JACTS

Travel Demand Forecasting And Modeling

The travel demand forecasting and modeling process for the Jackson Metropolitan Area was a cooperative effort between the Region 2 Planning Commission (R2PC), serving as the Metropolitan Planning Organization (MPO), and the Statewide and Urban Travel Analysis Section of the Michigan Department of Transportation (MDOT). MDOT undertook the lead role in the process, assuming responsibility for the development, calibration, validation, and application of the Travel Demand Forecast Model (TDFM) during the development of the Long Range Transportation Plan (LRTP). Both Parties worked collaboratively throughout the entire process, with R2PC acting as the liaison with local agencies and the Technical, Policy, and R2PC Committees.

Travel demand forecasting, including the identification and evaluation of regional (i.e. system-wide) transportation capacity deficiencies, is a key ingredient in the development of a LRTP. Both the identified deficiencies and the LRTP are dynamic, reflecting policies initiated under the Intermodal Surface Transportation Efficiency Act (ISTEA) and continued under subsequent bills up to the current legislation, Moving Ahead for Progress in the 21st Century (MAP-21). In essence, the capacity deficiency analysis and the LRTP are "snapshots in time," exhibiting the regional conditions and trends at the time for which they were developed. With that in mind, the LRTP is updated every three to five years, reflecting ongoing changes in the regional transportation system and land use conditions.

Travel demand forecasting and modeling is a valuable tool utilized in the capacity deficiency analysis of the Jackson Metropolitan Area's transportation system. The Model results are useful in the decision-making process that is a vital part of the LRTP development. The modeling process is a regional-level effort; in other words, the results should be evaluated and applied in terms of system-wide impacts, even though links of the roadway network could be evaluated individually. The identification and analysis of capacity deficient corridors and links is intended to serve as the basis for forming decisions regarding system improvement and expansion.

Forecasting Process Description

The Jackson Metropolitan Area TDFM is currently developed and maintained on a computer platform using Caliper's TransCAD Transportation Planning Software Package. The model is essentially a computer simulation of current roadway conditions and travel demand, and potential future roadway conditions and travel demand. The TDFM is a "regional-level" transportation planning model, focusing on long term transportation planning concerns. It generates link capacity deficiencies based upon a generalized 24-hour time period and 24-hour link capacities and traffic volumes, though various time-of-day periods are also accounted for in the model.

The travel demand forecasting and modeling process is usually accomplished through nine inter-related components (or steps) – Steps 2 thru 7 comprise the traditional "Four Step" Trip-End-Based Model structure (the output from one component is the input to the subsequent component):

1. **Data Collection**; in which regional socio-economic data and transportation system characteristics are compiled. This modeling component also includes the development of the roadway network, and the traffic analysis zone structure.
2. **Trip Generation** (i.e. the decision to travel and why); in which the frequency of trip origins and destinations are estimated, by trip purpose, and as a function of land use, household demographics, and other socio-economic factors.
3. **External Travel Estimation;** in which trips that originate and/or are destined outside of the model region are estimated.
4. **Trip Distribution** (i.e. the choice of destination); in which the trip origins and destinations are matched, determined by using a "gravity" model function.
5. **Mode Choice** (i.e. the choice of travel mode); in which the proportion of trips, between each trip origin and destination, that use a particular transportation mode are estimated.
6. **Auto Occupancy / Time-of-Day Factoring;** in which the daily trips are converted from "person" trips to "vehicle" trips and distributed into various daily time periods (e.g. AM Peak, PM Peak).
7. **Traffic Assignment** (i.e. the choice of route or path); in which the trips between each origin and destination are allocated, by a particular mode and time-of-day, to the transportation system.
8. **Model Calibration and Validation**; is the process by which the model is adjusted (i.e. calibrated), so that when applied, the model results simulate (within established validation criteria) the current, local observed conditions of the transportation system.
9. **Model Application / System Analysis**; in which a calibrated and validated model is used in the development of a LRTP, air quality conformity analysis, project identification and prioritization, and/or impact analysis.

Data Collection

There are two basic elements of data organization within the overall travel demand model structure; the roadway "network", and the traffic analysis zone (TAZ). The network (roadway links and attributes) generally consists of federal-aid eligible roads, usually ones that are classified functionally as interstate, freeway, principal and minor arterial, and major and minor collector. "Local" roads are included in the network to maintain continuity and connectivity, or if they are regionally significant or lie on a transit route (if transit is modeled). The TAZs, on the other hand, are geographic subdivisions of the modeled region. They are usually defined by homogeneous land use and human activity, and the compatibility with Census and jurisdictional boundaries, physical boundaries and the links that comprise the roadway network. Socio-economic data is aggregated to the TAZ-level, with each TAZ represented in the over-all model structure as a “centroid” (or point).

These two data elements are inter-connected through the TAZ centroids, by centroid-to-network “connectors”. Each centroid is linked, by at least one connector, to the adjacent transportation system; that is to say, the network includes a special set of links for each TAZ that joins the TAZ structure to the roadway network. Centroid connectors represent the local streets that are not included in the network, and they attach to the network at “realistic” locations. It is then possible for trips generated in and/or attracted to each TAZ to reach every other TAZ by way of a number of paths through the roadway network.

Socio-Economic Data

The socio-economic (SE) data represents the activity in the modeled region, usually defined by population and employment levels. The SE dataset was developed for the model base year of 2010, and forecast to the year 2040; the current decennial 2010 Census being the source of the population and household data, as well as data from the 2006-2010 Five Year American Community Survey (ACS). All model SE data forecasts were based upon economic and demographic data forecasts developed using the Regional Economic Models Incorporated (REMI) TranSight Model.

The 2010 population and household data was obtained at the Census block level of geography and aggregated to the model TAZ-level based upon the geographical TAZ-Census block equivalency. For this reason, TAZ boundaries are developed based upon Census geography for compatibility.

The 2010 employment data was derived from a list of businesses (employers), residing within the Jackson County area, that was created from a “master” list of business data purchased from two database sources; Claritas (a Nielson Company) and Hoovers (a Dunn-Bradstreet Company). The employment locations were geocoded and aggregated to the TAZ-level based upon geographical location.

Transportation System

The model roadway network was developed from Version 11 of the Michigan Geographic Framework (MGF), and consists of links classified functionally as interstate, freeway, principal and minor arterial, and major and minor collector. “Local” roads are included in the network where necessary to maintain continuity and connectivity, or if they were found to be “regionally significant” or if they were part of the local transit route system. The 2010 Base Year Roadway Network includes a total of 942 miles of roadway, representing the following breakdown based upon link functionality; 11% Interstate/Freeway, 3% Ramps, 5% Principal Arterial, 16% Minor Arterial, 54% Major & Minor Collector, and 11% Local. In addition to the roadway attributes that were acquired with the MGF network, roadway characteristics (to be used in the TDFM process) were compiled for each network link, including; area type coding, facility type classifications, number of lanes, lane widths, the presence of parking and continuous two-way left turn lanes, link capacities and free flow speeds, and link validation traffic volumes (i.e. observed data), among others.

Traffic Analysis Zones

The traffic analysis zone structure is a series of geographic subdivisions of the entire model region. The TAZ is the principal element by which the various SE data are introduced into the modeling process. A number of "Rules of Thumb" were followed when developing the TAZ structure for the model region, and some of the more critical guidelines include the following:

- The TAZ structure should be compatible with the model roadway network,
- The TAZ structure should be compatible with Census geography,
- The TAZ structure should be compatible with political boundaries,
- The TAZ structure should be compatible with the Michigan Statewide Passenger and Freight Model TAZ structure,
- The TAZ structure should observe natural (e.g. rivers) and man-made (e.g. railroads) boundaries,
- The TAZ structure should accommodate any local transit service routes.

The 2010 Base Year TAZ structure incorporates 491 TAZs and 46 External Stations (TAZs that are located at the model boundaries), with each TAZ maintaining a number of attributes, including; area type and transit service accessibility coding, terminal times, population (including K-12 children and worker breakdowns) and household (including auto availability) counts, employment levels, and school enrollment – all of which are used throughout the TDFM process.

Trip Generation and External Travel Estimation

Trip generation (and external travel estimation) is the first step in the traditional Four Step TDFM Process. In this step, the number of "person" trips of each trip purpose, those that originate or end in each TAZ (or external station – see below), is calculated. The SE data, land use information, and "observed" traffic data are the basic inputs to this step, with the premise that trips exist to achieve some social or economic purpose (e.g. work, school, shopping, etc.). Trips are "produced" by trip makers traveling to an activity, and trip makers are "attracted" by some sort of activity. Thus, the TDFM structure uses the concepts of productions and attractions to account for person trips generated within the model region – "observed" traffic data is used to account for trips generated outside the model region.

Several trip generation methods exist, and the cross classification and linear regression models were utilized in this particular modeling component – cross classification methods were used to calculate productions, while attractions were calculated using linear regression equations. These are the two most common modeling structures used to calculate productions and attractions by trip purpose.

External trip estimation was developed based upon "observed" traffic data collected at the boundaries of the model region (at the "external stations"). There are three types of external trips:

- Internal to External (I-E) trips – trips that originate within the model region, and terminate outside of the model region,
- External to Internal (E-I) trips – trips that originate outside of the model region, and terminate within the model region,
- External to External (E-E) trips – trips that both originate and terminate outside of the model region (i.e. thru trips).

Trip generation / external travel estimation is comprised of several trip types, mode types, and trip purposes:

- Internal-Internal (I-I) trips by auto, categorized as;
  - Home-based Other (HBO),
  - Home-based Retail (HBR),
  - Home-based K-12 School (HBS),
  - Home-based Work (HBW – further stratified by income group),
  - Non Home-based (NHB),
- Internal-Internal (I-I) trips by commercial vehicle and heavy truck,
- Internal-External (I-E & E-I) trips by auto and heavy truck,
- External-External (E-E) trips by auto and heavy truck.

The trip generation / external travel estimation component structure, factors, and parameters were developed as part of the recently completed "Urban Model Improvement Program", and are based upon the results of the "2004-2005 Comprehensive Household Travel Data Collection Program", both conducted by MDOT.

A balanced trip table (usually attractions are adjusted to match productions), in which trips by "non-motorized" modes are "factored" out, is the result of the trip generation / external travel estimation step. This balanced trip table is utilized as the input to the next step in the TDFM process, trip distribution.

Trip Distribution

Trip distribution involves the use of the results from the trip generation step (balanced productions and attractions by trip purpose), along with the model roadway network, to "match" trip productions with trip attractions – creating "trips" on the network from TAZ-to-TAZ. In this step, impedance (i.e. travel time) is accrued to and from each TAZ pair by traversing all available routes (i.e. paths) on the roadway network, with the goal of establishing a "shortest" path. The "gravity model" (a commonly used model structure) was employed in the trip distribution component. The gravity model utilizes the "relative attractiveness" and impedance (two conflicting influences) between all TAZ pairs, determining how many productions are to be matched with attractions between any given TAZ pairing. "Friction" factors (representing "perceived" time) are employed to help balance the conflicting influences of attractiveness and impedance, and thus they alter the trip distribution results so that they better match "observed" travel time distributions. The calibration of the gravity model includes the adjustment of these friction factors, so that the modeled travel patterns better match "observed" data.

The trip distribution "trip length frequency distribution" curves (per trip purpose) were developed as part of the recently completed "Urban Model Improvement Program", and are based upon the results of the "2004-2005 Comprehensive Household Travel Data Collection Program", both conducted by MDOT.

Mode Choice, Auto Occupancy, and Time-of-Day

The mode choice step utilizes the output from trip distribution (i.e. I-I auto production and attraction "person-trip" data by trip purpose) and allocates the trips among distinct travel modes. The "distinct" modes of travel are "Auto" and "Transit", based upon the Nested Logit Structure in Figure 11-1. The choice of the mode a trip maker will utilize is usually based upon the characteristics of both the trip maker and the purpose of the trip. However, a "simplified" method of mode choice is employed in this particular model component application, based upon an assigned TAZ-level qualitative assessment of transit service availability. The transit "share" is first calculated based upon this TAZ-level service assignment, with the auto share calculated as one minus the transit share. Mode share "factors" are then applied to the "auto shares" to develop the single occupancy vehicle (SOV), and shared ride (SR2, SR3+) breakdowns. Thus, the result of the mode choice component is a series of person-trip tables by travel mode and trip purpose for each TAZ origin-destination pair.

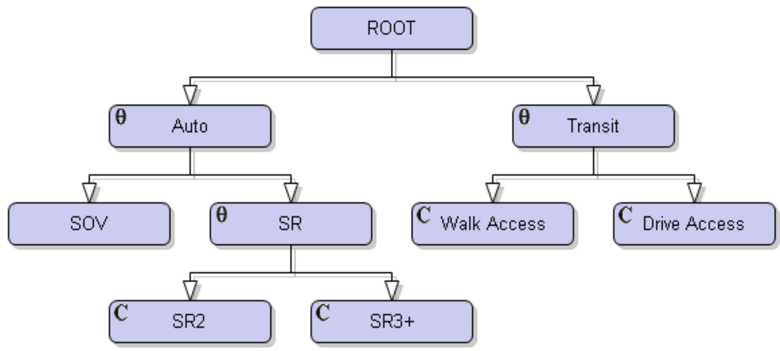

Figure 11-1: Nested Logit Structure

Prior to preceding onward to the trip assignment step, the person-trip data (the product of the mode choice step) are first converted from "person" trips to "vehicle" trips using auto occupancy modeling factors, and then distributed into various daily time periods (e.g. AM Peak, PM Peak) using time-of-day modeling factors. External (I-E, E-I, & E-E) trips, already in "vehicle" trip format, are also factored into the time-of-day periods. The final product (and input into traffic assignment) of the mode choice / auto occupancy / time-of-day step comprises a number of trip tables, categorized by mode and time-of-day period, in "vehicle" trip format.

The mode choice, auto occupancy, and time-of-day modeling factors/parameters were developed as part of the recently completed "Urban Model Improvement Program", and are based upon the results of the "2004-2005 Comprehensive Household Travel Data Collection Program", both conducted by MDOT.

Traffic Assignment

Traffic (or trip) Assignment is the final step in the traditional Four Step TDFM Process. In this step, trips (i.e. vehicle-based trips, by mode and time-of-day period) are assigned to a "route" (or path) on the roadway network between each trip origin and destination. The basic premise of trip assignment is that trip makers will choose the "best" path between each origin and destination. The determination of the "best" path is based upon selecting the route with the least "impedance". Impedance, in this application, is based upon travel time – calculated as a function of link distance and speed (and later as a function of link volume and capacity). Consequently, trip makers on the roadway network will choose the route, between each trip origin and destination, which minimizes travel time.

The "User Equilibrium" algorithm (a commonly used algorithm) was employed in the traffic assignment component. User equilibrium is based on the principle that while selecting the "best" route, trip makers will use "all" possible paths between an origin and destination that have equal travel time – so that altering paths will not save travel time. This algorithm attempts to optimize the travel time between all possible paths, reflecting the effects of system congestion.

Thus, the product of the traffic assignment component is a series of vehicle-trip (volume) tables, by mode and time-of-day period, for each link in the model roadway network. These "assigned" link volumes are then compared to "observed" traffic data as part of the model calibration, validation and reasonability checking phase of the process.

Model Base Year Calibration and Validation

The main purpose of the Base Year Model Calibration and Validation is to verify that the base year assigned volumes resulting from the traffic assignment component simulate observed base year traffic data. The terms model "calibration" and "validation" are often incorrectly interchanged: through model "calibration", various modeling components and/or parameters are adjusted in an effort to replicate observed base year data, or to produce more realistic results (i.e. more closely meet established validation targets); whereas model "validation" is the application of the "calibrated" model and the comparison of the model results to "observed" data. The model calibration and validation steps comprise a cooperative, and sometimes iterative, process; if issues are uncovered during the model application and validation, it might be necessary to return to model calibration in order to further adjust model components and/or parameters. The calibration / validation process is performed on each model component and the entire model system, preferably utilizing "observed" data that was not used for model estimation.

Application of the Calibrated / Validated Model

Forecasted travel volume (i.e. trips) is estimated by interchanging forecasted (2040) SE and transportation system data for the base year data (2010). The assumption is made that model formulae relationships developed in the base year model structure will remain constant over time; consequently, the same mathematical formulae, model structure and parameters are used for both the base and future year simulations.

Generally, three distinct alternative scenarios are developed for a LRTP:

- **Simulated Base Year (2010) volumes assigned to the Base Year (2010) Roadway Network**; this scenario includes the assignment of 2010 model volumes, generated using 2010 SE data, onto the roadway network representing 2010 conditions. This is referred to as the "validated", existing network scenario, or **"base-year"** alternative, and is a prerequisite for the other two scenarios.

- **Simulated Forecast Year (2040) volumes assigned to a Modified Base Year Roadway Network**; this scenario includes the assignment of 2040 volumes, generated using 2040 SE data, onto an amended roadway network representing 2010 conditions, and including any improvements completed since 2010 and future (near term) improvements for which funds have been "committed". This alternative characterizes future capacity and congestion problems if no further improvements to the transportation system are made. This "deficiency analysis" on the "existing plus committed" (E+C) network is also called the "do nothing", or **"no-build"** alternative, and includes only the E+C roadway system.
- **Simulated Forecast Year (2040) volumes on a proposed Forecast Year (2040) Roadway Network**; this scenario includes the assignment of 2040 volumes, generated using 2040 SE data, onto the roadway network as it is proposed to exist in the forecast year of 2040. This scenario is the long-range transportation plan **"build"** alternative. It includes the E+C roadway network, plus proposed capacity improvement and expansion projects.

Once the base and future trips have been estimated, a number of transportation system analyses can be conducted:

- Roadway network alternatives to relieve congestion can be tested as part of the LRTP. Future traffic can be assigned to an amended, existing roadway network (i.e. “No Build” Network) to represent the future impacts to the transportation system if no improvements were made. From this, improvements and/or expansions can be planned that could help alleviate demonstrated capacity issues.
- The impact of planned roadway improvements or expansions can be assessed.
- Individual links can be analyzed to determine which TAZs are contributing to the travel on that particular link (i.e. the link's service area). This can be shown as a percentage breakdown of total link volume.
- The impacts to the roadway network with or without a proposed bridge can be evaluated. The assigned future volumes on adjacent links would then be compared to determine traffic flow impacts.
- The impacts of land use changes on the roadway network can be evaluated (e.g. what would be the impact of a new major retail establishment).
- Road closure/detour evaluation studies can be conducted to determine the effects of closing a roadway and detouring traffic during construction activities. This type of study is very useful for construction management.