17 TRAVEL DEMAND MODELING

17.1 Purpose

The purpose of this chapter is to provide an overview for non-modelers of building and applying travel demand forecasting models. Modeling practice continues to evolve as methods and tools vary in their level of maturity at any given time. For example, ABM (Activity Based Models) which are discussed further below, are just starting to be created and used in Oregon.

This chapter focuses on travel demand modeling tools currently used in Oregon in TSPs, corridor plans, refinement plans, and project development. Post-processing of model volumes is addressed in Chapter 6. System level modeling for statewide applications, RTPs or Scenario Planning is discussed in Chapter 7. Mesoscopic modeling topics such as focusing, windowing, dynamic traffic assignment, and peak spreading are addressed in Chapter 8. For information on more advanced model topics, contact TPAU.

Many additional sources of information and training on modeling are available for those interested, such as on the ODOT Technical Tools website and FHWA's Travel Model Improvement Program (TMIP). Another source is the Greenhouse Gas Emissions Reduction Toolkit, which focuses on modeling tools used in Scenario Planning.

17.2 Travel Demand Models

Travel demand models are an important tool in analyzing proposed plans, projects and policies. Information from travel demand models is used by decision-makers to identify and evaluate different approaches to addressing transportation issues and to select policies and programs that most closely achieve a desired future vision.

Travel demand models represent travel decisions that are consistent with the actual travel trends and patterns. The travel demand model attempts to quantify the amount of travel on the transportation system. Through careful studies of data on people's travel behavior, mathematical relationships have been developed to predict how many trips people will make, where they will go, by which mode of transportation, and by which specific route. These decisions are influenced by the available transportation system, the spatial location of households and employment, household socioeconomics, and travel costs. Known Oregon travel behavior and relationships from household surveys are used to simulate the impacts on the actual transportation system.

Travel demand models can be used to forecast future travel patterns and demands due to changes in:

- Transportation system changes
  i.e., new roads, increased transit frequency, wider roads with more capacity, new pedestrian connection, closed roads, introduction of connected and automated vehicles (CAVs), etc.

- Land use changes
  i.e., more residential development, a new industrial site, etc.

- Demographics changes
  i.e., more or less people in a specific area, aging population, etc.

The model makes general forecasts of travel patterns 15 to 25 years into the future. Travel demand forecasting can test the impacts of critical "what if" questions about proposed plans and policies. Model outputs can provide users with a variety of information on travel behavior and travel demand for a specified future time frame, such as forecast of highway volumes for roadways, transit forecasts, or the effects of a proposed development or zoning change on the transportation system. In addition, travel demand models may help analysts understand the range of potential impacts from emerging trends and technologies such as CAVs. Appendix 6B provides guidance on CAVs and their potential effects, focused on the methods in the Highway Capacity Manual 7th Edition (HCM) for adjusting roadway capacity for the presence of CAVs in the traffic stream on freeways and at signalized intersections and roundabouts. Model results allow planners to analyze the effects of latent demand and other unanticipated impacts to the system.

Travel demand models vary in what they model and the level of detail they model. All model motor vehicle travel. Some model pedestrian, bicycle, commercial vehicle, transit (MPO areas), and/or freight travel. Some model policies, strategies, programs, investments, and/or emerging technologies such as connected and autonomous vehicles or vehicle miles traveled (VMT per capita. Some model operations, peak spreading, and reliability. The Portland Metro model is the most sophisticated in Oregon, with the ability to model many of the above variables. Some key limitations to be aware of in applying models are.

- Active modes including transit, bike and walk, require a Metropolitan Planning Organization (MPO) model.
- Transit system planning typically requires accurate forecasts of ridership at the route level. Due to insufficient observed data at the required level of resolution, TPAU-created MPO models do not output route ridership estimates.
- Bicycle and pedestrian facility planning: most travel forecasting models are not developed to estimate bicycle and pedestrian demand at the network or facility level. The models produce estimates of zone-to-zone bicycle and pedestrian person trips. They have been calibrated at a regional level for these modes but not at a zonal level or network/route level.
- Transportation Demand Management (TDM) planning: There is frequently the need to know how many trips could be reduced, particularly SOV trips, through workplace TDM strategies, such as preferential parking for rideshare, subsidies for transit riders, transportation allowances, and parking management programs. Trip-based models cannot provide this information because the model is structured at the Transportation Analysis Zone (TAZ) level and does not contain the variables that would allow these strategies to be reflected.

17.2.1 Model Types

The models discussed in this chapter are primarily urban or regional travel demand models. ODOT maintains and operates all the Oregon Small Urban Models (OSUM) and the following MPO/regional models: Corvallis-Albany-Lebanon (CALM), Bend-Redmond (BRM), Southern Oregon (covering the Rogue Valley and Middle Rogue MPOs; a.k.a. SOABM).

The three largest MPOs in Oregon maintain and operate their own travel demand models: the Portland Metro MPO model, the Salem/Keizer MPO model, and the Central Lane MPO model in Eugene - Springfield. All of the current ODOT and non-ODOT travel demand models are shown on the Oregon Travel Demand Models Map.

The trip-based travel demand model methodology has been the best practice standard for many decades. Activity Based Models (ABM) are a new approach that is being implemented.

The key difference between a trip-based travel demand model and an ABM is the treatment of travelers. Trip-based models estimate behavior and travel decisions for zones or groups of travelers. Activity based models work from a synthesized and discrete population for the area, using information and characteristics about individual travelers to estimate travel behavior and decisions made throughout the day. This higher level of detail adds complexity to ABMs but allows more detailed questions to be tested and more information to be provided for a variety of questions. ABMs allow for equity information to be better assessed; how different individuals are specifically impacted. Pricing strategies are also better tested and answered with ABMs.

While trip-based models will continue to be used in the foreseeable future, Oregon is moving towards implementing ABM models in MPO areas. The initial deployment is the SOABM model in southern Oregon, encompassing the Middle Rogue and Rogue Valley MPOs, with other MPOs being planned. The Statewide Integrated Model (SWIM) is also a unique version of an ABM.

17.2.2 Trip Based Models

There are two types of trip-based models used in Oregon: four-step and three-step. Four-step models consist of trip generation, trip distribution, mode choice, and trip assignment. Four-step models such as Joint Estimation Model in R (JEMnR) are used for MPO's. Oregon Small Urban Models (OSUM) are three step models used for non-MPO cities; they do not include the mode choice step.

The following sections further describe the trip-based model steps.

Trip Generation

A travel demand model divides the study areas into transportation analysis zones (TAZ). The main goal of trip generation is to predict the number of trips that are generated by and attracted to each zone in the study area. This stage of the model development process is only concerned with the number of trips that start or end in each zone, not with making the connection between zones. A trip is a one-way movement from an origin (which is always the beginning point of the trip) to a destination (which is always the ending point of the trip).

All the necessary inputs for trip generation are produced using a set of household sub-models that stratifies households by the number of workers, household size, and number of workers by household size. In this pre-generation process, estimates for the following demographic information are prepared for each zone:

- Number of Workers
- Presence of Children
- Auto Ownership

Trips produced by households in a zone are generated by applying trip production rates to the zone's household demographics. The trip production rates are developed from household travel behavior surveys and are applied by trip purpose (i.e., work, school, shop, etc.). An example trip production table is shown in Exhibit 17-1. In this example, the number of daily home-based shopping trips are shown by household size (number of people in the household) and number of workers.

Exhibit 17-1 Example Trip Production (Generation) Table

No. of Workers in HH	Household Size			
	1	2	3	4+
0	0.752	1.088	1.188	1.323
1	0.438	0.853	1.182	1.528
2	0	0.652	1.112	1.120
3+	0	0	0.563	1.046

Trip purpose is differentiated to support developing scenarios for different strategies or policies. Patterns of trips are different overall for different purposes: different distributions, different travel times, etc. Some examples of trip purposes are home based work and home-based school trips.

It is important to understand the difference between trip generation rates provided by the Institute of Transportation Engineers ITE Trip Generation manual (refer to Chapter 6) and model-based trip generation.

- ITE trip generation numbers are vehicle trips; model trips are generated as person trips and later converted to trips by mode.
- Generally for a single-family dwelling unit ITE estimates ten vehicle trips per day, which includes all trips made by the household occupants plus delivery or service provider trips. A travel demand model estimates approximately seven home-based vehicle trips per day involving the household occupants; delivery and service trips are captured separately as employment trips.

- Trip generation values in JEMnR are person trips, which are later converted to vehicle trips in the mode choice model. OSUM initially produces person-vehicle trips which are divided by average vehicle occupancy to convert to vehicle trips.
- For more information on ITE-based trip generation, refer to Chapter 6.

Trip Distribution, trip matrices

The trips produced during the trip generation process are distributed by trip purpose to the proper attraction zones. Trip distribution evaluates the probability of travel between each pair of zones based on factors including travel time, travel costs, and size and type of attractions at the destination. The distribution process explains where the trips produced in each zone will go, and how they will be divided among all other zones in the study area (i.e., trips from Zone A to Zone B, A-to-C, A-to-D, etc.). As an example, 100 trips from one zone might be defined as 50 work trips to Zone 'X', 20 shopping trips to zone 'Y' and 30 other trips to zone 'Z'. Additional information on trip distribution is available in Section 6.7.

An external sub-model deals with trips that either begin or end outside the study area. Internal-to-External refers to trips that begin inside but end outside the study area. External-to-Internal is the case where trips begin outside but end inside the study area. External-to-External is for trips that begin and end outside the study area but pass through the study area.

External trips are based on counts and projections of future growth based on historical trends or other methods. SWIM can be used in travel demand model development to estimate growth at external stations, where available (typically state highways and major local facilities).

Refer to Chapter 6 for information on manual (non-model) trip distribution methods.

Mode Choice (JEMnR Only)

Modes are used to categorize the transportation alternatives available for making trips in the study area. Mode choice converts trip demand to trips by mode assigned by time of day (TOD). TOD assigns daily demand by mode to the right hour of the day for production-to-attraction (P-A) and attraction-to-production (A-P) directions. For JEMnR, the time-of-day periods considered are peak and off-peak. JEMnR typically reports out seven different modes as listed below, based on household, socioeconomic and system accessibility attributes.

- Drive Alone – single occupant vehicle (SOV)
- Driver Passenger – The driver in a high occupancy vehicle (HOV)
- Passenger – passenger in an HOV
- Bike – bike mode
- Walk – walk mode

- "busWalk" – a trip that includes a transit vehicle, where the only mode to and from the transit vehicle is the walk mode (not by auto and not by bike)
- Park and ride to bus – a trip that includes a transit vehicle, where some portion of the trip to or from the transit vehicle is by other than walk mode – i.e., consists of park and ride, kiss and ride, or bike and ride trips

Trip Assignment

Trip assignment is the process of allocating vehicle/transit trips for each origin-destination pair in the trip tables onto the roadway/transit network. The allocation consists of identifying routes or paths through the network. The assignment process may be mode-specific, for example, paths for single occupant vehicles may be determined using different criteria than paths for non-SOVs.

Several methods exist for assigning trips from a trip table onto a network, including capacity-restrained, user equilibrium, and all or nothing (AON). Capacity-restrained and user equilibrium assignment methods account for congestion impacts by reducing travel speeds as traffic volumes increase using volume-delay functions, such as the Bureau of Public Roads (BPR) equation. For more information on the trip assignment process, refer to the Supplemental Materials section and consolidated document on the APM web page.

Oregon's models are built to interface with commercial traffic assignment software packages. Currently, Visum (PTV) is used for assignment for all models (i.e. JEMnR, OSUM, and ABM).

Prior to assignment, the daily demand is processed into period origin-destination (O-D) matrices for the assignment software. Two steps that complete this period O-D process are applying diurnal and directional factors.

Diurnal factors

Time-of-day (diurnal) factors are used to estimate travel by hour of the day by splitting the daily demand into its hourly components. These factors can be specific to one hour (peak) or multi hours (2 or more hours). Separate sets of factors are used for the internal-internal (I-I) trips and external trips. The I-I factors are broken down by trip purpose. These factors are typically estimated from data collected in a Household Survey for I-I trips. The external factors are also applied to the daily external-internal (E-I), internal-external (I-E), and external-external (E-E) trips. External factors are typically estimated based on traffic counts and vary by external station.

Directional Factors

Directional factors are used to convert the hourly I-I trips from production-attraction (P-A) to origin-destination (O-D). These factors are typically estimated from data collected in Travel Behavior Surveys. Directional factors, as such, are not used for the external (E-

I, I-E, and E-E) trips. For the E-I and I-E trips, the daily P-A matrices are converted to O-D matrices by summing them with their transpose and dividing by two.
After those factors have been applied and the O-D matrices by desired periods exist, trip assignment can be completed for each period.

Trip assignment is the process used to estimate paths the trips will take, which ultimately results in traffic flow on the network. Trip assignment is typically based on shortest path by travel time. This iterative process assigns trips to specific routes and establishes volumes on links taking into consideration network characteristics (i.e., speed, capacity, intersection controls, etc.) and as iterative assignments are made, congestion can build effecting travel time and path choice. Trip assignment is the final step in the model process, in which zone-to-zone trips from the trip distribution step are assigned to the auto and transit networks.

The trip assignment model can simulate volumes on the existing system or forecast volumes for alternative future scenarios. This allows evaluation of traffic volumes by time of day, by direction, and by mode on the street network.

OSUM

The Oregon Small Urban area Model (OSUM) is a 3-step trip-based travel demand model developed by ODOT to support smaller cities, which uses local data from eight Oregon rural counties to estimate travel behavior (survey data from 1996-1997). It does not include mode choice capabilities, but it provides an effective and efficient method of modeling where traditional forecasting techniques are not adequate.

A new model is usually triggered for a project, where the size and complexity of the local area (population generally >10,000) outstrips the ability of a cumulative analysis to forecast future volumes (refer to Chapter 6). Small cities in proximity may be grouped together into a single model, e.g. McMinnville-Dayton-Lafayette.

OSUM model updates are needed when the difference from model future year and project future year is more than five years. Significant changes to the network or land use may also trigger a model update: large development, major roadway network changes, and/or urban growth boundary expansion. There may also be a desire to change model type (e.g., conversion to ABM), which would require a new model development.

Some characteristics of the OSUM models are that OSUM uses a different fixed average vehicle occupancy for each of five trip purposes. There is no auto ownership information, no transit, walk or bike modes. The trip generation output reflects only auto trips.

The general structure of the OSUM model follows a process consisting of pre-generation, trip generation, trip distribution, and traffic assignment. Within the pre-generation step, all the necessary inputs for trip generation are produced using a set of household sub-models that stratify households by number of workers, household size, and number of workers by household size. The trip generation model generates average weekday vehicular person trip productions by trip purpose. Within the trip distribution step, a destination choice model is used to distribute I-I trips, while I-E, E-I, and E-E trips are handled with separate procedures. Prior to trip assignment, a special model is used to estimate the percentages of external-internal traffic at each external station as well as a daily through (external-external) trip matrix. Trip assignment is performed using a single-class, equilibrium capacity constrained technique.

Jointly Estimated Model in R (JEMnR)

Starting in the mid-1990s, ODOT and the MPOs coordinated their efforts to conduct household travel surveys and to use those surveys to develop a common structure for metropolitan areas utilizing a 4-step trip-based Travel Demand Model structure. As a result, almost all metropolitan area Travel Demand Models in Oregon developed after this time have similar capabilities and use a similar structure.
This initial structure was referred to as Jointly Estimated Model in R (JEMnR). The trip-based approach, e.g., JEMnR, is in the process of being replaced by activity-based models for ODOT-run MPO models and Portland Metro. ODOT MPO models are updated every five years as part of the federally mandated RTP process.

While the JEMnR model structure is similar among metropolitan areas, each model is developed and calibrated so that it reflects conditions and observed travel behavior present in each individual metropolitan area. Travel behavior is sensitive to household characteristics, land use and transportation system characteristics, travel time, and prices. The Portland Metro, the Salem/Keizer, and the Central Lane MPO models are trip-based and very similar to JEMnR but are slightly different in design and approach. While there are differences, JEMnR will be used generically to refer to all the trip based four-step MPO models.

JEMnR is an enhancement beyond OSUM models in that the code structure allows consideration of mode choice. Each mode requires significant data and effort to calibrate. There are statewide standards for consistency for calibration of the auto mode, but not for other modes. For example, the smaller population MPOs (Albany, Bend, Corvallis, Middle Rogue, and Rogue Valley) may not have the same level of data and calibration for active transportation modes as compared to Metro. Therefore while all JEMnR models have the same capabilities, the information that can be provided about modes varies.

17.2.3 Activity Based Models (ABM)

An ABM does everything the trip-based travel demand model does, but with considerably more behavioral content. It deals with individual persons with a comprehensive set of attributes that influence travel and linked trips or tours (i.e. home to shop to work) instead of groups of households and separate trips (i.e. home to shop and shop to work). The ABM is in a sense a simulation of a travel behavior survey. Thus all the questions that could be asked of a travel survey can be asked of an ABM. As such, it is a much more data intensive tool to develop and operate including data resources, staff training and education.A general comparison of ABM and trip-based models is provided in Exhibit 17-2. The table shows the relative ability of each to answer different types of questions.

Exhibit 17-2 Comparison of Trip-Based and Activity-Based Model Applications[1]

Policy Questions	Trip-Based	Activity-Based
Traditional highway projects	***	***
Transit expansion projects	**	***
Air quality conformity / emissions	***	***
Traffic impact studies (analysis)	**	*
Bike/walk planning	*	***
Land use planning – mixed-use, TODs	*	***
System management and operations – ITS / TSMO	*	**
Highway pricing studies	*	***
Equity analysis	*	***
Peak spreading	*	***
Vehicle miles traveled	**	***

[1]Suitability for Analyzing Topic: *** = Good **=Fair *=Limited

An ABM micro-simulates tours, which are groups of linked trips (i.e. trip chaining), as that is how trips occur. This provides context for trips that do not begin or end at home (e.g., mode for lunch trip may be affected by work commute mode) and allows household interactions for shared vehicle use. ABM models do not allow implausible change in modes during a tour like a non-ABM model can. Microsimulation of households and persons over an entire day of travel enables the evaluation of pricing strategies in the context of a household budget.

ABM output is stochastic rather than deterministic in nature, so multiple runs may be needed for a given scenario and an average taken for analysis results. Due to the stochastic nature of ABM models, they are not an ideal tool for traffic impact studies. For more information refer to Chapter 2 on analysis tools and Chapter 15 on traffic micro-simulation models.

Further guidance on ABM model applications is TBD, including when multiple runs are required, how many, and how the results should be averaged or aggregated and reported out.

The ABMs deployed in Oregon introduce three levels of zones with the typical transportation analysis zone (TAZ) created for auto transportation, the micro-analysis zone (MAZ) used to represent walk and bike travel, and transit access point (TAP) representing transit connections. Non-auto modes are captured better because the smaller MAZ structure better represents short trips which would have been within a larger TAZ. Because of the finer zone representation, the ABM has improved capabilities for active transportation, such as the bus, walk and bike modes; but the model output depends on the quality of the input data and level of effort put into calibration.

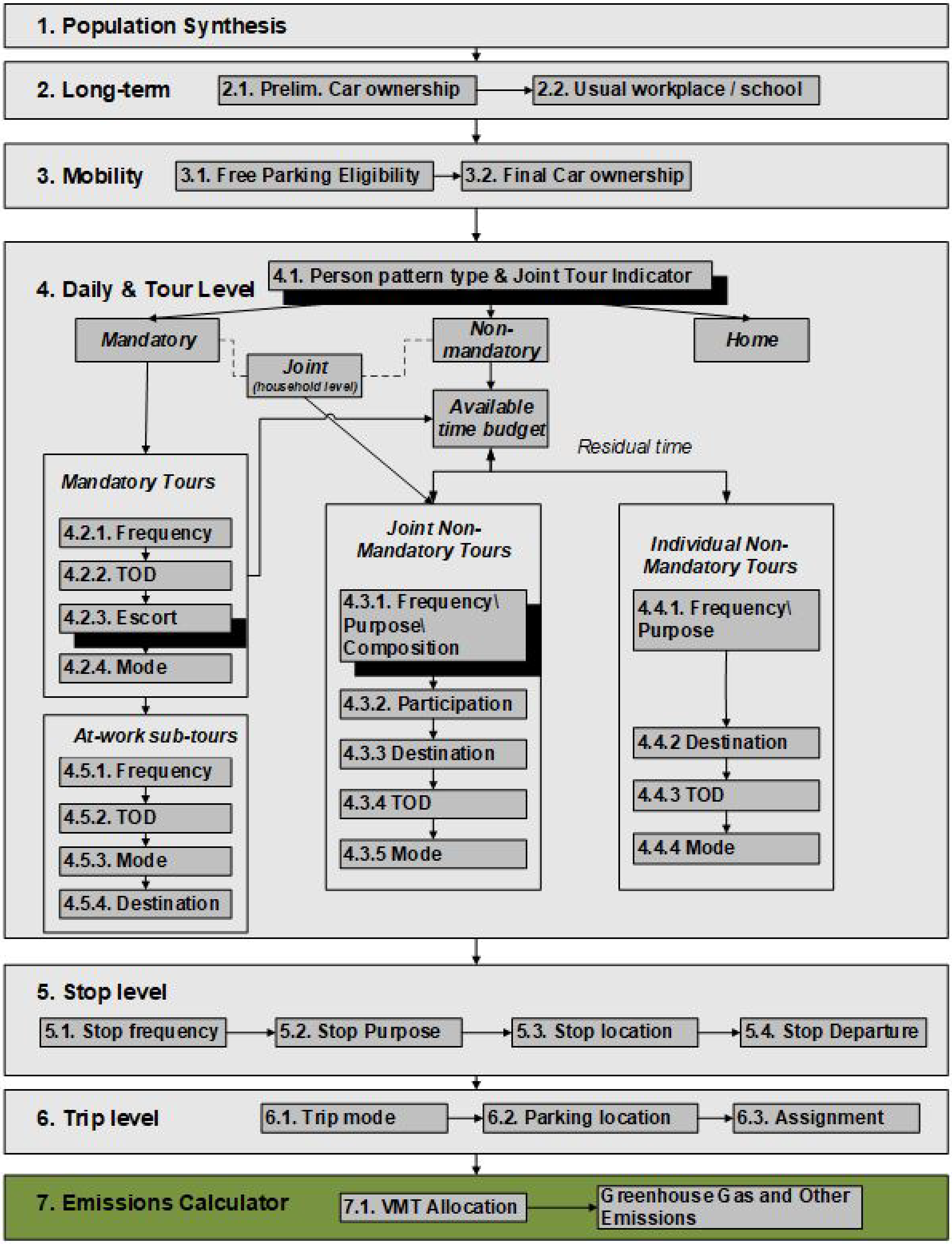
The best ABM application is for providing the required detail for long range regional transportation plans (RTP) required by the Federal Highway Administration (FHWA) and Federal Transit Administration (FTA) for metropolitan areas. The first ABM model in Oregon will be SOABM (Southern Oregon ABM), covering the Middle Rogue and Rogue Valley MPOs.

Activity Based Travel Demand Model Process

Activity-Based Model Components

The current Oregon ABM efforts use OR-RAMP (Oregon Regional Activity-Based Modeling Platform), a series of procedural steps, to run the ABM. The ABM flow chart is shown in Exhibit 17-3. The model starts with long-term and mobility choice models such as auto ownership and usual work and school location choice. Next, the model simulates a typical day of travel for each individual in the region. It starts with day pattern – whether a person stays at home on the simulation day, makes mandatory travel (work and/or school), and/or non-mandatory travel. For each type of travel, it then generates tours and assigns all the required attributes – purpose, destination, time-of-day, and mode. After generating tours, each tour is processed to assign the number of stops along the tour, their purpose, location, and time-of-day. These stops are then processed as trips to assign mode and parking location. Finally, trips are aggregated into demand matrices for assignment at the TAZ and TAP level in Visum. Each model component is described briefly below.

Exhibit 17-3 OR-RAMP Model Flow



17.2.4 SWIM (Oregon Statewide Integrated Model)

SWIM is an integrated tour-based ABM for the entire state. See Chapter 7 for more information. Because SWIM represents economic, land use and transportation behavior in an integrated platform, SWIM has many fundamental differences in comparison to a standard travel demand model. More information can be found here: https://github.com/tlumip/tlumip/wiki .

The following is a brief overview of the model flow in SWIM.

Model design features: The Statewide Model is described as an "integrated" model because the sub-models are interconnected. Information is shared back and forth between the sub-models, mimicking the reactive and interactive behaviors observed in the real world. The model is designed to represent how people and businesses share information and exchange goods and services based on prices and location. The integrated modular design better represents real-world conditions and activities, but requires an immense amount of data, significant development time, powerful computing capabilities and trained staff. For these two reasons, very few states have a statewide economic, land use and transportation model like Oregon's.

The Oregon Statewide Integrated Model consists of specialized sub-models that interconnect with each other:

- **Economic Model**: based on the official state revenue forecast prepared by the Department of Administrative Services, Office of Economic Analysis; provides statewide totals for employment by industry, inflation rate, imports and exports, unemployment rate,
- **Population Synthesizer**: simulates a population with observed Oregon characteristics such as age, household size, household location, income, occupation, worker/non-worker/student status,
- **Production Location Model**: simulates where businesses locate, the commodities they purchase to use as production inputs, number and type of workers hired, the amount of floor space they purchase/lease for their production facility, and production of goods and services sold based on market prices
- **Land Development Model:** identifies land availability based on floor space prices and vacancy rates for firms and households to rent or purchase,
- **Person Travel**: simulates person activities for a typical weekday for the people simulated by the Population Synthesizer, an activity involving travel is assigned a travel mode such as auto, transit, or rail,
- **Commercial Goods Transport**: simulates how commodities are moved as freight by different modes of transport, such as marine, rail, and truck for a typical weekday
- **External Goods Transport**: simulates freight movement for exports, imports and through the state,
- **Transport Model**: assigns trips to a computer network, trips generated in the Person Travel Model, Commercial Goods Transport model, External Goods Transport model

17.2.5 Related Tools

Related tools include: strategic tools (including VisionEval, RSPM/GreenSTEP) – refer to [GHG Modeling and Analysis Tools Overview](); GIS based land use tools such as PlaceTypes or Envision Tomorrow; land use allocation models such as MetroScope and UrbanSim. There are also many tools which use model output such as the MOtor Vehicle Emission Simulator (MOVES), Models used for system-level analysis are discussed in Chapter 7.

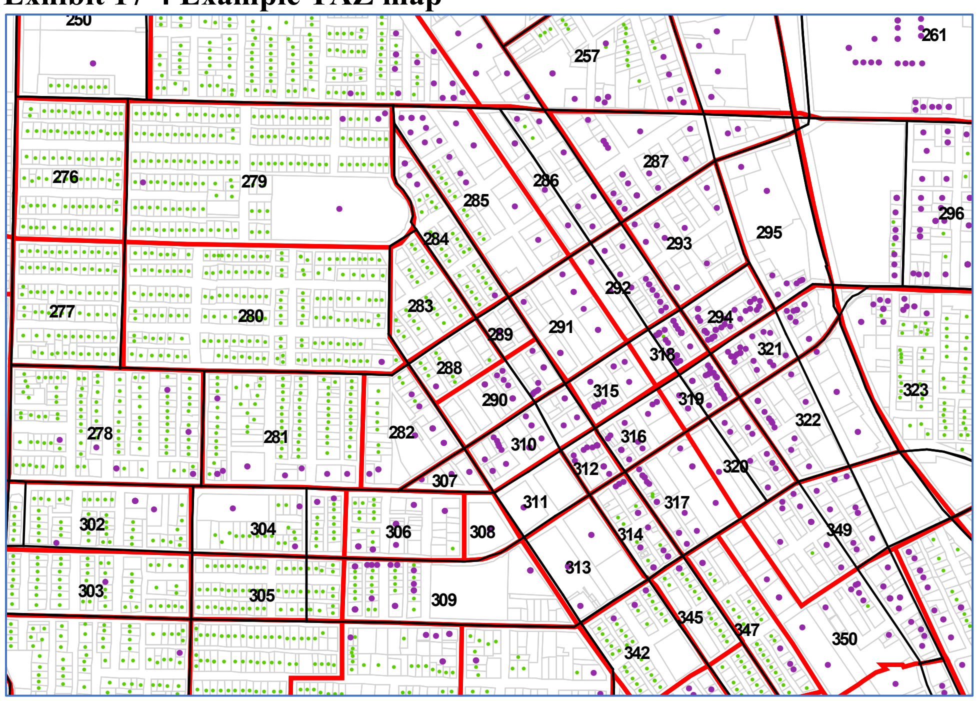
17.3 Model Building Process

17.3.1 Model Building Blocks

Model Zone Structure

The model or study area is broken into homogenous (similar) zones based on land use characteristics. Each zone is identified uniquely. Transportation Analysis Zones (TAZ) are one of the fundamental building blocks of the model. For the newer ABM platform micro analysis zones (MAZs) are another fundamental zone structure. All the land use information (households, employment, enrollment, zonal costs, hotel visitors, greenspaces) are coded to either of these MAZ or TAZ geographies depending on the platform. TAZ/MAZ are where trips originate from and are destined to. An example TAZ map for a portion of a model area is shown in Exhibit 17-4.

Exhibit 17-4 Example TAZ map



For the ABM platform, TAZs are one of the basic spatial units of travel analysis. All the model results can be analyzed at the TAZ level including commuting pattern and mode choice. TAZs are intended to model travel by automobile. Therefore, they can be much larger than MAZs because automobile impedance is less sensitive to small differences in zone size and shape. The size of TAZs can vary with the model application and can be as small as a city block or more than 10 square miles. A typical TAZ system should be specifically designed to fit local planning needs.

TAZ boundaries are typically based on natural and human-made features, such as rivers, canyons, ridges, railroads, and highways. City limits and urban growth boundaries may also determine boundaries.

Model extent is determined by a scoping exercise that depends on several factors such as the use of the model, population density, geography, roadway network and external station considerations.

Recognizing Boundaries

Census Boundaries

Zonal boundaries should follow Census boundaries as faithfully as possible. This is essential as the Census Bureau directly provides socioeconomic data at a variety of geographies including Census Block and Census Tract which can be used as inputs to the model with little or no manipulation. If a TAZ were to split a Tract or a Block, an allocation methodology to distribute the data from the split Census geography needs to be developed.

Physical Boundaries

Natural barriers such as rivers or mountains or man-made barriers such as railway tracks constitute physical boundaries. Physical boundaries restrict free movement and a centroid connector that passes over a barrier to access a road network would be unrealistic. This can be prevented by using the physical barrier as the zone boundary.

Jurisdictional/Political/Planning Boundaries

TAZ boundaries should be consistent with political boundaries such as city, county, MPO and state boundaries. This will help in performing sub-area analysis such as city-city/county-county flows. If the region uses planning districts for performing similar analysis it would be useful to align the TAZs with the planning district boundaries as well.

Zone Centroids represent the center of gravity for the activity in a TAZ. This is commonly not the geometric center of the zone.

Zonal Data

Zonal data or land use from the transportation context usually covers both the physical boundaries on a spatial entity of land (parcel, zones, district, etc.) as well as the demographic, social and economic factors. Land use information is essential in both understanding the present travel patterns and forecasting the future ones.

Travel is related to the population and employment characteristics of a zone. These characteristics are stored in a database used by the model. These data are collected to represent conditions in the model base year. Future land use data are prepared for each TAZ as well, based on input from the local jurisdiction, land use forecasting tools or other manual methods such as buildable land inventories.

Local Agencies are an important partner in developing the base and forecast land use (LU) data necessary for travel demand modeling. The model reflects the local LU data inputs, so it should reflect the local area. The local jurisdictions are asked to develop (or validate) the future LU data at the TAZ level for good reason; it should represent anticipated LU, based on current comprehensive plans and available buildable lands.

For modeling needs, land use information is collected for both population and employment dimensions.

Population

Travel from a zone is related to the population characteristics within the zone. This includes the number of persons residing in the zone as well as their characteristics such as the distribution of ages, income levels, students, and group quarters. Existing zonal population characteristics are obtained primarily from the U.S. Census. Census block group data gives household income, age, size, number of workers.

The make-up of households is integral to understanding the area population demographics. Household attributes such as size, income, auto-ownership, school/college age children, structure type are needed in demand forecasting.

The model uses households as the basic unit for trip generation. Each zone in the model is characterized by its distribution of household attributes, including number of persons, income level, number of autos owned, and type of dwelling unit, which are all factors in trip generation. For example, a zone with mostly high-income households would generate more trips per household than another zone with mostly low-income households, all else being equal.

Households are also classified by type of dwelling unit, such as single-family and multi-family dwellings. The type of dwelling unit is a factor in trip generation. Different types of dwelling units are correlated with different levels of access to automobiles. For example, single family dwellings on average generate more trips than multi-family dwellings because they have a higher level of access to automobiles.

Some additional important considerations related to households are that there can be multiple households in one dwelling unit. Dwelling units that are vacant contain no households. Similarly, group quarters are treated as a type of household with special treatment in the model, such as military barracks, assisted living, or student dormitories.

Employment
Employment is an important factor in defining people's daily activities. Employment tends to be more difficult to estimate and forecast than population. The primary reason might be the fact that employment depends upon local/regional economic forces. In contrast, population tends to grow in a more orderly/predictable fashion. In general, existing employment data used in the model comes from the Oregon Employment Department. Other employment data sources include the Bureau of Labor Statistics (BLS, part of the United States Department of Labor).

For employment data to be useful, they must contain three pieces of information: location of employment, number of employees, and an industrial code for the employer describing the type of work being performed at the job site. Employment data are usually acquired for a specific moment in time.

The model groups employment types into aggregated categories. The most common categories are industrial, service, and retail. Often subcategories are also designated. Some examples are manufacturing vs. non-manufacturing for industrial; trip-intensive vs. non-trip-intensive for retail; or separating out office under the service category. Special employment categories may also be used in the model, such as for hospitals or government.

Oregon models all categorize employment based on the North American Industry Classification System (NAICS). The NAICS "codes" are updated every few years. As an example, employment around server farms and new forms of telecommunications might be different in the 2017 codes than they would have been classified in the 1997 codes. ODOT reviews the employment categorization every time the codes are updated. The latest code set is 2017, which is what the discussion below assumes. In Oregon the employment categories used for the different model types are shown in Exhibits 17-5 through 17-7 below.

Exhibit 17-5 OSUM Employment Categories

Category	NAICS Definition
Retail	440000-459999
Service	520000-569999 and 620000-819999
Other	All other classified employment

Exhibit 17-6 JEMnR Employment Categories

Category	NAICS Definition
Agriculture & Forestry	000000-119999
Mining	210000-219999
Construction	230000-239999
Manufacturing	310000-339999 and 511000-512999
Transportation, Communications & Public Utilities	220000-229999 and 480000-499999
Wholesale	420000-429999 and 491110 (post office)
Retail	440000-459999 and unknown (999999)
Financial, Insurance & Real Estate	520000-531999 and 550000-559999
Service	515000-519999, 532000-549999, and 560000-819999
Government	920000-929999

Exhibit 17-7 ABM Employment Categories

Category	NAICS Definition
Construction	23 series (230000-239999)
Wholesale Trade	42 series
Retail Trade	44 series
Sporting Goods, Hobby, Musical Instruments, Book Stores	45 series
Accommodations and Food Services	72 series
Agriculture, Forestry, Fishing, and Hunting	11 series
Mining, Quarrying, and Oil and Gas Extraction	21 series
Utilities	22 series
Food Manufacturing	31 series
Wood Product Manufacturing	32 series
Primary Metal Manufacturing	33 series
Transportation	48 series
Postal Service	49 series
Information	51 series
Finance and Insurance	52 series
Professional, Scientific, and Technical Services	54 series
Management of Companies and Enterprises	55 series
Administrative and Support and Waste Management	56 series
Education Services	61 series
Health Care and Social Assistance	62 series
Arts, Entertainment, and Recreation	71 series
Other Services (except Public Administration) Religious	81 series
Public Administration	92 series

Certain employment categories have bigger impacts to the results than others. For example, retail/service has more regional impact than agriculture. The total employment must equal the sum of the employment subcategories (government, retail, etc.).

Confidentiality - All model base year employment data are confidential, as provided from the Oregon Employment Department (OED). The reason for confidentiality is so that no party can gain a competitive advantage over another company by knowing how many employees they have. Confidentiality agreements are required on a per project basis for any ODOT, local agency or consultant employees to have access to these data. For ODOT controlled models, TPAU coordinates these confidentiality agreements with OED. Future year data may also fall under the same confidentiality agreements if unchanged from the base year. Further instructions on completing a confidentiality form are found on the "Request for Travel Demand Model Run" form.

Schools and Universities are a special case since they are comprised of both employees and students. A common issue with school employment data is that it can be tied to the school district administration office rather than to the individual schools. The remedy would be to work with the school district to identify the employment for each school. The school district should be able to provide enrollment data as well to estimate student trips generated. Private school student trips if small are generally ignored. Larger private schools are handled on a case-by-case basis. This may also occur with large businesses with satellite offices or field work sites.

Regional employment totals should be compared to household information to ensure a reasonable balance of jobs to workers. In trip-based models this typically means having an employment to household ratio between 0.9 and 1.0. In activity-based models this means comparing total regional employment by category to total regional workers by category. Imbalances should be understood as they may need to be represented in the external model.

OED provides data on employers that have unemployment coverage. Small employers that do not provide this insurance such as agricultural or home businesses are not included. The worker to job balance may help to identify this. Some areas might have significant levels of this in which case region specific treatments may be warranted to properly capture total employment.

Other

There are several other types of land use data required by travel demand models such as parking, hotels, recreation areas, transit service attributes (e.g. percent of zone covered within a reasonable walk time), auto terminal time (time spent at the terminus of the trip, e.g. walking to your vehicle). These will vary depending on the model being used but can be equally important to having a well representative model.

Network

The model replicates the real-world transportation network using interconnected links, nodes and connectors. The network is a geographically scaled model of the transportation system on the ground and includes link lengths and alignments including curvature. Trips are routed along links from one node to the next, for example, from Node 101 to Node 102 to Node 103.

The network is a generalization of what is on the ground, and as such may not include all local facilities in the study area. Generally, only arterial and collector streets are included. Depending on the model, types of networks may include roadway, transit, rail, bike, and walk. Attributes are defined for each link or node on the network, which influence the travel being forecast on the network.

Nodes are representations of intersections, access points, or where link attributes change. Node attributes can include the following:

- **Intersection detail** – Intersection control is an important attribute in a travel demand model to estimate control delay. Some Oregon models only estimate control delay at signalized intersections. ABM models and subarea modeling can estimate delay for other types of controls such as roundabouts, stop control and ramp meters by including additional data such as lane configuration and signal timing such as the green time to cycle length ratio.
- **Turn restrictions** – The model can represent allowed turns including by vehicle classification depending on the model.

The model contains data for each link including length, travel time, and roadway capacity. Links are directional and are defined by a “from” node and a “to” node. Link attributes can include the following:

- Roadway
    - **Functional classification** – is used in the model as the basis for assigning parameters to links such as capacity or free-flow speed. The common classifications in order of hierarchy are freeway, arterials (principal and minor), collectors and local roads. These are further classified by urban or rural.
    - **Number of lanes –** Each link in a model is directional. Trip based models contain the number of directional through lanes for each link. For example a two-lane two-way roadway would have two links, with one lane attributed to each directional link. Models with detailed subarea networks also include the number of turn lanes or auxiliary lanes.
    - **Speeds –** Each link in a model is assigned a speed. The speed represents free-flow speed on the link. ODOT typically uses the posted speed to represent free-flow speed.

- **Traffic counts** – Directional traffic counts on links are used to validate the model's traffic assignment for the base year and to check reasonableness of future year model assignments.
- **Capacities –** Each link in a model is assigned a capacity. The capacity is used in calculating demand to capacity ratios and such as used in volume-delay functions, which are used to estimate delay and speed reductions, which can in turn affect route choice. Capacities are typically expressed as vehicles per lane per hour for the peak hour or peak period, which are then converted to total link capacity. Oregon models use some combination of area type and functional classes to derive the capacities for the model network. In some cases, models may make use of additional variables such as the presence of a median or signal progression factors. Capacity may be adjusted in future model runs to account for the presence of CAVs. Guidance on capacity adjustment factors for CAVs is provided in Appendix 6B and the Final Report for the project *Scenario Guidance for Travel Demand Modeling*, available on the APM website under Supplemental Materials.
- **Volume-delay functions (VDF) –** Volume-delay functions are used in capacity restraint traffic assignments. VDFs reduce travel speed with increased volumes as they approach capacity. VDFs are most often link-based but in some models can also be intersection-based. They vary by facility type and other factors. As the demand to capacity ratio increases, travel times increase, making a link less attractive and potentially shifting trips to other routes or time periods.
- **Link length** – Most new highway networks created for travel demand models are created by importing data from established GIS or linear referencing systems (LRS) datasets. Link lengths need to match the actual travel distance. Some modes may have separate links.

* Allowable Modes (not available for OSUM models) – links can be pedestrian and bike only, or auto only, transit, truck, or any combination of modes. ABM models can include carpool/HOV/HOT lanes. In some cases a managed lane is coded as a separate link.
* Tolls – ABM models can include the amount of toll on a link, which can be by vehicle type (SOV, HOV, truck, bus)
* Median Type – ABM models include a median attribute which assumes an increase in capacity for presence of a physical median barrier
* Progression Factor – an adjustment factor similar to HCM quality of progression
* Transit Routes (not available in OSUM models) – the following are attributes of specific transit routes
  - Fares
  - Frequencies
  - Stops
  - Occupancy

Connectors attach the physical road network to the zone which is represented by a zone centroid. Connectors have unconstrained (infinite) capacity. Connector considerations include:

- Allowable modes
- Connector length/speed (used to calculate travel time)
- Travel time by mode

Special Treatments

OSUM models can have special generators which are locations which have a hard-coded number of ITE trips. A similar treatment also exists in JEMnR models but is applied only to retail employment using a square footage basis. Within a model, certain land uses can be competitive even though in real life they are not (big-box retail store versus a truck stop). Models cannot distinguish the different trips within this commercial zone, so trips can be "stolen" from one attractor to feed another. Special generators are unique to the employer and should have a regional significance both inside and outside the model area. Special generators are typically used for land uses that would not receive the required amount of trips with normal model trip generation like with a regional mall; the model would base trip generation on employment but substantially underestimate the total volume generated from the customers. Adding a special generator requires the model to match an assigned number of trips; for example, if 5,000 trips are coded then 5,000 trips will be sent.

A reason why special generators might be considered is that model employment types are aggregated into broad North American Industry Classification System (NAICS) categories.
These are the standard categories used by federal statistical agencies in classifying business establishments. For example, the retail employment type does not differentiate between a coffee shop and Home Depot.

In OSUM, special generators are served first (they will always get the daily number of trips coded). The total special generator trips should not be greater than 50% of the total trips from the model. The special generators attract both internal-internal (I-I) and external-internal (E-I) trips so there is a need to determine the total number of trips that they are absorbing. Too many special generators will diminish the sensitivity of the model (forced or directed trips- no destination choice impacts such as congestion or other impedance effects) and they cannot be accommodated by just i-i trips as the external zones need to be adjusted to reflect regional significance.

The number of trip ends should be considered between the base and future year. Competition with other new or existing businesses needs to be considered, otherwise a special generator can inordinately attract trips from other zones, externals, etc. and not leave enough trips to satisfy other uses. It is important that the requestor understands the implications of how special generators affect regional trip generation.

There are instances where a special class of traveler may not be represented in census and city population totals. The following are examples where special treatments may be needed.

- University populations are sometimes captured in city populations (Corvallis as an example), however, travel for the university students differs significantly from the general population; therefore, a special model is required. For example, the OSU sub-model that exclusively deals with university travel within the CALM regional model.
- Some areas have a significant visitor travel component, such as Newport. Visitors are not captured in the general population totals but can be a significant impact on travel within the region. In these cases the visiting population needs to be separately accounted for such using a visitor sub-model. Lodging establishments (hotel/motel, RV parks, rental homes, campgrounds etc.) are equivalent to households for visitors with trips being typically attracted to recreation among other destinations.
- Models typically represent the average time of the year, but travel patterns and magnitudes in some areas in summer or other seasons may differ significantly and require a special treatment. A separate scenario is created by pivoting off the average annual model. The summer scenario would typically include an increased population or a visitor sub-model, increased employment, increased levels of external station volume, and summer special generators.

17.3.2 Base Year construction

Due to data availability and development timelines, it is common for the model base year to be several years prior to the current year. Models can take several years to develop. Some of the input data may lag by a few years by the time of starting the model, such as the employment data. It is important to understand this distinction of the model base year in comparison to the existing year. The model base year data are obtained from many different sources, including census data, state employment data, Origin and Destination trends or data, household travel surveys, traffic counts and field inventory. Collecting this information involves coordination with a variety of data providers and agency partners. Most of these data requirements are described under Model Building Blocks but are summarized here.

- Network
    - Base roadway network
    - Number of lanes
    - Traffic control
    - Posted speeds
    - Functional class
    - Other
- Zone construction
    - Households
    - Employment
    - Other
- Counts

    Traffic counts are needed to compare to model link volumes for the purpose of calibration or validation. Considerations for collecting and use counts include:

- Procedures to attribute counts onto a model network using either ArcGIS or Visum are contained in Appendix 17A. This includes how to use count processor spreadsheet tools found on the Technical Tools page under the Volume Development dropdown to prepare counts for import.
- Most model counts represent average weekday traffic volumes. Use of ATR data requires weekend data to be removed. Refer to Chapter 5 for procedures. These should be 48-hour directional counts. Note: at some locations with high summer travel, a summer day may also need to be developed if travel patterns are significantly different from off season travel
- For external stations, counts need to be at least 48-hour directional classification counts
- In some locations long duration (16-hour intersection counts) may be acceptable, if there are cost savings with other count needs
- After counts are collected, count adjustment factors are applied.
    - Seasonal adjustments are typically needed to estimate annual average volumes from short term counts.
    - Axle factors are used to adjust volume only road tube counts before use. Axle factor procedures are found in Chapter 5.
    - Directional factors are required for combined direction counts unless the road is one-way.
    - Growth factors are used to adjust counts taken in different years to estimate the volume in the model base year. Historical growth factor procedures are found in Chapter 5.

The following datasets are specific to the Base year construction due to the calibration requirements in the following section: Origin destination data from Bluetooth, AirSage, TomTom, etc. If origin-destination (O-D) data are available, it can be used to compare model O-D data. If unavailable, some models may require that O-D data be acquired, for example if visitors represent a significant component of travelers or if needed to validate the O-D patterns in the model.

Speed and/or travel time data sources and tools include Inrix, NPMRDS, and RITIS. These data are not needed for most model macro traffic assignment methods. For more advanced traffic assignment methodologies, speed data may be needed for reasonableness checking or to perform a speed calibration.

Treatment of External Traffic

SWIM is the primary source of external traffic data in most cases. The data are readily available and provides trends for truck and auto flows in Oregon. However, it is important to check the data for reasonableness. There can be areas such as close to borders where the routing trends may not match local data. In those cases there are additional methodologies that can be used to derive traffic patterns flowing into and out of urban areas, such as the Future Volume Tables (Chapter 6) for point volumes, sources of origin/destination data such as from private sources, or other methods from the literature.

Traffic Assignment Considerations

The choice of assignment method can impact the data needs and needs to be considered early in model scoping. There are variations in types of trip assignment methodologies, for more information refer to the Alternative Traffic Assignment Methods Framework Report. For dynamic traffic assignment refer to Chapter 8. Considerations relating to traffic assignment are discussed below.

Volume-delay functions (VDFs) are used in capacity restraint traffic assignments. Existing ODOT trip-based models use BPR volume-delay functions in their macro level traffic assignment treatment. The BPR functions are applied differently for signalized and unsignalized model links. Additionally peak assignment and daily assignment have unique VDFs and treatments:

- Daily- OSUM assigns each hour of day and then sums to generate daily volumes. JEMnR assigns daily (this includes transit) demand in total and PM peak hour only.
- Peak- for OSUM see above. JEMnR has its own hourly peak hour factor that generates demand and then assigns.

The planned use of the model may require finer detail of traveler segmentation. For example HOV policies require that HOV vehicles be assigned as a separate traveler class, rather than being grouped into a single traveler class.

17.3.3 Model Estimation

In short, travel demand models consist of mathematical relationships between employment, population, and other demographics to replicate trip making. Some of these relationships come from national data such as census or ACS (American Community Survey) or state specific data such as OHAS (Oregon Household Activity Survey).

For trip generation, OHAS is used to determine Oregon values for household size, e.g. number of people per household or trips per household. Some examples of the types of values obtained from OHAS are shown in Exhibit 17-8. Households can also be categorized by age, income, and other characteristics. From this data, basic relationships can be derived, for example how households with higher incomes drive more.

Exhibit 17-8 Persons and Trips by Household Size, Age and Income

Source: Daily Travel in Oregon: A Snapshot of Household Travel Patterns, ODOT, July 2018

The other components of model estimation are much more complex than trip generation. They require a fully functional zone structure and network. All base year inputs need to be assembled at the TAZ level to develop skim tables for the region. A skim table identifies travel times (or distances or costs etc.) between zone pairs. An example skim table is shown in Exhibit 17-9. These are needed to understand choices available to the travelers surveyed in the model regions.

Exhibit 17-9 Example Skim Table

HwyPK.skm-*1 SOVTime

*1 SOVTime | 2 SOVDist | 3 SOVToll | 4 HOVTime | 5 HOVDist | 6 HOVToll | 7 TDTime | 8 TDDist | 9 TrkTime | 10 TrkDist

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	3.42	6.16	10.33	12.41	16.26	11.14	12.57	16.33	18.26	15.14	17.86	20.43	18.87	23.73	22.07
2	6.16	3.17	7.65	7.91	11.88	6.64	9.00	11.83	13.77	10.65	13.38	15.95	14.37	19.24	17.59
3	10.22	8.18	2.16	4.38	6.99	6.50	3.29	11.69	13.62	9.83	9.68	11.33	11.83	15.35	13.89
4	12.43	7.92	4.34	2.57	7.49	6.23	3.79	11.42	13.36	10.24	10.18	11.83	12.33	15.86	14.40
5	15.75	11.41	6.35	6.89	2.66	5.34	4.41	7.08	9.39	5.24	3.65	6.21	5.79	9.50	7.86
6	11.24	6.74	6.04	6.32	5.90	3.30	4.86	7.09	9.02	5.75	7.58	10.16	8.58	13.45	11.80
7	12.66	8.99	3.25	3.80	5.01	4.86	2.13	9.98	11.99	7.85	7.70	9.36	9.85	13.38	11.92
8	16.47	11.96	11.28	11.55	7.77	7.12	9.98	1.96	2.90	3.44	5.88	7.23	4.91	10.44	8.79
9	18.40	13.89	13.21	13.48	10.09	9.06	12.03	2.90	2.30	5.37	8.20	6.95	4.33	8.57	7.27
10	15.27	10.77	9.77	10.32	5.93	5.74	7.84	3.44	5.37	2.80	5.68	8.25	6.67	11.55	9.89
11	18.00	13.50	9.75	10.30	4.36	7.59	7.82	5.88	8.19	5.70	2.40	3.06	4.60	7.12	6.47
12	20.51	16.01	11.25	11.79	6.86	10.10	9.30	7.18	6.94	8.20	3.02	2.15	3.84	5.63	4.98
13	19.00	14.49	11.83	12.38	6.43	8.58	9.89	4.91	4.34	6.68	4.55	3.83	2.55	6.86	5.21
14	23.81	19.31	15.28	15.83	10.16	13.40	13.34	10.44	8.54	11.49	7.08	5.64	6.86	2.09	3.32
15	22.17	17.67	13.91	14.46	8.52	11.76	11.97	8.80	7.26	9.85	6.43	4.98	5.22	3.34	2.62
16	24.43	19.92	17.81	18.36	12.69	14.00	15.88	10.34	8.43	12.11	9.62	8.17	8.14	4.30	4.75
17	26.02	21.52	20.62	21.12	15.50	16.68	18.69	10.52	9.58	12.99	12.43	10.98	10.96	7.12	7.57
18	22.32	17.81	15.90	16.45	10.94	11.90	13.97	7.33	6.30	9.80	8.86	7.40	6.03	6.53	5.22
19	13.13	17.69	11.58	15.39	18.00	17.82	14.31	22.94	24.94	20.84	19.16	20.54	22.02	24.35	23.90
20	7.88	12.44	6.33	10.53	13.14	12.65	9.44	17.84	19.77	15.98	15.83	17.48	17.98	21.50	20.04
21	7.08	12.05	12.33	15.70	19.14	14.44	15.45	19.63	21.57	18.45	21.12	23.48	22.15	26.99	25.34

Source: https://tfresource.org/topics/Skim_Matrix.html

Changes to the highway network must be reflected in the appropriate level-of-service data files (travel time skims) that are input to the model. Level-of-service refers to the characteristics of travel by mode between zone pairs, in the case of OSUM, peak and off-peak travel times between zone pairs.

Reasonableness checks for the level-of-service data (travel times) can be performed by developing a matrix histogram of zone-to-zone impedances or distribution curves using the density function in R. Potential problems may be reflected in unexpectedly large values or concentrations of zone pairs within lower or higher impedance intervals (a formation of an unexpected hump in the curve.

For a more complete understanding of modeling estimation refer to NCHRP Report 716 (Travel Demand Forecasting: Parameters and Techniques).

17.3.4 Calibration and Validation

If estimation was performed for the model region certain sub-models may not need further calibration. If model estimation was borrowed from another region, all sub-models need to be reviewed and calibrated to local data.

Calibration is an evaluation on how well the model replicates observed conditions. Calibration is an iterative process whereby the model parameters are adjusted until model estimates reasonably match the field-measured targets. Calibration requires both software expertise and knowledge of existing travel behavior.

Model validation is the process of testing the performance of the calibrated model using an independent data set (not previously used in the calibration). Validation is an additional check to confirm that a model has been correctly calibrated and closely match the existing conditions.

Calibration is usually performed according to the sequence of the model flow, starting with the higher order sub-models such as trip generation and ending with trip assignment. In a trip-based model the sequence includes trip generation, trip distribution, mode choice, and trip assignment. In an activity-based model the sequence includes long term decisions such as work location and auto ownership, tour generation, trip and stop choice, time of day models, and trip assignment.

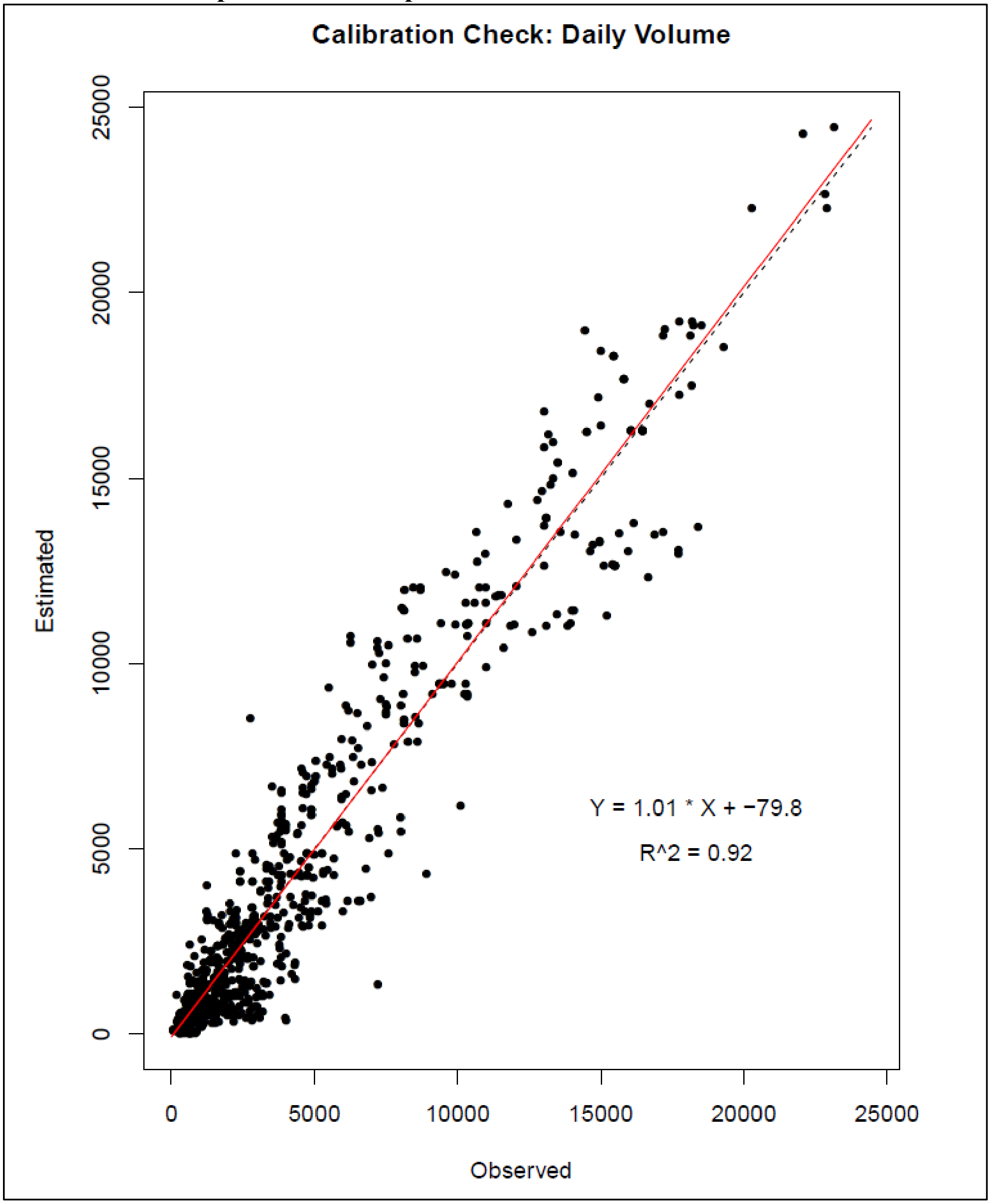
The trip assignment sub-model is common across all travel demand models. Traffic assignment is typically treated as a validation of the calibrated sub-models, which estimate travel behavior. It is common for a model to only be validated to daily and PM peak demand as these are the most common requested periods. Other periods such as mid-day, may be provided with the understanding that the information from these periods may not be validated.

Several measures are used to evaluate the performance of the travel demand model (for more details see model documentation). For traffic assignment validation, three primary types of comparisons are typically used. These are:

- Link scatterplots (by functional class)
- Percent root mean square error
- Screenlines

Link Scatterplots show the results of regressing assigned link traffic volumes on the corresponding link traffic counts. The scatterplot, together with the regression statistics, provide a measure of how well the model replicates overall traffic flows on the network. As shown in Exhibit 17-10, the model performs very well for the daily time period, with the slope of the regression line (1.01) near 1 and an R^2 (coefficient of determination) value of 0.92. A slope close to 1.0 is generally desired, and while there is no national accepted value, most calibration efforts seek to obtain an R^2 of 0.9 or higher. As would be expected, the data points for the lower-volume links generally are more widely dispersed around the regression line than those for the higher-volume links, indicating the larger degree of model error for the lower-volume links.

Exhibit 17-10 Sample Link Scatterplot



Percent root mean square error is a frequently used measure of the differences between values (sample or population values) predicted by a model. An example is shown in Exhibit 17-11, reported out by link functional classification.

Exhibit 17-11 Sample Percent Root Mean Square Error (% RMSE)

Table 27: % RMSE Daily Validation

Link Volume Category	Functional Classification	% RMSE
≥ 16,000 vpd	Freeway/Principal Arterial	11%
8,000 – 15,999 vpd	Principal Arterial	22%
4,000 – 7,999 vpd	Principal/Minor Arterial	43%
2,000 – 3,999 vpd	Minor Arterial/Collector	56%
1 – 1,999 vpd	Collector/Minor Collector	28%
All Links		32%

Screenlines

Screenlines are drawn to evaluate significant regional volume flows. An example would be a screenline between cities or major areas within a region. It is desired that the total amount of trips in the model across the screenline equals the count volume across the screenline. In most cases a model/count ratio within 10% is desired. An example summary of screenline results is shown in Exhibit 17-12.

Exhibit 17-12 Sample Screenline Results

Table 28: Daily Screenline Validation Analysis Results

East-West and North-South Screenlines	Northbound			Southbound			Both Ways		
East-West Screenlines	Counts	Model	Model/ Counts	Counts	Model	Model/ Counts	Counts	Model	Model/ Counts
EW-GP1 (South of Redwood Hwy 199)	29,511	23,915	0.81	29,481	23,506	0.80	58,992	47,421	0.80
EW-GP2 (South of G Street)	37,239	40,799	1.10	42,730	40,186	0.94	79,969	80,985	1.01
EW-GP3 (South of NW Hillcrest Dr)	31,108	26,660	0.86	27,382	27,287	1.00	58,490	53,947	0.92
EW-JCo4 (North of Fish Hatchery Rd/Jaynes Dr)	6,103	7,017	1.15	6,103	6,945	1.14	12,206	13,962	1.14
EW-JCo5 (South of Monument Dr/Three Pines Rd)	16,826	18,163	1.08	17,071	18,332	1.07	33,897	36,495	1.08
2010 DAILY EW-SCREENLINE SUB-TOTAL	**120,787**	**116,554**	**0.96**	**122,767**	**116,256**	**0.95**	**243,554**	**232,810**	**0.96**
North-South Screenlines	Eastbound			Westbound			Both Ways		
NS-GP1 (East of Willow Ln)	11,982	15,332	1.28	16,836	15,334	0.91	28,818	30,666	1.06
NS-GP2 (East of Redwood Hwy 199 NB)	37,566	30,873	0.82	36,815	28,520	0.77	74,381	59,393	0.80
NS-GP3 (West of Murphy-Willaims Hwy 238)	26,344	27,716	1.05	26,503	27,845	1.05	52,847	55,561	1.05
NS-GP4 (East of Beacon Dr) N of River	18,479	16,914	0.92	18,222	18,123	0.99	36,701	35,037	0.95
2010 DAILY NS-SCREENLINE	**94,371**	**90,835**	**0.96**	**98,376**	**89,822**	**0.91**	**192,747**	**180,657**	**0.94**
Total Daily Screenline Vallation Results	Northbound/Eastbound			Southbound/Westbound			All Ways		
	Counts	Model	Model/ Counts	Counts	Model	Model/ Counts	Counts	Model	Model/ Counts
2010 DAILY SCREENLINES	**215,158**	**207,389**	**0.96**	**221,143**	**206,078**	**0.93**	**436,301**	**413,467**	**0.95**

Vehicle Miles Traveled (VMT)

There is usually not observed "on-road" VMT data to measure against, but that measure of VMT is often reported out as an output of a travel model. As a reasonableness check, comparisons could be made, for example VMT summaries by functional class from HPMS if available for the region, or from previous or other travel model VMT estimates. An example comparison of VMT by functional class is shown in Exhibit 17-13.

Exhibit 17-13 Sample VMT Summary

VMT

FC	OBS	EST	DIF	%DIF
FREEWAY	392497	382120	10377	3
PRIN ART	330543	309096	21447	7
MIN ART	151414	125255	26159	21
COLLECTOR	145123	171235	-26112	-15
RAMPS	18541	16718	1823	11
TOTAL	1038118	1004424	33694	3

Oregon Administrative Rules (OAR) 660-012 now requires the calculation of VMT per capita under certain circumstances during the Transportation System Plan (TSP) process. The VMT used in those instances must align with the specific definition in OAR 660-012-0005(64), which is different than how VMT has been reported for HPMS purposes.

The methodology for calculating VMT per capita that aligns the definition and for the purposes contained within OAR 660-012 is provided in Appendix 17B.

17.3.5 Future scenario construction

The value of a travel demand model is not in reproducing historic traffic conditions but to estimate future travel patterns. Once the base year model is calibrated and validated, the next step is to build future scenarios.

Constructing a future scenario involves developing data inputs similar to the base year. In some ways the future is more difficult in that inputs are not observable to be easily tabulated. Even though there are no observable data there are accepted methods of estimating future conditions.

Population

State administrative rules require that Oregon models adhere to population control totals obtained from the Population Research Center (PRC) at Portland State University . These are provided as a coordinated population forecast by county, UGB, age, and gender. The totals are updated on a three-year cycle. Counties allocate population to cities and unincorporated areas to assess future changes. The PRC does not provide population controls by model boundary; the modeling team needs to consider buildable land, expected development, and work with the local government to populate model zones outside of jurisdictional boundaries.

When population is increased, the number of HH's also needs to be increased. When developing the future household totals, the team needs to consider the changing demographics for the region in the future year and how those impact the average household size. It may not be correct to assume the average household size will be the same in the future year as it was in the base year. The group quarters are subtracted from the total future population; this result is then divided by the future average household size to estimate the future number of households. For trip-based models, households are the key parameter rather than population.

Employment

There is no control total for employment. An initial estimate of future employment is needed as a starting point to check with local jurisdictions. The initial estimate can be made in a variety of ways: Oregon Department of Employment projections are available for up to ten years in the future; future employment can be estimated proportional to the increase in households. Running the model can indicate that further adjustments are needed, and employment can continue to be adjusted in an iterative process. The local government is consulted to approve the overall amount of employment by category and zones.

Zone Allocation
Both employment and households need to be allocated at the TAZ level. There are several considerations to keep in mind when doing this:

- Local government may be thinking in terms of planned additional dwelling units. Dwelling units (DU) are not equal to HH's as DUs can be single or multi-family HHs. DUs are converted to HH using a vacancy rate (HH = DU*(1 - Vacancy Rate)).
    - Generally a TAZ is assumed to not lose households or employment, unless there is urban renewal or redevelopment planned, which should be noted to explain the decrease.
    - At the zone level, the average person per HH is usually in the range of 1.0 – 3.0 and the state average is 2.2 – 2.3.
    - Approved development should be included in the future year estimates.
    - Buildable land inventory, given zoning requirements, can be used to estimate additional future households and employment allocation to zones. See Chapter 6 for more information on cumulative model forecasting.

Network

The network also needs to be constructed for the future year. The needs of the model dictate which future networks are required. For example, an MPO model requires an RTP scenario which includes the RTP projects (committed plus financially constrained). Common scenarios that can be constructed are:

- No build – Conditions on the ground at the time of the calibration (base) year
- Committed –Committed network projects (projects that are already funded/programmed at the time of the model build). This does not include the entire financially constrained project list; it is only the projects that are included in the STIP, CIP or TIP at the time of the model build.
- RTP – Regional Transportation Plan, this typically includes both future committed and financially constrained projects.
- TSP – Transportation System Plan, this typically includes the future committed projects, financially constrained, and potentially unconstrained projects
- Interim – some combination of projects above, for chosen interim year, based on discussion with project team

Considerations for the network:

- It's important to remember to include existing conditions that may include projects built since the base year.
- Transit improvements or changes need to be considered for MPO models
- Potential policy changes need to be considered, such as parking, tolling, and technology
- Capacity may change in the future network due to the presence of CAVs

<u>External</u>

The future year external stations' growth and trends are important inputs. At the external stations, future volumes are typically determined from historic growth trends, such as the Future Volume Tables (refer to Chapter 6). SWIM can also be used to help provide information on how external station growth may be impacted by large regional projects, such as the Newberg Dundee bypass. In addition to external station volumes, O-D patterns for volumes coming from external stations are necessary inputs. In recent years SWIM has commonly provided this information, although other sources and methods may be available.

Overall

Local buyoff on population, employment, zone allocation, and network are needed for constructing a future model. Validation is done by running the model, and checking that the results seem reasonable: expected volumes, capacity, d/c ratios, etc.

17.3.6 Model Documentation

After the model is completed, model documentation will be finalized. The model development report documents the model build process including discussion on the following information.

- Model Structure
- Model Network
- Survey Data
- Zonal Data
- External Model
- Sub-Model Calibration
- Assignment Validation
- Future Year Scenario Development

17.4 Travel Demand Model Outputs

Model runs provide most of the basic information needed for a typical plan or project analysis. Some information is readily produced, for example a peak hour volume assignment plot, while other information can be obtained with additional effort, such as an unconstrained run that keeps the demand constant to better understand route choice and latent demand. Some of the primary performance categories that can be addressed by a model include mobility and land use.

A Multi-Criteria Evaluation (MCE) tool is in use by Metro and is being deployed for ABM models to provide a consistent output set, such as the set of measures illustrated in Exhibit 17-14 below.

Exhibit 17-14 Illustrative Set of Measures from Multi-Criteria Evaluation (MCE)

#	Benefit	Category	Type	Quantities	Maturity	Confidence
1	Safety	Safety	Link	Fatal, Injury, Property-Damage Only Crashes	Proven	●●●●○
2	Travel Time	Mobility	OD	Minutes of travel time saved by mode	Proven	●●●●●
3	Travel Time Reliability	Mobility	OD	Decrease in travel time variability (standard deviation of travel time)	Emerging	●●○○○
4	Vehicle Operating Costs	Mobility	Link	Gallons of fuel consumed, VMT-based non-fuel costs	Proven	●●●●○
5	Vehicle Ownership Costs	Mobility	Zone	Number of household vehicles	Emerging	●●●○○
6	Emissions	Environment	Link	Tons of CO_2e, PM2.5, PM10, NOx, VOC	Proven	●●●●●
7	Surface Water	Environment	Link	VMT-based cost of impacts	Emerging	●●○○○
8	Noise	Livability	Link	VMT-based cost of impacts	Emerging	●●○○○
9	Physical Activity	Livability	OD	Quality-adjusted life years (QALYs) saved	Emerging	●●●○○
10	Travel Options / Choices	Accessibility	Zone	Monetary value of additional mode / destination options	Emerging	●●●○○

Equity is a lens or dimension that can be applied to any of these measures. For example, output such as accessibility or mode share can be sorted or filtered by equity factors such as income level, age, or vehicle ownership.

As ODOT moves forward with ABMs, higher resolution travel behavior data become available as the ABM estimates/synthesizes a region's activity survey. The ABM predicts a full daily record of travel expected to occur, with individual records for every trip, for every person. This allows data to be aggregated to answer very specific questions on travel within the model area, for the data fields available. For example, the model could test the effectiveness of free transit passes being provided for people working in a specific area. Some of the more common model outputs are discussed below.

1. Traffic Assignment

Traffic assignment is typically provided as the number of vehicles expected to use each link or segment of the network for a given period. Depending on the study, this may be for ADT or for a peak period. Vehicle assignment can be provided by trip purpose and traveler class.

With an ABM assignment, trip records will have information for any hour(s) of the day. Results are grouped into five bins for early morning, AM peak, mid-day, PM peak (typically one or two hours), and evening; an additional one-hour PM peak can be run if desired. Exhibit 17-15 gives an example of a traffic assignment plot.

Exhibit 17-15 Sample Model Output – Auto Volumes

2. Unconstrained Assignment

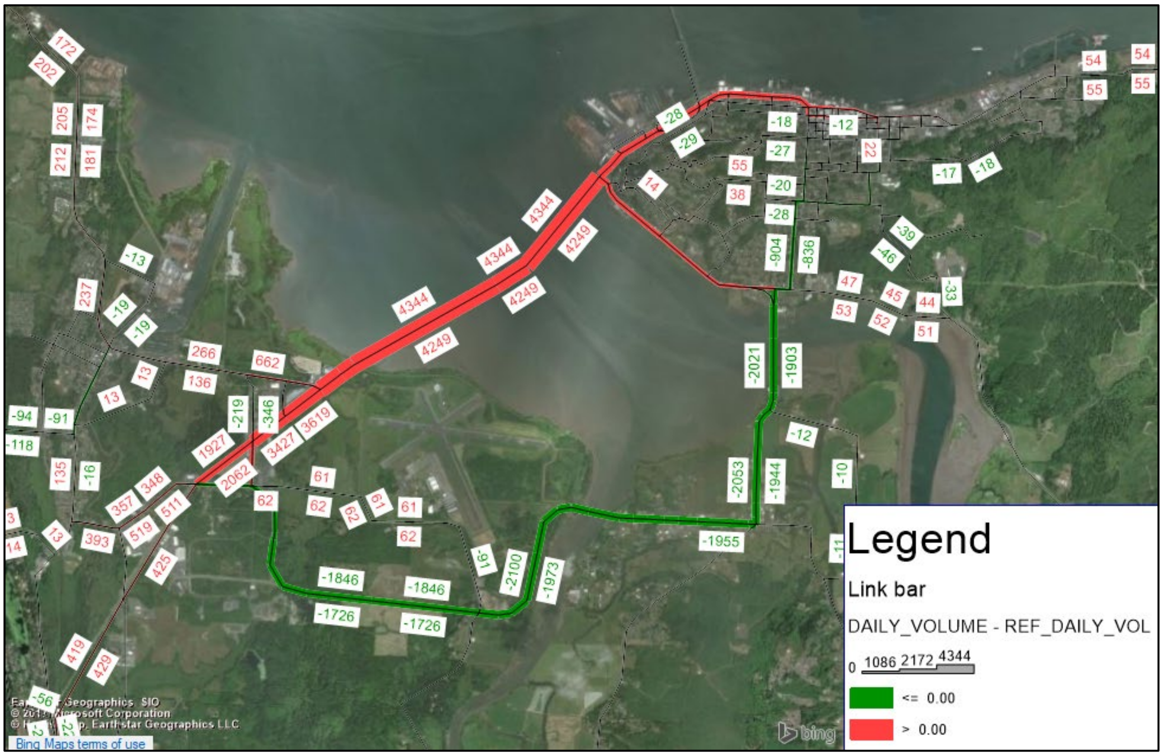
Model scenarios are typically run as capacity constrained. In a constrained model, growth may appear low when compared to growth based on historic trends, which is unconstrained. An unconstrained model run should be considered for any project as it assists with understanding travel patterns within the project area. A difference plot between the unconstrained and constrained scenarios can help identify links with significant capacity constraints. This assignment will show the desired path (where traffic wants to go) if capacity was unlimited. Large differences between constrained and unconstrained model runs points to latent demand concerns (see Section 6.12.2) and may be a flag for special consideration in post-processing.

An unconstrained run can be either using just the assignment model or with a full model run. If running only the assignment model, demand is held constant and trip distribution is not affected. With a full model run, trip distribution is allowed to change based on free-flow speeds instead of congested speeds. Typically unconstrained is run just for the assignment portion of the model because allowing trip distribution to recalculate based on uncongested conditions can be unrealistic. Running unconstrained just for the assignment portion provides an estimate of latent demand for corridors assuming set trip origins and destinations.

3. Scenario volume difference analysis

One scenario is compared with another scenario in terms of the link volume changes for the entire model network. Usually a typical land use or network scenario is chosen to compare with the base reference scenario to see how the action scenario is going to affect the no-action scenario. Exhibit 17-16 is an example of a difference plot. As an example, this can show the wider benefits of a project in terms of reduced volumes on other roadways even when volumes increase on the improved roadway due to latent demand.

Exhibit 17-16 Difference Plot



For initial screening and scenario development and sensitivity testing, running just the assignment portion of the model can save time and result in preliminary difference plots. The model assignment portion is likely to result in most of the link assignment differences between scenarios. The full model run is likely to only refine these results. The full model can be run once the set of scenario changes has been narrowed down. This can be a substantial time savings depending on the full model run time.

4. Demand to Capacity Ratios

A standard model output is a plot showing peak hour demand to capacity ratios on links. This is often used for preliminary screening of capacity issues. For this purpose raw model volumes are used and does not require post-processing. The d/c ratios are typically binned into ranges such at/near/or over capacity to flag potential deficiencies for further analysis. Refer to Chapters 9 and 10 for definitions and applications. Demand to capacity is used as an indicator of congestion when model volumes exceed model link capacities. Actual volumes never exceed actual capacity.

5. Select-Link Analysis

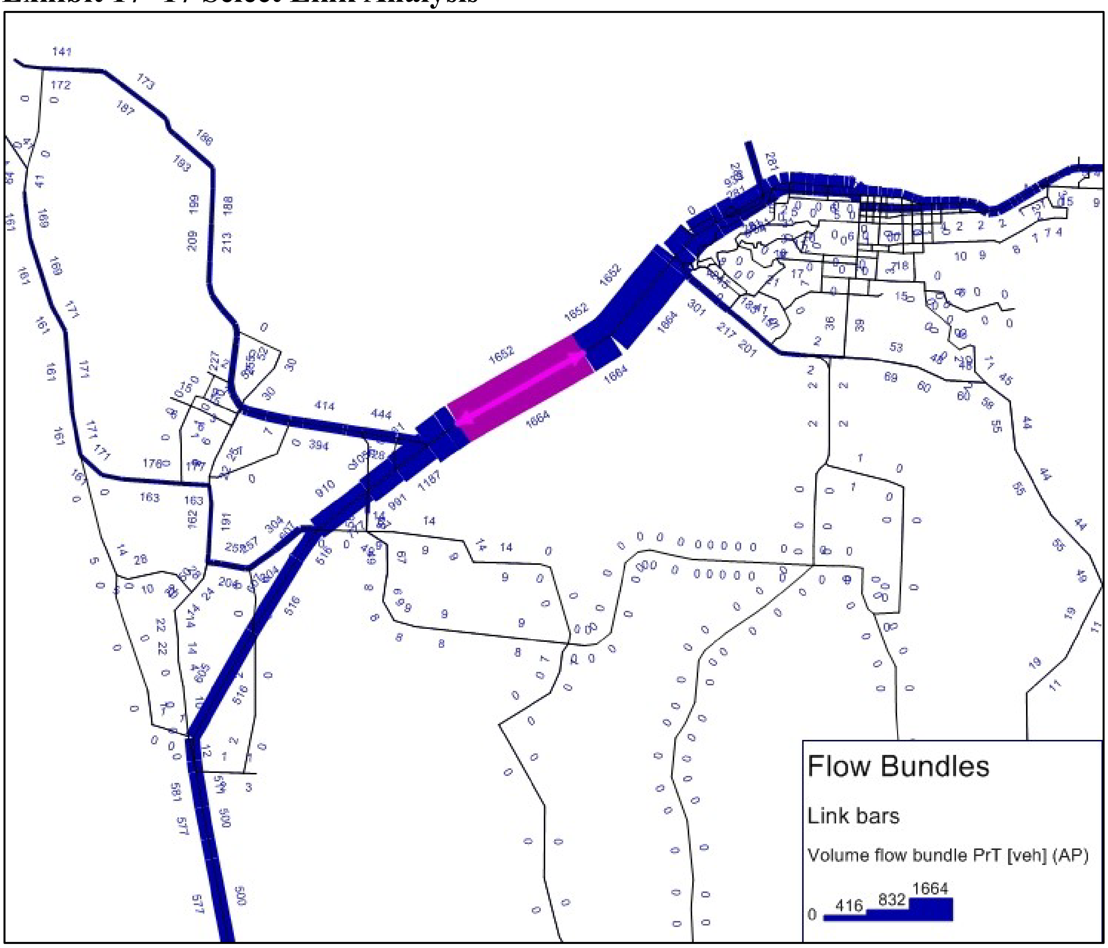
Select link analysis is often requested for supporting intersection turning volume post-processing according to the APM. For a given select link or series of links, a select link plot shows what other roads the trips on the link are traveling on or what zones the trips are traveling to or from. Specific software may have somewhat different terminology for this analysis. Raw model output is provided at the link level, not at the intersection turn movement level. Select-links can also be used to track trip assignments on specific links to assess impacts. Other examples of using select links are:

- Obtaining initial turn movement percentages for use in post-processing. See Chapter 6 for more information.
- Determining percentage of through trips through the project area
- Determine if trip assignments are reasonable after network changes are made.
- Determine weaving section flows if obtained on the mainline and ramp sections leading into and out of the weaving section.

Exhibit 17- 17 is an example of a select link plot. Some example questions that a select-link analysis can answer are:

- Where does a roadway improvement project draw traffic to/from?
- How does a street or bridge connection or closure impact its vicinity traffic flows?
- How does widening a roadway reduce traffic impacts on other parallel facilities?

Exhibit 17- 17 Select Link Analysis

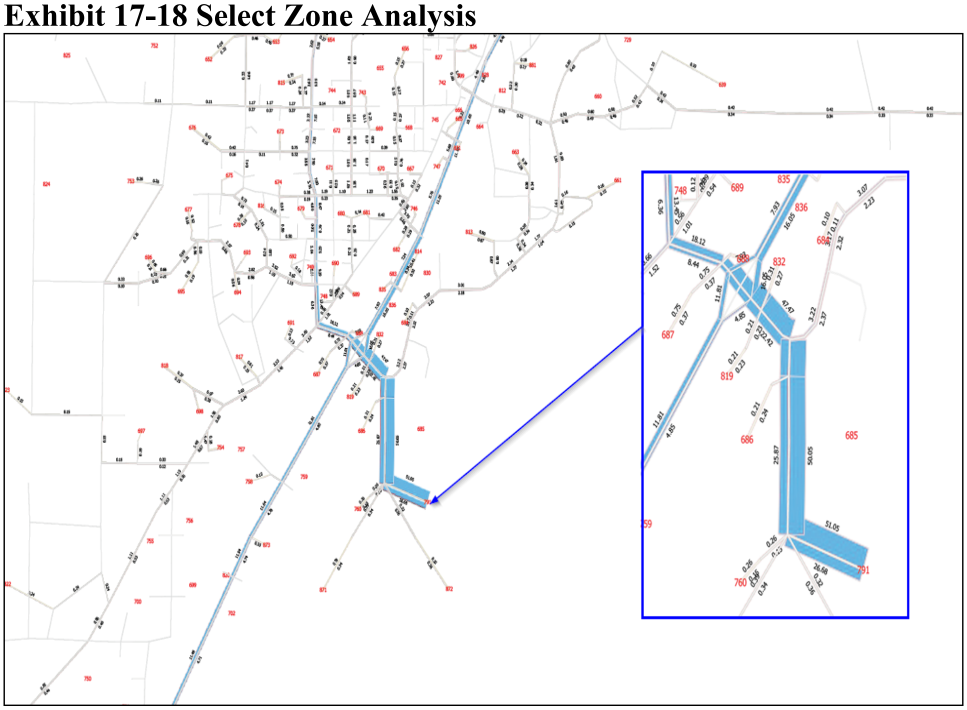


6. Select-Zone analysis

Select-zone analysis is requested when a new land development is placed in a zone or an existing development is relocated to a new zone. A select-zone plot shows the distribution of volume from/to a given zone across the model network. This is useful in determining, for example, volume distribution for a future development not included in the model. The trips to and from the new land use across the entire model network can be tracked through the select-zone volumes. Exhibit 17-18 is an example of select zone analysis. Some examples of use of select zones include:

- Impact area – the extent of the roadway network that a land use change has a significant impact on. Impact area is typically calculated using a threshold for significance, such as where existing AADT is increased by 10% or more.
- Proportional share – the proportion of trips that are contributed by a land use change. For example, where the need for a left turn lane is due to a left turn volume and the land use change contributes 30% of the total left turn volume.
- Impacts to specific facilities

Exhibit 17-18 Select Zone Analysis



7. Transit

The types of information for transit are similar to the auto mode. As an example, a select link/flow analysis can be obtained for transit lines like auto links at a stop or section of the route.

The level of calibration affects the overall accuracy of transit output and type of questions that can be answered. At a minimum calibration is done at the route level. Some models like Metro's calibrate at the level of stops. When requesting transit information a discussion with the regional modeler is needed to determine what information can be extracted and how it should be applied.

Several transit performance measures are possible (not exhaustive):

- Ridership, by route or by stops. Ridership at stops as an output needs to be carefully reviewed if the transit model was not calibrated at the stop level.
- Travel time/delay - running time same as vehicle travel time. Dwell time or stop time are inputs based on defaults in ODOT models.
- Accessibility – can be obtained for both accessibility to transit and by transit

8. Mode share

Only MPO level models include outputs on modes other than motor vehicles. The different modes available include auto, walk, bike, transit, SOV, HOV (carpool), trucks (emerging feature for newer models only). The information available for each mode depends on the level of calibration done for each mode. The design of the model determines the types of questions and outputs that can be modeled. For example, Metro's model was built to model HOV lanes, unlike JEMnR.

In general, model-wide mode share splits are commonly available and can be evaluated. Origin-Destination information by mode (and possibly by trip purpose) is also a common output that can be requested.

The disaggregate nature of ABM MAZs can better represent short trips that may be made by walk or bike modes. There would be less likelihood of needing to split a zone as compared to a trip-based model.

Some restrictions to be aware of include:

- Metro's model and SWIM are currently the only models that are calibrated to truck counts. SWIM can provide commodity flow in terms of dollars and tons moving by corridor.
- In general walk and bike are not assigned to the network, but zonal production information is available.

9. Other Model Outputs

- Vehicle Miles of Travel (VMT) – as part of the TPR reporting requirement for RTPs and TSPs, VMT per capita is reported for a subset of zones representing the UGB or a specific jurisdiction. VMT per capita (or other measurements of VMT) can be helpful to understand the impacts of regional scenario planning or financially-constrained project lists in TSPs. It can also be used as a data input into other tools to calculate measures such as GHG.

- Travel time – Model travel time can be provided at the link level for preliminary screening, for example for relative comparisons of travel time on key routes between alternatives. Model travel times can be particularly useful for links that are outside the project study area.
- Matrices based data – trip data can be provided at the TAZ or district level broken out by trip purpose. These data are typically summarized graphically or statistically using frequency distributions, charts, or maps. Some examples of matrix trip data available include:
  - Demand
  - Travel time
  - Trip length
  - Mode split
- Zonal summary information
  - Household/demographic information
  - Production/attraction information
- Regional information
  - Accessibility – refer to Chapter 9 for more information.
- Travel behavior information - ABM
  - Household level
  - Person level
  - Trip level
  - Tour level

17.5 Travel Demand Model Applications

The following guidance is primarily intended for analysts who are using travel demand models for facility level analysis, rather than regional analysis.

> *Most travel demand models were developed primarily for use as system planning tools and their traffic volume estimates are not sufficiently accurate to be used as direct inputs into facility-level planning and analysis. It is inappropriate to use raw model outputs as the basis for transportation and land use decisions that require consideration of detailed transportation and land use characteristics such as in analysis software such as Synchro, or in most deterministic, multimodal or microsimulation applications. Therefore, post-processing of model outputs to account for the influence of specific transportation and land use characteristics is mandatory. Methods used for post-processing must conform to procedures found in Chapters 5 and 6.*

The relative difference between the raw model output for two scenarios (e.g., current and future conditions) can be used directly such as for the screening of preliminary alternatives.

Seasonal adjustments are directly applied to the base traffic counts to represent average weekday volumes and should not be applied to model output. Refer to Chapters 5 and 6 for more information

If an official travel demand model exists (ODOT or MPO developed), it should be used as the basis for performing forecasts for plans, project development, and development review. Other considerations include:

- There are federal requirements that a travel demand model be used when an MPO is developing an RTP. Criteria and procedures for air quality conformity modeling are found in the [Clean Air Act Transportation Conformity Rule] [40 Code of Federal Regulations (CFR) Parts 51 and 93].
- NEPA requires that official population forecasts and the latest official financially constrained funded project list are used for land use in the travel demand model. For more information on the NEPA process refer to Chapter 10.
- Metropolitan area (MPO or ODOT developed) travel demand models shall be used for the calculation of VMT per capita to meet TPR-related requirements in OAR 660-012.
- As compared to the use of historical count growth rates; travel demand models can answer questions historical rates can't answer such as changes in policy, network, growth patterns (induced or latent demand), etc. Historical growth rates don't capture changes in trends, such as if UGB is to be expanded.
- Cumulative forecasting is limited to urban areas with generally less than 10,000 in population. Cumulative forecasting is specific to the project it is developed for; it cannot be readily adapted to other projects. Multiple scenarios or multiple purposes require a travel demand model.
- Enhanced zonal cumulative may be used in urban areas with up to 15,000 population. Refer to Chapter 6 for more information.

If the requestor simply needs base/future volume or land use data with no model modifications, previously generated model data are available through the model request process. If no network, land use or zone modifications are needed, previously generated base and future data can quickly be provided. Keep in mind that providing base year land use data (employment specifically) requires a completed confidentiality agreement before the request can be completed.

17.5.1 Typical Model Applications

SWIM model applications are discussed in Section 17.5.4.

1. System Planning: RTP/TSP

In system planning, models can be used to quickly assess the entire MPO/urban planning area which may contain multiple cities and the interactions between them. Use of demand-to-capacity ratios can indicate bottleneck areas or areas that potentially need improvements. Conceptual project scenarios can be added to test impacts on the overall network. These can be bundled into groups of projects for specific objectives (capital projects, multi-modal, mobility, etc.).

Impacts of land use changes can also be tested, such as in a UGB expansion scenario, nodal development, neighborhood urban centers, etc. Transit and other multimodal benefits can be evaluated depending on the detail of the individual networks (i.e. walk, bike and transit) and zone structure. If the model has enough detail, such as economic sensitivities, items like congestion pricing, parking pricing, tolling and travel demand management policies or programs can be evaluated. Scenarios could be developed to test the potential effect of emerging trends and technologies such as CAVs. For example, scenarios could assess the potential effect of CAVs on model outputs with a range of CAV market penetration rates. ABMs typically allow for this additional functionality, depending on the level of effort or calibration.

Models can also be used to create and evaluate accessibility, connectivity, and equity measures. Some operational strategies can be modeled such as TDM or ramp metering. System planning projects that come out of modeling are generally high level such as "Widen to four lanes", or "Add overcrossing", etc. which are consistent with the general level of detail available.

Scenarios can be modeled where the population controls are exceeded: number of households (HH) must be increased or decreased accordingly to balance. A variety of different future land use scenarios can be modeled within the system planning process.

ABMs can model GHG more appropriately than trip-based models by being able to represent individuals with specific vehicle types, powertrains, and vehicle ownership.

Metropolitan travel demand models are the tool of choice for calculating VMT per capita, using the methodology in Appendix 17B, to meet Transportation Planning Rule requirements. SWIM is the preferred model for use to determine latent demand to meet requirements in OAR 660-012-0830. For some "Rule 0830 projects", regional travel demand models, provided land use is modified between scenarios, may be used to forecast latent demand.

2. Air Quality Conformity

Some areas have air quality issues which require them to go through an air quality conformity analysis which requires that improvements on the system not add more emissions than the specific target values. These can be for carbon monoxide (CO) or particulate matter (PM). Trapped PM from woodstoves has been the focus of most Oregon air quality (AQ) issues such as in Grants Pass and Klamath Falls. This application work is an intermediate step (as used as input data to another air quality model) in the overall process and typically requested by DEQ, or a council of governments. TPAU does not do the actual air quality analysis or post-process the speed or travel time data generated.

The overall roadway network, including any improvements, is analyzed by EPA's MOtor Vehicle Emission Simulator (MOVES) emission tool using speed and vehicle miles traveled (VMT) by link as the primary inputs. Project effects need to be balanced to meet the conformity process. Certain projects could lessen VMT and emissions if trips are shortened or mode shifted or allow travel at faster speeds. Conversely, some projects like a new interchange could encourage travel and increase VMT and emissions.

The air quality conformity process typically requires creation of interim year scenarios which requires modifying the network and land use data to:

- Determine compliance with air quality conformity
- Modify regional transportation plans
- Determine impacts of a regional project

3. Facility Plans and Project Development

IAMPs (Interchange Area Management Plans), refinement plans, and modernization projects typically deal with smaller areas or individual facilities or corridors. This type of model application will be generally more specific, rather than across an entire urban area, e.g. adding or modifying roadway connections such as at an existing interchange. Alternative changes to individual facilities can be tested with different link attributes such as speeds or number of lanes or one-way/two-way directions to determine impacts. Land use scenarios with different levels of growth can be evaluated and compared with a baseline scenario for a localized zone or the entire urban area. The use of models for preliminary screening of alternatives is discussed in Chapter 10.

It is important to be aware that when applying an ABM model, the model complexity and the stochastic approach and uncertainty means that individual runs will differ. As with microsimulation, multiple runs will need to be combined and may require post-averaging of run results, adding to the timeline as compared to trip based models.

For congested areas, ABMs allow for some temporal shifting while trip-based models do not, but dynamic traffic assignment (DTA) would be required to fully represent significant congestion (see Chapter 8).

There are a variety of travel demand models that can be used: small city, MPO, or statewide, depending on the project. For example, SWIM could be used to estimate trends and thus impacts in an area that does not have a local travel demand model. Examples include estimating overall truck flow through an area, or highway to highway distribution percentages, such as would be used in long term highway closures.

17.5.2 Model Familiarity and Checking

Model Documentation/Structure

The model documentation and structure should be reviewed by the analyst. The information is primarily available from the model documentation narrative. Based on the information in the narrative, the analyst can obtain the Base and Future Year network and zone plots or GIS layers. More information including how to request model data can be found on the ODOT Planning and Technical Guidance webpage.

The analyst can also work with modeling staff to obtain the data tables containing network and TAZ attributes. Items to review may include:

- Type of model (OSUM, JEMnR, ABM, etc.)
- Existence of multiple model versions to identify the version appropriate for use
- Model Years (Calibrated, Base Year, Future Year, Interim Years)
- Previous scenarios that have been run / tested such as financially constrained or Regional Transportation Plans (RTP).
- Projects included in the scenarios of interest
- Model Calibration Information (Level of detail, peak hour, …)
- Special generators in or near the study area
- Incorporation of large-scale changes in the project area since the base year, either transportation improvements or land uses

Model Representation of Study Area

Travel Demand Models are built and calibrated primarily as system level tools, and generally do not have a high degree of network detail. A given study area may not be represented to the degree of detail needed by the project. Potential study area refinements should be identified and discussed with the modeler. There may be issues within a study area that are significant to the project analysis but were not significant at the regional level the model was built for. Some issues may be adjusted within the model, while others are best handled through post-processing.

The following guidelines are provided to assist the analyst in evaluating the existing model relative to a particular study area and purpose. This should include verifying reasonability and evaluating if the level of representation is sufficiently detailed. The analyst should coordinate with the modeler on any potential refinements identified. Items to review within the project study area are listed as follows:

Network

- Links and Nodes – Review the level of detail of the network components and whether it accurately depicts the road system in the study area. Review for potential need for additional links.
  - The analyst needs to review the network considering what projects are included that may not yet be built. For example, there may be three un-built projects from the TSP included in the future year model. Depending on the year of construction the non-study projects would likely be in the future no-build model runs but the study project would not be included. The study project would only be in a future (build) alternative.
- Centroid connectors – Review the number and connection locations that represent the loading of the trips onto the network. Adjustments or additions may be needed. Additional connectors to different roadways do make a difference. It is undesirable to have multiple connectors to a single roadway section except when windowing or focusing a model. Multiple connectors to the same roadway section split the total volume up and the loading will be dependent on the shortest path.
  - Connectors should be checked visually for the following elements. Connectors represent the local accesses and streets in a model network, so they must represent the loading patterns to the adjacent facilities. Every zone must have a centroid connector, for ingress/egress, connected to the facility or segment. A single segment can have no more than one connector and a zone is limited to a maximum of four connectors. Connectors shall not connect directly to an intersection node as it makes post-processing more complex when dealing with turn movements. Depending on the scenario, connectors can change number and location for a given zone to expedite post-processing.
  - Connectors must have no capacity constraints (Capacity = 9999 in EMME; Visum is automatic default). Connectors must also have applicable modes indicated, directionality (in and out but not always at the same location), and a fixed speed of 25 mph (except at external stations where the speed should represent the facility speed, i.e. 55 mph). Non-transit or non-multimodal networks should only have the auto mode coded. Depending on model approach, transit networks may require transit and walk modes in addition to auto. The walk mode can share or have its own connectors. Connectors must have a realistic link length based on average distance from the center of activity (centroid) to the specific roadway link.
- Nodal Attributes – Review the turn movement restrictions and traffic control type (signalization, stop-controlled, roundabouts, etc.). For ABM models, turn lanes and signal timing parameters should be reviewed and refined if needed.
- Link attributes – Verify facility type, functional class, speed, number of lanes, lane capacity and VDFs. Default link capacities for OSUM and JEMnR models are based on functional class and area type, as shown in Exhibit 17-19.

Exhibit 17-19 Default Model Link Capacity per Lane - Based on Functional Class and Area Type[1,2]

	FC Type	*1 (CBD)*	*2 (CBD Fringe)*	*3 (Urban)*	*4 (Rural)*
Freeway/Interstate	1	1900	1900	1900	1900
Principal Arterial	2	700	800	850	950
Minor Arterial	3	575	625	700	760
Collectors	4	450	500	525	650
Local	5	400	450	500	625
Ramps	30	700	800	850	1000
Centroid Connector & External Stas.	99	Always 9999			

[1]For Oregon Small Urban Models (OSUM) & JEMnR
[2]Similar information for ABM models can be found here.

TAZs – Size and demographics

Local Agencies are responsible for the base and forecast land use data necessary for travel demand modeling. Of these land use data inputs, the most common to focus on are total population, households, and employment by sector (Agricultural, Education, Government, Industrial, Retail, Service and Other).

Zonal data may need to be updated to reflect current conditions within a study area. A discussion with the modeler should determine whether the model is sensitive enough to reflect the differences desired. Items to review include:

- Population and number of households, existing and future. Population is typically constrained by control totals obtained from the PSU Population Research Center. However, scenarios can be modeled where the population controls are exceeded. Population totals are usually provided at city/UGB level and typically not the model level. When population is increased the number of households also needs to be increased. Population by zone is the sum of the average household size by zone multiplied by the number of households by zone and added to the group quarters population for that zone.
- Number and type of employees, existing and future – note that a confidentiality agreement may need to be signed before the existing employment information can be shared with the analyst. There are no specific controls or constraints on changes to employment, but it is important to be aware that certain employment categories have bigger impacts on the results than others. For example, retail/service has more regional impact than agriculture. The total employment must equal the sum of the employment subcategories (government, retail, etc.). Further discussion on the proper way to address significant or large land use changes can be found in the Modeling Procedure Manual for Land Use Changes (MPMLUC).

- Size and detail of zones – some large zones may need to be smaller to better represent travel patterns within a given study area. For example in a large mix-used zone there may be a need to understand trips by all modes between the different uses. By splitting the original TAZ or MAZs, the intra-zonal trips become inter-zonal ones that can be reported. Also, on high planning level studies zones may be aggregated into districts like for travel patterns across an entire community.
- Trips generated and distributed are consistent with the demographics of the zone.

Checking Model Application Output(s)

The results of a model run within the study area should be reviewed by the modeler and the analyst to determine if the model behavior is reasonable and logical. The modeler has a protocol for validation including runs or checks that all steps of the model are performing reasonably. This is to validate that model outputs within the study area makes sense. There may be coding errors or anomalies that show up in the output that should be corrected. For congested study areas testing might be needed to verify that outputs are reasonable. The analyst can assist the modeler with knowledge of the area, project and specific issues.

The analyst should understand how well the Base Year model corresponds to the Existing Year volumes developed from study area traffic counts and whether deviations may be coding errors which can subsequently be corrected. The Base Year model volumes should be projected to the existing year to compare to the count-based Existing Year volumes.

Future year model assignments should also be reviewed based on expected changes and may be compared to historic trend forecasting. Changes not meeting expectations should be examined in terms of land use, socio-economic data and network coding for potential explanations. Any identified disparities should be documented.

Different model application techniques are useful in reviewing model behavior, including select-link and select-zone plots. The analyst should check whether results are reasonable and logical. Any apparent anomalies should be discussed with the modeler and explanations should be documented. The modeler should also be checking the outputs for reasonableness. For example, changes to land uses or the network may have occurred since the model was developed. For some disparities such as where model and actual travel paths are significantly different and unexplained, it may be appropriate to post-process the model assignment by manually re-assigning trips.

17.5.3 Model Modifications

1. Modifying link attributes or adding or removing a link

Modifying links is one of the most basic (in whole or part) model applications in assignment software. This type of application typically includes modifying attributes. Typical examples might be to assess the:

- Impacts of adding or removing a roadway or a travel lane which might require adding and deleting links and/or modifying attributes such as speed or capacity.
- Impacts of converting to or from a couplet (one-way to two two-way links)
- Impacts of a speed zone change
- Impacts of work zones (short/long term effects) through reduced number lanes, total closure, and/or reduced capacity
- Impacts of adding links specific to transit, bike and walk to address new mixed-use development or transit-oriented development (TOD) that might create new pedestrian pathways
- Impacts of adding ramp metering by reducing the capacity attribute at an on-ramp

2. Modifying, adding or deleting nodes

Modifying, adding or deleting nodes is another basic model application in assignment software. This type of application typically includes any kind of link changes as adding new links will require adding or removing links. Additional nodes may be required to properly shape a roadway. Typical examples of modifying nodes are done to assess the:

- Impacts of adding or modifying intersection traffic control
- Impacts of turn restrictions such as one-way or right-in/out
- Impacts of medians (turn restrictions)
- Impacts of additional TAZ connectors (changing the loading location for a TAZ)

3. Modifying connectors or partitioning a zone

Modifying or adding zones may be needed for applications involving new developments, Urban Growth Boundary (UGB) expansions, mixed use subdivisions, Transit Oriented Developments (TODs) that require partitions to keep zones homogeneous. Connectors must be managed anytime changes are made to the TAZ or MAZ structure. Connectors may need to be moved, deleted, or added to depending on the type of change to the TAZ or MAZ. Some typical examples are:

- Zone split for new development to allow quantification of trips between zones (expose the intra-zonal trips)
- Adding zones for a UGB expansion
- Districting (grouping) of TAZ’s to determine large scale origin-destination (OD) flows or trip patterns
- When a new roadway will split/change the travel patterns for a large zone.
- Splitting a transit-oriented development to help show walk trips versus vehicle trips.

4. Modifying land use attributes

Land use attributes are typically compiled in an spreadsheet. This can include changes to household or employment categories. All land use changes must be submitted as part of the completed model application. Typical examples are for assessing the:

- Impacts of zone changes
- Impacts of special generators
- Impacts of different land use scenarios for a local jurisdiction or landowner request e.g. TIAs
- Impacts of parking pricing scenarios

5. Modifying/adding transit services

Transit services are only modeled in MPO areas (JEMnR or ABM models). Transit networks are separate from auto networks and may involve bus routing. When adding transit to a network in JEMnR, the walk attributes (access to transit) must also be addressed. Some typical examples include:

- Impacts of adding or removing transit routes, transit links
- Changes to transit headways
- Network-wide impacts of adding transit centers, park and rides, stops (locations only - not for specific routes)
- Updating transit or master plans
- Quantifying Vehicle Miles Traveled (VMT) reductions and other strategic policies
- Transit signal priority (ABM or Metro model or focused trip-based model)
- ABM modeling of travel demand policies or programs

6. Subarea (windowing and focusing) modeling

Sometimes more detail is needed within a certain area such as a downtown to improve the post-processing of link and turn movement volumes. This may involve creating more zones or adding more details for zone, link and node attributes. A typical example would be a downtown refinement plan involving investigation of couplets, multimodal improvements, intersection traffic control, or modified intersection lane configurations. Complex transportation impact and project analyses may require use of subarea modeling. Mesoscopic modeling including windowing and focusing of travel demand models is addressed primarily in Chapter 8.

There are two different ways this can be done, either through focusing or windowing. If the subarea is done through focusing where detail is added within the model, the subareas can be integrated with the rest of the model. This detail can be smaller zones, additional centroid connectors, modifying VDFs and nodal delay, adding more network links and refining network attributes. The area needs to be large enough to minimize border effects from transitioning the level of detail in adjacent zones/areas (altering the assignment in the area around the focused area). The focused area for this reason should be larger than the study area. This focusing may be done by the modeler or the analyst (if they have the software and expertise).

The windowing process results in cutting out an area from the model. This windowed out area cannot be added back to the original model. The difference from focusing is that trips that cross the windowing cutline are held constant from those in the original scenario. Many of the same details as used in focusing can be used in this technique. Other than physically, "cutting out the area", this work is typically done by the project analyst rather than the modeler. The model request must include an exhibit indicating the boundaries of the cut area. The analyst would use other forecasting tools like Visum to make the refinements as well as reduce the post-processing.

Some models have bike and walk networks (including off-street paths) which would potentially allow for a windowing or focusing effort to develop a bike trip assignment. Calibration (by mode or by route etc.) would require significant inventorying effort including bike counts. Quality of service could be incorporated by adding attributes such as Level of Traffic Stress (LTS) data. Some models can also capture the trip purpose such as recreation, school or work trips.

7. Creation of Interim, Reference, or Future Year Scenario

Models initially have a single base and future scenario. TSP, air quality conformity, or regional projects/plans planning horizon years often do not line up. Volumes typically can be extrapolated, at most five years beyond the base and future year scenarios. Beyond five years, the creation of new reference or future year scenarios is necessary. This work does not involve calibration or validation, so does not replace the calibrated scenarios or constitute a model update. The requestor should work with the model team to develop all zone, network, and land use data to support the creation of these types of scenarios. These may include different network assumptions (e.g. unpaved roads, important for air quality conformity models) from production model. In summary, these scenarios will be created when:

- Planning horizon is greater than five years beyond the future year scenario or available years do not match desired planning horizon such as a TSP, RTP etc.
- Air quality conformity analyses are being done, which will typically require interim years if not within an MPO area

17.5.4 SWIM Model Applications

Since its original creation in the late 1990's SWIM has matured beyond the higher-level policy scenarios described in Chapter 7. Over the past two decades, the types of uses for SWIM has broadened and will likely continue to evolve. A current list of all the ways SWIM has been used is listed here: https://github.com/tlumip/tlumip/wiki/Applications.

SWIM applications have started to fall into the following categories:

- Large statewide policy impacts (see chapter 7 for examples)
- Commodity Flow Analysis for Policy or Specific Facilities
- Resilience testing relating to road failure or work zone closures
- Volume growth or distribution estimates for areas that do not have a travel demand model
- Providing flow information in and out of defined areas, such as external models for urban area models.
- Intercity passenger travel (vehicle, rail, transit)
- Forecasting latent demand to meet requirements of OAR 660-012-0830(5)(c)

SWIM has also been used to develop focused area models; an example is the focused model developed for Marion County. SWIM has potential to provide similar focused models for smaller cities where the main questions are on State highways or other higher functional class roadways. This is an option to consider where a full OSUM development might not be worth the time / cost.

17.5.5 ODOT Model Request Process

Model requests are a collaborative process between the requestor and the modeler. It is important for the requestor and modeler to discuss the nature of the request to determine the needed approach. Model requests range from very basic, using available information; to very complicated, requiring extensive calculations and processes. If the request includes obtaining a copy of the base year employment data, completed confidentiality agreement is required before the request will be processed. A map of available transportation models in Oregon is available on the Planning Section website on the Technical Tools webpage.

For application of ODOT models, a "Request for Travel Demand Model Run" form must be submitted. The form serves as a guide to assembling the information needed in order to process the requested model runs. It is highly recommended to discuss the request with modeling staff prior to submittal since the modeler needs to understand the study purpose and objectives to help identify the best model application methodology, the relevance of model variables, or even whether a model application is necessary. The requestor needs to understand the model, its limitations, level of detail, sensitivity to variables, to obtain the appropriate output needed for the project and to properly interpret the model results.

Several items need to be discussed and clearly determined and specified on the request form, such as:

- Name and version of the model
- Model years requested
- Scenarios requested
- Study area
- Projects to include
- Network changes to include

- Land use changes to include
- Project alternatives to be evaluated
- Output requested, such as:
    - Volume plots – daily and/or specific hour (peak)
    - Bandwidth plots
    - Select link or select zone runs
    - Difference plots
    - Demand to capacity ratio (DCR) plot
- Output format (file type)

A map should be attached to the request illustrating locations of changes as described on the request form. Model parameters must be used when specifying changes, such as using "From Node - To Node" for changes to links. New links and nodes need to have attributes specified (speed, number of lanes, functional class, capacity, and traffic control). For most requests, changes should be listed separately for each scenario on attachments.

Changes to land use must include:
- TAZ number
- Desired splitting of zones
- Relocation of centroid connectors.
- Population change
- Change in number of households
- Employment change by industry category

For land use changes, see the Modeling Procedures Manual for Land Use Changes .

Appendix 17A – Network Count Attribution

Appendix 17B – Calculating Vehicle Miles Traveled (VMT) - Overview and Procedures

REFERENCES

1. Horowitz, Alan, et al. "Analytical travel forecasting approaches for project-level planning and design." No. Project 08-83. 2014.
2. Systematics, Cambridge, Inc., "NCHRP Report 716: Travel Demand Forecasting: Parameters and Techniques." Transportation Research Board of the National Academies, Washington, DC (2012).