Appendix C: Modeling Process

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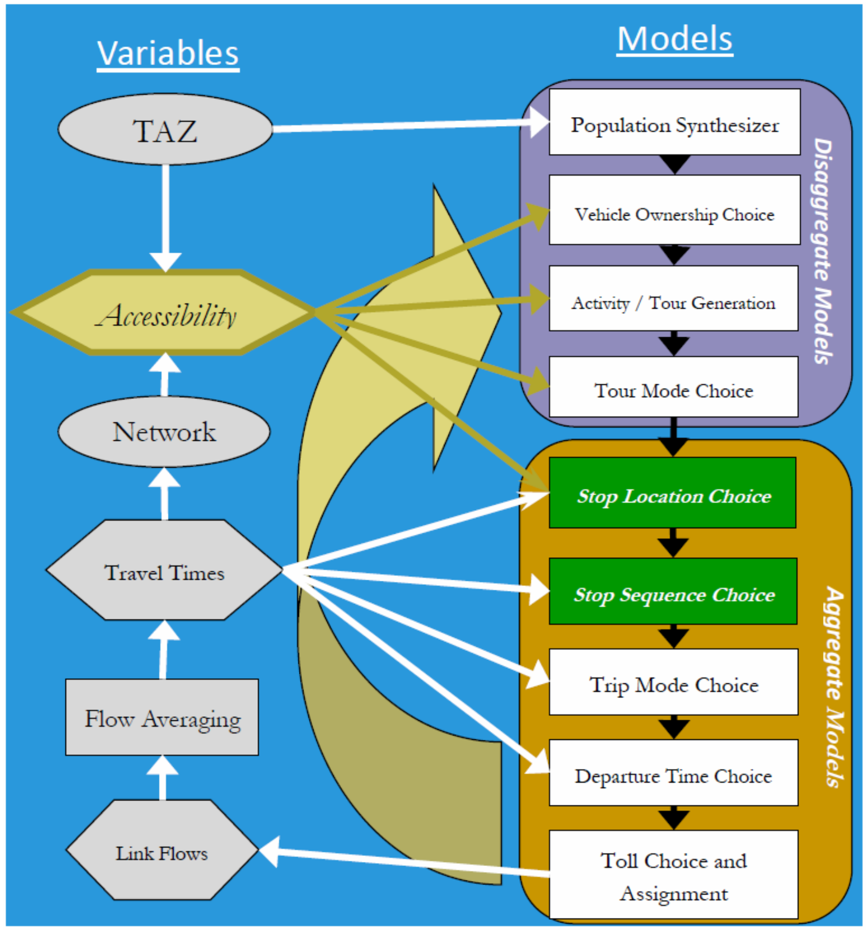
Figure C-1: The MACOG Hybrid Model Design



Source: MACOG Travel Model: Model Development and Validation Report

Travel demand forecasting models (TDMs) are a major analysis tool for the development of long-range transportation plans. These mathematical models are designed to calculate the number of trips, connect their origins and destinations, forecast the mode of travel, and identify the roadways or transit routes most likely to be used in completing a trip. Models are used to determine where future transportation problems are likely to occur, as indicated by modeled roadway congestion. Once identified, the model can test the ability of roadway and transit system improvements to address those problems.

For the 2045 Transportation Plan, in coordination with the Michigan Department of Transportation (MDOT) and the Southwest Michigan Planning Commission (SWMPC), MACOG contracted with Resource Systems Group (RSG) to expand the travel demand forecasting model into Niles, Michigan to the north of the urbanized area as well as the rural counties of Kosciusko and Marshall County to the south. A hybrid model, blending aspects of traditional four-step models and activity-based models, the model can be described as trip-based, as it produces aggregate trip table matrices of trips between origins and destinations rather than disaggregate records detailing individual travelers' activities. However, it can also be described as tour-based since the travel patterns predicted can be mathematically proven to be consistent with tours and all travel is segmented within the model by types of tours, eliminating the non-home-based trips problematic in traditional four-step models.

Unlike traditional four-step models which are entirely aggregate and activity-based models which are entirely disaggregated, the hybrid model includes both aggregate and disaggregate component models. Despite the inclusion of disaggregate choice models, there are no random number draws or Monte Carlo simulations included in the TDM. As a result, the model results are reproducible, unlike the results of activity-based or other simulation models. Any difference between two model runs is directly attributable to differences in their inputs as with traditional trip-based models. Whereas, in simulation models, multiple model runs are necessary when comparing alternatives to ensure that the difference between model runs results from differences in the alternative inputs rather than from differences in the random numbers drawn for each run.

Significant elements of the TDM are as follows:

Socioeconomic Inputs

HELPViz Land Use Model

HELPViz was developed by RSG as part of the Sustainable Evansville Area Coalition's Regional Plan for Sustainable Development. Using the Land-Based Classification System's activity-based codes, local 2002 aerial photography and 2013 oblique photography was used to describe land use changes in Elkhart and St. Joseph County over a 10-year period which was then used to adapt HELPViz to the area.

This land use model offers sensitivity to land use zoning, building codes and infrastructure facilities such as the transportation network, water and sewer utilities. HELPViz allocates the future population and employment regional totals to the TAZs based on build out capacities, the transportation network and infrastructure facilities. HELPViz uses a Nested Logit model framework and uses information at both TAZ and parcel levels.

Michigan Population Forecasts

Travel demand models are driven, in part, by the relationship of land use activities and characteristics of the transportation network. Inputs to the modeling process include the number of households, population in the households, vehicles, and employment located in a given TAZ.

The collection and verification of the socioeconomic data for the Michigan portion of the model was a collaborative effort between SWMPC, their committee members, and MDOT. Household, population, and employment data from the 2010 U.S. Census, the 2015 American Community Survey, Claritas and Hoovers employment databases was presented to SWMPC's Technical Advisory and Policy Committees. They were asked to provide detailed information about new development and where employers or population had been lost. The revised data was included in the travel demand model.

Kosciusko and Marshall County Demographics

Future population and employment growth in Kosciusko and Marshall County was based on a methodology used by the Hillsborough County Metropolitan Planning Organization in Florida. Local control totals based on Census counts were used to distribute growth to urban cores and areas of influence surrounding the various cities and towns while limiting overall growth to independent county control totals established using Woods and Poole data. This includes the average household income, average students per household, and average workers per household by horizon year.

The allocation methodology for population and employment to vacant developable lands was accomplished using a multi-step process that culminated in the allocation of growth based on the results of a gravity model. The gravity model distributes growth based on the attractiveness of a census block multiplied by the attractiveness of an activity centroid divided by the square of the distance between the two.

Using feedback from stakeholders that was digitized using a 500' grid, a residential density value was assigned to each square. Based on the density value of each grid, a priority would be assigned to the square from 1-3. This value, aggregated to the Census Block level, is the basis for the attractiveness score of the Census Block.

Population Synthesis

The TDM generates a disaggregate synthetic population of households based on the supplied demographic information associated with the traffic analysis zones. For each zone, individual households are created. Each household has a total number of persons, workers, students, and a binary variable indicating whether any of the household members is over the age of 65. Each household also has an income variable that indicates whether the household belongs to the lower (under $35,000/year), middle ($35,000 - $75,000/year) or upper (over $75,000/year) income category, each of which comprises approximately a third of the households in the region. The number of vehicles available to each household is modeled separately, after the population synthesis, based on these variables and other variables describing the zone in which the household is located.

Tour and Stop Generation

The TDM generates tours and stops rather than trips. The number of tours and stops of each type is estimated using multiple regression models applied to the disaggregated synthetic population of households. First, the number of tours, of each type, is estimated for each household. Then, for each stop type, the ratio of stops per tour is modeled and the total number of stops produced by multiplying this ratio by the number of tours. (See Table C-1)

In this framework, the modeled behavior is dominated by the tour generation equations, with the stop generation playing a secondary role (in some ways similar to, albeit simpler than, activity-based approaches which allow more tradeoffs). This is reflected in their goodness-of-fit which is quite good for the tour generation equations, but rather modest for stop generation since stop rates per tour are relatively constant.

Although cross-classification models were once viewed as an advance over regression models for generating trips, this was due to their ability to reduce aggregation bias compared to regression models which were applied to zones as a whole. By applying regression models instead to a disaggregate population, aggregation bias is eliminated altogether in the approach adopted here. While cross-classification models are limited to two or three variables at most, regression models can include more variables, introducing sensitivity in resulting trip rates to factors like gas prices and accessibility variables, in addition to the basic demographic characteristics. Although interaction effects were widely tested, the only interaction effect that proved significant was the interaction of gas prices and household income; increasing gas prices decreased certain stop rates, but only for low income households.

The number of work tours was mostly a simple function of the number of workers. Vehicle ownership, the presence of seniors and household income offered some additional explanatory power. The presence of seniors

Table C-1: Factors Affecting Household Tour and Stop Generation

	Workers	Non-Workers	Students	Seniors	Vehicles	Income	Gas Price	Accessi-bility
Work Tours	+			-	+	+		
Work Stops	+			-	+	+		-
Other Stops	+	-	+	-	+	+		
School Tours			+			+		-
School Stops			+			+		-
Other Stops			+			+		-
Other Tours	+	+		+	+		-	
Short Maintenance Stops	+	+		+	+	+	-	
Long Maintenance Stops	+	+	-	+	+		-	
Discretionary Stops	+	+	+	+	+	+	-	
Key	+	**Variable (column) increases tour/stop rate (row)**			-	**Variable (column) decreases tour/stop rate (row)**		

Source: MACOG Travel Model: Model Development and Validation Report in a household made work tours slightly less frequent, perhaps because senior workers are less likely to work full time.

The number of work stops is calculated for each household and allocated to income groups based on the household's income. The number of work stops per work tour is relatively constant. However, the number of work stops per work tour is slightly higher for high income workers, probably reflecting greater frequency of eating out for lunch which results in two work stops (before and after lunch). Accessibility also makes work stops marginally more frequent because it implies that commute times are shorter, so it is easier to get back and forth between home and work, such as going home for lunch, returning to work after dinner, work activities on weekends, etc.

The number of other stops per work tour is significantly increased by the number of household students from workers stopping to drop off students on the way to work and decreases with the number of non-workers in the household who can drop off the students instead. Here also, we see income and vehicle ownership increasing other stops on work tours, again perhaps increased lunch stops out.

The number of other (non-work) tours made by a household is most influenced by the number of non-workers in the household: more non-workers generate more non-work tours. However, the non-work tours are also increased albeit less by workers and are more frequent for households with seniors and more vehicles. Non-work tours also decrease slightly as gas prices rise. The number of short (under 30 minutes) maintenance stops per other tour was largely constant, but somewhat higher for households with more people and income. The number of long (over 30 minutes) maintenance stops was also fairly constant and increased with the number of vehicles available; however, it also decreased with the number of students, who may curtail long shopping activities. The number of discretionary stops decreased slightly with the presence of seniors and increased with income and students with cars.

Tour-Based Modal Choice

In the model, as in activity-based models, the mode of travel is developed in two stages: tour mode choice and trip mode choice. After tours are generated, they are assigned a primary mode by tour mode choice models. Then, after the spatial distribution of stops creates trips, individual trips are assigned a mode based on the primary mode of the tour in trip mode choice models. (See Table C-2 on the following page)

The model makes use of four primary tour modes:

- Private Automobile
- Public Transit
- Walk / Bike
- School Bus

The primary mode for a tour is determined by a simple set of definitions or rules.

- Any tour containing a school bus trip is a school bus tour.
- Any other (non-school bus) tour containing a public transit trip is a public transit tour.
- Any other (non-transit) tour containing a private automobile trip is an automobile tour.
- Any other tour, which contains only walk or bike trips, is a non-motorized tour.

In this framework, the primary choice determining transit mode share is the tour mode choice. Trip mode choice ultimately reduces mostly to the determination of vehicle occupancy for automobile tours or the allocation of access modes for transit tours. Even in advanced activity-based models, fixed shares or other simple heuristics have been used for trip mode choice; whereas, tour mode choice models are more comparable to mode choice in traditional models.

The incorporation of behaviorally sensitive tour mode choice models in the TDM represents significant added value as compared to the previous model in which mode shares were fixed and totally insensitive to demographics, levels-of-service, or any other policy variables. The model produces, in addition to automobile trips by occupancy class, the system-level transit ridership, the number of transit trips generated by each residence zone, and the total regional number of daily walk/bike trips. Moreover, the model architecture allows for the straightforward addition of future component models to produce transit and non-motorized trips at the route/street level. These component models and level of spatial fidelity could be developed in a future model upgrade.

The key difference between the tour mode choice models and those common in activity-based models is the way in which they measure the level-of-service provided by each competing mode and the related assumption of the hierarchy of travelers' choices (i.e., whether travelers' destination choices depend more on their mode choices or vice versa).

In activity-based models, as in traditional four-step models, tour mode choice is modeled after destination choice (or distribution) and can therefore use actual travel times between origins and destinations as level-of-service variables. This traditional model structure was first developed for very large metropolitan areas with significant choice rider markets and is more sensitive to changes in level-of-service provided by transit improvements and for testing their impacts on transit route ridership. However, it may be oversensitive to level-of-service variables and a source of optimism bias in transit forecasts, as this model structure is built on the assumption that travelers are more likely to change mode than destination. This may well be the case for affluent choice riders for their work commute in large cities. However, there are

Table C-2: Factors Affecting Tour Mode Choice

	LOS	Cost		Demographics					Built Environement		
	Accessibility by Mode	Gas Price	Bus Fare	Workers	Students	Senior HH	Income	Vehicle per Person	Percent Sidewalks	Activity Diversity	Intersection Density
Work Tours											
Auto	+	-	+		+	+	+	+	-	-	
Transit	+	+	-		-	-	+	-	-	-	
Non-Motorized	+	+	+		+	-	-	-	+	+	
School Tours											
Auto	+	-					+	+			
Transit	+	+					-	+			
Non-Motorized	+	+					-	-			
School Bus	+	+					-	-			
Other Tours											
Auto	+	-		+	+	+		+		-	-
Transit	+	+		+	-	-		-		-	-
Non-Motorized	+	+		-	+	-		-		+	+

Key	
	+ Direct Increase
	+ Indirect Increase
	- Indirect Decrease
	- Direct Decrease

Source: MACOG Travel Model: Model Development and Validation Report many situations where it is more reasonable to assume that travelers are more likely to change destinations than mode.

Local household survey data offer some support of this general assumption for the region that travelers are more likely to change destination than mode of travel. In general, this assumption seems more appropriate in markets similar to MACOG with few choice riders, where mode choice is generally a foregone conclusion on which destination choice is conditioned. For example, either the traveler has access to a car and does not even think of riding transit or they do not have access to a car and rely on transit, choosing their destinations, possibly even workplace, based on where the transit system can get them. "Reverse hierarchy" models such as those developed for the TDM, which represent destination (or stop location) choice conditional on mode choice, still take the level-of-service provided by competing modes into account and allow for changes in ridership based on improvements to transit or highway modes. However, they measure the level-of-service provided by each mode not directly by the travel times between origins and destinations but indirectly by the accessibility to various types of destination provided by each mode to a residence zone.

Departure Time Choice

The regional travel model includes departure time choice models which distribute trips throughout the day. The models are capable not only of producing the traditional AM, PM and off peak trip tables for standard assignments, but also can produce trip tables for any or all 15-minute periods from 6 am to 9 pm. These 15-minute trip tables should be of significant value for traffic micro-simulations and could be used in the future in conjunction with a dynamic network assignment.

In addition to adding temporal resolution, the departure time choice models add sensitivity to new variables, most notably travel times and accessibility. The new models will reflect shifts in travelers' departure times in order to avoid longer travel times. This effect, commonly referred to as peak-spreading as travelers leave earlier or later to avoid peak traffic, was modest, but already statistically significant in the household survey data. The effect was evident for all tour types but was most significant for Other Tours, which, in general, presumably have more flexibility in the timing of their activities than the other tour types.

The models also incorporate accessibility variables which allow departure times to vary geographically in the model, e.g., lower accessibility, rural travelers might generally leave for work earlier (since they have further to go to get to work).

Home-based and non-home-based trips for each tour type are represented by different models, since the first and last trips of a tour have different temporal distributions compared with mid-tour non-home-based trips. This segmentation is particularly important for midday/lunch traffic which is associated primarily with shorter, mid-tour non-home-based trips, as opposed to the am and pm peaks which are more associated with longer home-based trips.

University Student Travel Models

The university student travel models are supported by the Michiana Area College Travel Study. The College Travel Study closely paralleled the Michiana Area Household Travel Study in questionnaire structure and content. Six colleges agreed to participate in the study: Bethel College, Goshen College, Holy Cross College, Ivy Tech Community College, the University of Notre Dame, and Indiana University – South Bend.

Before administering the College Travel Study, the survey was soft-launched to 25 students from Goshen College. Goshen College was gracious to agree to soft-launch the survey as a way to test the data and ensure that the survey questions were clear and relevant to students taking the survey. After the soft-launch was completed, the data was reviewed. The College Travel Study was then administered with each participating college sending out an invitation email. Survey administration began on Wednesday September 18, and closed on October 14. This survey administration timing was specifically selected to ensure that the survey started after classes were in session (and the add/drop period had passed) and the survey was completed prior to the October break period. A total of 672 students completed the survey.

Truck Model

Based on the method recommended in the Quick Response Freight Manual II, a commercial vehicle model was developed for predicting trips for four-tire commercial vehicles, single unit (SU) trucks, and multiple unit (MU) trucks. The model uses a four-step process. These steps are trip generation, distribution, choice of time of day and trip assignment. In addition, the special trip generators of inter-region and inter-modal trucks were added in the model to better replicate the current inter-region and inter-modal truck movements.

The inputs to trip generation are the number of employees and the number of households by Traffic Analysis Zone (TAZ). These rates were obtained by adjusting the original generation rates in the Quick Response Freight Manual. To replicate the current truck traffic condition in the study area, the rates for four-tire commercial vehicles were further adjusted by a factor of 0.10.

The external-internal (EI) and internal-external (IE) truck trips were classified as a distinct type of trip in order to better replicate the in-balance direction truck flows at different time periods. Before the trip distribution, the trip origins and destinations were balanced for all TAZs and external stations for the following types of trips:

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

For four-tire commercial vehicles, it is assumed that the normal EI-IE trip attractions are proportional to the trip destinations. At the beginning, destinations are used as the normal EI-IE trip attractions and the balancing process scales to the total adjusted attractions.

For single-unit and multi-unit trucks, a destination choice model was applied separately to internal & external trips. The destinations chosen in these models (the sum over all origins) are scaled to the total number of trips produced in generation. This vector is then used as both the productions and attractions for a doubly-constrained gravity model to distribute the truck trips.

The time-of-day assignments were implemented in order to obtain better model results.
To facilitate this, the trip tables from trip distribution must be factored to reflect morning peak, midday, and off-peak periods prior to trip assignment. The hourly time-of-day factors were derived from classification traffic counts provided by MACOG and applied to the MACOG Regional Travel Model.