	0
43	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0

Table 25. Calibrated Friction Factors [1]

Time	Trip Purpose									
	HBW	HBO	HBSCH	HBS	HBU	NHBW	NHBO	EIW	IEW	ENW
1	25207.704	126686.78	1008.3	126686.78	2409.6	198261.641	198261.641	25207.7042	25207.704	198261.6
2	21983.38	23662.144	1008.3	17324.287	2409.6	17814.6504	17814.6504	5495.84508	5495.8451	17814.65
3	19282.104	8528.2884	1635.1	20584.865	3721.3	1952.34811	3063.45922	1809.12267	1809.1227	4174.57
4	16952.644	6523.0293	1789.7	26092.117	14987.5	1448.39315	2073.39313	1059.54022	1059.5402	1448.393
5	405700.79	14585.153	13135.5188	617013.2	22026.3	1947.11044	3294.46803	108144.931	108144.93	849850
6	100900.01	4310.7665	3920.076	100354.6	3.682E+09	638.888889	202.777778	98174.5678	98174.568	98599011
7	100892.15	3535.0429	3916.58829	103580.51	5.346E+10	464.674122	147.355082	88620.3119	88620.312	1710843
8	90883.145	1366.1196	2764.036	64848.013	1.972E+10	352.483087	110.943156	730636.379	730636.38	4511440
9	90747.345	1165.191	2716.25599	65575.006	3.843E+09	276.160963	87.381395	30130.2396	30130.24	7625.697
10	18155.658	570.5566	594.447	18182.708	91377161	189.81375	67.86869	8134.24374	8134.2437	619286.3
11	18148.514	484.36909	546.092	17712.82	81484233	148.298076	55.990396	1516.38127	1516.3813	1004.389
12	8159.305	354.03258	328.214317	4031.346	802253.05	65.775683	45.158819	597.497187	597.49719	744.2418
13	7195.849	320.30154	250.894055	3792.413	485308.91	50.089893	38.395757	418.172984	418.17298	93.5088
14	7115.084	226.17143	243.5	3679.533	31169.052	41.052704	32.879959	357.017847	357.01785	131.3112
15	7109.71	207.03247	202.118	3122.454	4467.7184	15.601178	28.638627	91.44831	91.44831	5.515182
16	7047.819	124.15125	200.81	970.632	38.450178	10.928855	25.06773	44.425003	44.425003	0.210961
17	7022.878	111.23227	90.817	967.46119	34.635625	3.411834	18.507322	34.698558	34.698558	3.271203
18	5809.621	63.831	75.391	165.87718	3.601994	2.999792	16.481401	25.40012	25.40012	0.028432
19	5801.756	59.474576	36.415151	154.548	2.697	1.214666	3.602452	22.182484	22.182484	0.180414
20	2776.73	8.693373	32.329	120.221	2.6	0.711577	3.19534	11.073575	11.073575	0.089869
21	2767.959	7.83919	30.828	90.28	2.223	0.511642	2.851703	6.862122	6.862122	0.000538
22	1909.404	6.627091	20.369594	85.182	2.1	0.264004	2.510709	4.778796	4.778796	0.027473
23	1830.734	6.246609	16.926	58.646	1.1	0.225622	2.216192	2.391633	2.391633	0.000025
24	1025.3572	5.806958	16.485072	51.99	1.1	0.20388	1.89149	1.754653	1.754653	0.009065
25	1013.969	5.448	10.651372	49.23	1.1	0.186914	1.724941	0.803485	0.803485	0.000223
26	1010.415	4.599538	14.87277	25.305	1.1	0.165928	0.789471	0.695669	0.695669	0.001807
27	985.661	4.038407	11.048	18.024	1.1	0.145489	0.702748	0.43523	0.43523	0.000448
28	941.272	3.656763	10.199	17.283	1.1	0.130555	0.648047	0.372925	0.372925	0.000079
29	656.63764	3.092345	4.083	16.708	1.1	0.095132	0.557917	0.335319	0.335319	0.000328
30	575.49656	2.670867	4.149	5.525633	1.1	0.059574	0.46575	0.29658	0.29658	0.000002
31	2.016734	0.755132	2.333	5.422	1.1	0.05393	0.11366	0.13778	0.13778	0.000091
32	0.1	0.642875	1.422	6.748773	1.1	0.047188	0.086251	0.106811	0.106811	0.000005
33	0.08	0.341667	1.068	3.277	1.1	0.04289	0.070438	0.078925	0.078925	0.00001
34	0.08	0.317882	0.838	2.917	1.1	0.039535	0.0577	0.07384	0.07384	0.000002
35	0.08	0.279343	0.8	2.694	1.1	0.034341	0.047403	0.056294	0.056294	0.000005
36	0.08	0.255889	0.7	2.212	1.1	0.031333	0.039049	0.044184	0.044184	0.000001
37	0.08	0.229459	0.642	2.19	1.1	0.029328	0.03225	0.036502	0.036502	0.000007
38	0.04	0.197237	0.422	2.095	1.014	0.0267	0.0267	0.03285	0.03285	0.000002
39	0.03	0.182821	0.28	2.03	1.01	0.022156	0.022156	0.025434	0.025434	0.000005
40	0.01	0.182775	0.24	1.977	1.01	0.018426	0.018426	0.020799	0.020799	0.000026
41	0.01	0.169902	0.19	1.966	1.01	0.015356	0.015356	0.018932	0.018932	0
42	0.01	0.143667	0.18	1.534	1.01	0.012822	0.012822	0.017563	0.017563	0.000054
43	0.01	0.126953	0.14	1.459	1.01	0.010727	0.010727	0.016465	0.016465	0.010727
44	0.01	0.118136	0.13	1.398	1	0.008991	0.008991	0.015467	0.015467	0.008991
45	0.01	0.093533	0	1.209	0.82	0.007548	0.007548	0.014443	0.014443	0.007548
46	0.01	0.075196	0	1.159	0.7	0.006348	0.006348	0.013772	0.013772	0.006348
47	0.01	0.062085	0.1	0.918	0.6	0.005346	0.005346	0.012876	0.012876	0.005346
48	0.005	0.053312	0.1	0.759	0.5	0.00451	0.00451	0.012147	0.012147	0.00451
49	0.005	0.027755	0.1	0.66	0.4	0.00381	0.00381	0.011091	0.011091	0.00381
50	0.005	0.02604	0.1	0.602	0.4	0.003223	0.003223	0.010497	0.010497	0.003223
51	0.005	0.020922	0.1	0.567	0.36	0.00273	0.00273	0.007579	0.007579	0.00273
52	0.005	0.016173	0.1	0.541	0.35	0.002315	0.002315	0.005156	0.005156	0.002315
53	0.003	0.015283	0.1	0.1	0.35	0.001966	0.001966	0.004572	0.004572	0.001966
54	0.003	0.011	0.1	0.1	0.34	0.001672	0.001672	0.00423	0.00423	0.001672
55	0.003	0.010745	0.1	0.1	0.33	0.001423	0.001423	0.003752	0.003752	0.001423
56	0.003	0.008625	0	0.1	0	0.001212	0.001212	0.003452	0.003452	0.001212
57	0.002	0.006374	0	0.1	0	0.001034	0.001034	0.00299	0.00299	0.001034
58	0.002	0.005576	0	0.1	0	0.000883	0.000883	0.002664	0.002664	0.000883
59	0.002	0.004881	0	0.1	0	0.000755	0.000755	0.000439	0.000439	0.000755

D. MODE CHOICE MODEL

The trip generation models generate numbers of person trips and the trip distribution models allocate these trips for trip production zones to attraction zones for each trip purpose. These trips must be further divided into trips by various transportation modes and then converted to vehicle trips and passenger trips for the purpose of predicting vehicle flows on the roadway network and passenger flows on the transit routes. The Genesee County model divides the person trips into trips of five modes: car driver alone, car share ride, transit (bus), and non-motorized (walk/bike). The nested logit model is decided to be used for the Genesee County model, and its structure is shown as follows:

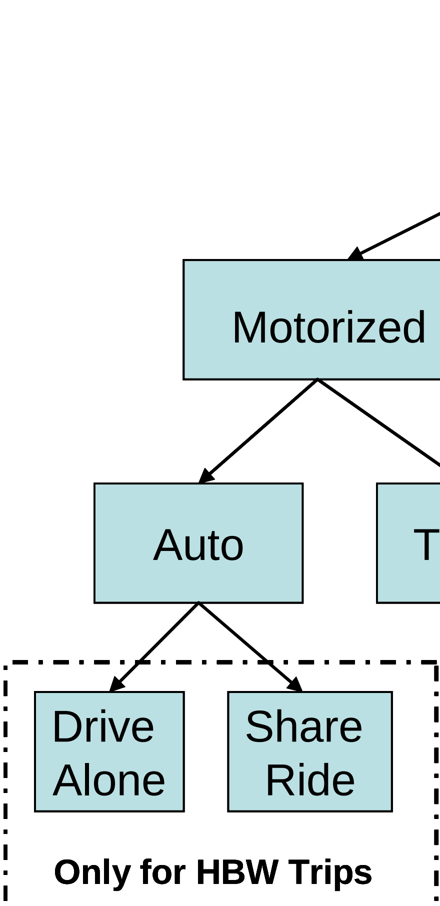

Figure 16. Structure of Mode Choice Models

The mathematical formulation of the nested multinomial logit model structure is as follows:

$$P_{DA} = P(DA \mid Auto, M) * P(Auto \mid M) * P(M)$$
$$P_{SR} = P(SR \mid Auto, M) * P(Auto \mid M) * P(M)$$
$$P_{Tr} = P(Tr \mid M) * P(M)$$
$$P_{Wlak} = P(Walk \mid NM) * P(NM)$$
$$P_{Bike} = P(Bike \mid NM) * P(NM)$$

Where: P_i is the probability of choosing mode alternative i ,
i is Drive Alone(DA), Share Ride(SR), Transit(Tr), Walk or Bike,
$P(i \mid Auto, M)$ is the conditional probability of choosing i from among DA and SR,
$P(j \mid M)$ is the conditional probability of choosing j from among Auto and Transit,
$P(s \mid NM)$ is the conditional probability of choosing s from among Walk and Bike,
$P(M)$ is the probability of choosing Motorized mode,
$P(NM)$ is the probability of choosing Non-Motorized mode.

$$P(M) = \frac{e^{U_M}}{e^{U_M} + e^{U_{NM}}} \quad \text{and} \quad P(NM) = \frac{e^{U_{NM}}}{e^{U_M} + e^{U_{NM}}}$$

U_M and U_{NM} are the Utilities of the motorized and non-motorized modes, and its expressions are,

$$U_M = a1 + Logsum(M) * \ln(e^{U_{Auto} + U_{Tr}})$$
$$U_{NM} = a2 + Logsum(NM) * \ln(e^{U_{Walk} + U_{Bike}})$$
$$P(j \mid M) = \frac{e^{U_j}}{e^{U_{Auto}} + e^{U_{Tr}}} \quad \text{and} \quad P(s \mid NM) = \frac{e^{U_s}}{e^{U_{Walk}} + e^{U_{Bike}}}$$

Logsum(M), Logsum(NM), a1 and a2 are constants. U_A is the Utility of the auto modes and its expressions is,

$$U_{Auto} = a3 + Logsum(A) * \ln(e^{U_{DA} + U_{SR}})$$
$$P(i \mid Auto, M) = \frac{e^{U_i}}{e^{U_{DA}} + e^{U_{SR}}}$$

The utility expression for each available choice mode *(i)* is specified as a linear function:

$$U_i = b_1 * IVTT_i + b_2 * OVTT_i + b_3 * Cost_i + b_4 * SE1_i + b_5 * SE2_i + b_6 * SE3_i + b_0$$

Where: $IVVT_i$ is the In-Vehicle Travel time of mode alternative i
$OVTT_i$ is the Out-Vehicle Travel Time of the description of alternative i
Cost is the fare related cost when choice bus otherwise it is the distance related cost
$SE1_i$, $SE2_i$ and $SE3_i$ are the socio-economic indicatorss of alternative i

The mode choice model calibration is based on the *Travel Counts Household Travel Survey data and the 2007 bus on-board survey*. The 2000 CTPP data is used as the reference for HBW trip as well. The indicators and coefficients mentioned above can be found in the following table.

Table 26. Coefficients of Utility Function and Nested Logit Parameters

	HBW					HBO				NHB			
	DA	**SR**	**Transit**	**Walk**	**Bike**	**Auto**	**Transit**	**Walk**	**Bike**	**Auto**	**Transit**	**Walk**	**Bike**
Constant	0	0.8306	-5.559	0	2.5	0	-2.962	0	2	0	-4.312	0	2
Travel Time	-0.069	-0.1724				-0.492				-0.108			
Travel Distance	-0.138	-0.0701		5.308	1.327	0.506		5.308	1.327	0.341		5.308	1.3271
Distance > 1 Mil					2.902				2.902				2.9024
WRK_HH	-0.436	0.2351				-0.738							
VEH_Hh	0.6196	-0.8217				1.965							
MED_INC	0	0				1E-04							
Fare			-0.5059				-0.5992				-0.2912		
1/IVTT			0.6937				0.9384				-2.2486		
1/OVTT			19.4008				2.3292				0.5451		

Nested Logit Coefficients	**HBW**	**HBO**	**NHB**
Motorized Logsum	-1.203	0.856	5.518
Motorized Constant	0	0	0
Non-Motorized Logsum	0.063	-0.17	0.0277
Non-Motorized Consta	-4.851	0.003	-7.3087

E. TIME-OF-DAY CHOICE MODEL

Using the MI Travel Counts dataset for all TMA trips, a frequency distribution was calculated by departure hour for each trip purpose. The percent distribution is shown in the Figure below.

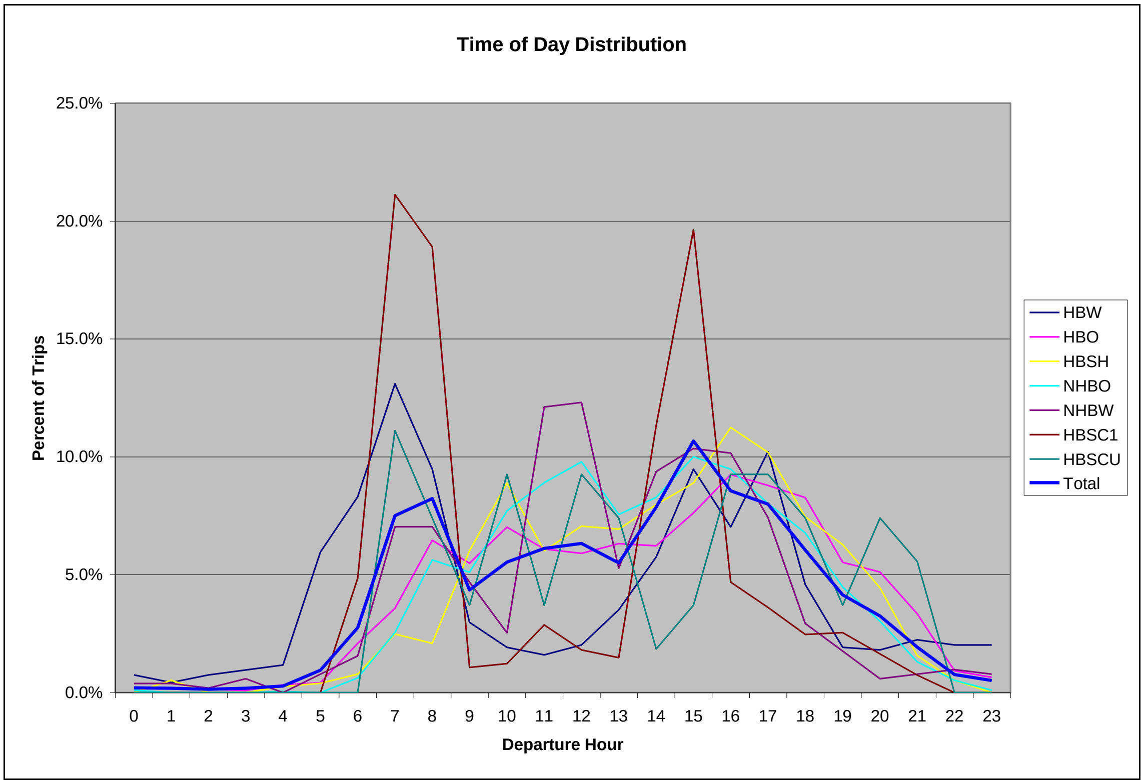

Figure 17. Time of Day Distribution of Trips

The periods were identified based on observations of the hourly traffic counts available in the region. Four time periods were identified for the Genesee County model. Those periods are:

- AM Peak: 6:00am – 9:00am
- Midday: 9:00am – 3:00pm
- PM Peak: 3:00pm – 6:00pm
- Night: 6:00am – 6:00am

Based on the MI Travel Count database, and records specific to Genesee County, period factors were calibrated. The factors represent the number of trips that depart during each period as defined above. The period trips are disaggregated into P to A and A to P direction. The directional factors are developed from the MI Travel Counts using the direction of travel reported in the survey. Trips from home to work would be considered in P to A direction. Conversely, trips from work to home are in the A to P direction. The following tables report the directional factors for home based trips (HBW and HBO purposes). Non home based trips typically assume a fifty / fifty directional factor.

Table 27. Hourly Distribution of Trips

Departure Hour	HBW	HBO	HBSH	NHBO	NHBW	HBSC1	HBSCU	Total
0	0.7%	0.2%	0.0%	0.1%	0.4%	0.0%	0.0%	0.2%
1	0.4%	0.2%	0.5%	0.0%	0.4%	0.0%	0.0%	0.2%
2	0.7%	0.1%	0.0%	0.0%	0.2%	0.0%	0.0%	0.1%
3	1.0%	0.1%	0.0%	0.0%	0.6%	0.0%	0.0%	0.2%
4	1.2%	0.3%	0.3%	0.1%	0.0%	0.0%	0.0%	0.3%
5	6.0%	0.4%	0.4%	0.0%	0.8%	0.0%	0.0%	1.0%
6	8.3%	2.1%	0.8%	0.6%	1.6%	4.8%	0.0%	2.8%
7	13.1%	3.6%	2.5%	2.6%	7.0%	21.1%	11.1%	7.5%
8	9.5%	6.5%	2.1%	5.6%	7.0%	18.9%	7.4%	8.2%
9	3.0%	5.5%	6.0%	5.1%	4.7%	1.1%	3.7%	4.4%
10	1.9%	7.0%	8.9%	7.7%	2.5%	1.2%	9.3%	5.5%
11	1.6%	6.1%	6.0%	8.9%	12.1%	2.9%	3.7%	6.1%
12	2.0%	5.9%	7.1%	9.8%	12.3%	1.8%	9.3%	6.3%
13	3.5%	6.3%	6.9%	7.6%	5.3%	1.5%	7.4%	5.5%
14	5.8%	6.2%	8.0%	8.3%	9.4%	11.3%	1.9%	7.9%
15	9.5%	7.6%	8.9%	10.0%	10.4%	19.6%	3.7%	10.7%
16	7.0%	9.2%	11.2%	9.5%	10.2%	4.7%	9.3%	8.6%
17	10.2%	8.8%	10.2%	8.0%	7.4%	3.6%	9.3%	8.0%
18	4.6%	8.3%	7.5%	6.8%	2.9%	2.5%	7.4%	6.0%
19	1.9%	5.5%	6.3%	4.5%	1.8%	2.5%	3.7%	4.1%
20	1.8%	5.1%	4.4%	3.0%	0.6%	1.6%	7.4%	3.3%
21	2.2%	3.3%	1.6%	1.3%	0.8%	0.7%	5.6%	1.9%
22	2.0%	0.9%	0.5%	0.5%	1.0%	0.0%	0.0%	0.8%

Table 28. TOD Directional Factors By Trip Purpose

Period	HBW		HBO		NHB	
	Prod-Attr	Attr-Prod	Prod-Attr	Attr-Prod	Prod-Attr	Attr-Prod
AM_Peak	26.60%	2.05%	6.00%	2.50%	2.70%	2.70%
Midday	8.10%	10.30%	22.00%	17.40%	24.00%	24.00%
PM_Peak	2.30%	22.00%	11.00%	12.60%	12.50%	12.50%
Overnight	13.00%	15.65%	11.00%	17.50%	10.80%	10.80%
Total	50.00%	50.00%	50.00%	50.00%	50.00%	50.00%

Table 29. TOD Directional Factors for EI-IE Trips

Period	EI Work		IE Work		E Non-Work	
	Prod-Attr	Attr-Prod	Prod-Attr	Attr-Prod	Prod-Attr	Attr-Prod
AM_Peak	25.00%	1.80%	24.00%	1.50%	2.00%	2.00%
Midday	9.10%	10.00%	9.10%	9.10%	23.00%	23.00%
PM_Peak	2.70%	23.35%	1.35%	22.50%	11.00%	11.00%
Overnight	13.20%	14.85%	15.55%	16.90%	14.00%	14.00%
Total	50.00%	50.00%	50.00%	50.00%	50.00%	50.00%

Table 30. TOD Directional Factors for Transit Trips

Period	EI Work	
	Prod-Attr	Attr-Prod
AM_Peak	26.60%	2.05%
Midday	8.10%	10.30%
PM_Peak	2.30%	22.00%
Overnight	13.00%	15.65%
Total	50.00%	50.00%

F. TRUCK MODEL

Based on the method recommended in *Quick Response Freight Manual* (1996), a commercial vehicle model was developed for predicting trips for four-tire commercial vehicles, and trucks. Trucks include single unit trucks with six or more tires, and combination trucks consisting of a power unit (truck or tractor) and one or more trailing units. The model uses a four-step process. Theses steps are trip generation, distribution, choice of time of day and trip assignment.

The inputs to trip generation are the number of employees and the number of households by Traffic Analysis Zone (TAZ). The daily trip generation rates shown in the following table are for trip Origins (O) and Destinations (D). These rates were obtained by adjusting the original generation rates in *Quick Response Freight Manual.* To replicate the current truck traffic condition in the Genesee County, these rates were further adjusted by a globe factor 0.45. For example, the final combination truck rate per retail employee is 0.02925 that is equal to original rate 0.065 multiplied by 0.45.

Table 31: Daily Trip Generation Rates

Generator (Employment and Household)	Commercial Vehicle Trip Destinations (or Origins) per Unit per Day		
	Four -Tire Vehicles	Trucks (Single Unit 6+ Tires)	Trucks (Combination)
Agriculture, Mining and Construction	1.11	0.289	0.174
Manufacturing, Transportation, Communications, Utilities & Wholesale Trade	0.938	0.242	0.104
Retail	0.888	0.253	0.065
Office and Services	0.437	0.068	0.009
Households	0.025	0.010	0.004

The productions of External-Internal and Internal-External (EI-IE) truck trips are obtained from the external trip model. Since there is no freight and truck survey available for Genesee County, it is assumed that the EI-IE truck trip attractions are proportional to the truck destination trips. At the beginning, the truck trip destinations are used as initial EI_IE truck trip attractions, and then the balance process scaled the total truck trip attractions to match the total truck productions, i.e. the total truck counts of all external stations. The truck trips are summarized in **Table 32**.

Table 32. Summary of 2005 Trip Generation

Trip Type		Number of Trips	
		Original	Balanced
4-tire Commercial Vehicle	Origin (O)	60,901	60,901
	Destination (D)	60,901	60,901
Truck	Origin (O)	19,769	19,769
	Destination (D)	19,769	19,769
EI-IE Truck	Production (P)	20,248	20,248
	Attraction (A)	19,769	20,248

A special truck trip generator was set up for the airport. The number of total daily truck trips of the airport is obtained by multiplying 6.0 to the transportation employment.

The EI-IE truck trips were classified as an individual type of trips because there was the trip information available from the major truck generator survey. Before the trip distribution, the Trip O and D were balanced for all TAZs and external stations for the following types of trips:

- EI-IE truck trips of all TAZs and external stations;
- Internal-to-Internal (II) truck trips of all TAZs;
- Internal-to-Internal (II) 4-tire commercial vehicle trips of all TAZs.

The gravity model was employed to distribute zonal trip origins to destinations. The form of the gravity model is expressed as:

$$T_{ij} = O_i \frac{D_j F(t_{ij})}{\sum_j D_j F(t_{ij})}$$

Where T_{ij}= trips between TAZ *i* and TAZ *j*;
O_i = total trip originating at TAZ *i*;
D_j= total trip destined at TAZ *j*;
$F(t_{ij})$ = friction factor between TAZ *i* and TAZ *j;*
t_{ij} = travel time between TAZ *i* and TAZ *j*.

For both internal and EI-IE truck trips, friction factors recommended in *Quick Response Freight Manual* were used as a starting point and then adjusted to replicate the local traffic condition. The recommendation has the following form:

Four-tire commercial vehicles:

$$F_{ij}=e^{-0.13*t_{ij}}$$

Trucks:

$$F_{ij}=e^{-0.08*t_{ij}}$$

The average travel time of all trip types are given in **Table 33**. The four-tire commercial vehicle has the shortest average travel time of 11.39 minutes while the EI-IE truck has the longest travel time of 18.38 minutes.

Table 33. Average Travel Time by Trip Type

Trip Type	Average Travel Time (minutes)
4T commercial Vehicle	11.39
Internal Truck	12.84
EI-IE Truck	18.38

The time-of-day assignments were implemented in order to obtain the better model results. To facilitate it, the trip tables from trip distribution must be factored to reflect morning peak, midday, evening peak and off-peak periods prior to trip assignment. The hourly time-of-day factors recommended in *Quick Response Freight Manual* were aggregated into the periods defined in the following table and applied for the Genesee County Travel Demand Model.

Table 34. Time of Day Factors

Period	**4-Tire Commercial Vehicle**	**Truck**	**EI-IE Truck**		
			Total	Departure	Return
AM Peak – (6-9am)	20%	17%	17%	7%	10%
PM Peak – (3-6pm)	24%	17%	17%	10%	7%
Mid-day (9am-3pm)	33%	42%	42%	21%	21%
Night (6pm-6am)	23%	24%	24%	12%	12%

As explained in the previous section, trip assignment for the Genesee county model follows time-of-day procedures instead of running a single 24-hour assignment. For each of four time periods, both a truck trip table and a 4-tire commercial vehicle trip table were developed, and then were assigned onto the network simultaneously with auto trips by using the multi-model multi-class equilibrium assignment method. Total 24-hour link volumes were then obtained by aggregating the truck, and auto loadings by time period.

G. VEHICLE TRIP ASSIGNMENT AND FEEDBACK LOOP

The assignment of trips to the network is the last step of the traditional sequential modeling processes. It provides the foundation for validating the model's performance in replicating base-year travel patterns. Once the base-year assignment is validated, it is further used to forecast future traffic conditions on the network and to evaluate any transportation improvements in the future.

The Genesee County model utilizes a time-of-day modeling procedure. In this procedure, a 24-hour trip table is broken into tables of AM-Peak, PM-Peak, Mid-Day and Off-Peak periods. For each time period, a two-step assignment procedure is implemented. The first step, which is referred to as "priority pre-loading", is to assign the external-to-external auto trips and the truck trips onto the roadway network separately. Then the internal auto trips are assigned onto the network with considerations of these preloading volumes. The assignment method is user equilibrium assignment.

The assignment using the free-flow speed/travel time is a common procedure adopted by most regional and urban travel demand models. The addition of a Feedback loop is an update to the Genesee County model. After the initial assignment, link congested travel time is estimated based on loading resulted from each TOD assignment and 24-hour average travel time is calculated by weighted average method. The 24-hour congested travel time is then fed back into the Trip Distribution model to redistribute person trips in the next iteration. The redistributed trips are used to run the TOD assignments in the next iteration. The flowchart of these procedures is given in **Figure 18**.

Vehicle Trip Assignment Procedures

Given a network and a demand matrix, traffic assignment allows one to establish the traffic flow patterns and analyze congestion points. Traffic assignment is a key element in the urban travel demand forecasting process. The traffic assignment model predicts the network flows that are associated with future planning scenarios, and generates estimates of the link travel times and related attributes that are the basis for benefits estimation and air quality impacts. The traffic assignment model is also used to generate the estimates of network performance that are used in the mode choice and trip distribution stages of many models.

Historically, a wide variety of traffic assignment models have been developed and applied. Equilibrium methods take account of the volume dependence of travel times, and result in the calculation of link flows and travel times that are mutually consistent. Equilibrium flow algorithms require iteration between assigning flows and calculating loaded travel times. Despite the additional computational burden, equilibrium methods almost always is preferable to other assignment models.

In many urban areas, there are many alternate routes that could be and are used to travel from a single origin zone to a single destination zone. Often trips from various points within an origin zone to various points in a destination zone use entirely different major roads to make the trip. In some instances, reasonable alternate routes may be so numerous that they cannot be easily counted. For the traffic assignment model to be valid, it must correctly assign car volumes to these alternative paths.

From a behavioral perspective, traffic assignment is the result of aggregating the individual route choices of travelers. Assignment models, not surprisingly, also differ in the assumptions made about how and which routes are chosen for travel.

The key behavioral assumptions underlying the User Equilibrium assignment model are that every traveler has perfect information concerning the attributes of network alternatives, all travelers choose routes that minimize their travel time or travel costs, and all travelers have the same valuations of network attributes. First proposed by Wardrop, at user equilibrium (UE), no individual travelers can unilaterally reduce their travel time by changing paths (Sheffi, 1985). A consequence of the UE principle is that all used paths for an O-D pair have the same minimum cost. Unfortunately, this is not a realistic description of loaded traffic networks (Slavin, 1996).

MMA Assignments

Multi-Modal Multi-Class Assignment (MMA) is a flexible master assignment routine designed for use in major metropolitan areas, and is directly applicable in statewide or interregional models. Note that, while most MMA models are just multi-modal, the model in TransCAD is multi-modal and multi-class.
The MMA model is a generalized cost assignment that lets you assign trips by individual modes or user classes to the network simultaneously. This method allows you to explicitly model the influence of toll facilities of all types as well as HOV facilities. Each mode or class can have different network exclusions, congestion impacts (passenger car equivalent values), values of time, and toll costs.

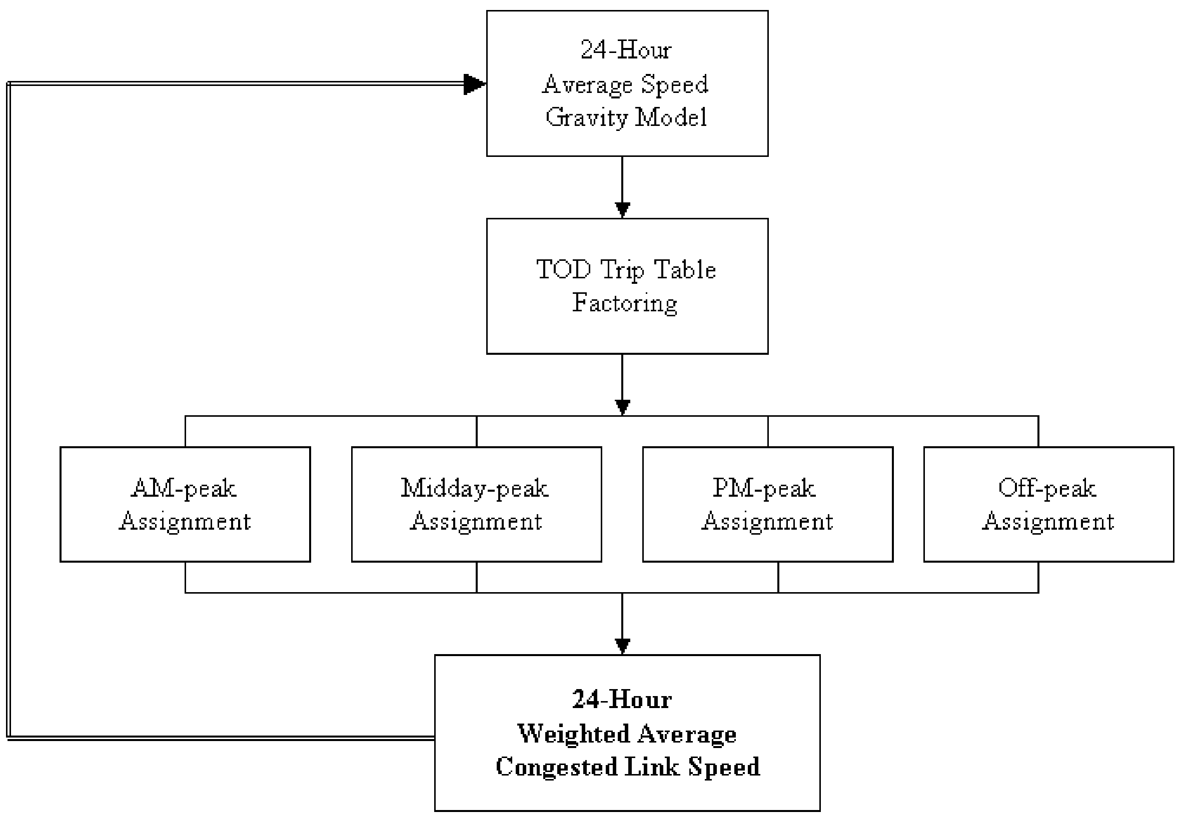

Figure 18. The Modeling Procedures of the Genesee County Model

As explained in the previous section, trip assignment for the Genesee County model follows time-of-day procedures instead of running a single 24-hour assignment. For each of the four time periods, a truck trip table developed for the respective time period was pre-assigned before an auto trip table was assigned. Then, an origin and destination auto trip table for the time period was assigned with truck trips preloaded. This process was repeated for all time periods. Total 24-hour link volumes were then obtained by aggregating the truck and auto loadings by time period. Each of these assignments utilized a user equilibrium method.

The congested travel time for each link is calculated by using the Bureau of Public Roads (BPR) form of the volume delay function with link specific parameters. The volume delay function is used to adjust the link's free-flow speed on the basis of its volume to capacity ratio to account for congestion related delay. The alpha and beta parameters for the BPR equation which are used in both the travel model's assignment procedure as well as the post-processing are coded on the network links. Several sets of volume-delay parameters were applied in the Genesee County model to different classes of roadway. Due to the method of capacity estimation adopted for the model which specifies an absolute capacity rather than a practical capacity, the Genesee model uses different volume delay parameters than many models which use practical capacities. The default sets of volume-delay parameters for the Genesee County regional model are presented in **Table 35**.

Table 35. Default Volume Delay Function Parameters by Roadway Class

Function Class	a	b
Rural Interstate	0.95	5.00
Rural Prin Arter	0.72	2.70
Rural Min Arteri	0.53	2.20
Rural Maj Collec	0.43	2.10
Rural Min Collec	0.43	2.10
Rural Local Road	0.43	2.10
Urban Interstate	0.95	5.00
Urban Expressway	0.95	5.00
Urban Prin Arter	0.50	2.50
Urban Min Arteri	0.45	2.30
Urban Collector	0.40	2.10
Urban Local Road	0.40	2.10
Ramp	0.68	2

Feedback Loop

Steps in the travel demand model process require feedback iterations to reach systemic equilibrium. Feedback from trip assignment to trip distribution provides more accurate travel times reflecting congestion. Considering that the inter-zonal travel time is input to the distribution stage, the feedback will improve the trip distribution results for providing more reasonable trip tables to trip assignment.

In this model update, trip distribution, time-of-day choice and trip assignment were re-computed after the weighted average daily congested travel time feedbacks to the time impedance matrix. The feedback process employed the Method of Successive Average (MSA). In the MSA method, assigned link volumes from previous iteration are weighted together to produce the current iteration's link volumes; Adjusted congested time is then calculated based on the normal volume-delay function. This adjusted congested time is then fed back to calculate the travel time between each OD pair. This feedback process is kept until the maximum iteration equals 10 or the stop criterion is reached.

Vehicle Trip Assignment Data Inputs

The data inputs used in trip assignment and validation process included:

- **Origin-Destination Vehicle Trip Tables.** Outputs from the trip distribution and subsequent matrix manipulation procedures. These tables are vehicle trip matrices by time-of-day.
- **Highway Network.** The Genesee County Model highway network with key link attributes such as link free-flow travel times, link peak and off-peak capacities, and link-specific BPR parameters.
- **Turn Restrictions.** Turn prohibitors at intersections and interchanges where a certain movement(s) is prohibited.

H. TRANSIT TRIP ASSIGNMENT

Below are some considerations to take into account when deciding which transit assignment method to use.

Most users should use either Pathfinder or the Stochastic User Equilibrium (SUE) method. Pathfinder is easier to use, faster to compute, and more conventional in terms of application practice. SUE is more complex and is not traditional. It is intended only for advanced users.

All transit assignments should be tested and calibrated before use. For testing, an appropriate system with zonal connectivity and reasonable routings between key origin and destination pairs should established.

One way to do this is to perform assignments using data from onboard surveys. A stop-to-stop assignment can be performed prior to an origin to destination assignment. This smaller assignment will help evaluate the routes and parameter settings that are being used.

For the methods that feature combined headways, one should not usually combine services from different modes. Travelers usually have decided which mode they will take before arriving at their boarding stop. Combining disparate services will overstate their attractiveness in this instance.

Also, services with long headways should not be combined. Empirical evidence and logic indicates that when headways are long, travelers time their arrivals at their boarding point. A maximum initial waiting time can be specified in these instances.

Different values of time may be used as well as different weights for various components of travel time. It is also important to reflect behavioral realism in the parameter settings. For example, if travelers do not make more than two transfers, the number of transfers in the assignment should be limited to a maximum of two.

The smallest differences in traveler preferences can lead to a different choice of the best transit path. For example, some travelers find walking more onerous than others and might choose a closer stop for boarding or alighting even if the service is slower in terms of total time. For the greatest accuracy, using market segmentation in transit assignment may be considered.

The use of weights is popular, but should not be ad hoc. There should be some empirical basis for weighting wait times relative to in-vehicle times. Deriving the weights from a mode choice model is not really satisfactory because the mode choice model parameters are conditional on the characteristics of the best transit paths, which are a function of the weights used in pathfinding. Stated preference surveys are one way to compute weights that breaks this dependency.

Attributes of the best transit paths are used in transit planning and for developing inputs for mode choice models. Historically, a number of transit network route choice models have been proposed. The main differences among these models are the hypotheses made on the traveler's route choice. In the user interface, TransCAD provides the shortest travel cost path method, the path pathfinder method, and the optimal strategy method for finding the best paths and path attributes (skimming). The shortest travel cost path method is used in the Genesee Model, and it finds the single best path from an origin to a destination that minimizes the total generalized travel cost. On any path segment only one transit line will be chosen, even if the segment is served by several transit lines with identical travel times. Fares can be used in finding the best path. The detail explanations of other two skimming methods can be found in the TransCAD manual.

The generalized travel costs are the combination of in vehicle travel time, access/egress time, waiting time, transfer time, dwelling time, transfer penalty and fare together with its weights. The network settings for finding Shortest Generalized Travel Cost Path include the following configurable settings:

- The travel time field to use to determine best paths, skim variables or perform assignments
- The network attributes containing route headways, transfer penalties, dwell times and layover times
- Limits on the number of transfers, maximum and minimum wait time, total trip cost, maximum transfer times, maximum access and egress times, and maximum modal travel times
- Weights to assign to waiting times, travel times, dwell times, non-transit times, and transfer times
- Fare structure information
- Mode-specific information
- Route-stop-specific information

There are six types of settings in the Shortest Path Transit Network Settings dialog box:

SettingsDescription

- General.
  Sets the travel time field, path method and maximum trip cost, transfer time, maximum number of transfers, and centroids
- Mode.
  Sets the mode table and mode transfer table, and some mode specific restrictions and defaults. In the Genesee Model, there is no mode setting
- Fare.
  Sets the fare to be flat, zonal-based, or mixed
- Weights.
  Sets the weighing factors to be used for all components of the transit network when determining the best path
- Other.
  Sets the headway, transfer, dwelling and layover time parameter, and sets minimum and maximum times for waiting, access, egress, and travel times

Many transit network settings can be specified at the route level, at the mode level, or globally for all the routes in the network. Route-level values come from a field in the route layer, mode level values come from a field in the mode table, and global values are entered directly in the transit network settings dialog box. The route-level values have the highest priority. However, the route attribute may be missing, because "None" was chosen from parameter drop-down list or the value stored in the table is missing. In this case TransCAD will try to find the value in the mode table, if modes are defined in the Mode tab. If the value is also missing from the mode table, the global value will be used. The transit system configuration of the Genesee model is listed as follows:

- Time Value ($/min.) 0.2
- Max Access Time (min.) 30
- Max Initial Waiting Time (min.) 30
- Max Egress Time (min.) 30
- Max Transfer Waiting Time (min.) 30
- Max Transfer Time (min.) 30
- Max Transfer Number 2
- Transfer Penalty Time 1.5
- Min Init Wait Time (min.) 2.00
- Min Transfer Wait Time (min.) 2.00
- Max Trip Time (min.) 120
- Max Trip Cost 120
- Dweling Time (min.) 0.2
- Walk Weight Factor 3.00
- Wait Weight Factor 1.00
- Fare Weight Factor 1.00
- Link Time Weight Factor 1.00
- Transfer Penalty Time Weight Factor 1.00
- Dwell Time Weight Factor 1.00
- Interarrival Parameter 0.15
- Use Park and Ride NO

H. CALIBRATION/VALIDATION

Total link daily assignment from the base year TOD assignments was validated by comparing the percentage difference between observed traffic count and estimated model volume on the link. The systemwide calibration/validation was performed by roadway functional classification, volume-group range, screenline, major corridors, and area type.

The calibration and validation tasks began with the development of a special calibration report program, which is referred to as "CAL_REP". CAL_REP was originally developed by Bernardin, Lochmueller & Associates, Inc. as part of the Indiana Reference Modeling System (IRMS) for the purpose of quantifying model errors and assisting in the diagnosis of assignment problems. For the Genesee model, a new version of CAL_REP which was customized to best fit to the model was developed using the Geographic Information System Developer's Kit (GIS-DK) script language. This program was then embedded as a post-processing module in the user model interface for easy access and implementation. The features of the model interface and the post-processing module are given in the "Technical Memorandum: Travel Model User's Guide".

The new version of CAL_REP was designed to report modeling errors for the:

- network as a whole,
- functional classes,
- volume group ranges,
- designated screenlines,
- designated corridors,
- area types,
- truck trip, and
- time periods.

Error statistics reported and used for diagnosing the possible sources of model error are:

- percent root mean square errors,
- systemwide average error,
- mean loading errors and percentage errors, and
- total VMT errors and percentage errors.

The calibration and validation tasks were based on following a decision-tree that begins with finding "global" problems in the model. This beginning approach to correct global problems then moved on the "sub-area" errors, and was completed by focusing on specific link problems.

The global problems were first identified by a systemwide average error and a systemwide vehicle miles traveled (VMT). All model components affecting these problems were revisited and corrected where necessary. These efforts included:

- Modification to global trip production rates,
- Adjustment of friction factors,
- Adjustment of nested logit functions,
- Adjustment of timer-of-day factors,
- Adjustment of volume-delay functions,

- Modification to external trips.

The sub-area and individual link problems were then identified and applied with the following corrections:

- Application of local adjustment factors for trip generation,
- Modification to centroid connectors, and
- Adjustment of volume-delay functions.

Criteria for acceptable errors between observed and estimated traffic volumes vary by facility type, according to the magnitude of traffic volume usage. For example, higher volume roadways have stricter calibration guidelines than those with lower volumes. Acceptable error standards used for the calibration/validation efforts in this model are shown in **Table 36**. These thresholds were adopted by the Michigan Department of Transportation (MDOT).

Table 36: MDOT Highway Validation Standards

Category	**MDOT Standards**
Total VMT % Error	± 5%
Screenline/Cutline % Error	± 10%
Freeways	± 6%
Major Arterials	± 7%
Minor Arterials	± 10%
Collectors	± 20%
Trunk Line	± 6%
All Area Types	± 10%
Volume Group 1,000 ~ 2,500 vpd	± 100%
Volume Group 2,500 ~ 5,000 vpd	± 50%
Volume Group 5,000 ~ 10,000 vpd	± 25%
Volume Group 10,000 ~ 25,000 vpd	± 20%
Volume Group 25,000 ~ 50,000 vpd	± 15%
Volume Group > 50,000 vpd	± 10%

The 2005 model daily vehicle assignment to the 2005 AADTs using the MDOT targets (see above) at the network, area type, cutline, screenline, volume group and network link levels at a minimum. On the whole, the model is at –2.84% loading error and –2.11% VMT error. The systemwide % RMSE is at 27.70%. The Percent Root Mean Square Error (% RMSE) is the traditional and single best overall error statistic used for comparing loadings to counts. It has the following mathematical formulation:

$$\%RMSE = \frac{\sqrt{\sum (Count - Loading)^2 / n}}{Mean\ \text{Count}} \times 100$$

A model is in a high degree of accuracy when the systemwide % RMSE of the network gets down in the range of 30%. When evaluating % RMSE for groups of links disaggregated by volume ranges, relatively large errors are acceptable for low volume groups. But, the errors should become smaller as volume increases.

Table 37 lists the model performance by the roadway functional class. "% Error" represents the percentage difference between ground counts ("Average Counts") and model estimates ("Average Loading"). **Table 38** shows the model performance by screenline/cutline.

For the links where counts are higher than 1,000 vehicles per day, comparisons were made by volume-group between modeled and observed traffic counts. **Table 39** summarizes the errors by volume-group in comparison to calibration criteria identified in **Table 36**. The "% Threshold" column shows the target error standards adopted for this model. Comparison of % Error with % Threshold indicates that the model far exceeds the calibration minimum criteria for all volume ranges. Also, as volume increases, smaller % RMSE and % errors are observed.

Table 40 shows the model performance by time periods and **Table 41** lists the mode performance by area types.

The transit assignment model results are summarized in **Table 42**. Overall the model has 28.44% difference to the ADT ridership counts.

Table 37. Model Performance by Functional Classification

Functional Classification	Average Counts	Average Loading	% RMSE	% Error	VMT % Error	% Threshold (for % Error)
Rural Interstate	20,303	20,302	0.019	-0.002	0.00	±6
Rural Prin. Arterial	15,185	15,696	16.024	3.368	5.77	±7
Rural Minor Arterial	7,066	7,291	34.367	3.188	3.73	±10
Rural Major Collector	3,193	2,871	46.132	-10.068	-12.86	±20
Rural Minor Collector	1,967	2,173	54.660	10.482	15.65	±20
Rural Local Roads	0	0	0.000	0.000	0.00	n/a
Urban Interstate	28,939	30,062	12.104	3.879	1.35	±6
Urban Expressway	25,897	27,124	9.427	4.737	2.65	±7
Urban Prin. Arterial	17,357	17,258	23.438	-0.568	-0.27	±10
Urban Minor Arterial	8,586	7,820	33.826	-8.932	-10.33	±20
Urban Collectors	4,049	3,805	61.678	-6.037	-6.72	±20
Urban Local Roads	0	0	0.000	0.000	0.00	n/a
Trunk Line	18,582	188,442	19.550	-0.760	n/a	±6
All	**11,103**	**10,787**	**27.70**	**-2.84**	**-2.11**	n/a

Table 38. Model Performance by Screenline/Cutline

Screenline/Cutline	Average Counts	Average Loading	% RMSE	% Error	% Threshold (for % Error)
Irish Road	6,176	6,493	41.52	5.14	±10
Elms Hogan	9,851	10,574	30.52	7.34	±10
Pierson Road	13,334	14,432	27.30	8.24	±10
Hill Road	15,645	16,444	18.94	5.11	±10
Ray Road	13,227	13,201	19.62	-0.20	±10
NE CBD Screen	17,489	16,862	21.79	-3.59	±10
Flint River	20,212	21,799	21.74	7.85	±10

Table 39. Model Performance by Link Volume Group

Volume Range	Average Counts	Average Loading	% RMSE	% Error	% Threshold
1,001 ~ 2,000	1,520	2,219	123.99	46.01	±100
2,001 ~ 3,000	2,557	2,419	54.88	-5.40	±100
3,001 ~ 4,000	3,490	3,283	53.74	-5.93	±50
4,001 ~ 5,000	4,504	4,216	52.71	-6.40	±50
5,001 ~ 6,000	5,444	4,586	47.01	-15.76	±25
6,001 ~ 8,000	7,099	6,727	40.91	-5.24	±25
8,001 ~ 10,000	9,015	8,927	30.54	-0.97	±25
10,001 ~ 15,000	12,368	11,706	25.62	-5.35	±20
15,001 ~ 20,000	17,432	16,890	23.58	-3.11	±20
20,001 ~ 25,000	22,732	22,420	20.48	-1.37	±20
25,001 ~ 30,000	26,893	26,465	15.18	-1.59	±15
30,001 ~ 40,000	35,045	35,866	11.19	2.34	±15
40,001 ~ 50,000	44,148	45,574	8.39	3.23	±15
>50,000	0	0	0.00	0.00	±10
All	**11,103**	**10,787**	**27.70**	**-2.84**	

Table 40. Model Performance by Time of Day

Period	Average Counts	Average Loading	% Error	% RMSE	VMT % Error	% Threshold
AM Peak Period	1462	1321	-9.66	44.38	-13.98	n/a
Midday	3947	3724	-5.65	29.89	-3.77	n/a
PM Peak Period	2627	2594	-1.28	31.22	-0.97	n/a
Night	2913	2837	-2.61	33.30	-0.77	n/a
Daily	**11,103**	**10,787**	**-2.84**	**27.70**	**-2.11**	n/a

Table 41. Model Performance by Area Type

Area	Average Counts	Average Loading	% Error	% Threshold
CBD	7679	7862	2.39	±10
Urban	13731	13053	-4.94	±10
Suburban	10936	10816	-1.09	±10
Fringe	7386	7204	-2.46	±10
Rural (incls external links)	6685	6683	-0.03	±10

Table 42. Transit Model Performance by Route

ROUTE_ID	ROUTE_NAME	Count	Model Result	Difference (%)
9	Lapeer Road	1372	1943	41.59
6	Lewis-Selby	346	757	118.69
2	ML King Avenue	1596	1352	-15.27
5	Dupont	1256	1319	5.01
13	Crosstown North	388	1279	229.56
3	Miller-Linden	1282	2273	77.27
12	Beecher-Corunna	1170	969	-17.17
11	Fenton Road	666	1193	79.16
8	South Saginaw	772	1542	99.71
10	Richfield Road	890	1294	45.36
7	Franklin	1300	1256	-3.35
14	Downtown-Campus	277	436	57.47
4	Civic Park	1278	1260	-1.38
1	North Saginaw	1582	1333	-15.72
Total		14175	18206	28.44

VIII. MODEL POST-PROCESSORS

A. POST_ALT

The outputs of the travel model are the loaded volumes of autos and trucks by direction and time-of-day on the various facilities in the model's roadway network. However, for planning and air quality purposes it is often important and helpful to further process the model outputs to produce estimates of speeds and level-of-service and to aggregate both these and the loadings (in terms of vehicle miles of travel) in various ways. All of this is done for the Genesee County Travel Demand Model by a post-processor to the travel model called POST_ALT. The POST_ALT program can be run after any model run, and produces estimates of level-of-service and average speeds by time-of-day for each link in the roadway network as well as a report which computes statistics for groupings of roadway segments in the network such as by functional class, area type, or corridor.

1. Estimation of Hourly Average Speeds and Volumes

The hourly average speed for each link is calculated by using the Bureau of Public Roads (BPR) form of the volume delay function with link specific parameters. The volume delay function is used to adjust the link's free-flow speed on the basis of its hourly volume to capacity ratio to account for congestion related delay. The alpha and beta parameters for the BPR equation which are used in both the travel model's assignment procedure as well as the post-processing are coded on the network links. Several sets of volume-delay parameters were applied in the Genesee County model to different classes of roadway. Due to the method of capacity estimation adopted for the model which specifies an absolute capacity rather than a practical capacity, the Genesee County model uses different volume delay parameters than many models which use practical capacities. Initial parameters were developed from analysis of the data on average speeds from the congestion management study and modified through the process of validation of the assignment.

The estimation of link free-flow speeds is based on posted speed and facility type and is treated in Chapter IV in this document. The capacities used in the estimation of average speeds are also the same capacities used in the travel model proper developed using techniques from the HCM 2000 and are described in detail in Chapter V in this document. The last input to the volume delay function, the volume, is estimated by apportioning the model's assigned volumes in each period and direction using an hourly distribution developed together with the peak-hour traffic percentages from observed data. The hourly distribution of trips is displayed in the figure and table below.

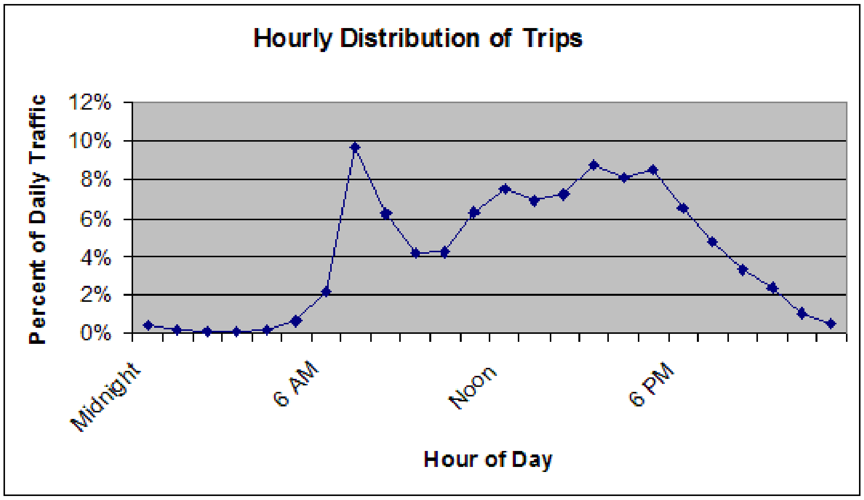

Figure 19. Genesee County Hourly Distribution of Total Traffic

Table 43. Distribution of Total Traffic by Hour

Period	Hour of Day	Percent of Daily Traffic	Percent of Period Assignment
Off Peak	1 AM	0.18%	0.31%
	2 AM	0.13%	0.22%
	3 AM	0.14%	0.24%
	4 AM	0.19%	0.32%
	5 AM	0.66%	1.12%
	6 AM	2.16%	3.68%
AM Peak	7 AM	9.67%	60.90%
	8 AM	6.21%	39.10%
Off Peak	9 AM	4.19%	7.13%
Off Peak	10 AM	4.25%	7.24%
	11 AM	6.27%	10.67%
	Noon	7.48%	12.73%
	1 PM	6.93%	11.78%
	2 PM	7.22%	12.28%
PM Peak	3 PM	8.75%	34.53%
	4 PM	8.09%	31.90%
	5 PM	8.51%	33.57%
Off Peak	6 PM	6.50%	11.06%
	7 PM	4.74%	8.07%
	8 PM	3.32%	5.65%
	9 PM	2.38%	4.05%
	10 PM	1.05%	1.79%
	11 PM	0.53%	0.90%
	Midnight	0.45%	0.76%

POST_ALT's speed estimation was calibrated to observed average speeds by time of day on major corridors from several congestion management studies. The calibration effort resulted in applying correction factors for signal delay and by area type. Signal delay was intentionally underrepresented in the travel model proper since using true delays would result in underloading of signalized facilities. This is due to a common psychological underestimation of the impact of signal delays on travel time. Similarly there is a psychological bias for certain trip attractors in urban areas and central business districts, and using true speeds in the model would cause under-assignment in the more densely developed areas.

2. <u>Estimation of Level of Service</u>

Three types of Level Of Service (LOS) estimation produced by POST_ALT are provided for general system level planning purposes and are not intended to replace manual level of service analyses for corridor planning and design purposes. These three types of LOS estimation are,

- HCM 2000 method
- Volume/Capacity Ratio Method
- Genesee County Congestion Management System (CMS) Method

Due to a variety of factors including the general assumptions regarding the percent of traffic in peak hour and peak fifteen minute periods and inherent limitations of the travel model to reproduce peak period directional splits, POST_ALT's estimates of level of service are not as accurate as manual estimates for particular corridors which make use of corridor specific assumptions. It is therefore important that specific level of service analyses still be done for detailed planning when examining specific corridors and improvements.

POST_ALT estimates the HCM LOS using the criteria set forth in the HCM 2000. For the purposes of level of service analysis, the facilities in the model's roadway network are grouped into three facility types: freeways, expressways and rural multilane highways; rural two-lane roads and highways; and urban streets. Each of these facility types are dealt with separately in the Highway Capacity Manual and use differing criteria for determining level of service. Level of service for freeways, expressways and rural multilane highways is determined by peak period flow density in terms of passenger cars per lane per mile. For, rural two-lane roads and highways, level of service is determined by percent time following and average speed. For urban streets, level of service is determined on the basis of average speed alone. For all facility types, a peak hour factor of 0.92 is assumed in urban areas and 0.88 is assumed in rural areas. The peak hour volume is assumed to be 60.9% of the AM period loading or 34.53% of the PM period loading. The directional split from the model for the peak period is used.

POST_ALT also estimate the LOS based on the Genesee County Congestion Management System (CMS). This method uses the daily capacity and loaded daily volume for the estimation.