Appendix D: Travel Demand Model

Introduction
This appendix is a general overview summary of technical aspects related directly to the BMCMPO travel demand model (TDM) developed in 2013-2017 and embodied within the BMCMPO 2040 Metropolitan Transportation Plan. The following narrative provides an overview of the model, the network attributes, traffic analysis zones, trip generation, destination and mode choice, traffic assignments, and statistical model validation. More detailed technical documentation is available upon request.

Model Overview
The BMCMPO maintains a Travel Demand Model covering Monroe County developed with TransCAD Transportation Planning software (https://www.caliper.com/tctraveldemand.htm) for travel demand modeling serving as a macro-level analytical tool for the Bloomington-Monroe County area. Travel demand forecasting commonly uses complex statistical models for predictive changes in transportation system travel patterns resulting from alternative exogenous and endogenous policy assumptions including land use policies and use, demographic characteristics, employment, and multimodal transportation supply networks.

The BMCMPO model design focuses on transportation planning efforts at a regional scale and as a useful tool the 2040 Metropolitan Transportation Plan. The travel demand model further retains vital importance with respect to the 2045 Metropolitan Transportation Plan as an overarching guide for policy-level investment decisions until 2020 Census block geography data becomes available for reassessments and/or recalibration.

Conventional Travel Demand Models use a four-step process. Each step of the TDM simulates the traveler’s decision-making on one aspect of trip making. For example, trip generation predicts whether to make a trip while trip distribution finds where to go. Mode split determines which transportation mode to use for specific trip purposes, and traffic assignment estimates which route to take for the trip. This conventional approach follows four sequential steps:

- **Trip Generation** - this initial step translates household and employment data into person trips using trip generation rates established during model calibration.

- **Destination Choice** - this second step estimates how many trips travel from one transportation analysis zones (TAZ) to any other zone with the distribution based on the number of trips generated in each of the two zones, and on factors that relate the likelihood of travel between any two zones to the travel time between the two zones.

- **Mode Choice** – this third step estimates the proportions of the total person trips which use transit and ride-sharing modes as opposed to single occupant vehicles for travel between each pair of zones.
• **Trip Assignment** - this final step assigns trips from one zone to another to specific travel routes between the zones. The assignments to routes do consider effects, such as traffic congestion.

The BMCMPO Travel Demand Model uses a feedback loop referenced by the following illustration to pass congested speeds back through the modeling steps so that trip distribution and mode choice components produce results that are consistent with modeled congestion for a given scenario. The following illustration depicts the generalized modeling process.

Development of the BMCMPO Travel Demand Model required various data and information to run each of the four steps of the TDM. Much of these data and information were attributes assigned to each TAZ. Statistical analysis, network attributes, and other parameters used to establish a Base Year (2013) condition for comparisons of future conditions or scenarios employed the same four-step process, but with projected data values. The general aspects of Transportation Analysis Zones, Trip Generation, Destination and Mode Choice, and Traffic Assignment and Validation provided below illustrate the relationships of data, attributes, and model parameters used for the Travel Demand Model.
Transportation Analysis Zones (TAZ)
A total of 591 Transportation Analysis Zones (TAZs), including 34 external stations, were developed for the BMCMPO Travel Demand Model based on 2010 U.S. Census Block geography. Each TAZ identifies total population, households, household characteristics, employment, school enrollment and other socioeconomic data for key attributes. The Travel Demand Model developed in 2013 contains significantly more TAZs than the previous BMCMPO travel demand models (e.g., 1993, 2003) thereby allowed for a more refined level of detail analysis for key spatial attributes. For example, the Base Year 2013 refinement includes group quarters associated with Indiana University which were not been accounted for within TAZ development of models prior to 2013.

The aggregation of population and household data from the 2010 Census into each BMCMPO Travel Demand Model TAZ resulted in a total Monroe County population of 137,976 located within 68,624 households. TAZ attribute development additionally used household and economic data from the 2010 Census. This approach represented key household characteristics, which typically affect the number of trips made by household members (e.g. average household size, median household income, average number of workers per household, average number of vehicles per household).

School enrollment and employment are additional key attributes aggregated into each TAZ. School enrollments identified a total population of 14,660 K-12 students, and a 50,948 higher education enrollment population (41,997 for Indiana University and 8,951 for Ivy Tech) for Monroe County trip assignments. Travel demand model assignments for employment included a total of 79,738 employees for Monroe County by North American Industry Classification System (NAICS-based) employment types. This resulted in a total population of 8,376 retail jobs, 10,066 industry jobs, 3,140 office jobs, and 58,156 service employment jobs.

Another attribute of TAZs used was their classification by area types (rural, suburban and urban). This information is required for speed and capacity estimation of network links. The area types were determined by combined criteria of population and employment density for each TAZ and followed the following tabular guidelines:

<table>
<thead>
<tr>
<th>Area Type</th>
<th>Population Density (Persons/mile²)</th>
<th>Employment Density (Jobs/mile²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td>Less than 1,500</td>
<td>AND Less than 400</td>
</tr>
<tr>
<td>Suburban</td>
<td>400 to 1,000</td>
<td>OR 1,500 to 2,000</td>
</tr>
<tr>
<td>Urban</td>
<td>1,000 or greater</td>
<td>OR 2,000 or greater</td>
</tr>
</tbody>
</table>

Bloomington-Monroe County Metropolitan Planning Organization
2045 Metropolitan Transportation Plan – Working DRAFT
Trip Generation

Trip generation represents the initial step of the travel demand model development. Attributes assigned to each TAZ translate this information into person trips using trip generation rates, household worker stratification curves, and household market segmentation (automobile ownership). Approximately 75% of the Bloomington-Monroe County households have two people and two or less workers. Household stratification is used because the number of employed workers and size of the household strongly influence the trip generation (e.g. home-based work, home-based other, home-based shop, home-based school).

Likewise, the market segmentation strongly influences trip generation when factoring in the number of autos available to adult household members. The auto ownership variable is key to the trip generation process. The inclusion of the auto ownership model allows the regional travel model sensitivity to different types of urban development and/or non-auto infrastructure (transit and non-motorized). The market segmentation element of the trip generation process categorized household automobile ownership into Zero Auto, Autos Less than Workers, Autos Greater than Workers.

Truck/commercial vehicle trips represent another aspect that the Travel Demand Model incorporates into the trip generation step. Generally, truck trips correlate with local employment aspects generated by commerce activities.

Destination and Mode Choice

The next step of the BMCMPO Travel Demand Model TDM first estimated how many trips travel from one TAZ to another TAZ. The number of trips generated in each of the two zones and use factors such as the likelihood of travel between any two zones to the travel time between the respective two zones determines trip distribution. This step included time of day factors, peak travel, and other attributes to estimate trips. Another aspect that the TDM is the use of a congested travel time feedback loop for assessing consistency with air quality and travel speeds as they are interrelated.

The Travel Demand Model next estimated the proportions of the total person trips by mode type between each pair of zones. This Mode Choice step uses a regression or logit model to assign the probability of using a particular travel mode based upon the utility of that mode in relation to the sum of the utility for all modes. The utility measure is specific to each travel mode, while the coefficients for travel time and cost are generally held constant for all modes for a given trip purpose and population. This regression assumes an improvement in one mode will divert trips proportionately from all other modes. For example, a transit improvement that attracts an additional five percent of all trips would reduce trips on all other modes by five percent. It also has the ability to recognize the potential for something other than equal competition among modes. In this instance, a reasonable assumption for a premium express transit service would attract more diversion from the parallel local bus service than from the auto modes. Finally, it also relates the mode choice to the type of trip generation (e.g. home-based work, home-based other, home-based shop, home-based school).
Another unique aspect of the BMCMPO Travel Demand Model is the inclusion of urban design attributes. There are strong correlations in the Bloomington-Monroe County area between land uses and transportation needs. The development and use of a “5D Score” relates land development types and their respective impact on travel behavior (e.g. low density tends to favor high VMT and high density tends to favor low VMT on a per capita basis). The 5D Scores used Density, Destination, Design, Diversity, and Distance to Transit as part of the Mode-Choice step.

**Traffic Assignment and Validation**

Accurately representing the transportation network of Monroe County is a fundamental part for the successful validation of the BMCMPO TDM. The City of Bloomington and Monroe County provided roadway traffic counts and transit ridership data, and a variety of GIS files of roadways, transit routes, bike routes, trails/paths, traffic signals and parcels data. All these data incorporated for model network development established an accurate representation of transportation infrastructure conditions in Base Year 2013. Technical analysis considered aspects of future networks, highway speeds, capacity estimation, delays, external stations, growth rates, truck traffic, transit network, and other network attributes.

Trip assignment step is the last step of the conventional four-step model process. The standard approach to this process takes trips from the various trip generation tables and assigns trips to the network according to a mathematical algorithm ensuring that all zone to zone trips use paths that minimize the total travel time of all trips on the network. This step is also the last step in the feedback loop that returns updated highway travel times to the trip distribution step which generates revised trip tables based on these updated travel times. This loop ensures the establishment of consistent, stable highway travel times before the final set of highway and transit trips prior to network assignment. Trip assignment uses the following steps: Highway Assignment (equilibrium assignment for peak periods, off peak period, by single occupancy vehicle, high occupancy vehicle, trucks, bikes, and pedestrians), Congested Travel Speeds (standard design curves), and Count Data (local, INDOT).

Validation of the BMCMPO Base Year (2013) Travel Demand Model included comparative measurements against recorded historical data for the Bloomington-Monroe County region. Calibration of a Travel Demand Model takes place at each step in the modelling process involving initial estimations followed by an iterative refinement of the various parameters and coefficients of the model components by comparing model results to observed conditions. This iterative process continues until calibration refinements have resulted in satisfactory results. Once validated, the model becomes a tool for the prediction of future travel patterns with a high degree of confidence.

A Root Mean Squared Error (RMSE) statistical methodology validated for different volumes, facility and area types. In regard to RMSE, The model is generally within the desirable range of error for high-volume roads and overall, but above desirable targets for low-volume roads, which are more difficult to replicate, given the inherently smaller margins of error afforded.
The BMCMPO travel demand model 2013 Base Year model exhibited a high degree of statistical validation in comparison to documented traffic volume counts showing an overall 26.2% RMSE and a 1.5% count Vehicle Miles of Travel (VMT) error. The system-wide modeled 2013 Base Year VMT estimate is consistent with the 2005 Highway Performance Monitoring System (HPMS) estimate (within -5%). The figure below illustrates in graphical form estimated traffic flows of the BMCMPO Travel Demand Model in relation to actual traffic counts as an element of the validation process.