Chapter 8
Travel Demand Forecasting & Modeling

The Travel Demand Forecast Model (TDFM) for the Jackson MPO was developed in cooperation between the Region 2 Planning Commission (R2PC) and the Urban Travel Analysis unit within the MDOT. MDOT was the lead role in the development, calibration, validation, and application of the Travel Demand Forecast Model (TDFM or “model”). The Jackson MPO acted as the liaison among members of the public, local agencies, the JACTS Technical Committee, the JACTS Policy Committee, and the Region 2 Planning Commission. R2PC and MDOT collaborated on the development schedule of the model, as well as on the dissemination and distribution of model input and output data for review, comment, and subsequent approval.

Travel Demand Forecast Models are used to identify and evaluate the capacity demands of a region’s federal-aid road network. Identification of roadway capacity deficiencies and analysis of the system as a whole, for the base year through and up to the horizon year of the plan in order to determine where future congestion is projected to occur, is vital in the development of the plan.

The TDFM results are useful in aiding the decision-making process. The identification and analysis of congested corridors and links are intended to serve as the basis for forming decisions regarding system improvement, expansion, or for other roadway capacity changes. The roadway congestion analysis and the plan (prepared by the MPO with input from the MDOT) are "snapshots in time, “reflecting the conditions and trends at the time of development. As economic conditions, transportation system trends, financial outlooks, and land use environments change, it is important that the plan be updated to reflect and account for these changes. The plan, following federal laws and regulations, is reevaluated and/or updated every five years to reassess the travel demands on the federal-aid transportation system. Along with the plan update, the TDFM is also redeveloped or updated to include the changes associated with the new plan. Socio-economic trends and forecasts are also reexamined, which alters travel behavior and demand on the federal-aid road network and may potentially change the strategies of the Jackson MPO.

This chapter describes the base, interim, and horizon years Travel Demand Forecast Model development process for the 2050 Long Range Transportation Plan.

Model Process Description

Travel demand forecast models (TDFM) are computer simulations of current and future traffic conditions. The Jackson TDFM is a regional-level transportation planning model, developed by MDOT using the TransCAD Transportation Planning Software Package, provided by Caliper, and focusing on long-term transportation planning concerns and regional travel characteristics. Model results provide road link traffic volumes (known in the modeling tool as “traffic flow”) for AM Peak (7:00am – 9:00am), Mid-Day (9:00am – 3:00pm), PM Peak (3:00pm - 6:00pm), and Off Peak (6:00pm – 7:00am) periods as well as for the 24-hour time period. The traffic flows are then compared to the capacity allowance of the road links providing a volume-over-capacity ratio for each period which is used to calculate the level of relative congestion on the road links.

The urban TDFM development process for Jackson consists of the inter-related steps below. The traditional "Four-Step" trip-end based model structure consists of steps 2 through 5. The output from each step is used as the input in the following step.

Step 1. Data Development, Collection, and Organization

Regional socio-economic data (SE-data) and transportation system characteristics are collected. This step also includes the development of the model road network and the Travel Analysis Zone (TAZ or "zone") structure.

Step 2. Trip Generation

Determines who is making trips, how many are being made, and why (for what purpose) they are being made. It does this by calculating the number of trips produced in or attracted to a TAZ by trip purpose based on land use, household demographics, employment, and other SE-data characteristics.

Step 3. Trip Distribution

Determines where people are making trips by calculating how much travel occurs between TAZs, based on the "attractiveness" of the other zones.

Step 4. Mode Choice and Time of Day

Determines how people are making trips (by what mode), and when they are making them (what time of day), by allocating trips across the model network into modes of travel such as auto, non-motorized, and transit. After the split into modes, the auto trips are distributed into one of the time periods.

Step 5. Traffic Assignment

Determines what specific routes people are making for their trips based on the shortest travel time, by assigning auto trips between zones to a route/path in the transportation system.

Step 6. Model Calibration/Validation

Involves adjusting the model and verifying that the volumes simulated in traffic assignment replicate (as closely as possible) actual, observed traffic counts within a set of established validation criteria.

Step 7. System Analysis and Model Applications

Involves the use of the calibrated and validated model in the development of the metropolitan transportation plan, Air Quality conformity analysis, project identification and prioritization, and/or impact analysis.

The following sections present detailed information on how these steps were performed in the Jackson Travel Demand Model development.

Data Development, Collection, and Organization

There are two main modeling components that are required to be constructed prior to model development: model road network and traffic analysis zone.

The model road network includes various roadway attributes and generally contains links of the "collector" functional classification and higher. “Local” roads are included in the model network only to maintain continuity, for connectivity purposes, or if these links are regionally significant.

The traffic analysis zones (TAZ or “zones”) are geographic areas determined based on the similarity of land use and human activity, compatibility with jurisdictional boundaries, presence of physical boundaries, and the links that make up the road network. The TAZs layer contains SE and employment information for each one of the model zones.

The model road network and the TAZs are mutual. Each TAZ is represented on the model road network as a node called centroid. The TAZ centroid is located at the center point of activity within the TAZ area. All trips that use the model road network start or end at a TAZ centroid. Trips “produced” from or “attracted” to each centroid are connected to the main road system via special model road links called “centroid connectors.” These “hypothetical” connections carry the trips produced from and/or attracted to the respective TAZ. Special development criteria are used to ensure centroid connectors meet the main road network system at realistic locations.

Both TAZ and network files contain information required to run the model and were developed for the base year 2018, then for the interim years 2025, 2030, 2040, and the horizon year 2050. After the development, TAZ and network layers were provided to the Jackson MPO staff and Jackson Technical Advisory Committee members for review and comment.

Model Road Network

The model road network consists primarily of the federal-aid road system within Jackson MPO and was obtained from the Michigan Roads and Highways network. Aerial images, site visits, and old Jackson model networks were also used in the process when needed.

The network layer contains fields required for the model runs as well as informational fields such as Road Names, Federal-Aid Status, Facility Type Classification, Area Type, Number of Thru-Lanes, Road Direction, Posted Speed Limit, Lane Width, parking availability, Prohibited Turns, Center-Left Turn Lanes, link capacity, free-flow speed, traffic counts, among others.

The Jackson 2018 calibrated/validated network includes approximately 950 miles of roadway network (excluding centroid connectors) with the classifications in Table 8-1:

Table 8-1: TDFM Network Mile Summary

	CBD	Urban	Suburban	Fringe	Rural	**Total**
Freeway	0	7	30	26	38	**101**
Freeway-to-Freeway Ramp	0	0	4	0	0	**4**
Freeway On-Ramp	0	2	3	2	3	**10**
Freeway Off Ramp	0	2	3	2	3	**10**
Principal Arterial CLTL	2	8	4	1	2	**17**
Principal Arterial	0	8	15	2	5	**30**
One-way Minor Arterial	0	0	2	0	0	**2**
Minor Arterial with CLTL	0	6	3	1	0	**10**
Minor Arterial	0	13	41	41	45	**140**
One-way Collector	0	1	0	0	0	**1**
Collector with CLTL	0	1	0	0	0	**1**
Collector	0	13	71	181	244	**509**
Local Road with CLTL	0	0	0	0	0	**0**
Local Road	1	14	26	48	26	**115**
Total	**3**	**75**	**202**	**304**	**366**	**950**

The base network plus completed projects between 2018 and 2022, as well as the committed projects on the Transportation Improvement Plan (TIP), were accounted for the development of interim and future-year model road networks.

Traffic Analysis Zones (TAZs)

Travel Analysis Zones (TAZ or "zone") are geographic divisions of the model area and provide the structure for housing the Socio-Economic (SE) data approved by the MPO. The SE data associated with each TAZ represents the activity within TAZ and is used to generate the trips that are modeled across the road network.

The 2018 TAZ structure development started by using the TAZ structure from the most recent TDFM, which was used in the 2045 LRTP. Adjustments to the structure were made based on previous recommendations, changes in socio-economic conditions, and to account for changes in traffic loading to the model road network. The 2050 LRTP TDFM has a total of 581 TAZs (534 within Jackson County and 47 of which are used as External Stations containing information about trips coming from outside of the model area).

Socio-Economic Data

Socio-economic data (SE-data) is comprised of demographic and employment information. The SE datasets were collected and processed for the model base year of 2018, and then forecasted out to the LRTP horizon year of 2050.

Other than the population, households, and employment data described in Chapter 7 – Socio-Economic Conditions, characteristics from the 2018 American Community Survey (ACS) 5-Year Estimate as the number of workers per household, the number of K12 students per household, vehicle availability, income levels, among others were used in the development of the model. Enrolment data were also used in the model and were collected from the Michigan School Data website.

As mentioned in chapter 7, after the initial collection of the base year SE data and the forecast SE data development, a thorough review by Jackson MPO staff and Jackson Technical Advisory Committee were conducted. Once reviewed, changes were incorporated into the population, occupied housing units, and employment dataset, and then formally provided to the various MPO committees for approval. Jackson MPO committees approved the base year SE-data and the future year forecast SE-data for inclusion into the TDFM respectively in August 2021 and September 2022.

Trip Generation

Trip generation is the first step of the four-step TDFM and it is the process by which the model translates the socio-economic data into numbers of person trips. In this step, internal person trip productions and attractions are calculated for each TAZ, for various trip purposes, based on the relative SE data available for the TAZ. Generally, households produce trips and employment places attract trips. The five trip purposes used in the Jackson model are home-based work (HBW), home-based retail (HBR), home-based school (HBS), home-based other (HBO), and non-home based (NHB).

Several Trip Generation methods exist, each having its own strengths and weaknesses. In this model, cross-classification methods were used to develop the trip productions. Cross-classification is used to combine two different data variables, such as household size and household income to develop the zonal trip production rates. Trip attractions for this model used a simple regression equation. Both, trip production rates and trip attraction equations for each trip purpose of Jackson model were developed by MDOT Statewide and Urban Travel Analysis Section based on the most recent household travel survey data available – the 2015 *Comprehensive Household Travel Data Collection Program / MI Travel Counts III* (MITC3).

After calculated, trip productions and trip attractions were balanced so that the total productions and attractions were equal for the entire model area.

The methods described above apply to person trips that are generated for TAZs that are within the model area, called internal trips. Trips that originate or end outside the model area are called external trips. External trips that originate inside the model area and travel outside the model area are identified as "internal to external" (I-E) trips, and trips from outside the model area (external) into the model area are referred to as "external to internal" (E-I) trips. Trips that pass through the model area without stopping are called "external to external" (E-E) trips. External travel is originally provided from the Michigan Statewide model. The information is then further processed and combined with traffic count volumes to develop an estimate of the number of E-I, I-E, and E-E trips for the model area.

Person trips calculated during the trip generation step include Non-Motorized (NM) trips. However, NM trips are relatively minor for this model area when compared to the total amount of trips being generated in the model area, therefore NM trips were not distributed, nor assigned to the road network, but simply taken out of the total person trips being produced. Non-motorized factors for each trip purpose were also developed by MDOT Statewide and Urban Travel Analysis Section based on MITC3.

Commercial vehicle trips are also calculated during the trip generation step. Internal-Internal and Internal-External commercial vehicle production and attractions are based on employment numbers by sector and are obtained using regression equations. After calculated, production and attraction commercial vehicle trips are also balanced to guarantee that every I-I and I-E commercial vehicle trip produced is attracted somewhere. External – External commercial vehicle trips are also calculated based on information from the Michigan Statewide model combined with traffic count volumes.

The output of the Trip Generation step is a balanced trip table containing passenger car trips for all trip purposes and commercial vehicle trips, which is used as one of the inputs for the next step of the traditional four-step TDFM, Trip Distribution.

Trip Distribution

The second step of the four-step TDFM process is called Trip Distribution. In this step, the balanced trip table from the Trip Generation stage (balanced productions and attractions by trip purpose) along with the model road network, are used to determine how many trips produced in a zone will be attracted to each of the other zones.

Travel time between zones and a mathematical model called “gravity model” based on the attractiveness of each zone and how far people are willing to travel for different purposes are used in this step to best replicate the potential travel along the model road network and to show a reasonable interaction between one TAZ to another.

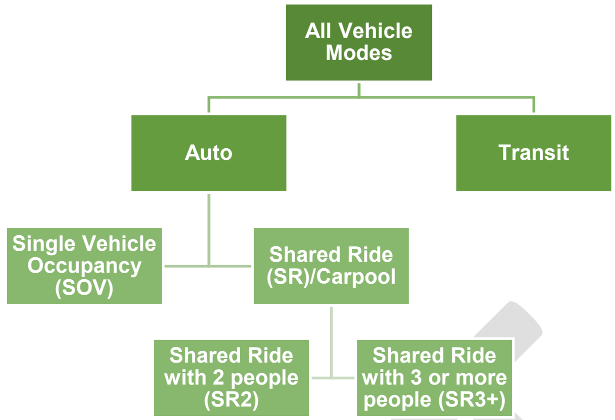
The gravity model assumes that a destination zone attracts trips based on the activity in that zone (number of employees and/or households) and the proximity to the zone of origin. Using the gravity model, trips produced in one zone are "distributed" to all other zones. The gravity model is calibrated using successive friction factor adjustments to produce model travel time trip length distributions for each trip purpose that are consistent with the travel time observed on the most recent household travel survey data available – the 2015 *Comprehensive Household Travel Data Collection Program / MI Travel Counts III.*

The results of the Trip Distribution step are matrices that provide a breakdown of relative TAZ to TAZ interactions by the various trip purposes and trip modes. The results of Trip Distribution are used for the next step, Mode Choice.

Mode Choice and Time of Day

Mode Choice is the third step of the four-step TDFM process. At this stage in model development, all trip data, except for external travel data, are in “person-trip” format. The trips must be allocated to distinct vehicular modes, which are auto and transit trips. The chart below provides a brief overview of the types of vehicle modes that are used to allocate the person trips for this model.

Figure 8-1: Motorized Modes



Transit trips, different than auto trips, are not assigned to the TDFM road network due to the complex nature of the trip interactions and socio-economic conditions related to transit ridership. The TDFM used for MTP purposes is to analyze regional transportation patterns, and not necessarily micro-level or individual trip characteristics. As such, mode choice for this model used a simplified approach where transit trips are initially calculated prior to auto trips and then subtracted from the total vehicular trips. The resulting trip total is then broken into various auto shares: Single Occupancy Vehicles (SOV), Shared Rides with two people (SR2), and Shared Rides with three or more people (SR3+). Shared Rides may alternatively be referred to as “carpooling” or “High Occupancy Vehicles” (HOV). The result of the mode choice component is a series of person-trip tables by vehicular mode and trip purpose for each TAZ Origin-Destination pair.

The mode choice step also includes Auto Occupancy and Time-of-Day sub-steps. In the auto occupancy sub-step formulas are applied for each purpose to convert person trips to vehicle trips. Once the person trips become vehicle trips Time of Day (TOD) modeling factors are applied to split these vehicle mode trips into one of the four TOD periods (AM, MD, PM, and NT). The finalized product from the Mode Choice step is a number of tables representing vehicle mode trip categories by each time period.

Mode Choice, along with auto occupancy and Time-of-Day modeling, factors, and parameters are based on data provided by the *2015 Comprehensive Household Travel Data Collection Program/MI Travel Counts III* program conducted by MDOT.

Traffic Assignment

Traffic (or “Trip”) Assignment is the final step in the traditional four-step TDFM and is the process of route selection between zones. This step takes the trips distributed in the previous phase and assigns them a path on the roadway using the underlying principle of a TDFM that trip makers will use the “best” route, based on travel time.

Different methods and supporting functions can be used in the traffic assignment step. The Jackson model uses the bi-conjugate Frank-Wolfe equilibrium assignment method which takes advantage of multi-threaded processors and converges relatively quickly when compared to other available equilibrium assignment methods.

This assignment method considers the volume as well as the capacity of the road links. During this process, a roadway that is reaching or has reached its maximum capacity will result in reduced travel time. As such, the assignment routine will include these time reductions when choosing the “best” path and if the delay is significant, an alternative road may be used to accommodate that traffic. This continues until the system reaches equilibrium.

After the first iteration of the traffic assignment, the model starts a processed call feedback loop. In this process, the congested travel speeds resulting from the traffic assignment are used to re-compute zone-to-zone travel times. At this point, a comparison is made between the initial and the updated zone-to-zone travel times. If the travel times are not reasonably similar, the updated travel times are then used to rerun trip distribution and the subsequent model steps. This process is repeated iteratively until a convergence criterion or iteration limit is met.

When the feedback convergence criterion is met the Traffic Assignment step results in a series of vehicle-trip (modeled traffic volume or “traffic flow”) tables, by vehicular mode, and separated into TOD, for each model road link within the model road network which is considered the final output of a TDFM.

Post processes then sum all 4 periods’ traffic volumes creating a volume that represents the number of vehicles that travel on that link (road) over a typical twenty-four-hour day. The “assigned” 24-hour link traffic volumes are then compared with “observed” traffic data (i.e. traffic counts) as part of the model calibration, validation, and reasonability review.

Notice that the TDFMs used for LRTP purposes do not include human-related factors when assigning trips, such as road geometrics (hills, tight curves, etc.), road conditions, and other considerations.

Model Calibration/Validation

The most important, and ultimate goal of the TDFM is to ensure that the base year assigned volumes are reflecting the observed base year conditions. To achieve this goal the TDFM base year assigned volumes need to be within a reasonable level of the traffic counts collected around the model base year. Traffic counts on the federal-aid road system from all respective maintaining road agencies within the MPO are crucial to perform these comparisons and without this information, the effectiveness of the model is limited. For the 2050 LRTP TDFM calibration process, traffic counts provided by MDOT Transportation Data Management System (TDMS) and local road agencies within Jackson MPO were used.

Very often the preliminary model results don’t meet the established criteria and model adjustments are needed. These model adjustments are called model calibration and consist of returning to a previous step in the modeling process to calibrate inputs and/or outputs data when it is necessary. Model calibration is applied for each step of the TDFM development process and for the entire model system to adjust the model to achieve model outputs that simulate (within established validation criteria) the actual base year traffic counts. When the calibration is completed, the base year model is considered validated or statistically acceptable.

Application of the Validated Travel Demand Forecast Model

Once the model is validated it can be used (confidently) to forecast "future travel demand". The base year socio-economic data is substituted by forecasted socio-economic data and the base road network is substituted by a road network accounting for changes finalized or committed on the TIP. Then the trip generation, trip distribution, and traffic assignment can be repeated, and future trips can be simulated as part of the planning process. The assumption is that model formulas and relations developed for the base year model structure remain constant over time, as to provide an unbiased forecast. For the 2050 Long Range Transportation Plan, five scenarios were developed: Base year 2018 (validated), Interim year 2025, Interim year 2030, Interim year 2040, and Horizon year 2050. The model results for the base year and the horizon year scenarios are discussed in more detail in Chapter 9: Roadway Congestion, Congested Links, and Recommended Projects.

Different scenarios can be prepared & tested anytime for any significant developments of housing or employment, or for changes to the transportation network as needed. The Jackson TDFM can also be used for additional transportation system analysis outside of the planning process, which includes, but is not limited, to the following:

- Impact analysis for planned roadway improvements, expansions, or other capacity-altering alternatives
- Impact analysis of land use changes on the network (e.g., what are the impacts of a new major retail store being built).
- New accessibility, such as a proposed bridge, can be tested to identify traffic flows to and from the new roadway and for adjacent roadway links. Limiting factors, such as the closure of a bridge can also be tested.
- Road closure, road restriction, and/or detour evaluation studies can be conducted to determine the effects of closing a roadway, and/or restricting capacity, and detouring traffic during construction activities, which are useful for construction management and are also referred to as "Work zone testing".
- Individual links can be analyzed to determine which TAZs are contributing to traffic flow on that particular link. The results can be shown as a percentage breakdown or by raw volumes. This analysis is referred to as selected link analysis.
- Potential improvements to relieve congestion can also be tested. Future traffic can be assigned to the existing network to show what would happen in the future if no improvements were made to the present transportation system. From this, improvements can be planned that would alleviate demonstrated capacity problems.
- Model runs as part of air quality conformity analysis if required.