MODELING PROCEDURES MANUAL

FOR LAND USE CHANGES

Oregon Department of Transportation
Transportation Planning Analysis Unit

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MODELING PROCEDURES MANUAL FOR LAND USE CHANGES

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A. INTRODUCTION

There is little information available about commonly accepted practices for the application of travel models and model output data for the analysis of transportation impacts of proposed land use changes. The purpose of this manual is to provide ODOT staff, local agencies, consultants and others with information about how to use ODOT's travel forecasting models to analyze these impacts.

Improper and inconsistent application of travel forecasting models and model output data can result in information that misrepresents potential impacts. This can create confusion among those involved in the technical and decision-making process, and lead to poor decisions regarding proposed land use changes that will degrade the value of investments in Oregon's transportation infrastructure. This manual will serve as a reference document to provide standardized and consistent guidance on when and how to apply models and how to use model output to analyze the impacts of proposed land use changes.

To prepare this manual, a technical advisory committee comprising model developers and users was formed to discuss and resolve issues and to provide input on a reasonable set of guidelines.

The manual is structured from the perspectives of:

1. A model user who is considering how to best apply a model to produce data for the analysis of transportation impacts, and
2. A transportation analyst who is trying to decide whether a model is the appropriate tool, and if so, what types of output should be used.

The manual sections correspond to a logical sequence of questions that a model user or analyst may have regarding the use of a model for the analysis. By applying the guidelines within each section to the specific needs of the analysis, the manual user is taken through a step-by-step process for deciding whether to use a model and if so, how to do this in the appropriate way.

The manual is divided into the following sections:

A. Introduction

B. What are the Questions to be Answered About the Transportation Impacts of a Proposed Land Use Change?

This section helps the analyst frame the questions to be answered about the impacts of a proposed land use change. Several important questions common to many proposed changes are discussed, including consistency with Transportation System Plan (TSP) population and employment totals, consistency with local transportation plans, effects on ODOT facilities, and environmental impacts.

C. What is a Travel Forecasting Model?

Background information is provided about various aspects of travel forecasting models, such as model components and input data, model development, accuracy of model outputs, and the use of model outputs with other tools.

D. Can a Travel Forecasting Model be Used to Help Answer the Questions?

Criteria are presented for determining whether a model is the appropriate tool for analyzing a specific proposed land use change. One set of criteria can be used to decide whether a model is applicable for the analysis, while a second set of criteria answer the question about whether a model is the best tool for the analysis.

E. What Types of Output are Available to Help Answer the Questions?

The different types of model output available for the analysis of various proposed land use changes are described. Examples of outputs that may be used to answer the questions outlined in Section B are provided, as well as information on how the outputs can be organized by geographic scale, network scale, time period, and travel market segment.

F. What is the Appropriate Way to Apply the Model to Produce the Output?

Model application guidelines are presented for four types of proposed land use changes: site development proposals, zoning changes, comprehensive plan updates, and land use changes within interchange management plan areas.

G. How Should the Model Output be Used?

Guidelines about how to use model output data for analysis and presentation purposes are provided.

B. WHAT ARE THE QUESTIONS TO BE ANSWERED?

The first step in identifying the transportation impacts of a proposed land use change is to determine what questions need to be answered, i.e., what potential impacts need to be analyzed. The questions will vary depending on the character of the land use change, because an impact that may be important for one type of land use change may not be relevant for another. For example, the change in area-wide vehicle miles traveled (VMT) may be a significant issue for a large-scale comprehensive plan amendment, but probably would be very small for a site development proposal.

Initially, all questions should be considered, whether or not a model could be used to help answer them. In a subsequent step of the process, criteria can be applied to determine which questions may be answered either directly or indirectly with a model.

Several important questions common to many proposed land use changes are discussed in detail below.

Consistency with TSP Population and Employment Totals

A key requirement of the Transportation Planning Rule (TPR) is that future development and the planned transportation facilities included in the local TSP should be consistent with one another. Consistency ensures that the capacity of the future transportation system is not exceeded by the trips generated by development. The level of future development assumed in a TSP is reflected in the area-wide population and employment totals used to develop it. If a proposed land use change causes the totals to be exceeded, the associated system-wide travel demand may not be consistent with the level of demand assumed in the TSP. This could result in the future transportation system not having enough capacity. To avoid this, it is important that proposed land use changes adhere to the TSP population and employment totals.

The size of a proposed land use change relative to the TSP population and employment totals is also an important consideration. If the TSP totals are exceeded, then the travel forecasts for the proposed change would not be consistent with the provisions of the TPR or the forecasts used to develop the TSP.

Several questions that may need to be answered about the relationship between the proposed land use change and the TSP population and employment totals are discussed in the following sections.

Would the Proposed Land Use Change Create a Jobs-Housing Imbalance?

An important determinant of area-wide travel patterns, particularly in small and medium-sized communities, is the relationship between total households and total employment. Areas with significantly more households than employment tend to have higher proportions of internal-external trips, as workers and shoppers travel to employment and retail centers outside of the area. The opposite is true in areas with greater employment than households, as workers and shoppers are drawn to employment and retail centers within the area from external locations. Areas with more balanced households and employment tend to have higher percentages of internal-internal trips.

Large proposed land use changes consisting primarily of employment with very few households or a large number of households with little or no employment may result in future travel patterns that are significantly different than the existing trip distribution or the future distribution reflected in the TSP forecast.

Determining whether a land use change will create an imbalance relative to the jobs-housing ratio assumed within the TSP is important for two reasons:

- If the land use change is implemented as proposed, then the jobs-housing imbalance could result in the creation of longer-distance trips having origins or destinations outside of the area, with a concentration of these trips on state highways. This would be an undesirable outcome with regard to minimizing VMT growth and reducing environmental impacts.
- If the transportation impact analysis is conducted based on traffic forecasts that reflect the jobs-housing imbalance, then the analysis will not accurately identify the true impacts of the change.

In order to determine if a land use change would result in an imbalance, the regional jobs-housing ratios with and without the change should be compared. The "without change" case is defined as the ratio of total employment to total households contained in the TSP land use data. This reflects the locally adopted land use policies regarding regional employment and households. The comparison of the jobs-housing ratios serves as an indicator of whether the proposed change is consistent with the allocation of future land uses reflected in the TSP.

If the jobs-housing ratio with the proposed change varies by more than ± 5% from the "without change" ratio, then it is likely that the proposed change is not consistent with the established allocation of future land uses. The development of travel forecasts based on such a scenario may lead to inaccurate estimates of future volumes that could bias the transportation impact analysis.

TPAU staff will be responsible for comparing the jobs-housing ratios. This will be done by:

1. Calculating the total households and total employment contained in the TSP horizon year scenario.
2. Calculating a "without change" jobs-housing ratio based on the household and employment totals from Step 1.
3. Adding the number of households and/or employment for the proposed change to the household and employment totals from Step 1.

4. Calculating a "with change" jobs-housing ratio based on the household and employment totals from Step 3.
5. Calculating the percentage difference between the "without change" and "with change" ratios.

The jurisdiction in which the proposed land use change is located will be expected to provide the data for the proposed change. This will include the number of dwelling units and/or building square footages. TPAU staff will then convert these quantities into estimates of the number of households and/or employment.

If the transportation impact analysis will be performed for an interim year, then the household and employment totals will be estimated using one of the methods described in Section F.

If the difference in the jobs-housing ratios exceeds the ± 5% limit, then TPAU will inform the local jurisdiction about the results and the likelihood of an unrealistic travel forecast.

It is not the intent of ODOT to try to influence local land-use decisions through the comparison of the "without change" and "with change" job-housing ratios. The only purpose of this check is to determine whether the proposed land use change is reasonably aligned with the allocation of future land uses reflected in the TSP and in so doing, help ensure the development of reasonable travel forecasts.

Would a Jobs-Housing Imbalance Generate Supporting Development?

A proposed land use change with a large imbalance between households and employment may not truly represent the full effects of the change on local development. An example of this would be a proposed change that includes a significant increase in the amount of local employment without an increase in the number of households. In reality, such a change would likely induce at least some growth in the number of local households. Failure to include other development associated with a land use change could misrepresent the actual impacts of the change on the transportation system.

If a proposed land use change will create a jobs-housing imbalance because the supporting development has not been included as a part of the proposal, then the imbalance should be addressed prior to developing the travel forecasts. Once a local jurisdiction has been informed of an imbalance by TPAU, it is the responsibility of the jurisdiction to provide TPAU with a reasonable set of land use adjustments that resolves the problem.

Three possible adjustments that can be made to the future land use assumptions are:

1. Including the supporting development by increasing the number of households (or employment) within the local area (i.e., the UGB). With this option, the total number of households or employment within the local area would be increased by the amount necessary to restore the original job-housing ratio (i.e., the ratio

without the proposed change). The local jurisdiction would determine where the additional households or employment would be located and provide revised land use data to TPAU. This should be coordinated with DLCD because it would result in an increase in the total number of households or employment within the local area.

2. Reflecting the supporting development by increasing the total of households (or employment) outside of the local area. With this option, the total number of households or employment outside of the local area would be increased by the amount necessary to offset the change in the jobs-housing ratio within the local area. This would be the same increase as with the first option, but would occur outside rather than inside the local area. To reflect this in the model, the number of internal-external (I-E) or external-internal (E-I) trips would need to be adjusted upward by the appropriate amount.

   If this option is followed, it would be the responsibility of the local jurisdiction to obtain a statement from the regional coordinating agency (either the county or MPO) that the assumed household or employment increase is consistent with growth expectations for the area outside the local jurisdiction's UGB.

3. Reducing number of households or employment for other locations within the local area by an amount equal to the increase for the proposed change, so that the imbalance is eliminated. With this option, reducing the growth in households or employment in other locations by an amount equal to the increase for the proposed change would maintain the future jobs-housing ratio as well as the regional household and employment totals. The local jurisdiction may decide where the reductions should occur and provide the revised land use data to TPAU. If the local jurisdiction does not do this, TPAU will reduce the growth in other locations in proportion to each location's share of the total growth without the proposed change. This will also be the default procedure if the local jurisdiction does not provide TPAU with revised land use assumptions using one of the three options.

   If the third option is followed, and the proposed change accounts for over 50% of the total planned growth in households or employment for the local area, then the local jurisdiction should coordinate with the Department of Land Conservation and Development (DLCD) to ensure that the resulting distribution of growth is reasonable. An example of an unreasonable distribution of growth would be if the number of households or employment for the proposed change was greater than the total increase for the local area without the change, there would be negative growth in other locations.

B. WHAT ARE THE QUESTIONS TO BE ANSWERED?

When Should TSP Population and Employment Totals Be Modified?

If a land use change does not adhere to the TSP population and employment totals, consideration should be given to adjusting the existing totals.

Ultimately, this decision needs to be made by the local jurisdiction, in coordination with DLCD. The key question is whether the proposed land use change can be considered a part of the projected growth included in the future land use assumptions for the TSP or if it will be additional growth, beyond what was anticipated when the future land use assumptions were established.

The example above in which the number of households or employment for the proposed change exceeds the total growth for the entire area is a clear case in which at least a portion of the additional households or employment (the portion that is greater than the total growth for the area) is not included in the original growth assumptions. Even if the additional population or employment is lower than the total growth for the entire area, however, it may still be considered additional growth beyond the existing TSP total if the proposed change is for a type of development that was not originally anticipated. An example of this would be the establishment of a new, specialized industry in a local area that was not anticipated at the time the future land use assumptions were developed.

The local jurisdiction should consider modifying the TSP totals whenever:

1. The population or employment for a proposed change that is not accounted for within the existing TSP total exceeds the projected growth for the TSP total by 10% or more; and
2. The proposed land use change is approved by the local jurisdiction and DLCD.

This adjustment would help ensure that the proposed change is reflected in future planning efforts and would serve as an acknowledgement that the TSP may need to be updated to be consistent with the revised total.

A local jurisdiction may request the preparation of travel forecasts by TPAU for purposes other than the identification of transportation impacts of a specific land use change. These could include the investigation of the effects of land use policy changes, UGB amendments, or changes in the distribution of land uses.

The differences between the land use assumptions for exploratory analyses and the existing TSP population and employment totals are not as critical as the differences with proposed land use changes, because the results of the analyses will not be used to make decisions about land use changes that may impact the transportation system. Therefore, requests for travel forecasts for these purposes will be handled differently by TPAU than the procedures described in this manual. The exploratory nature of the analyses needs to be clearly understood and agreed to by the local jurisdiction and TPAU prior to the preparation of the forecasts, however.

Consistency With Local Transportation Plans

As described in ODOT's *Development Review Guidelines*,[1] the standards used to determine whether the transportation effects of a proposed land use change are consistent with the functional requirements for transportation facilities are linked to the approval criteria used by local jurisdictions when reviewing land use/development applications. The approval criteria are contained within the land development regulations that implement the local comprehensive plan. Local jurisdictions must make findings of compliance with these regulations to support the approval of most land use actions.

Although land development regulations vary from jurisdiction to jurisdiction, most contain approval criteria that require adequate public infrastructure to support proposed land use changes. In the case of transportation facilities, this relates to the levels of mobility and safety of a facility with the additional traffic generated by a proposed change.

Performance standards to assess the adequacy of mobility and safety are contained in local TSPs. For roadways, these standards typically measure performance in the areas of capacity and level of service (LOS), safety, traffic operations, geometrics, and access spacing. LOS standards for state highways must reflect the mobility standards contained in the Oregon Highway Plan,[2] expressed as maximum volume-to-capacity (v/c) ratios by facility and area type. Access spacing standards for state highways must reflect the provisions for access management contained in ORS Chapter 374 and the Access Management Rule (OAR 734, Division 051), which define ODOT standards and procedures to manage access to state highways to the degree necessary to maintain functional use, highway safety, and preservation of public investment.

For specific types of land use changes, the performance standards contained in TSPs are used to determine whether a change would, as defined in the TPR, "significantly affect" an existing or planned transportation facility. These changes include amendments to a functional plan, an acknowledged comprehensive plan, or a land use regulation. As defined in Section 660-012-0060(1) of the TPR, a change of this type significantly affects a transportation facility if it would:

1. "Change the functional classification of an existing or planned transportation facility;
2. Change the standards implementing a functional classification system; or
3. As measured by the end of the planning period identified in the adopted TSP:

    - Allow land uses or levels of development that would result in types or levels of travel or access that are inconsistent with the functional classification of an existing or planned transportation facility;

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[1] Oregon Department of Transportation, Development Review Guidelines, (2005)

[2] Oregon Department of Transportation, 1999 Oregon Highway Plan, (2006)

- Reduce the performance of an existing or planned transportation facility below the minimum acceptable performance standard identified in the TSP or comprehensive plan; or
- Worsen the performance of an existing or planned transportation facility that is otherwise projected to perform below the minimum acceptable performance standard identified in the TSP or comprehensive plan".[3]

If a local jurisdiction determines that there would be a significant effect, it is required to "put in place measures to assure that the allowed land uses are consistent with the identified function, capacity, and performance standards of the facility." These include:

- Adopting measures that demonstrate consistency between the allowed land uses and the transportation facility;
- Amending the TSP or comprehensive plan to provide improvements adequate to support the proposed land use change;
- Altering land use types or densities to reduce auto travel demand and meet travel needs through other modes;
- Amending the TSP to modify the planned function, capacity, or performance standards of the transportation facility; or
- Providing other measures as a condition of development, including transportation system management measures, demand management, or minor transportation improvements.

ODOT Asset Management

One question of particular interest to ODOT is the effects of proposed land use changes on ODOT facilities. Specifically, would a land use change have the effect of shortening an asset's life cycle?

Roadways and structures are the primary ODOT asset categories affected by the additional travel from new development. The effects of development are determined both by the volume and type of traffic (auto vs. truck). The additional traffic can have negative impacts on these assets by accelerating their rate of deterioration as well as their design obsolescence.

The rate of deterioration is determined primarily by truck volume. Trucks account for the majority of pavement wear, which increases exponentially with axle weight and the number of axle loadings. Truck traffic also results in significant damage to highway bridges. Damage typically occurs within the bridge deck and superstructure elements, resulting in accelerated maintenance, rehabilitation, or replacement work to keep structures at an acceptable service level.

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[3] Oregon Land Conservation and Development Department, OAR 660-012-0060, (2008).

The additional traffic volume from new development can accelerate the rate of design obsolescence of roadways and structures by creating deficiencies in capacity, safety, traffic operations, and geometrics prior to the end of a facility's expected life cycle. Examples of volume-related deficiencies in each of these areas include:

- Capacity – Inadequate freeway interchange configuration.
- Traffic operations – Lane modifications required to accommodate increased weaving volumes.
- Safety – Addition of traffic to an existing safety problem location.
- Geometrics – Bridge widening due to increased traffic volume.

Several traffic flow measurements may be applied for the "with" and "without" land use change scenarios to determine if a proposed change would lead to inefficient utilization of ODOT assets. These are:

- Total traffic volume by time period (daily, peak hour)
- Traffic volume by vehicle type (truck vs. auto)
- Quality of flow (LOS, volume/capacity ratio)

Environmental Impacts

Large proposed land use changes, such as comprehensive plan amendments, zoning changes, or large commercial developments, may have significant air quality and noise impacts due to increased traffic volumes. Depending on the size of the proposed change, the size of these impacts may range from small-scale "hot spots" to area-wide impacts. Although air quality and noise analyses currently are not conducted for proposed land use changes, model volumes could be used to support the development of vehicle trip estimates for land use changes that may be needed as input to vehicle emissions and noise prediction models.

To facilitate air quality analysis for area-wide studies, such as the TIP/Air Quality Conformity Determination ODOT developed the "calculate emissions in R" (cER) program. cER produces estimates of vehicular emissions for various types of pollutants based on emission rates developed with the Mobile 6.2 software package. Inputs to the program include network link data, such as volume, capacity, length, and facility type, and origin-destination trip data for a specified analysis year and time period (see program flow chart in Appendix B).

The required inputs for ODOT's noise analysis procedure are described in ODOT's *Analysis Procedures Manual*[4] (APM). The traffic inputs for each link include:

- Length
- Total volume for the peak hour and peak truck hour

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[4] Oregon Department of Transportation, Analysis Procedures Manual.

- Volume by vehicle class (auto, heavy truck, and medium truck) for the peak hour and peak truck hour
- Speed

To apply this procedure, existing traffic volumes are obtained from traffic counts and speeds are assumed to be either posted speed limits or operating speeds. Future link speeds are calculated within a special program.[5]

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[5] The EISBase program is used to produce final link volumes and speeds for all noise analysis scenarios. See ODOT's *Analysis Procedures Manual* for a description of this program.

C. WHAT IS A TRAVEL FORECASTING MODEL?

A travel forecasting model is a set of sequential models linked by their inputs and outputs. Each model in the set attempts to replicate a particular aspect of travelers' decision-making behavior. This is done with mathematical equations that represent the relationship between the behavior that is being modeled and the variables that explain that behavior. An example of this is the trip generation model, in which the number of daily trips generated within an area is estimated based on the number of households by household category (size of household, income level, number of workers, etc.).

The following sections provide information about the individual model components, as well as model accuracy, data needs and resolution of model output, model calibration and validation, and the use of model output with other analysis tools.

Model Accuracy

There can be significant variation in the accuracy of model output depending on the scale of the geographic area and the length of the time period being considered. Typically, the accuracy of the output increases with the level of geographic aggregation and the length of the analysis period. For example, region-wide VMT estimates are usually more accurate, in relative terms, than VMT estimates for a small subarea of the region. Likewise, travel volume estimates for the daily time period tend to be more accurate than volume estimates for the peak hour or peak period.

The same is generally true regarding the accuracy of model output for various facility types and levels of facility aggregation, i.e., the higher the facility type and the greater the level of aggregation, the more accurate are the estimates. For example, freeway volume estimates are usually more accurate than those for local roads, and screenline volumes are more accurate than those for individual roadway links which, in turn, are more accurate than estimates of intersection turning movement volumes. Therefore, varying accuracy by geographic scale and time period is an important consideration in the use of model output for the analysis of proposed land use changes.

Model outputs commonly used in transportation impact analyses are network traffic volumes (link or screenline) and VMT estimates. Screenline and link volumes can be used for the analysis of area-wide and corridor level impacts, while interchange and local area impacts are typically analyzed using link volumes only.

Because model performance can vary greatly, the general level of accuracy of these outputs can best be described in terms of model validation targets. For screenlines, ODOT has established a validation target of ± 10% for AM and PM peak hour volumes.[6] For peak hour link volumes, ODOT has defined the following targets:

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[6] Oregon Department of Transportation, Travel Demand Model Development and Application Guidelines, (1995)

- 75% of freeway link volumes within ±20%;
- 50% of freeway link volumes within ±10%;
- 75% of major arterial link volumes with ≥10,000 vehicles per day within ±30%; and
- 50% of major arterial link volumes with ≥10,000 vehicles per day within ±15%.

FHWA has recommended the following validation targets for daily link volumes, based on facility type and volume range:

Table 1
FHWA Validation Targets[7]

Facility Type	% Error
Freeway	± 7%
Major Arterial	10%
Minor Arterial	15%
Collector	25%

AADT	% Error
<1,000	± 60%
1,000 – 2,000	47%
2,500 – 5,000	36%
5,000 – 10,000	29%
10,000 – 25,000	25%
25,000 – 50,000	22%
>50,000	21%

For VMT, FHWA recommends that area-wide VMT estimates should be within 5% of the observed values.

Although non-auto mode shares and transit line boardings may also be used to assess the transportation impacts of a proposed land use change, it is difficult to know the accuracy of these outputs because the model is typically calibrated at the system level only for the non-auto modes.

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[7] USDOT Travel Model Improvement Program, Model Validation and Reasonableness Checking Manual, 1997.

Data Needs and Resolution of Output

Data Needs

There are two primary types of data required for developing and applying models. Model development, which includes the estimation, calibration, and validation steps (discussed below), relies on observed travel data. At a minimum, this includes link traffic counts to determine if the model is adequately replicating existing volumes. These can be used individually to validate the model's traffic assignment results or they can be aggregated to the screenline level to check the accuracy of area-to-area travel flows. Other observed travel demand data that are helpful for assessing area-to-area travel flows are household travel survey data, origin-destination survey data, and Census Journey-to-Work data.

If the model contains a mode choice component, observed values of area-wide modal shares are also needed to calibrate the mode choice model. Link travel speeds may be useful for the adjustment of the model's VDFs.

In addition to the standard model inputs required to apply a model for any forecast, the inputs needed for a proposed land use change are:

- Estimates of the number of households and/or employment by type associated with the proposed change; and
- Any network changes that may be needed to accommodate the proposed change.

If the initial land use estimates for the proposed change are expressed in quantities, such as the number of dwelling units or building square footages, these need to be converted to the number of households and employment by type for input to the model. If changes are needed to the future transportation network to support the proposed land use change, these need to be coded within the model's network. The procedures for preparing project-related land use data and network changes are described in Section F.

Resolution of Output

The usefulness of a model in general and, specifically, for analyzing the transportation impacts of land use changes, depends heavily on the level of resolution of the model output as well as its accuracy. The geographic resolution of the output data is determined by the level of detail used to represent the transportation network (number of nodes and links and their attributes) and land use (number of transportation analysis zones, or TAZs). The resolution of travel demand is determined by how finely the travel demand market is segmented within the model by trip purpose, time-of-day, and socioeconomic category. The accuracy of the output is determined both by how well the model has been calibrated and validated and the accuracy of the model input data.

The level of network detail within most of ODOT's models includes facilities with a functional classification of collector or higher. In some cases, local roads that function as collectors or provide important local area connections are also included. A general rule of thumb is that the network should include all facilities with a functional classification one level below the lowest classification for which forecasts are to be produced. For the zone system, the level of detail needs to be consistent with that of the network to ensure accurate loading of trips onto the network. As an example of an MPO model, the Corvallis Area MPO (CAMPO) model network contains roughly 1,100 nodes, 4,000 links, and 360 TAZs. The CAMPO model network and zone system are shown in Figure 1. Models for non-MPO areas typically have smaller networks and TAZ systems. For example, the Grants Pass model has 825 nodes, 2,600 links, and 265 TAZs.

With many models, the network and zone system are defined in enough detail to produce output at the level of geographic resolution required to support the analysis of most proposed land use changes. There are some cases, however, where a greater level of detail may be needed. This may be because a proposed land use change is located near the fringe of the modeling area where the model network is coarser and TAZ sizes are larger, or because the size of the proposed change is small enough that it could not be differentiated from the surrounding area without disaggregating the zone system and refining the network. In these instances, a special model application technique called focusing can be used to bring the model into a higher level of resolution in the area of interest. This technique is discussed in Section G.

The resolution of travel demand reflected in the model output is determined by the internal structure of the model components. Within all of ODOT’s models, travel demand output is produced by trip purpose and time-of-day. An example of output by trip purpose is trip matrices, which contain the number of person trips or vehicle trips between each TAZ pair. This information could be used to identify the composition of trips produced by or attracted to a proposed land use change. Output by time period includes trip matrices as well as link volumes, which could be used to determine differences in the impacts of a proposed change throughout the day. Within ODOT’s MPO models, trip matrices are also produced by income group. The relative accessibility of a proposed development for different income groups could be analyzed with this data.

Model Components

ODOT has developed models for the Corvallis, Rogue Valley, and Bend area MPOs and smaller urban areas throughout the state (see Figure 2). All of the models were developed based on two prototypes, called JEMnR (Joint Estimation Model in R) for MPO areas, and OSUM (Oregon Small Urban Model) for small urban areas. Because they were developed using prototypes, all of the models within each class share the same structure. The major components or modules of the MPO models are:

- Pre-generation
- Trip generation
- Trip distribution
- Mode choice
- Time-of-day factoring

Figure 1
MPO Model TAZ System and Network

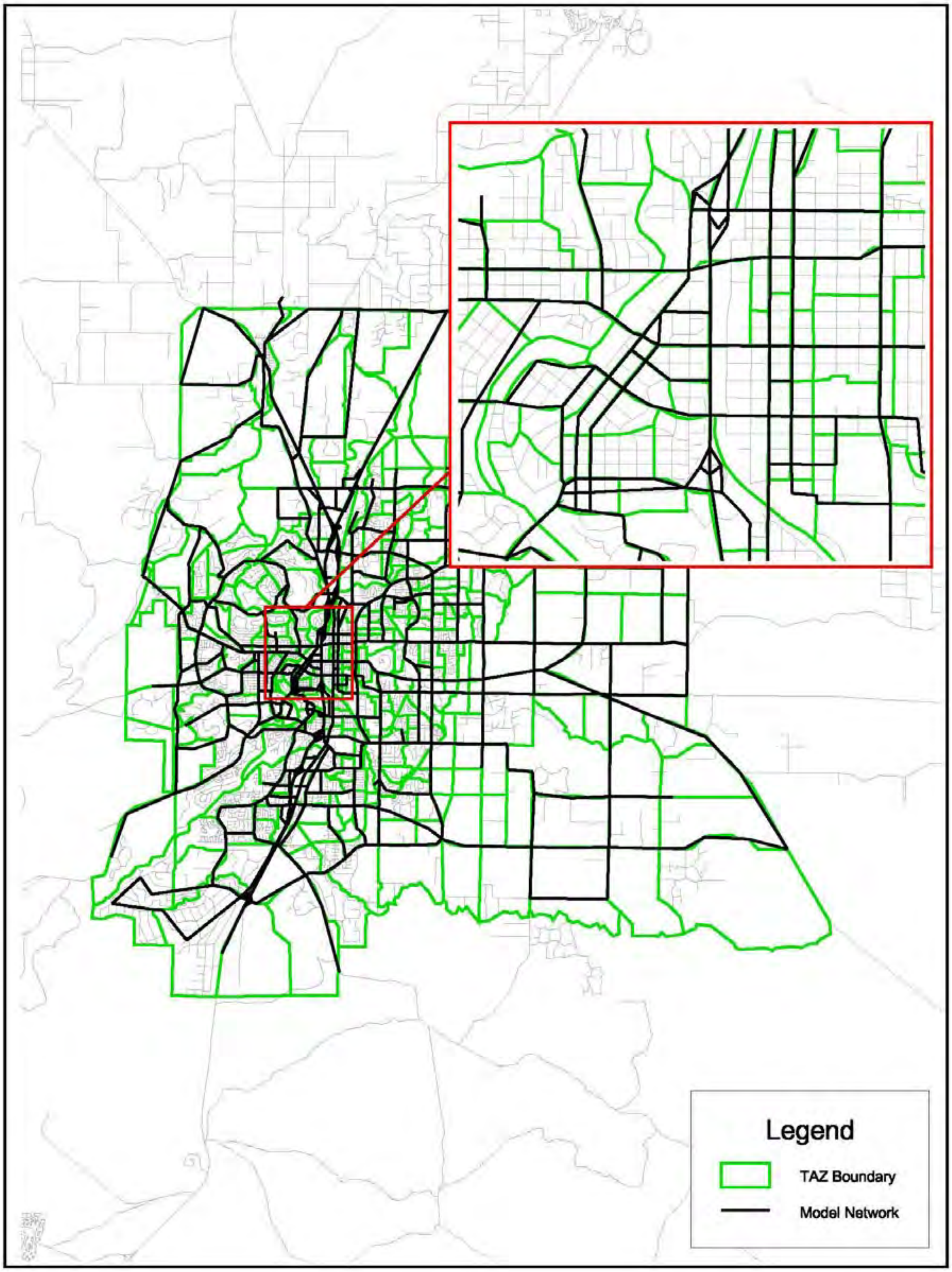
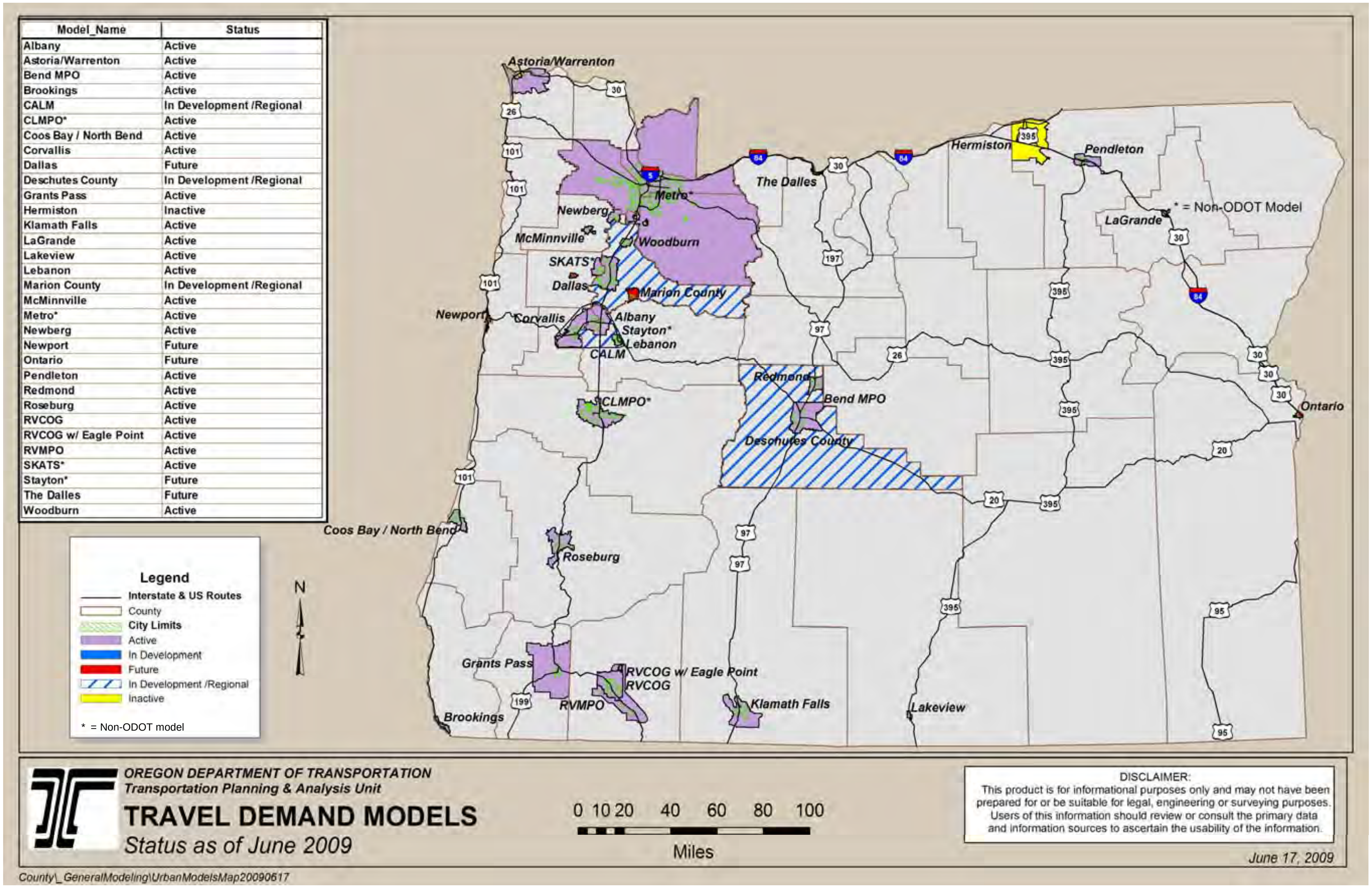


Figure 2
Locations of Travel Demand Models



Model_Name	Status
Albany	Active
Astoria/Warrenton	Active
Bend MPO	Active
Brookings	Active
CALM	In Development /Regional
CLMPO*	Active
Coos Bay / North Bend	Active
Corvallis	Active
Dallas	Future
Deschutes County	In Development /Regional
Grants Pass	Active
Hermiston	Inactive
Klamath Falls	Active
LaGrande	Active
Lakeview	Active
Lebanon	Active
Marion County	In Development /Regional
McMinnville	Active
Metro*	Active
Newberg	Active
Newport	Future
Ontario	Future
Pendleton	Active
Redmond	Active
Roseburg	Active
RVCOG	Active
RVCOG w/ Eagle Point	Active
RVMPO	Active
SKATS*	Active
Stayton*	Future
The Dalles	Future
Woodburn	Active

Legend
- Interstate & US Routes
- County
- City Limits
- Active
- In Development
- Future
- In Development /Regional
- Inactive

* = Non-ODOT model

DISCLAIMER:
This product is for informational purposes only and may not have been prepared for or be suitable for legal, engineering or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information.

- Network assignment

A flowchart showing the basic components of the MPO model structure is presented in Figure 3. The general structure of the small urban area models is the same, except these models do not include a mode choice component. Other than network assignment, all of the model components shown in Figure 3 are implemented within a set of custom software modules developed by TPAU staff. Trip assignment is performed using either the EMME or VISUM software packages.

A brief description of each component is provided below.

Pre-Generation

In the pre-generation step, a set of household submodels are used to cross-classify the total households within each TAZ by household subcategory. The cross-classified households are a required input for the trip generation model. Starting with an initial cross-classification of households by household size, income, and age-of-head-of-household (HIA), the submodels further disaggregate the households to produce the following distributions:

- Households by number of workers (0, 1, 2, 3+) by HIA (WHIA)
- Households by WHIA by number of autos owned (0, 1, 2, 3+) (WHIAC)
- Households by number of children (0, 1, 2, 3+) by HIA (KHIA)

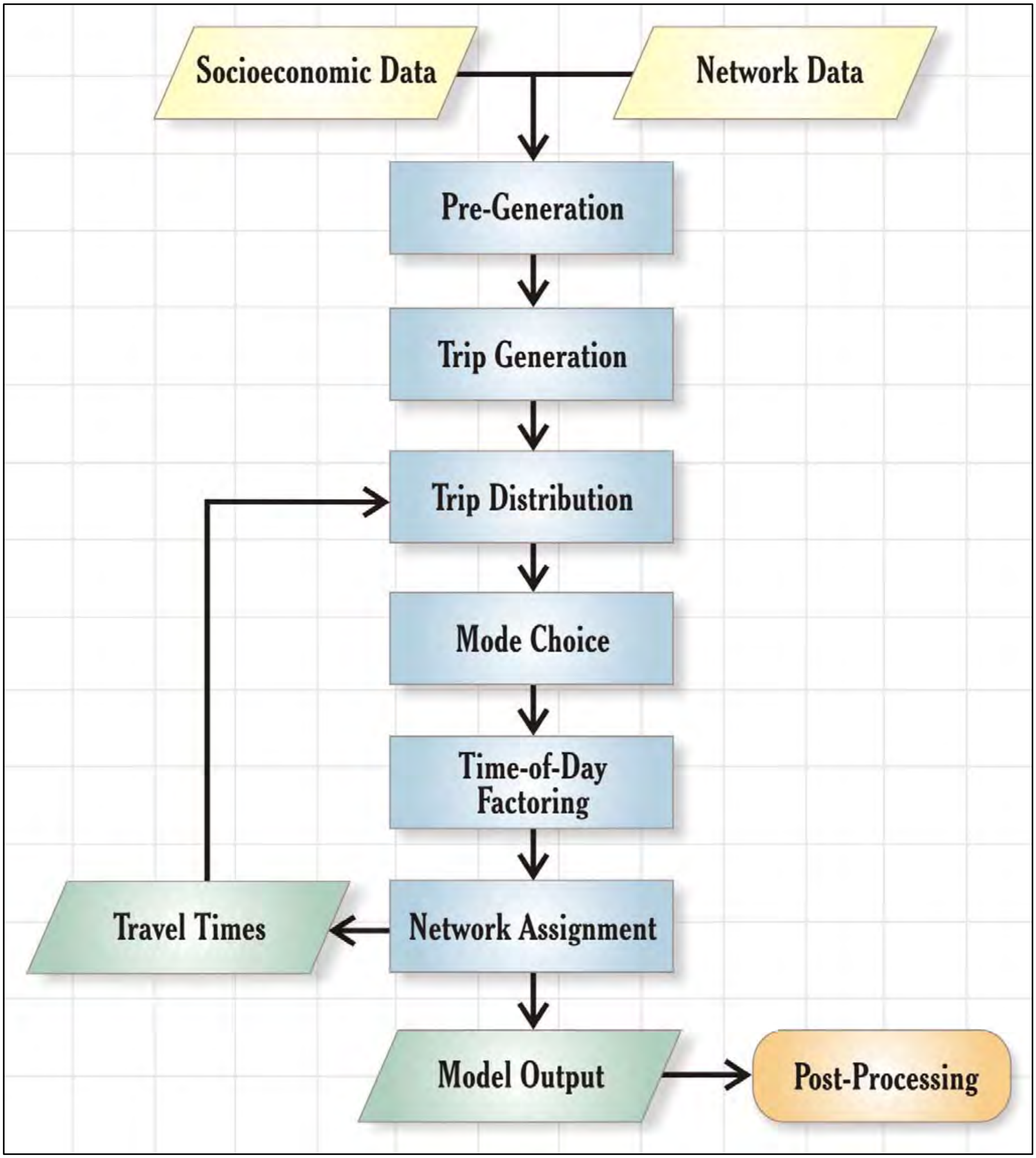
Census data is used to calibrate the models to match the existing proportions of households by worker and auto ownership class for the modeling area.

Trip Generation

The trip generation model estimates the number of average weekday person trips produced by the households within each TAZ using the cross-classified household data output by the household submodels. Trip productions are estimated for the following trip purposes:

- Home-Based Work (HBW)
- Home-Based Shopping (HBshop)
- Home-Based Recreation (HBrec)
- Home-Based Other (HBoth)
- Home-Based College (HBcoll)
- Home-Based School (HBsch)
- Non-Home-Based Work (NHBW)
- Non-Home-Based Non-Work (NHBNW)

Figure 3
ODOT MPO Model Structure



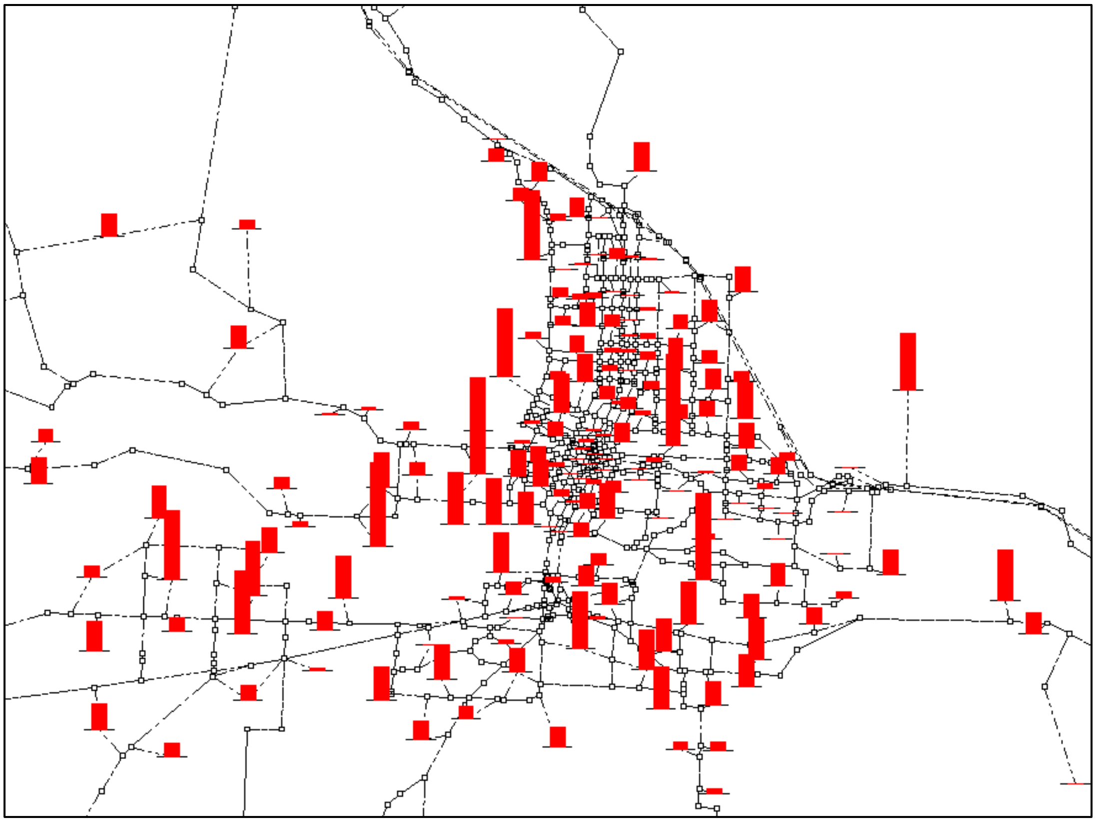
For each TAZ, the number of households in each household subcategory are multiplied by the appropriate daily trip production rate. These rates vary by household subcategory.

Table 2
MPO Model
HBshop Trip Production Rates

Number of Workers	Household Size			
	1	2	3	4+
0	0.654	1.475	1.440	1.793
1	0.365	0.965	1.170	1.807
2		0.668	0.937	1.511
3+			1.006	1.235

The number of estimated trip productions for each household subcategory is summed by trip purpose, resulting in a set of total daily trip productions by trip purpose for each TAZ. An example of this output is shown graphically in Figure 4. The trip productions are used as input to the trip distribution model.

Figure 4
Small Urban Area Model
HBshop Trip Productions



Trip Distribution

The trip distribution model links the trip productions for each TAZ estimated by the trip generation model to destination TAZs to create interzonal (zone-to-zone) trips. This is done separately by trip purpose. The number of trips from a particular zone to another zone is determined by:

- Number of trip productions in the zone
- Attractiveness of the other zone relative to the combined attractiveness of all other zones

The attractiveness of a zone is based on:

- Accessibility of the zone from the production zone
- Employment by type in the zone
- Number of households in the zone

Accessibility is represented as a composite accessibility utility for all available modes between a zone pair. The accessibility utility for each mode is expressed as a combination of the travel time and cost for that mode.

The form of the trip distribution model used within both the MPO and small urban area models is the destination choice model. Within the model, the attractiveness of travel from one TAZ to another TAZ is calculated as a travel utility. An example utility equation for the HBshop trip purpose from an MPO model is shown below:

$$U_{ij} = 1.809*LogSum_{ij} + \log (RetEmp_j + 0.025*NonRet_j + 0.019*Hhold_j)$$

where:

U_{ij} = utility of travel from zone *i* to zone *j*
$LogSum_{ij}$ = composite accessibility utility for all travel modes from zone *i* to zone *j*
$RetEmp_j$ = retail employment in zone *j*
$NonRet_j$ = non-retail employment in zone *j*
$Hhold_j$ = number of households in zone *j*

Once the travel utilities are calculated, the probability of travel from zone *i* to zone *j* is calculated as:

$$Prob_{ij} = \frac{\exp(U_{ij})}{\sum_{k=1}^{K} \exp(U_{ik})}$$

where:

Prob_{ij} = probability of travel from zone *i* to zone *j*

$\exp(U_{ij})$ = exponentiated utility of travel from zone *i* to zone *j*

$\sum_{k=1}^{K} \exp(U_{ik})$ = sum of the exponentiated utilities of travel from zone *i* to all zones *k*, inclusive of zone *i*, of which there are *K* zones in total

The number of trips between zone *i* to zone *j* is then calculated as:

$$\mathrm{TotTrips}_{ij} = \mathrm{Prob}_{ij} * \mathrm{Prods}_{i}$$

where:

$\mathrm{TotTrips}_{ij}$ = total trips from zone *i* to zone *j*
Prob_{ij} = probability of travel from zone *i* to zone *j*
Prods_{i} = trip productions in zone *i* (from trip generation model)

The output of the trip distribution model is a set of zone-to-zone person trip matrices, with one matrix for each trip purpose. These are used as input to the mode choice model. An example trip matrix for a simple 5-zone TAZ system is shown in Figure 5. The zone-to-zone trips for a TAZ in a small urban area model are shown graphically in Figure 6.

Figure 5
Example Trip Matrix

		Attraction TAZ				
		1	2	3	4	5
Production TAZ	1	3	11	9	6	2
	2	7	1	15	8	5
	3	12	7	9	4	2
	4	1	5	10	6	3
	5	0	4	2	7	16

Mode Choice

The mode choice model splits the total zone-to-zone trips by trip purpose output by the trip distribution model into zone-to-zone trips by mode. Only the MPO models contain a mode choice component. The trips are split between the auto, transit, bicycle, and walk modes.

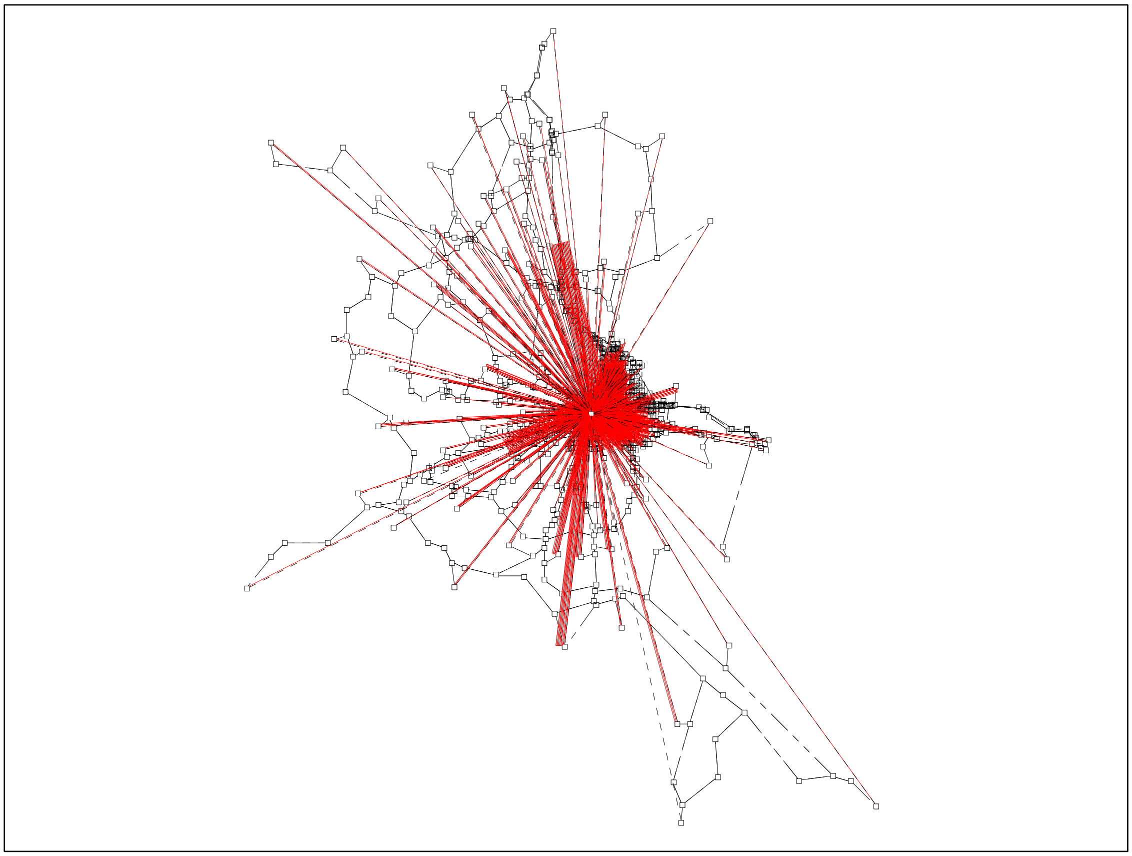
In the first step of the process, modal shares are estimated for each zone pair. These are based on the attractiveness of each mode relative to the combined attractiveness of all other modes.

Figure 6
Small Urban Area Model
Zone-to-Zone Trips

The attractiveness, or utility, of traveling via a particular mode is determined by:

- Total travel impedance for the mode
- Socioeconomic characteristics of the households in the production zone
- Land use characteristics of the trip production and trip attraction zones

Travel impedance is reflected within the modal utilities in the same way that it is within the accessibility utilities for the trip distribution model, i.e., as a combination of travel time and cost. The socioeconomic characteristics of the households in the production zone are used to represent how travelers value each mode differently, depending on such factors as income, auto availability, number of workers, and household size. The land use characteristics reflect the amount of employment and intersection density near the production and attraction zones of the zone pair. An example modal utility equation from an MPO model is shown below:



$$U^{a}_{ij} = -4.00 - 0.035*IvTime_{ij} - 0.099*WalkTime_{ij} - 0.580*LowInc*OpCost_{ij} - 0.542*MidInc*OpCost_{ij} - 0.36*HighInc*OpCost_{ij} + 0.789*MixTotA_{j} - 2.019*\log(TripDist_{ij})$$

where:

U^{a}_{ij} = utility of traveling from zone *i* to zone *j* via Mode *a*
$IvTime_{ij}$ = in-vehicle time from zone *i* to zone *j* via Mode *a*
$WalkTime_{ij}$ = walk time from zone *i* to zone *j* via Mode *a*
LowInc
MidInc
HighInc = "dummy" variables (0, 1) for low, medium, and high-income households in production zone *i*
$OpCost_{ij}$ = operating cost from zone *i* to zone *j* via Mode *a*
$MixTotA_{j}$ = composite measure of employment density and intersection density within ½ mile of attraction zone *j*
$TripDist_{ij}$ = trip distance from zone *i* to zone *j* via Mode *a*

Once the modal utilities are calculated, the probability of travel from zone *i* to zone *j* via Mode *a* calculated as:

$$Prob_{a|ij} = \frac{\exp(U^{a}_{ij})}{\sum_{m=1}^{M}\exp(U^{m}_{ij})}$$

where:

$Prob_{a|ij}$ = probability of choosing Mode *a* for travel from zone *i* to zone *j*
$\exp(U^{a}_{ij})$ = exponentiated utility of travel from zone *i* to zone *j* via Mode *a*
$\sum_{m=1}^{M}\exp(U^{m}_{ij})$ = sum of the exponentiated utilities of travel from zone *i* to zone *j* for all Modes *m*, inclusive of Mode *a*, of which there are *M* modes in total

The number of trips between zone *i* and zone *j* using Mode *a* is then calculated as:

$$Trips^{a}_{ij} = Prob_{a|ij} * TotTrps_{ij}$$

where:

$Trips^{a}_{ij}$ = trips from zone *i* to zone *j* via Mode *a*
$Prob_{a|ij}$ = probability of choosing Mode *a* for travel from zone *i* to zone *j*
$TotTrps_{ij}$ = total trips from zone *i* to zone *j* (from trip distribution model)

The output of the mode choice model is a set of zone-to-zone person trip matrices by mode, with one matrix for each mode. These are used as input to the time-of-day trip factoring step.

Time-of-Day Factoring

In the time-of-day factoring step, the daily modal trip matrices by trip purpose output by the mode choice model are factored to create modal trip matrices by time period. Within this step, the trips are also converted from the production-attraction format used within the trip generation, trip distribution, and mode choice models into the origin-destination format required to assign the trips to the network in the trip assignment step. The time-of-day/directional factors vary by trip purpose and mode. The output of the time-of-day factoring step is a set of modal trip matrices by time period. Trip matrices can be produced for any time period of the day, although the time periods most frequently used for analysis are the AM/PM peak hour/peak periods. For this reason, these are the time periods typically used in the model validation process, in which the model output is compared to observed travel data to assess the model's performance (see below). Therefore, model output for other time periods may not be as reliable as that for the AM/PM peak hour/peak periods.

Network Assignment

In the final step of the modeling process, the trip matrices by time period from the time-of-day factoring step are assigned to the network. This can be done for both the auto and transit modes, although typically auto assignments only are performed because the model is not calibrated/validated at the individual transit route level. The network models currently in use do not support detailed bicycle or pedestrian assignments, because there is generally not a need for information at this level of detail.

Auto assignment is performed with either the EMME or VISUM software packages. This is done using a capacity constrained, equilibrium assignment method. The underlying principle of this technique is described as follows in the *EMME/2 Users Manual*:[8]

> "The behavioral assumption of the equilibrium traffic assignment problem is that each user chooses the route that he perceives the best; if there is a shorter route than the one that he is using, he will choose it. This results in flows that satisfy the user optimal principle, that no user can improve his travel time by changing routes. The consequence is that the equilibrium traffic assignment corresponds to a set of flows such that all paths used between an origin-destination pair are of equal time".

A set of VDFs are used within the assignment process that estimate network link travel times based on link length, link capacity, and traffic volume. As volume increases, travel time increases at an increasing rate, reflecting the delay effects of network congestion.

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[8] Les Conseillers INRO Consultants, Inc., EMME/2 Users Manual, (1999).

The functions may vary by facility type to reflect differences in the relationship between congestion and delay on various roadways.

As shown in Figure 3, a feedback feature is included in the process in which travel times from the current iteration of network assignment are used as input to the next iteration of trip distribution. This feedback process is performed for multiple iterations until an equilibrium condition is achieved, such that additional iterations would result in minimal changes in the modal trip matrices and network travel times from one iteration to the next.

The output of the auto assignment are traffic volumes and travel times for each link in the network. A matrix containing zone-to-zone travel times based on the link travel times is also produced, which is used as an input to the trip distribution model in the feedback process.

Model Calibration and Validation

Model calibration is the process of adjusting a model’s parameters until its trip estimates are similar to observed travel data. This data is obtained from sources such as household travel surveys or origin-destination surveys. Model validation is the assessment of a model’s overall performance by comparing the model’s estimated base year network volumes to traffic counts.

Because link traffic volumes are the most frequently used model output for analysis purposes, the accuracy of these volumes is generally the most important consideration for model validation. In addition to screenline volumes and VMT estimates discussed earlier, there are several other commonly applied validation measures based on link volumes. These are:

- Percent root mean squared error (%RMSE)
- Link scatterplots
- Percentage of links by error range

These measures can be computed by time period and facility type, so that a model’s accuracy can be assessed for the time period and facility types having the most importance for the analysis to be performed.

In rough terms, the % RMSE represents the average relative difference between the assigned traffic volumes and traffic counts and is calculated as follows:

$$\%RMSE = \frac{100 * \sqrt{\left[(Observed - Estimated)^2 / N \right]}}{Observed}$$

The FHWA suggests an aggregate validation target of 30% for this measure.[9] Example % RMSE values by volume category and functional classification for an MPO model are shown below. These results illustrate the earlier discussion about greater model accuracy, in general, for higher facility types and higher-volume roadways.

Table 3
%RMSE for MPO Model

Link Volume Category	Functional Classification	% RMSE
≥ 12,000 vpd	Principal Arterial	13.5%
8,000 – 11,999 vpd	Principal/Minor Arterial	13.1%
4,000 – 7,999 vpd	Minor Arterial	23.5%
2,000 – 3,999 vpd	Minor Arterial/Collector	49.9%
1 – 1,999 vpd	Collector/Local	69.6%
All Links		30.1%

Link scatterplots, together with regression statistics, provide a measure of how well a model replicates overall traffic flows on the network. An example scatterplot is shown in Figure 7. The FHWA's suggested validation target for the R^2 statistic, which measures the closeness of fit of the regression line between the model's link volumes and traffic counts, is 0.88 for peak hour assignments.[10] The slope of the regression line should also be close to 1. The tighter dispersion of points around the regression line for higher-volume links again illustrates the greater accuracy of models for higher-level facilities.

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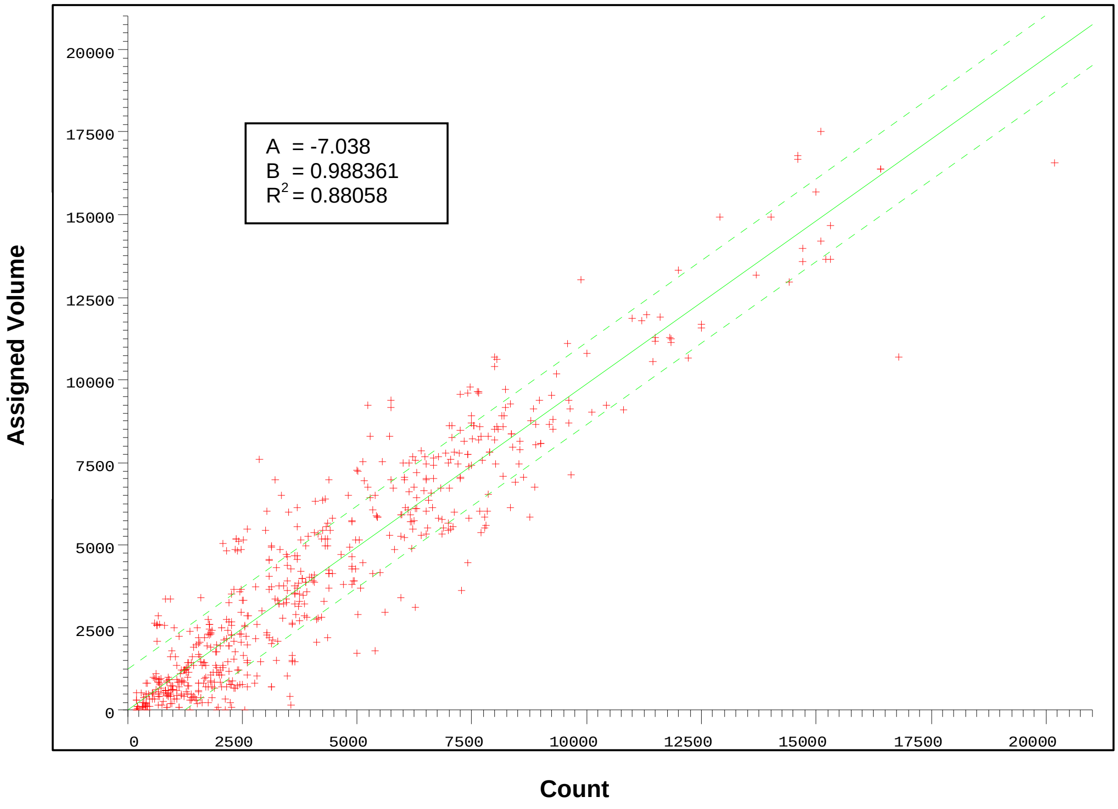
[9] 9 Travel Model Improvement Program, Model Validation and Reasonableness Checking Manual, (1997).

[10] Travel Model Improvement Program, Model Validation and Reasonableness Checking Manual, (1997).

Figure 7
MPO Model Link Scatterplot



Summarization of the percentage of links by error range provides a good indication of the size and distribution of a model's link volume estimates. As shown in the tables on the following page, models are capable of producing accurate volume estimates for a significant percentage of the links in a network.

Transit validation is typically not done for ODOT's models because the mode choice model is calibrated at the system level only.

Combined Analysis With Other Tools

A significant advantage of using a travel forecasting model to analyze the transportation impacts of a proposed land use change is in using the model output to develop post-processed volumes that can be input to other transportation analysis software packages to provide a more detailed assessment of the impacts. These packages extend the benefits of models by providing information on transportation system performance measures in the areas of capacity/LOS, traffic operations, and safety. The key model outputs for most of these packages are network travel volumes or trip matrices. Some packages, such as air quality analysis programs, use other model outputs, such as VMT and trip length frequency distributions.

Table 4
Relative Link Volume Error
For MPO Model

All Links			
Error Range	**% of Links**	**Error Range**	**Cumulative % of Links**
>+100%	3.8%	+ or -15%	37.0%
+50% to +100%	5.2%	+ or -30%	58.1%
+30% to +50%	7.0%	+ or -50%	75.3%
+15% to +30%	9.8%	+ or -100%	96.2%
0% to +15%	18.8%	> +100%	100.0%
-15% to 0%	18.2%		
-30% to -15%	11.2%		
-50% to -30%	10.3%		
-50% to -100%	15.7%		
Total	100.0%		

% Overestimated Links	44.6%
% Underestimated Links	55.4%
Overall % Error	-1.0%

Table 5
Relative Link Volume Error vs. FHWA Targets
For MPO Model

Volume Range	FHWA Targets*	% of CAMPO Model Links Within Target
10,000 – 25,000	25%	97.2%
5,000 – 10,000	29%	85.4%
2,500 – 5,000	36%	71.5%
1,000 – 2,500	47%	56.0%
< 1,000	60%	57.5%

* Source: USDOT Travel Model Improvement Program, Model Validation and Reasonableness Checking Manual, 1997.

Examples of software packages that can be used with model outputs to analyze the effects of proposed land use changes are:

- Traffic simulation

  - Synchro/SimTraffic
  - VISSIM
- Capacity analysis
  - HCS
  - TRAFFIX
  - Synchro
  - TRANSYT-7F
  - FREQ
  - aaSIDRA
- Air quality analysis
  - cER
  - MOBILE6
  - MOVES

Model volumes can be used to develop post-processed volumes that are input to traffic simulation and capacity analysis software packages.[11] Some traffic simulation packages, such as VISSIM, are also capable of using model trip matrix information. The *HSM* methodology used for the prediction of average crash frequency, crash severity, and collision types also uses link volumes.

ODOT's cER air quality analysis program uses the following model link data:

- From/to node
- Volume
- Capacity
- Free flow speed
- Length
- VDF
- MOBILE6 facility type
- TAZ location

In addition, cER uses model trip matrices to estimate zonal emissions.

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[11] See ODOT's *Analysis Procedures Manual* for a description of the post-processing procedures.

D. CAN A MODEL HELP ANSWER THE QUESTIONS?

A travel forecasting model can be an extremely valuable tool for analyzing the transportation impacts of proposed land use changes. In some cases, it is the only tool that is adequate for this purpose. In other instances, however, a model may not be the appropriate tool, either because the model outputs are not relevant to the questions that need to be answered or at the required level of detail, or there are other tools that can provide the needed information more efficiently. Having identified questions about the transportation impacts of a proposed land use change, it must then be decided whether a model is the best tool to provide the information to answer them.

Is a Model an Option?

The first question to be considered in deciding whether a model should be used is whether it is really a practical option for the analysis. While a model could be useful for the analysis of any proposed land use change, there are several factors related to the characteristics of a proposed change and the requirements of the analysis that may make model application more appropriate in some cases than others.

In general, the benefits of using a model for the analysis of a proposed land use change increase with the size of the change. Below a certain size, these benefits may not be large enough to offset the time and cost required to apply a model, especially if other analysis options are available. As a rule-of-thumb, model application becomes the most beneficial for proposed land use changes that will generate 5,000 or more primary[12] trips per day. There are many exceptions to this guideline, such as proposed land use changes located in smaller urban areas, where a smaller development may have significant impacts over a wider area. In this case, with a larger area to be analyzed, a model may be very useful in tracking project trips, as an example. Another example in which a model may be applied in a more limited manner for a smaller proposed change would be to perform a select zone assignment for a project TAZ.[13] This information could be used to manually distribute project trips throughout the study area for a traffic impact analysis.[14]

Another factor to consider is whether the type of proposed land use change is one that can be adequately represented within the existing model structure. Proposed changes that do not conform to common commercial, industrial, or residential land use types may be difficult to reflect in the model. It is possible that these uses could be defined as special generators, but this would require additional data and, possibly, adjustments to the standard model. This would be important to do for larger proposed changes of this type

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[12] Primary trips are defined as new trips on the system, as compared to pass-by trips, which are existing trips that stop as they pass by a development. An example of a development that would generate 5,000 primary trip ends per day is a typical 75,000 – 100,000 square foot retail development (per ITE trip generation rates).

[13] A select zone assignment identifies the number of trips on each link in the network originating from a specified TAZ.

[14] See ODOT's *Analysis Procedures Manual* for guidelines for this procedure.

and so would warrant the additional effort. For smaller proposed changes, however, this may not be practical.

The future years to be used in the analysis may also be a relevant consideration in determining whether the use of a model is a reasonable option. For proposed developments that will generate less than the 5,000 trips/day guideline discussed above, ODOT's *Development Review Guidelines*[15] state that the analysis years to be used are the year-of-opening and 10 years beyond the year-of-opening. The future year land use data for the model, however, typically corresponds to the long-range planning horizon of the local comprehensive plan and the TSP as required by the TPR, which is 20 years or longer. Therefore, if a model is to be applied for proposed developments of this size, interim year land use data would need to be available. There are several methods for preparing this data (see Section F), which would be an extra step in the model application process. The benefits of model application in these cases would need to be weighed against the additional effort required to develop the future land use data. An alternative to developing interim year land use data that can be used in certain circumstances is to interpolate between link volumes for the model base year and long-range forecast year. A similar technique is to interpolate between the trip tables for the base and forecast years. These approaches are described in Section F.

The type of model output and level of accuracy of the output needed for the analysis also need to be identified when considering whether the use of a model is a viable option. If the specific type of output needed for the analysis cannot be produced within the existing model structure, then obviously it should not be used. An example of this would be if detailed information on the effects of a transit-oriented development (TOD) proposal were needed, but the model was not structured to be sensitive to this type of development. (See Section F for a discussion of the modeling requirements for TODs). Also, in some cases, the accuracy of the model output simply may not be high enough for purposes of the analysis.

Is a Model the Best Option?

If it has been determined that model application is a reasonable option to help answer the questions about the transportation impacts of a proposed land use change, how can it be decided whether this is the best option?

For analyzing the effects of a proposed land use change and, specifically, for the development of traffic forecasts, there may be other tools that should be considered in addition to a travel forecasting model. For example, ODOT's *Analysis Procedures Manual*[16] contains guidelines for applying two other methods referred to as "Historical Trends" and "Cumulative Analysis". If optional tools are available, then several factors should be considered in determining which one to use:

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[15] Oregon Department of Transportation, Development Review Guidelines, (2005)

[16] Oregon Department of Transportation, Analysis Procedures Manual

- How well the tool will satisfy the data requirements of the analysis, both in terms of the type and quality of the data produced.
- The level of effort and amount of time required to produce the data. In the case of a model, this may include the need to update or refine the model and the availability of qualified staff to apply the model.
- Beyond the immediate data needs for the analysis, the likelihood of additional data being required for other analyses, such as examining the effects of alternative land use assumptions or developing additional impact measures. One advantage of a model is that, once it has been set up, it is relatively easy to apply for different scenarios and to produce different types of output as compared to manual methods.

TPAU staff can be contacted if there is a question about whether a model can be applied, whether a model is the best option, or how to conduct the analysis. TPAU regularly provides consultation about the appropriateness of using models for the analysis of proposed land use changes and how this should be done.

E. WHAT TYPES OF MODEL OUTPUT ARE AVAILABLE?

Types of Output

Models can be used to provide a wide range of information for the analysis of the impacts of proposed land use changes. It is important to understand that models are an extremely flexible resource for this purpose. Many times, the use of a model is limited to the development of network travel volumes for input to other analysis tools. However, there are a number of other outputs that can be easily produced and applied, either directly or with other analysis tools, to broaden the understanding of what the impacts of a proposed change might be. Any measures based on network (link) or interzonal (TAZ-to-TAZ) trips or travel times can be supported with model output. These may be existing measures or new measures created for the specific analysis needs of a proposed land use change.

A few examples of how models can be used to help answer questions about the impacts of proposed land use changes are listed in Table 6 on the following page. Illustrations of several of these outputs are shown in Figures 8 and 9. Figure 8 is a plot showing link d/c ratios, with text and color-coded bandwidths on the links depicting the d/c values.

Figure 8
Link D/C Ratios

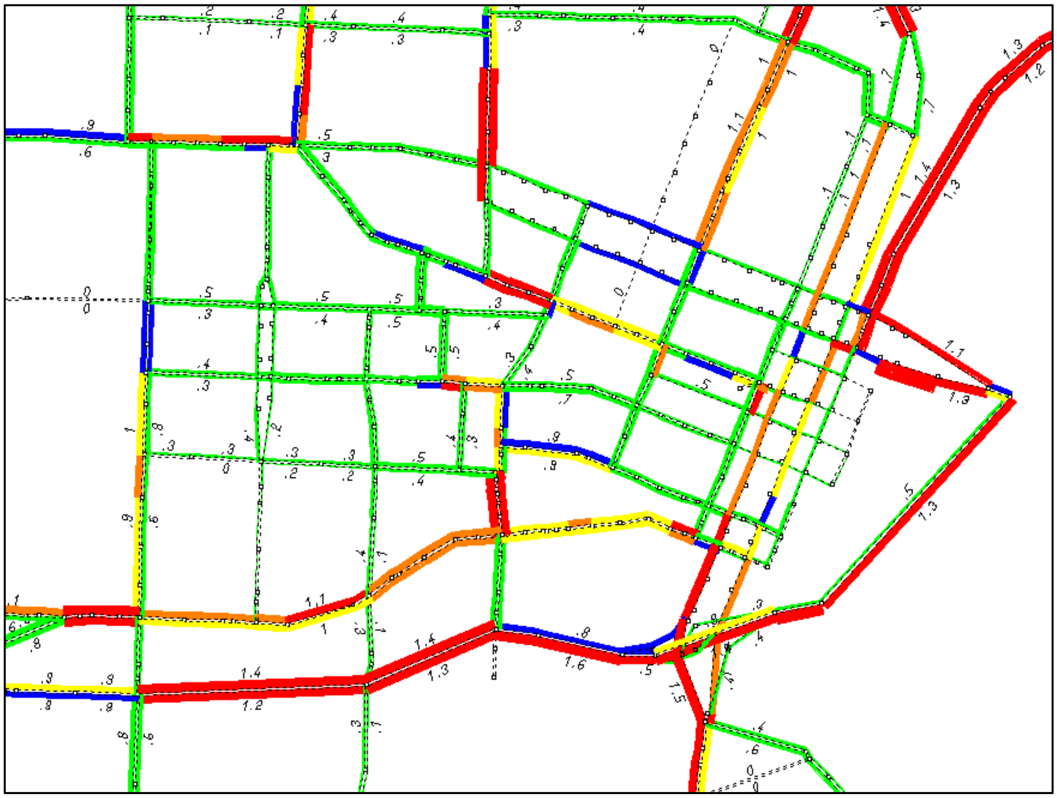

Table 6
Example Model Outputs for Analysis of Transportation Impacts

Analysis Area	Example Model Outputs
Capacity/LOS	• Link volumes* • Link demand/capacity (d/c) ratios[17]
Traffic Operations	• Link volumes by time period or facility type • Link speeds by time period or facility type
Environmental Impacts**	• Link volumes by time period • Link speeds by time period • Origin-destination trip data by time period
Other	• District-to-district travel times • Select link volumes or flow bundles • Select zone volumes • Screenline travel volumes • Trip length frequency distributions with average trip lengths • Vehicle hours of travel • Vehicle hours of delay • VMT by facility type or trip type • Congested lane miles by facility type • Modal shares

* Link volumes can be used to develop post-processed link and/or intersection turning movement volumes for use in this type of analysis.

** Model outputs shown are inputs for ODOT's cER air quality analysis program.

Figure 9 shows the results of a select link assignment, which identifies all of the trips on the network using a specific link.

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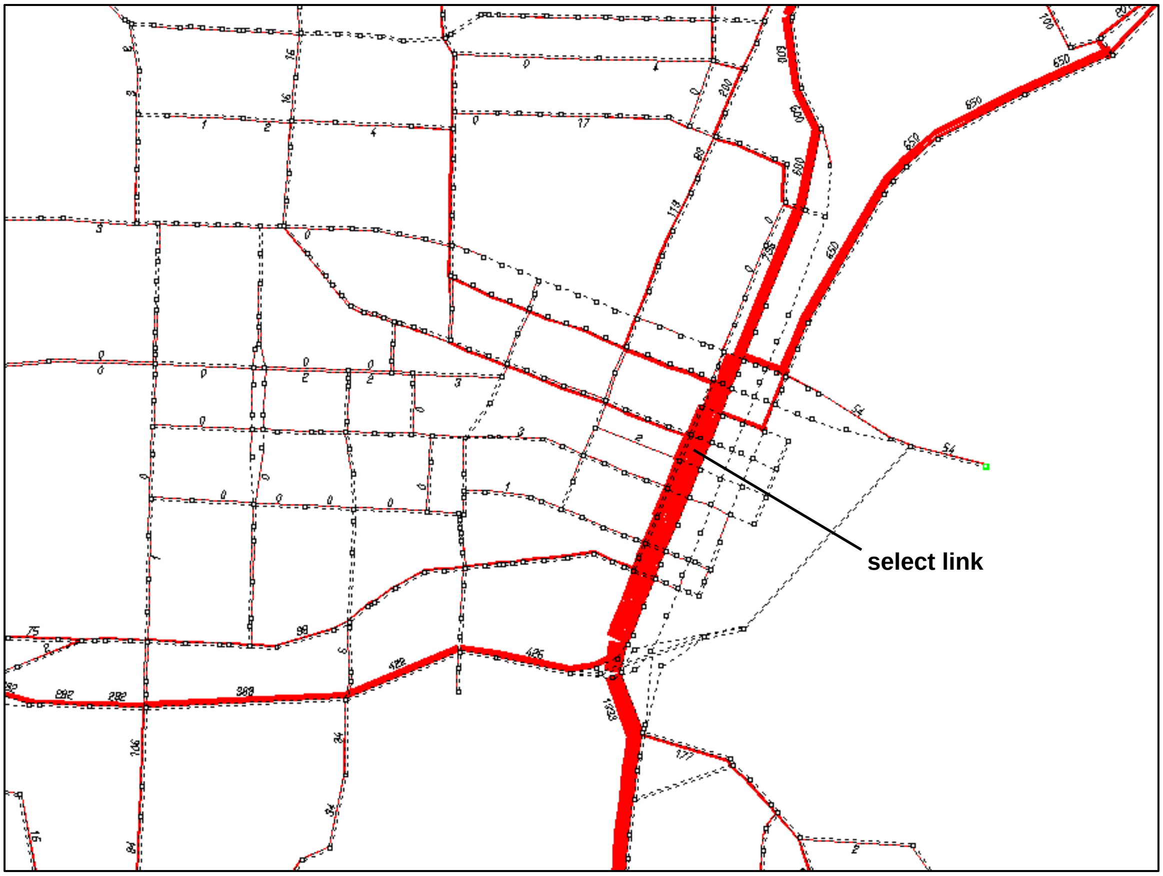
[17] The demand/capacity ratio is the ratio of link demand to capacity. With models, it is more appropriate to use this measure rather than the v/c ratio because the model's link volume estimates are not necessarily limited to link capacity. Therefore, the demand/capacity ratio represents the relationship of potential demand to facility capacity.

Figure 9
Select Link Assignment



select link

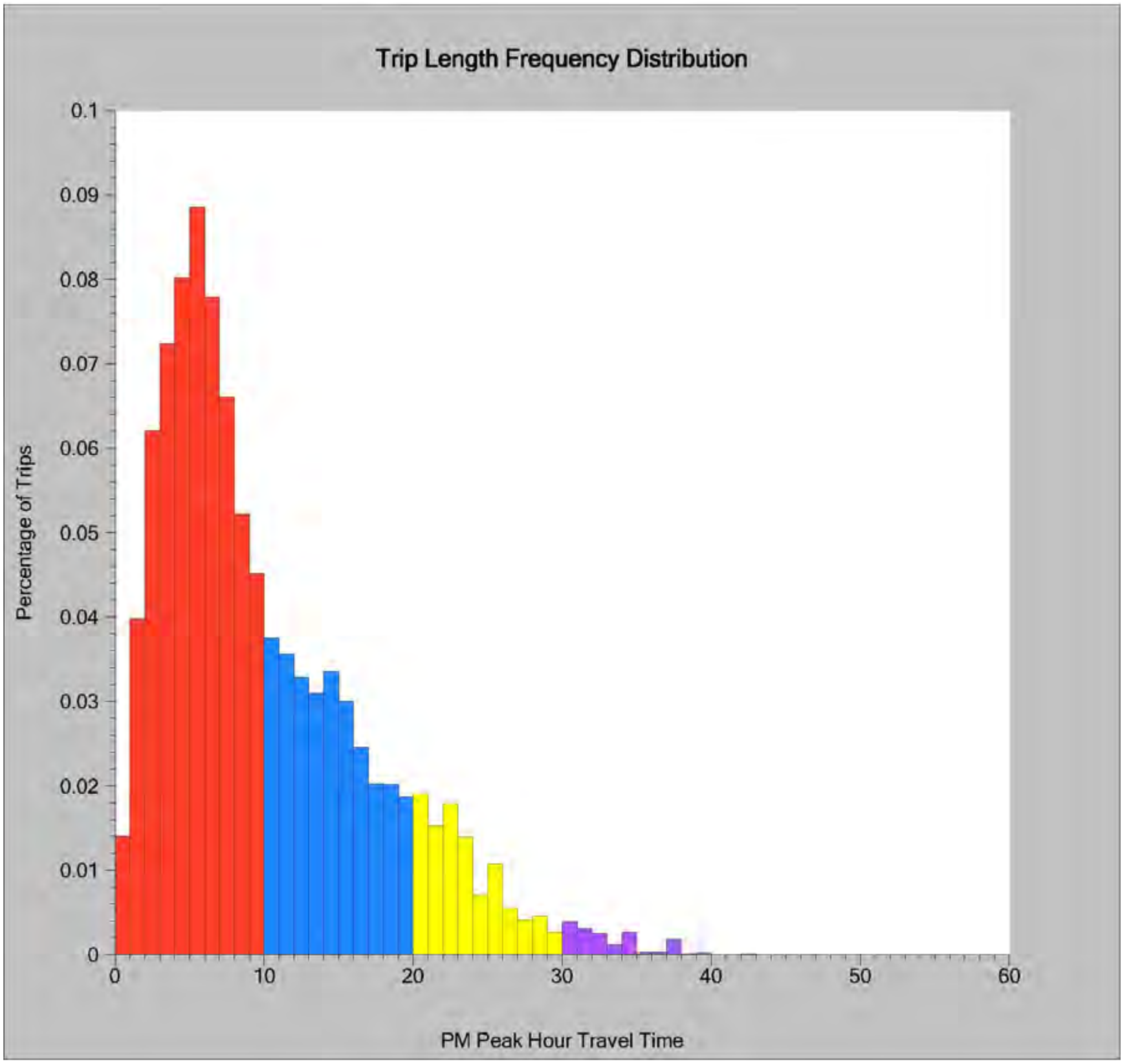
A variation of the select link assignment is a select zone assignment, which tracks all of the trips to/from a particular TAZ through the network. This information may be valuable for identifying which portions of the network would be used by the trips from a proposed land use change. Figure 10 is a trip length frequency distribution. It is developed using the model's interzonal trip and travel time data and could be used to identify the percentage of trips to/from a proposed development within each travel time interval, as well as the average trip length.

Resolution of Output

Depending on the type of proposed land use change being considered and the questions about transportation impacts to be answered, model output can be produced in a variety of ways within each of the four dimensions of the data:

- Geographic
- Network

Figure 10
Trip Length Frequency Distribution



- Time-of-day
- Market segment

The number of ways the data can be produced depends on the model structure. The level of detail that can be achieved within the geographic and network dimensions is determined by the level of refinement of the TAZ system and modal networks.

The appropriate geographic scale of the data depends on the size of the area of influence of the proposed change. Because comprehensive plan amendments and zoning changes may cover larger areas and include significant amounts of potential development, the scale of the output could be at the regional or even super-regional level. Land use changes within interchange areas and site development proposals typically have smaller areas of influence, so the scale of the output would generally be at the subarea level and below. Examples of the influence areas of a proposed zoning change and smaller site development are shown in Figures 11 and 12. The colored links represent those portions of the network that would have a greater than 10% increase in traffic with the proposed change.

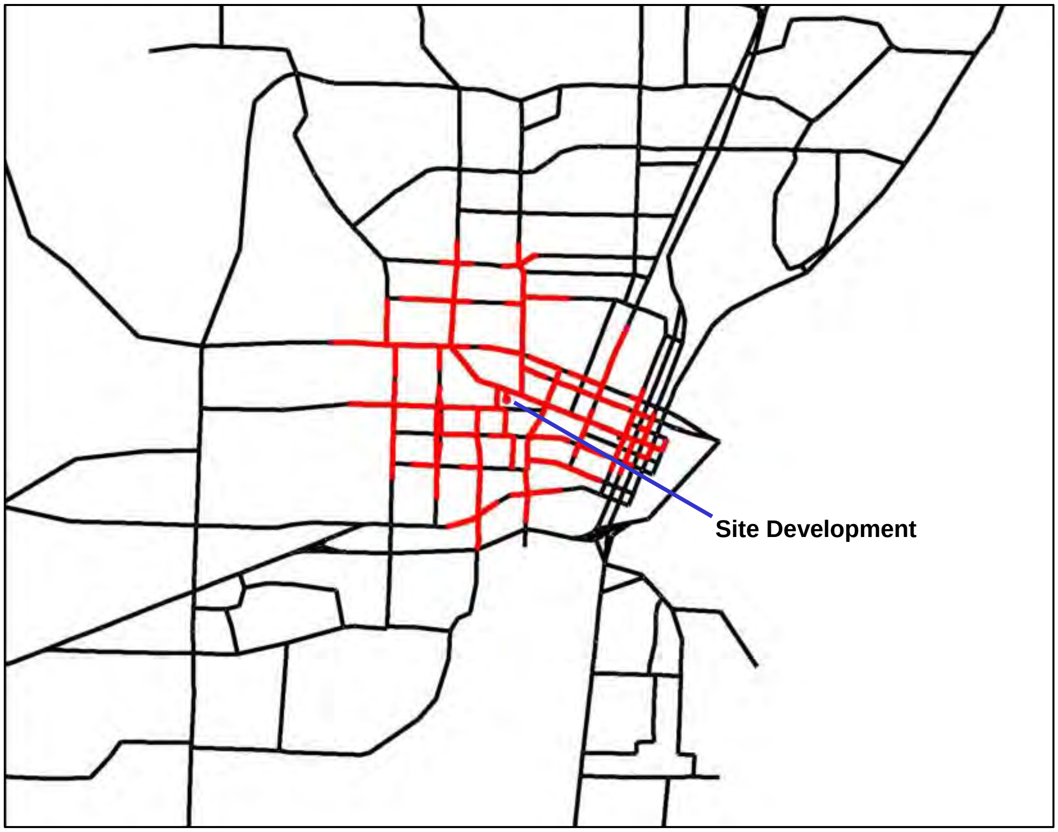
The appropriate network scale is also somewhat related to the size of the area of influence. Screenline volumes showing area-to-area travel flows may be used for the analysis of comprehensive plan amendments and, depending on their size, zoning changes. For all types of proposed land use changes, post-processed volumes may be used to determine impacts along corridors and at intersections.

ODOT's MPO and small urban models both provide travel data by time-of-day. With the MPO models, the time periods are specified by the user. The small urban area models automatically produce travel data by hour-of-the-day. For most types of proposed land use changes, peak hour volumes would be used for analysis and informational purposes, while daily volumes generally would be used for informational purposes only.

Market segmentation for both the MPO and small urban area models includes trips by trip purpose. In addition, the MPO models provide origin-destination (O-D) trip data by

Figure 11
Influence Area for Zoning Change

Figure 12
Influence Area for Smaller Site Development



income category (low, medium, and high) as a standard output. Other types of market segment data can be produced as a special output. An example of this would be the number of one-car households located within 30 minutes of transit travel time from an employment area.

Market segmentation data can be used for the analysis of any type of proposed land use change. However, these types of questions are typically more related to larger proposed land use changes, such as comprehensive plan amendments and zoning changes.

Examples of Output

It is important to use the types of model output that will result in an accurate, unbiased representation of the transportation impacts of a proposed land use change. Use of model data that is inconsistent with the questions being asked will lead to incorrect answers or, if it is not at the proper level of resolution, answers that are either too general or overstate the accuracy and precision of the model's forecasts. Certain types of model output, generally at the higher levels of aggregation (e.g., screenline volumes), may be used directly for assessing impacts. Link volumes are used to develop post-processed volumes that are input to other analysis procedures.

E. WHAT TYPES OF MODEL OUTPUT ARE AVAILABLE?

The following examples of model output may be helpful in answering the four types of questions discussed in Section B that are common to many proposed land use changes. Because many larger-scale land use changes such as comprehensive plan changes and zoning changes may involve more complex issues than smaller changes, example model outputs for examining policy or system-level questions related to these changes are also provided.

Consistency with Transportation Plans

All transportation plans contain mobility standards reflecting the desired quality of travel flow on various types of transportation facilities. Two measures of quality of flow on roadways are LOS and v/c ratio.

Models can produce estimates of link volumes for "with" and "without" proposed land use change" scenarios that can be used to develop post-processed volumes. The post-processed volumes can be input to capacity analysis tools to compute the LOS or v/c ratio along roadways impacted by the proposed land use. Comparison of the LOS or v/c values with the standard will determine if the proposed change will be consistent with the mobility standards of the transportation plan.

At a coarser scale, link d/c ratios can also be produced by the model for relative comparison. D/C ratios are based on link demand rather than link volume, which is constrained by the physical capacity of the link. Also, the model link capacities reflected in d/c ratios are not as detailed as the capacities used in capacity analysis tools such as those in the *Highway Capacity Manual (HCM).*[18] Therefore, d/c ratios shall not be considered the same as v/c estimates developed using actual capacity analysis procedures. They are, however, a good rough indicator of congestion levels within the network and the relative differences in congestion between network alternatives (i.e. under, near, or over capacity).

ODOT Asset Management

As described in Section B, traffic volumes output by a model for the "with proposed land use change" scenario can be used to determine if the additional traffic generated by the proposed change would:

- Increase the rate of deterioration of ODOT roadways and structures.
- Increase the rate of design obsolescence of ODOT roadways and structures by creating deficiencies in the areas of capacity, safety, traffic operations, and geometrics prior to the end of a facility's expected life cycle.

Total traffic volumes by time period and volumes by vehicle type (truck vs. auto) from the model can be used to identify these impacts. Model volumes can also be used to develop post-processed volumes for estimating LOS and v/c ratio measures to identify

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[18] Transportation Research Board, Highway Capacity Manual, Special Report 209, (2000).

capacity deficiencies that may contribute to the premature obsolescence of ODOT facilities.

As noted earlier, ODOT's MPO and small urban area models currently do not have the capability to produce separate truck traffic forecasts. This feature will be added in the future, however.

Environmental Impacts

For large proposed land use changes, such as comprehensive plan amendments, zoning changes, or large commercial developments, model outputs may be used to support the application of ODOT's cER air quality analysis program, described in Section B. These outputs are described in Section C.

The cER program can be used with outputs from both the MPO and small urban area models. Some of these outputs are used to support the use of Mobile 6.2 within cER for the estimation of pollutant emission rates. In the near future, ODOT will be replacing MOBILE6.2 with the EPA's MOVES (Motor Vehicle Emission Simulator) software package. MOVES estimates emissions for on-road and non-road mobile sources and allows multiple scale analysis ranging from fine-scale studies to regional emissions forecasting. The data needs of MOVES will also be supported by model output.

Policy/System-Level Issues

Beyond the basic impacts of proposed land use changes discussed above, certain types of larger-scale changes may raise more complex questions that need to be considered by local officials and the public in making quasi-judicial or legislative land use decisions.

A quasi-judicial procedure, referred to as a "Type III" decision by many local jurisdictions, is applied where the approval criteria involve substantial discretion by the decision-maker. Type III procedures involve notice, a public hearing, and an opportunity for appeal. Zone changes that are consistent with the underlying comprehensive plan designation, subdivisions and conditional use permits are typically classified as Type III procedures. A "Type IV" procedure is used for "legislative decisions that generally affect large areas". The notice requirements are usually broader than a quasi-judicial review and allow more time for comment, often including public hearings before more than one decision body. Comprehensive plan map amendments and related zone changes, plan and zoning code text amendments, urban growth boundary amendments and some annexations are processed through Type IV procedures.

Travel demand forecasting models are well-suited for providing information on policy or system-level issues associated with these types of proposed land use changes. Model output can be used to develop performance measures that inform policy-makers about how their decisions regarding large proposed land use changes will affect transportation system performance, transportation system users, and the transportation system/land use balance. ODOT has investigated and recommended several model-supported measures that would be helpful for this purpose.[19] These are summarized briefly below.

Urban Mobility

The Texas Transportation Institute has developed a group of urban mobility measures that are included as part of the annual Urban Mobility Report (UMR) for U.S. urban areas. **Travel delay** is the amount of additional time spent in travel, relative to free-flow conditions. The **travel time index** is the ratio of peak period travel time to free-flow conditions and represents the percentage of additional time needed for making a trip in the peak period. The **annual cost of congestion** is calculated from the travel delay measure and has three components: passenger vehicle delay costs, freight vehicle delay costs, and the cost of additional fuel consumed due to slower and uneven travel speeds.

Each of these measures could be calculated for a proposed land use change to determine how well the area of the proposed change would be served by the existing or future transportation system and the travel time and cost impacts of the proposed change on the overall transportation system.

Transportation Cost Index

This is an accessibility measure that is analogous to the Consumer Price Index (CPI). The CPI measures the relative cost of purchasing a market basket of goods and services. It may be used to compare living costs in different areas and changes over time. The Transportation Cost Index (TCI) measures the relative cost of accessing a market basket of travel attractions. A market basket is defined as a group of destinations that provides a good set of choices for meeting daily living needs. The TCI may be used to compare accessibility by trip purpose, travel mode, income group, geographic area, and time period. Travel demand models provide information that may be used to define the travel market basket and calculate transportation costs.

This measure could be used to identify the affordability of transportation from alternative sites for a proposed land use change and suggest improvement measures that may reduce this cost.

Non-Auto Accessibility

The non-auto accessibility measure identifies the percentage of the travel attractions for the TCI measure that are accessible by non-auto travel modes. It measures the degree of auto dependence fostered by the land use and transportation systems. It is primarily

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[19] Oregon Department of Transportation, Transportation Planning Performance Measures, (2005)

influenced by land use, but is also affected by non-motorized network connectivity and transit system coverage and service frequencies. This measure could be used to help determine the potential for non-auto trip making from a specific site for a proposed land use change.

Auto-Dependence Index

The Auto Dependence Index (ADI) compares the Transportation Cost Indices for auto and non-auto modes to indicate the degree of auto-dependence fostered by the land use and transportation systems. It is similar to the Non-Auto Accessibility measure, but also reflects where travel costs by the auto and non-auto modes are out of balance. It is computed as the ratio of non-auto TCI to auto TCI. A value greater than one indicates that the land use and transportation system fosters auto-dependence, because auto travel is less costly than travel by other modes. Larger ADI values indicate greater auto-dependence. This measure could be used to help determine the potential auto vs. non-auto trip making from a specific site for a proposed land use change.

F. HOW SHOULD THE MODEL BE APPLIED?

Once the needed model outputs have been identified, the proper approach for applying the model must be determined. While there are general model application methods for analyzing different types of land use changes, the approach taken for a specific land use change is strongly influenced by the details of the proposed change and the features of the model. Therefore, a fair amount of judgment is usually required in identifying the appropriate application method.

To assist in the decision-making about how, specifically, to apply a model for a proposed land use change, recommendations are provided below on a range of common model application issues. The recommendations cover the following four main categories of proposed land use changes:

- Site Development Proposals
- Proposed Zoning Changes
- Comprehensive Plan Updates
- Proposed Land Use Changes Within Interchange Management Areas

Site development refers to the development of individual sites or parcels of land. Generally, more detailed information is known about the characteristics of site developments than other types of land use changes, such as the particular type of retail or industrial use or even the future occupant of the site. The time frame for development is also usually shorter. Depending on the size of the development, this may be only 1 – 2 years. In practice, some site development proposals are also tied to zoning changes, so that consideration of the proposal would involve two land use decisions. The keys for effectively applying models for site developments are:

- Having an adequate understanding of the trip characteristics of the proposed development.
- Providing input data to the model that accurately describes the development within the parameters of the model.
- Applying the model in a manner that is consistent with the nature of the development and at the proper level of resolution.
- Producing the type of output needed for the analysis and in the required format.

Zoning changes, for purposes of the discussion below, do not include changes with site development proposals attached to them. The area of a proposed zoning change may be quite small, but it is usually larger than that of a site development proposal and may be substantial. Fewer details may be known about the ultimate uses of the rezone area, and the proposal may result in a greater mix of future uses. As described in Section E, zoning changes that are consistent with the underlying comprehensive plan are Type III land use decisions requiring a quasi-judicial review procedure, while zoning changes associated with comprehensive plan amendments are Type IV decisions requiring legislative review. The time frame for development with a zoning change can range from short-term to long-term.

Comprehensive plan updates are generally the largest type of land use change considered by local jurisdictions, with potentially the most significant impacts to the transportation system. These are Type IV land use decisions requiring legislative review. The time frame for development is usually mid- to long-term. Information about the development that will occur with a comprehensive plan change is usually very general, corresponding to the broad land use categories of the comprehensive plan. For model application, more and broader assumptions about the proposed change may need to be made, such as:

- Definition of the supporting transportation network
- Modification of the TAZ system
- What the regional jobs-housing balance will be
- Whether adjustments to regional population and employment totals need to be made
- Percentage of external trip making
- Inclusion of special generators

The development of these assumptions may require significant coordination with multiple local agencies.

Land use changes within interchange management areas are different from the other types of changes not because of their character or size, but their location. Because traffic operations within interchange areas tend to be more complex, different analysis methods may need to be used. This, in turn, may require different model outputs. Areas of special emphasis may include greater TAZ system detail within the interchange area to allow the identification and tracking of trips to/from specific areas of development and more refinement to the roadway network to support the more detailed traffic analysis that is typically performed for interchange areas.

Model Application Issues

The list of issues discussed below is not intended to be all-inclusive, but contains guidelines related to a range of issues that are frequently encountered when trying to apply models for the analysis of the transportation impacts of proposed land use changes. For guidelines related to general model application procedures, see ODOT's *Travel Demand Model Development and Application Guidelines*.[20]

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[20] Oregon Department of Transportation, Travel Demand Model Development and Application Guidelines, (1995)

Size of Development

This issue applies primarily to proposed site developments and is related to the question of whether the size of a development may be too small for model application to be worthwhile. In Section D, a trip generation guideline of 5,000 or more primary trips per day was identified as the development size for which model application is generally most beneficial. There may be many exceptions to this rule-of-thumb, however, depending on the type of development, where the development will be located, the type of data needed for the analysis, and the availability of other methods. For example, model application may be very valuable for a smaller development located in a small urban area that may have relative impacts that are as large or larger than a major development in a metropolitan area. In cases where it is not clear whether a proposed development is large enough to warrant model application, TPAU staff should be consulted.

Alternatives to Full Model Application

Full model application involves processing all of the model components shown in Figure 4 using inputs that reflect the proposed land use change. While the time required to do this for a single model run is not significant once all of the input data has been prepared, the total time requirement for performing multiple model runs may be. An example of where multiple model runs may be needed is if the ultimate size and/or composition of the proposed development has not been decided, and testing of various sizes or development types is needed to make this determination. If, for example, 20 model runs were required to establish the final project scenario, the time and cost to do this might be prohibitive.

For exploratory scenario testing such as this, it may be possible to use alternative methods for the development of model-based outputs that would not require application of the complete model. Two of these methods are:

- Interpolation of model output
- Partial model application using modified trip matrices

The interpolation of model output would involve performing several model runs for representative project scenarios, and then interpolating between the model outputs for these runs to derive data for alternative project scenarios. For example, if there was a question about how large a proposed development should be, model runs could be performed for small, medium, and large-sized project scenarios. For a small/medium-sized project alternative, link volumes could then be derived by interpolating between the link volumes from the model runs for the small and medium-sized projects. This would provide rough volume estimates for the analysis of this test scenario.

The second method involves modification of the trip matrix that is used for trip assignment to reflect the proposed land use change. Normally, the creation of this matrix is a result of running the model through the time-of-day factoring step shown in Figure 4. With the alternative method, these steps in the modeling process are skipped, and the assignment trip matrix for the “without project” scenario is modified to include the trips for the proposed change. This is done by:

- Adding a new TAZ for the proposed project within the trip matrix and network;
- Copying the trip distribution within the matrix for a neighboring TAZ having similar distribution characteristics;
- Rebalancing the modified matrix using estimated origins and destinations for the project TAZ; and
- Running an assignment using the rebalanced trip matrix and the modified network.

This procedure should be used only if certain conditions are met:

- Would the proposed development be large enough to cause a significant shift in travel patterns over a wide area compared to the distribution of trips within the “without project” trip matrix? If so, then the entire model should be rerun to adequately reflect the new distribution.
- Is there a neighboring TAZ with similar development whose trip distribution could be copied and used for the TAZ containing the proposed development? If not, then the entire model should be rerun to estimate the actual trip distribution for the proposed development.
- What is the required level of accuracy of the model output for the area immediately surrounding the proposed development? If a higher level of accuracy is required, then the entire model should be rerun to better reflect the actual distribution of trips in the immediate vicinity of the proposed development.

These alternative methods are most appropriate to use for proposed site developments and smaller zoning changes. Larger land use changes would probably not meet the first condition described above, so that a standard model run should be performed.

Regardless of which alternative method is used, once the scenario testing is finished, a complete model run must be performed for the final project to produce the output to be used in the analysis of impacts.

Model Focusing

Model focusing is a special procedure used when greater detail is needed within the model network and TAZ system to adequately represent a portion of the modeling area. It involves disaggregation of the TAZs within the “focus” area, as well as refinement of the network to be consistent with the smaller TAZs. This method is used for general subarea modeling, but is also an excellent tool when more detailed and accurate model output is needed for the analysis of the impacts of a proposed land use change, particularly in the immediate vicinity of the proposed change. The need for model focusing may be higher in the fringes of the modeling area, where TAZ sizes tend to be larger and the network may be less detailed.

F. HOW SHOULD THE MODEL BE APPLIED?

The focusing technique is applied after the standard (non-focused) model has been run. At this point the following procedure is used:

1. The standard TAZ system and network are refined in the vicinity of the proposed land use change.
2. The origins and destinations for the original or "parent" TAZs from the "with project" model run are allocated to the disaggregated TAZs using one of several possible weighting schemes. Examples of weights that may be used are the sum of population/households plus employment and total trip generation for the disaggregated TAZs.
3. The assignment trip matrix from the "with project" model run is expanded to reflect the revised TAZ system.
4. The expanded matrix is balanced using the disaggregated origins and destinations from Step 2.
5. A new trip assignment is run with the trip matrix from Step 4 and the refined network.

This focusing procedure should be applied first for the model base year. The results should then be compared to outputs from the standard model and observed data to ensure that the focus model is functioning properly. Link volumes should be compared to traffic counts within the rezone's area of influence using measures such as relative and absolute error, %RMSE, and scatterplots of observed vs. estimated volumes with R^2 values. Additional checks are select zone and select link assignments to check the reasonableness of route choice, and travel time isochrones for selected rezone area TAZs. Once the focus model has been validated, it can be applied in the same manner for the "with project" scenario.

In addition to the greater accuracy and level of detail that can be achieved with model focusing, another advantage of this approach is that trips from the proposed land use area can be tracked through the network by running a select zone assignment. This information can be used for purposes such as fair share cost assessment.

The key factor to be considered in determining whether the focus modeling procedure should be used is whether the standard TAZ system and network will produce model outputs that are accurate and detailed enough for the analyses to be performed. If so, then this approach is probably not necessary.

Focus models can be applied for land use changes of any size, from site developments to large-scale comprehensive plan amendments. A comparison of the TAZ systems and networks for a standard model vs. focus model is shown in Figures 13 and 14.

Preparation of Land Use Inputs

For general planning purposes, land use quantities for proposed land use changes are

Figure 13
TAZ System and Network for Standard Model

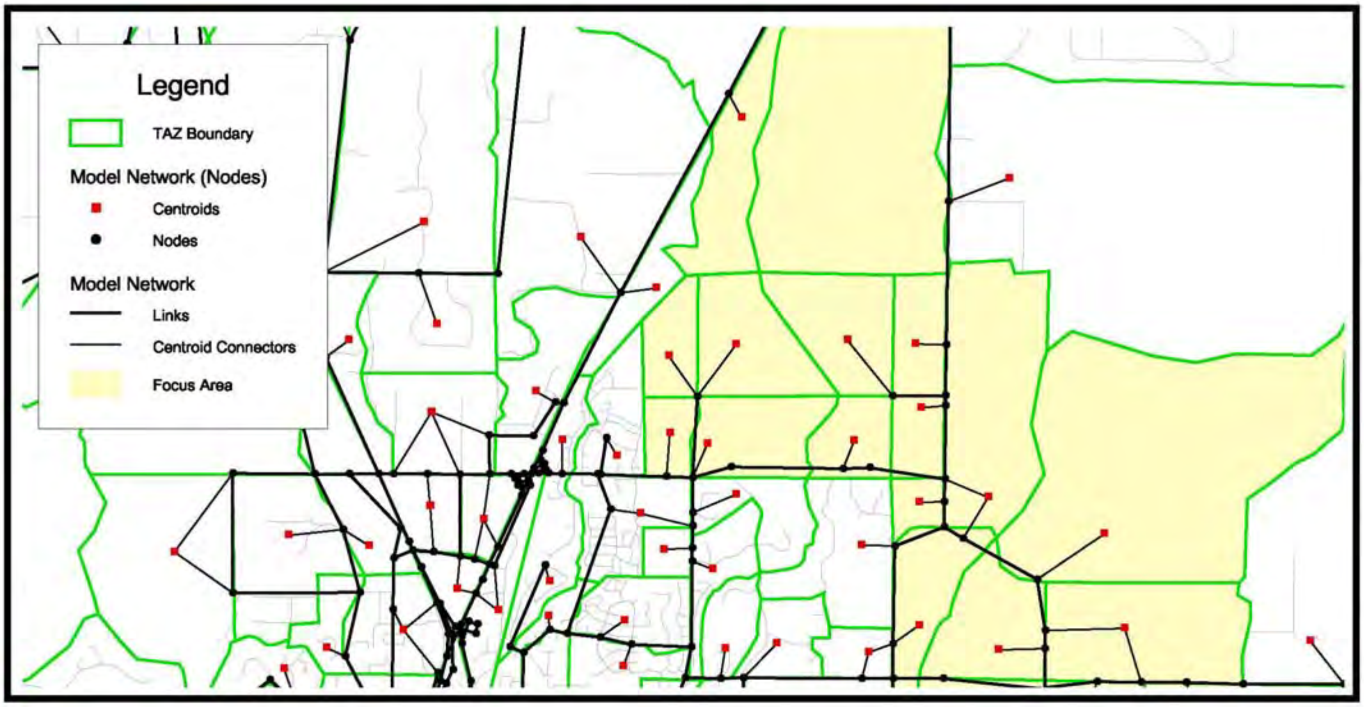
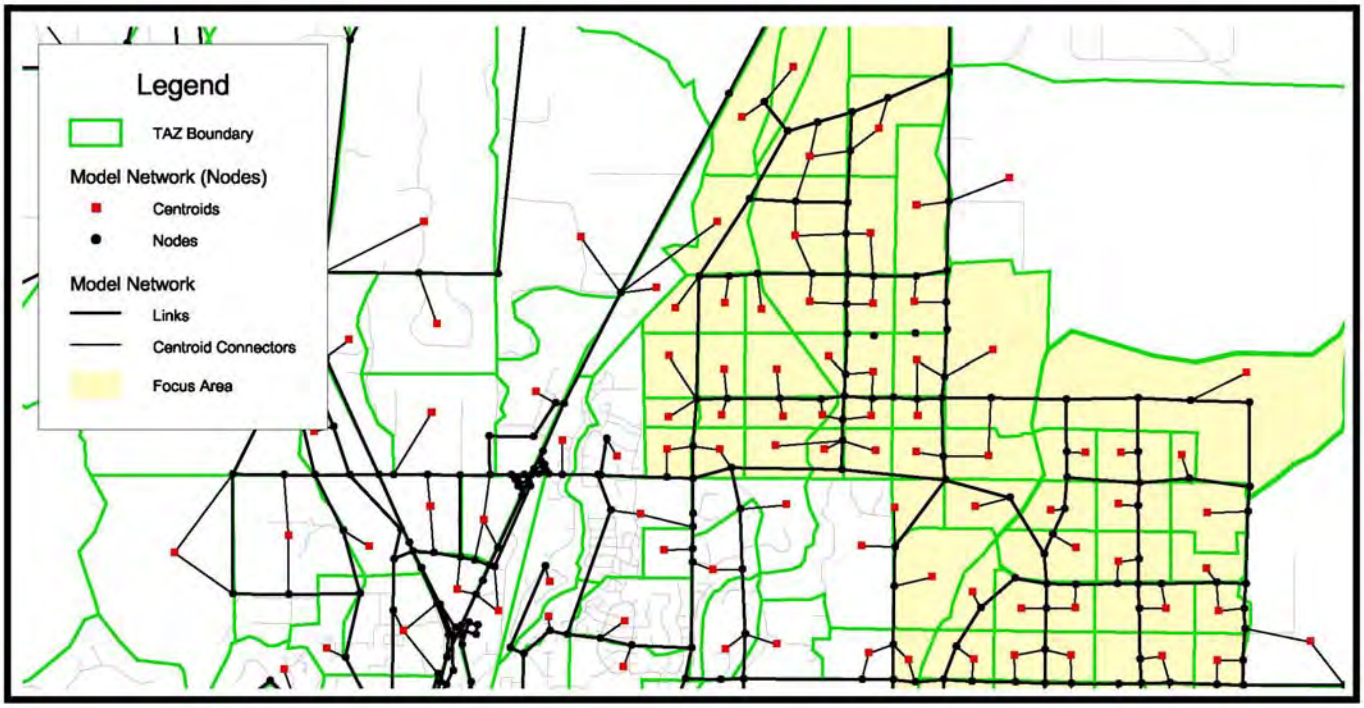


Figure 14
TAZ System and Network for Focus Model



specified in different units than what is needed for travel forecasting models. For site developments, the proposed land uses are usually defined in terms of the number of dwelling units for residential uses and building square footage for non-residential uses. For zoning changes and comprehensive plan amendments, fewer details may be known about the ultimate uses of the development area. The land uses may be identified in more general terms, such as gross acres of land by zoning or comprehensive plan category rather than the number of dwelling units or building square footages.

In either case, for model use, the land use quantities need to be converted to the number of households by socioeconomic category for residential uses and employment by type for non-residential uses. Similar conversion processes are used for both types of proposed changes, but are slightly different due to the different level of detail of the original data.

For site developments, the general process for residential uses is to apply an assumed vacancy rate to the number of dwelling units to obtain an estimate of the number of total households. The total households are then broken down by socioeconomic category by applying household distribution percentages from a neighboring or similar TAZ.[21] Non-residential land uses are converted to employment by type by applying employee densities to the square footages and then allocating the employment to the appropriate category.

The process for zoning changes and comprehensive plan amendments involves additional front-end steps to estimate the number of dwelling units or building square footages from general land use quantities, such as gross acres of land by zoning or comprehensive plan category. Assumptions about the percentage of land to be set aside for public uses, such as streets, must first be applied to obtain estimates of net developable acres. Following this, density assumptions can be applied to the estimates of net developable acres (dwelling units per acre for residential uses and floor-area ratios for non-residential uses) to derive estimates of the number of dwelling units and building square footages. The remaining steps of the process are identical to those for proposed site developments.

If TPAU will be applying the model for the analysis of a proposed land use change, the land use input data may be prepared by either the local jurisdiction or TPAU staff. If the local jurisdiction prepares the input data, then the original land use quantities should be provided to TPAU together with the input data. TPAU staff will use this information to review the reasonableness of the data. If TPAU prepares the input data, the local jurisdiction only needs to provide the initial land use quantities and TPAU will perform the conversion based on an understanding of the proposed land use.

With either approach, TPAU will be involved only in the preparation of the land use data for the model. The determination of what the proposed land use will be is strictly a local land use decision.

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[21] A similar TAZ is an existing TAZ having household demographics comparable to those of the expected household types for the site development.

Identification of Network Changes

In addition to defining the land use quantities that will determine the travel demand generated by the proposed change, the transportation network/supply that will support the proposed land uses must also be represented in the model. For smaller land use changes, the existing network structure for larger facilities (functional classification of collector or higher), may be adequate for this purpose, so that no changes to the model's network would be required. For larger land use changes, however, particularly those located near the periphery of an urban area where the existing network may be sparse, there may be a need to define additional facilities.

If the proposed change is for a site development, the project proponent will sometimes provide this information. In many cases, however, there will be no information about the associated network changes that need to be coded in the model. Therefore, an important issue is how to identify these changes.

It is not possible to define a step-by-step process for the identification of network changes because many of the decisions will depend on location-specific conditions. However, there are several general factors that should be considered. These are:

- Structure of the existing network near the area of the proposed change;
- Planned improvements included in the local transportation system plan;
- Level of refinement of the surrounding TAZs (see discussion above if model is to be "focused");
- Level of detail required for the model outputs; and
- Network coding conventions for the existing model network.

For the definition of a future "baseline" network, it is also important to check with ODOT and local transportation system providers about which improvements can be considered reasonably likely to receive funding by the end of the planning period.

Participants in the identification of future network changes related to the proposed land use change should include ODOT, the local jurisdiction, and the project proponent (if applicable).

Use of ITE-Type Trip Generation Rates

ODOT's *Development Review Guidelines*[22] provides guidance for the development of Traffic Impact Studies (TISs). As stated in the *Guidelines*, "A TIS will usually be necessary to determine whether a development proposal will have a "significant effect" on a transportation facility as spelled out in TPR section 0060." If the proposal is for an amendment to a functional plan, an acknowledged comprehensive plan, or a land use regulation and the TIS shows that it will have a significant effect, then the TPR requires that the local jurisdiction "put in place measures to assure that the allowed land uses are

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[22] Oregon Department of Transportation, Development Review Guidelines, (2005)

consistent with the identified function, capacity, and performance standards of the facility". The results and recommendations of the TIS are also used by ODOT and local jurisdictions to support decisions regarding the denial, approval, or "approval with conditions" of local land use proposals and highway approach permit applications.

Within a TIS, to estimate the trip generation for a land use proposal that does not have specific identified uses, the *Guidelines* recommend that a reasonable worst-case land use should be assumed based on the uses allowed outright under the current or requested zoning. An example provided in the *Guidelines* describes a 20-acre site that is proposed to be rezoned from an industrial use to a commercial use, but no specific type or size of the commercial development has been identified. In this case, it should be assumed that the property will develop at the highest trip generating uses allowed under the new zoning – retail, a fueling station, and a fast food restaurant with a drive-through window, for example. One source of information about the trip generation rates for specific land uses recommended by the *Guidelines* is the ITE's *Trip Generation*[23] report.

The trips for a specific development estimated by a model, however, may not be the same as those calculated using trip generation rates from the ITE's *Trip Generation* report. This is because the number of trips for a specific development estimated by a model depends on the total number of trips produced by all households within the region, as well as the desirability of the development for attracting those trips compared to all other similar developments in the region (see also Section C).

Within a model, total trip generation is constrained by the number of households in the region. Unless an increase in the number households is assumed in association with the proposed development, there would be no increase in the total number of trips generated with the proposed development. Rather, the same number of trips would be spread more "thinly" between existing developments and the proposed development.

Because trip generation using ITE trip generation rates is based only on the characteristics of the development (type and size) and does not consider other factors such as the number of supporting households or competing developments, ITE-type trip generation estimates may be higher than those produced by a model. Therefore, they may be more representative of a "reasonable worst-case" development scenario.

Thus, for the purpose of analyzing the impacts of proposed land uses, it may be appropriate to substitute within the model ITE-based trip estimates in place of the trips estimated by the model. This should be decided based on a comparison of the model trips vs. the ITE-based trips. The ITE-based trips should be used if it is determined that the difference in trips is large enough that it could affect the decision regarding the denial, approval, or conditions of approval of the proposal or the findings of "significant effect".

This approach should be followed for non-residential development proposals only (or the non-residential portion of a mixed-used proposal), because there is no downward bias in

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[23] Institute of Transportation Engineers, Trip Generation, 8th Ed., (2008)

the model's trip generation estimates for residential development, which are based on the number of households by household type. This is similar to the ITE trip generation methodology for residential development, which is based on the number of dwelling units by dwelling unit type.

The detailed steps for applying this approach are described in Appendix A. It is noted that work trips are excluded from this adjustment process, since work trips are estimated within the model based both on the total number trips produced by the region's households as well as the number of trips that a development is expected to attract. Therefore, it is assumed that the number of work trips estimated by the model for a proposed development should be similar to the number reflected within the ITE-generated trips.

Representation of Mixed-Land Uses

Accurate representation of mixed-use characteristics in the model is important to adequately account for the effects of this type of development on travel patterns. There are two primary effects on trip making within the development area compared to trips in other areas, related to the proximity of households to employment with this type of development:

- Shorter trip lengths (trip distribution)
- Higher non-auto mode shares (mode choice)

ODOT's MPO and small urban area models are somewhat sensitive to the trip distribution effects of mixed use development by estimating higher percentages of intrazonal trips, or shorter interzonal trips, for TAZs containing this type of development. Within the MPO models, the mode choice effects of mixed-use development are reflected with two variables:

- A composite accessibility or "mix" variable reflecting retail employment density and intersection density near each zone; and
- A second composite accessibility or "mix" variable reflecting total employment density and intersection density near each zone.

The composite accessibility variables are included to account for both the relative magnitudes of and interactions between household density, employment density, and intersection density (a measure of street connectivity) – three urban design variables correlated with travel behavior. Intersection density is included as a component of these variables because higher levels of street connectivity intensifies the effect of mixed-use development by facilitating travel between nearby origins and destinations via non-vehicular modes.

For the models to be sensitive to the mixed-used development characteristics of a proposed land use change, it is important that accurate data about these characteristics is provided for input to the model.

The small urban models, which lack a mode choice component, do not directly account for the effects of mixed-use development on mode choice. This may be less of a problem in these areas, because development densities may be lower than in MPO areas.

For a proposed land use change that contains a considerable amount of mixed-use development, if it appears that the effects of this development are underestimated by the model based on an examination of the model's estimates of trip lengths and mode shares, it may be possible to manually adjust the trip matrices to better reflect the expected effects. This should be done only if it is clear that there is a significant underestimation and there is adequate information available to guide the decision about what the appropriate adjustment should be.

Representation of Special Attractors

Travel forecasting models are set up to estimate the average travel characteristics of a set of broad land use categories. Because of this, the model may not be able to accurately represent a proposed development that has special travel characteristics related to trip generation, trip distribution, mode choice, or time-of-day distribution. In these cases, consideration may be given to defining the development as a special attractor, so that it can be treated differently within the model.

Airports, stadiums, universities, and major hospitals are examples of special attractors in larger urban areas. In smaller urban areas, special generators may be developments of a much smaller scale, such as shopping mall, large employment sites, community colleges, and even large shopping centers. This is because within smaller areas, the relative effects of these developments are much greater than what they would be in a metropolitan area.

Within both the MPO and small urban area models, special retail attractors are differentiated through the use of attraction factors, which increase the attractiveness of these developments to a higher level than what the model would normally estimate. The local jurisdiction should consult TPAU staff if it considers a proposed development to be a special attractor to determine the appropriate value of the attraction factor. Because attraction factors reflect the relative desirability of a development as a destination, the value of a factor may change over time. For example, if there is only one shopping mall within an area in the short-term, but in the long-term another mall will be built, then the value of the factor would likely be higher in the short-term than the long-term.

The use of attraction factors is generally limited to proposed site developments, because not enough is known about the specific characteristics of the future development associated with a zoning change or comprehensive plan amendment.

Representation of Transit-Oriented Development (TOD)

Transit-oriented development refers to compact, mixed-use development within walking distance of public transportation. TOD creates communities where people have access to transportation and housing choices by increasing location efficiency and allowing people to walk, bike and take transit for their daily trips.

The special characteristics of TODs can be represented within ODOT's MPO models. Typically, these include:

- Low transit access times
- High transit service levels
- High transit accessibility to regional employment areas
- Supporting collector service to transit trunk lines
- Higher development densities within walking distance of transit
- Mixture of residential and non-residential uses in close proximity
- Well-developed pedestrian and bicycle networks
- Reduced or managed parking within walking distance of transit

To model a TOD, there must be a coded transit network within the model. Currently, all of ODOT's MPO models include this feature. A TOD should be designated as a separate TAZ (or TAZs) within the model so that its area and characteristics can be more accurately defined.

The model can be used to estimate the effects of a TOD on travel demand if the following information is provided:

- Transit lines serving the TOD
- Transit service frequencies, including peak and off-peak headways
- Transit stop locations
- For each TOD TAZ:
    - Percentage of total households within walking distance (¼ mile) of transit service (peak and off-peak)
    - Percentage of total employment within walking distance of transit (peak and off-peak)
    - Short-term and long-term parking costs
    - Number of local intersections within ½ mile of TAZ
    - Retail employment within ½ mile of TAZ
    - Total employment within ½ mile of TAZ
    - Households within ½ mile of TAZ

Because ODOT's small urban models do not contain a mode choice component, TODs cannot be explicitly reflected within these models. Adjustments could be made to the trip matrices output by the model to estimate the reduced auto shares and increased transit shares resulting from transit-oriented development. However, this is not recommended because the effects of this development are very location or context-dependent, making it difficult to apply a “one-size-fits-all” adjustment factor. Unless adequate information is available about these effects from a study for an equivalent TOD, adjustments should not be made to trip matrices for the purpose of reflecting TOD land use effects.

Adjustments for External Trip-Making

Within the model, external-internal trips (trips produced outside of the modeling area destined for TAZs within the modeling area) are distributed to internal TAZs based on the relative attractiveness of each TAZ. The measure of attractiveness that is used does not reflect how far the TAZ is located from the external station nor the specific characteristics of the development within the TAZ. Likewise, internal-external trips are distributed to external stations based on the number of external trip ends at each station, but the distance or travel time from the internal TAZ to the external station is not considered.

This works well for estimating most external trip making, but if a proposed land use change has special trip distribution characteristics, these may not be reflected within this general approach. For example, a shopping mall in a smaller urban area may attract a higher proportion of its trips from outside of the local area compared to a normal shopping center, functioning as a regional attractor. The trip distribution for a proposed land use change may also be significantly different if it is located near the periphery of an urban area. This may be true for an employment or retail center that draws many of its employees or customers from outside the local area because it is more accessible, resulting in a higher proportion of external-internal trips. Similarly, a housing development near the edge of an urban area may be a desirable residential location for workers with jobs outside of the area, resulting in a higher proportion of internal-external trips.

If this is a significant issue, then special provisions could be made within the model to better represent the specific external trip making characteristics of the proposed land use change. This would require defining the area of the proposed land use change as a separate TAZ or TAZ(s) within the model. The potential adjustments include:

- Using special internal-external and/or external-internal trip percentages for the proposed land use TAZ(s); and
- Adjusting the number of internal-external and/or external-internal trip ends at the appropriate external stations.

These changes should be considered only if there is strong evidence to suggest that the proposed land use change would have significantly different external trip making characteristics and there is adequate information to support the adjustments.

Development of Interim Year Forecasts

The standard time periods that model output is available for most of ODOT’s models is the model base year and the planning horizon year for the local TSP. There may be instances, however, when future travel volumes are needed for interim years. An example of this is a year-of-opening analysis of the transportation impacts of proposed development. ODOT's *Development Review Guidelines*[24] suggest that analyses for proposed developments should be performed for various future years depending on the development's daily trip generation and phasing, including year-of-opening/year-of-phase-opening, 5 years after opening/buildout, or 10 years after opening/buildout.

The difficulty in developing model forecasts for interim years is that future year land use data for the model area and assumptions about future network improvements that are input to the model are usually only available for the TSP horizon year. One way to address this problem would be to simply interpolate between the model outputs (e.g., link volumes) for the base year (without proposed change) and TSP horizon year (with proposed change). This could only be done, however, when a relatively constant rate of growth in development could be assumed for the local area throughout the planning period and there would be no major changes to the transportation network. If major development or major improvements to the network would occur at uneven intervals during the planning period, then interpolation of model output would likely not provide accurate estimates of interim year volumes, because these changes would not have been explicitly reflected within the model.

A second approach would be to interpolate between the base year (without proposed change) and horizon year (with proposed change) assignment matrices and then rerun the assignment. This would be an improvement compared to the first approach, because the effects of the interim year trips on assignment would be reflected within the model, but these would not be included within the trip generation, trip distribution, or mode choice components of the model.

A third approach would be to develop land use data for the model area and a network scenario for the interim year and then run the entire model using these inputs. The land use data could be developed in several ways:

- Local jurisdiction develops the data based on future development plans;
- TPAU staff interpolates between the base year and horizon year data; or
- TPAU staff interpolates between the base year and horizon year data and provides the interpolated data to the local jurisdiction for adjustment based on future development plans.

There would be a degree of uncertainty about the timing of future development with any of these methods. The definition of an interim year network scenario would likely be more straightforward than an interim year land use scenario, because more is usually known about the timing of future transportation improvements based on information sources such as the STIP and local TSP.

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[24] Oregon Department of Transportation, Development Review Guidelines, (2005)

Even with the uncertainty about land use assumptions, the third approach would be preferable, in most cases, to the first two approaches because the interim year land use and network improvements would be reflected within all components of the model.

The first two approaches could be applied relatively quickly. The third approach could also be applied fairly quickly if the interim year land use data was developed using interpolation only. The time requirement would be somewhat greater if the interpolated data were adjusted by the local jurisdiction, and significantly higher if the land use data were developed "from scratch".

Development of Alternate Year Forecasts

There may be some cases where an additional year (i.e. future year +1, +2, +3years) needs to be considered. Extrapolation of model assigned volumes may be acceptable in some cases, such as;

- Study areas near the periphery of the urban model
- Links that have a below a d/c ratio below 1
- For analysis that is less than 3 years beyond the future year

Reasonableness Checks of Model Output

Once a model has been applied to produce forecasts for a proposed land use change, the model outputs should be checked for reasonableness prior to being used for analysis purposes. The decision about which reasonableness checks to make will depend partly on how the output will be used, but there are several basic checks that should be made in all cases. These checks are shown in Table 7 and are applicable to all types of proposed changes.

Table 7

Model Output Reasonableness Checks

Reasonableness Check	Purpose
1. Total person trip ends for proposed change TAZs	Verify that appropriate number of trips have been estimated in trip generation, trip distribution steps
2. Select zone assignments for proposed change TAZs	Check reasonableness of trip distribution and assignment
3. Link volumes with and without proposed change	Assess reasonableness of number and location of trips on the network for proposed change
4. Travel time isochrones for proposed change TAZ*	Validate roadway network and traffic assignment
5. Mode shares for proposed change TAZ	Assess reasonableness of mode share estimates**

* Particularly important if network changes have been made to support the proposed land use change. This check can also be used to determine if assumed network changes will provide adequate accessibility for the proposed change.

** Applicable only if auto reduction-type measures have been included in the model for the proposed change.

G. HOW SHOULD THE MODEL OUTPUT BE USED?

Analysis Using Model Output

After the required model output has been produced, it is important to apply the data in the appropriate manner to answer questions about the transportation impacts of a proposed land use change. ODOT's *Analysis Procedures Manual*[25] provides guidance on the use of model output data for the estimation of future traffic volumes based on modeled traffic growth rates (post-processing), as well as the identification of future travel patterns using select link/select zone traffic assignments. There is a variety of other model outputs that can also be used, as described in Section E.

Model Output Format

Model output data can be produced in graphic, tabular, or file formats. Graphic output includes network plots that show any of the network-based model data, such as link volumes and travel times. Matrix data, such as zone data and zone-to-zone travel volumes, can be shown graphically on plots or histograms. Virtually any of the model network or matrix data can be summarized in tabular format by the required categories. For use in other transportation analysis software, model output can be produced in various file formats, such as spreadsheet, .csv, or text file formats. Within each of these formats, the outputs can be disaggregated to various levels of resolution within the geographic, network, time, and market segment dimensions of the data.

Model Output for Local vs. Area-Wide Impact Analysis

Model output can be used to analyze both localized and system level impacts of proposed land use changes. The analysis for site developments, smaller-scale zoning changes, and proposed land use changes within interchange management areas tends to be more localized, focusing on impacts within the immediate vicinity of the project. Examples of model outputs commonly used for analysis at the local level include:

- Link volumes used for post-processing. Post-processed volumes can be used for capacity analysis and corridor traffic operations analysis and simulation.
- Select zone assignments used for identifying project trip distribution percentages. The trip distribution percentages can be used for the manual assignment of project trips in traffic impact studies.
- Trip matrices used for subarea network traffic simulation.
- Select link assignment volumes used for estimating fair shares of system improvement costs.

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[25] Oregon Department of Transportation, Analysis Procedures Manual

- Plots showing traffic diversion caused by increased traffic volumes with the proposed change.
- Link d/c plots with and without the proposed change indicating relative congestion levels.

Model outputs used for the analysis for comprehensive plan amendments and large-scale zoning changes may include some of the examples listed above. However, because of their large size, the area-wide impacts of these changes should be examined using other types of measures that can be produced by a model. Examples of these include:

- VMT by facility type or trip type
- Congested lane miles by facility type
- Vehicle hours of delay
- Vehicle hours of travel
- District-to-district travel times
- Modal shares
- Trip length frequency distributions

Presentation of Model Output

In addition to using model output for the analysis of the transportation impacts of proposed land use changes, it can also be used to explain the impacts to the various interest groups involved in a proposed change. The type of model output used to describe the impacts should be tailored to each group, because each group will have different areas of interest and different levels of understanding.

The general types of interest groups involved in the review of transportation impacts of proposed land use changes are decision-makers (committee members, policy-makers, and elected officials), the general public, and technicians (engineers and planners).

Some examples of the specific areas of interest of decision-makers are:

- Impacts by jurisdiction (state vs. local transportation facilities)
- Cost-related impacts
- Facility-specific impacts
- Consistency of the impacts with the local TSP
- Asset management
- Fair-share cost responsibilities for required system improvements

Any model output presented to decision-makers should allow them to quickly grasp the story line of the analysis findings. The presentation should distill model output into a summary or graphic format, reflecting key themes of the findings. An example of this would be a select link plot showing the distribution of traffic volumes from a proposed land use using an important link in the roadway network. The information should be presented in common language and in terms easily understood by a non-technical audience.

The primary areas of interest for the general public are usually related to what the capacity, safety, or traffic operations impacts of a proposed land use change may be on known “hotspots” in the network or in parts of the network near their home or workplace. Model output for the public should comprise a limited set of basic measures and be presented in graphic or simple tabular format. Examples of this are link d/c plots and volume difference plots showing traffic volumes with and without the proposed land use change. The use of acronyms and abbreviations should be avoided (e.g., “HBW” should be spelled-out as “home-based work”). The presentation should be in common language easily understood by a non-technical audience.

Model output for technicians may be much more extensive and detailed than what is provided to decision-makers or the general public. This may include an expanded set of impact measures, as well as documentation on the methodology and assumptions used for the model application.

H. GLOSSARY OF TERMS

calibration

The process of adjusting a model's parameters until its trip estimates are similar to observed travel data.

household travel survey

A survey conducted to identify the travel and socioeconomic characteristics of households within the local model area. The data obtained from the survey is used to develop the model.

link scatterplot

A plot comparing traffic counts to link volumes from the model assignment. Each link is shown as a point on the plot, with the x-coordinate representing the traffic count and the y-coordinate representing the model volume. Scatterplots are used to assess how well the model estimates traffic volumes on a system-wide basis.

model focusing

A special procedure used when greater detail is needed within the model network and TAZ system to adequately represent a portion of the modeling area. It involves disaggregation of the TAZs within the "focus" area, as well as refinement of the network to be consistent with the smaller TAZs.

model node

A model network feature representing street intersections/access points or transit stops. At non-intersection locations, nodes may also be used to reflect roadway curvature. A special type of node called a centroid defines the location of a TAZ within the network.

model link

A model network feature representing road segments that connect model nodes. A special, artificial link called a centroid connector is used to connect TAZ centroids to the network.

post-processing

The application of growth factors to traffic counts to derive estimates of future traffic volumes. The growth factors are calculated as the relative or absolute difference between base year and future traffic volumes from the model.

select link assignment

A special type of auto assignment in which the assignment paths of all trips using a select link are stored, allowing network plots to be produced showing the total volume of these trips on each link in the network.

select zone assignment

A special type of auto assignment in which the assignment paths of all trips originating from or destined to a select zone are stored, allowing network plots to be produced showing the total volume of these trips on each link in the network.

transportation analysis zone (TAZ)

A spatial unit representing a small subarea of the modeling area. Most modeling areas comprise hundreds of TAZs. They are used to reflect land use characteristics within the model.

transportation modeling

Transportation modeling is the simulation of the various elements of the transportation system. Different types of models are used to simulate different elements. For example, travel demand models are used to estimate the future volume of person travel, while microsimulation models are used to simulate traffic flows on the roadway network.

travel demand model

A travel forecasting model is a set of sequential models linked by their inputs and outputs. Each model in the set attempts to replicate a particular aspect of travelers' decision-making behavior. This is done with mathematical equations that represent the relationship between the behavior that is being modeled and the variables that explain that behavior.

trip length frequency distribution

A distribution of the number of zone-to-zone trips estimated by model by travel time or travel distance interval.

TSP population/employment total

An area-wide population/employment total that serves as the basis for the development of TSPs.

validation

The assessment of a model's overall performance by comparing the model's estimated base year network volumes to traffic counts.

volume-delay function

A function used within the trip assignment component of the model to estimate link travel times. Travel delay is estimated based on the relationship between link volume and link capacity expressed within the function.

APPENDIX A ITE TRIP GENERATION ADJUSTMENT PROCEDURE

The following procedure may be used to substitute trip ends (origins and destinations) calculated for a proposed land use using ITE trip generation rates for those estimated by the model. The ITE-based trip ends should be calculated using the standard ITE trip generation methodology, including adjustments for pass-by and diverted linked trips. A flow chart of the procedure follows the steps outlined below.

1. Create land use input data for the model that includes the proposed development:

    - Add new land use (employment by type) for the development TAZ(s), with no adjustment (reduction) in land use for the other TAZs; or
    - Add new land use for the development TAZ(s), with a reduction in land use growth for the other TAZs (either proportional scaling or selective decreases).

2. Run the model with the land use data from Step 1; save the assignment period vehicle trip matrices by trip purpose.
3. Sum the non-work trip matrices from Step 2 to create a total non-work vehicle trip matrix.
4. Create O and D vectors for the work trip matrix from Step 2 and the non-work trip matrix from Step 3.
5. For the development TAZ(s), calculate:

    a. Total Os and Ds using ITE trip generation rates.
    b. Internal-internal (I-I) percentages[26] of total origins and destinations using the total vehicle trip matrix from Step 2.
    c. ITE-based I-I Os and Ds by multiplying the Os and Ds from Step 5.a by the I-I percentages from Step 5.b.
    d. Non-work trip percentages of total I-I origins and destinations using the work and non-work vehicle trip O and D vectors from Step 4.
    e. ITE-based non-work trip Os and Ds by multiplying the Os and Ds from Step 5.c by the non-work trip percentages from Step 5.d.
    f. Differences between the ITE-based non-work trip Os and Ds from Step 5.e and the model non-work Os and Ds from Step 4.

6. In the non-work trip O and D vectors from Step 4, zero-out the O’s and D’s for the development TAZ(s), then proportionally scale down the Os and Ds for the non-development TAZs by the amount of the differences in the non-work Os and Ds for the development TAZ(s) calculated in Step 5.f.
7. Insert the ITE-based non-work trip Os and Ds for the development TAZ(s) from Step 5.e into the non-work trip O and D vectors from Step 6.

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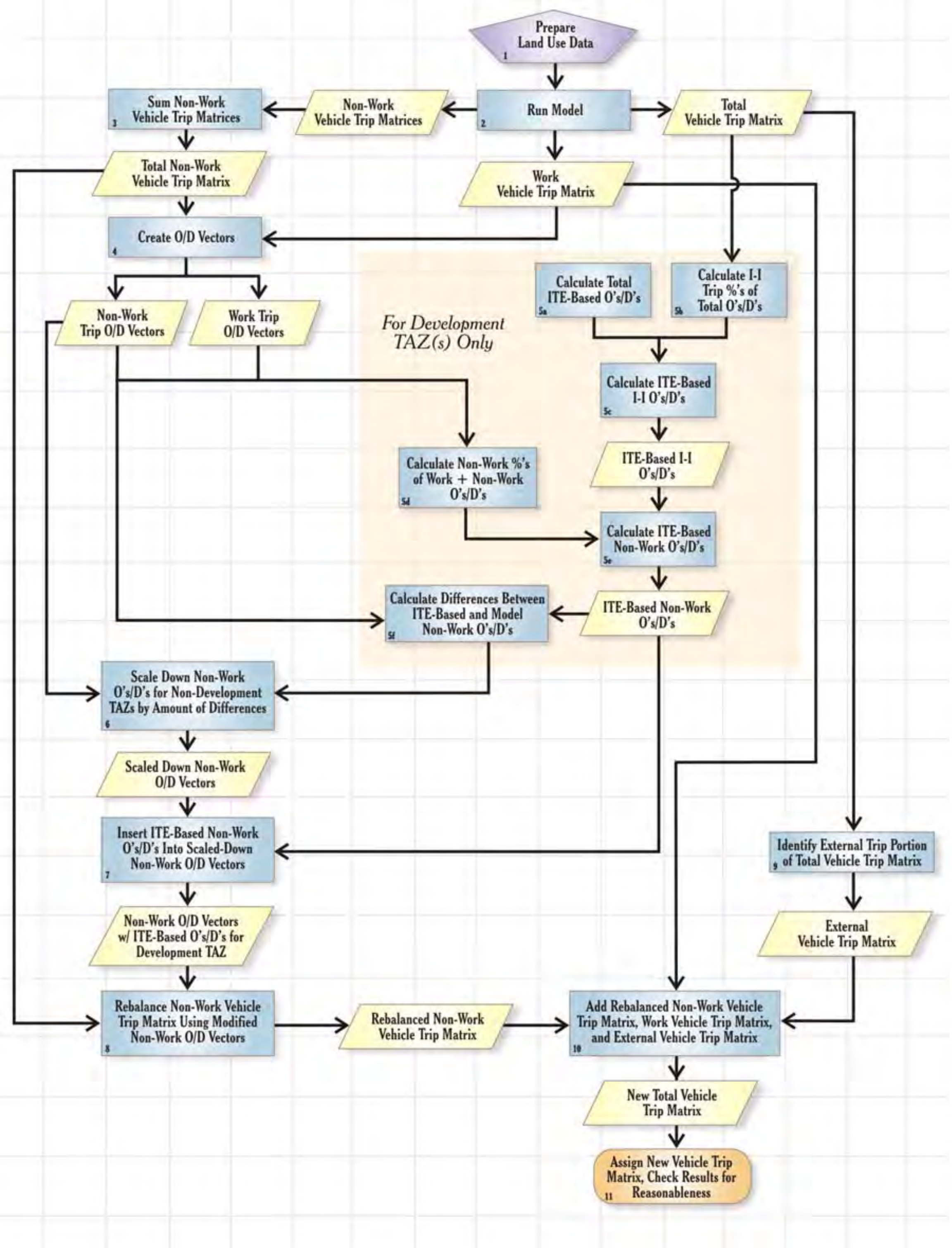
[26] Refers to I-I trips for the modeling area.

8. Rebalance the non-work trip matrix from Step 3 using the modified non-work trip O and D vectors from Step 7.
9. Identify external trip portion of total vehicle trip matrix from Step 2.
10. Add the rebalanced non-work trip matrix from Step 8, the work trip matrix from Step 2, and external portion of the total vehicle trip matrix from Step 9 to create a new total vehicle trip matrix.
11. Assign the new vehicle trip matrix; check results for reasonableness.

Figure A-1
ITE Trip Generation Adjustment Procedure



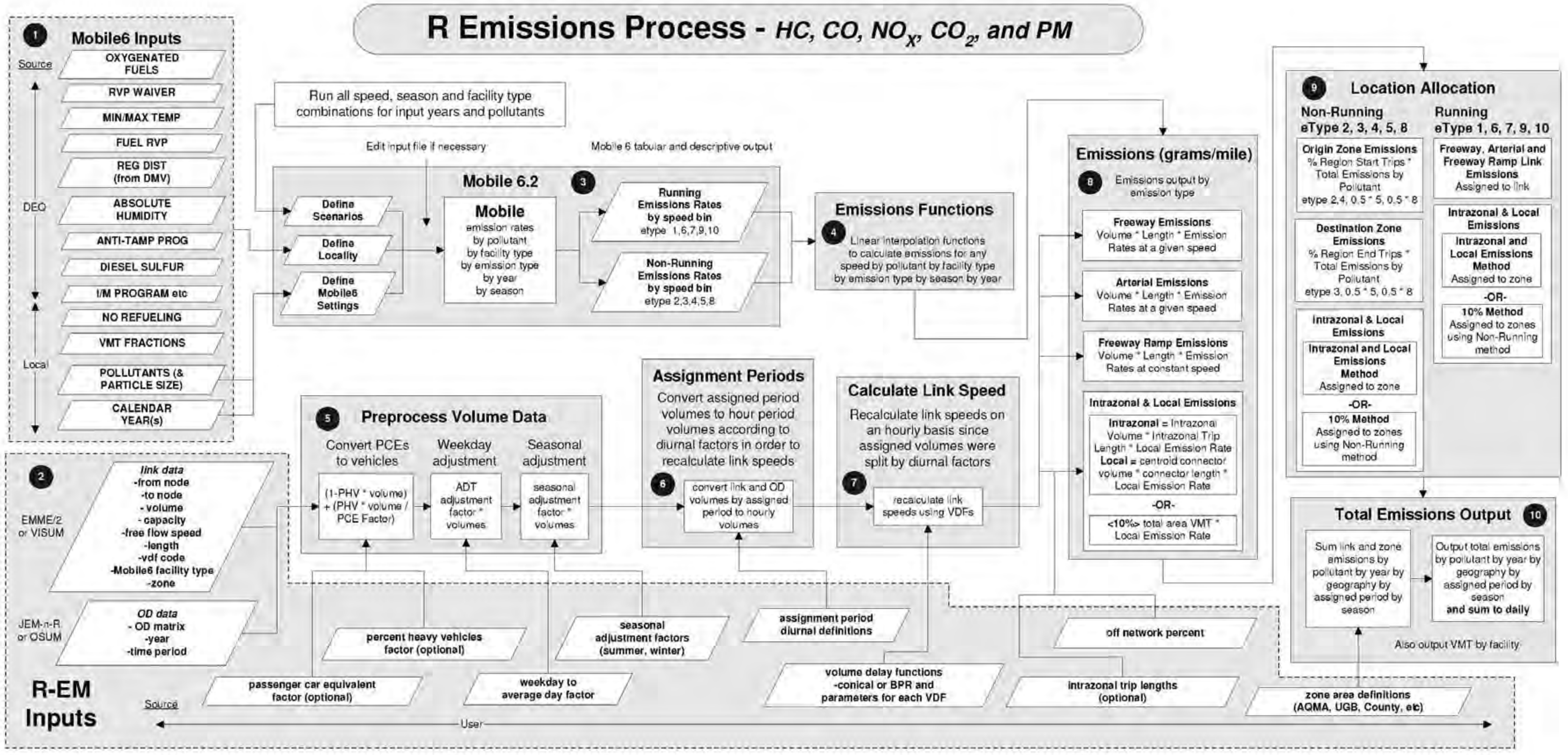
APPENDIX B   cER AIR QUALITY ANALYSIS PROGRAM

To facilitate air quality analysis for area-wide studies, such as the TIP/Air Quality Conformity Determination, as well as project studies, ODOT developed the “calculate emissions in R” (cER) program. cER produces estimates of vehicular emissions for various types of pollutants based on emission rates developed with the Mobile 6.2 software package.

Within cER, input link volumes are adjusted to reflect traffic for an average day during the summer and winter seasons and then converted to equivalent hourly volumes for the analysis period (see Figure B-1). The hourly volumes are used within a set of volume-delay functions (VDFs) to estimate link travel speeds. The model VDFs, however, are calibrated to estimate the correct assignment of trips on the network and not to produce refined estimates of link speeds. While the estimated speeds are generally within a reasonable accuracy range, it would be desirable to have more accurate estimates for the purpose of identifying emission rates. Therefore, a future enhancement will be to revise the VDFs within cER to provide refined speed estimates.

Based on the estimated speed, an emission rate is selected for each link in the network. Running emissions are calculated by facility type as the product of link volume, link length, and the emission rate. The running emissions are assigned to individual zones according to the location of the link and then combined with estimates of zonal non-running emissions to produce total emission estimates by zone. These can be summed to any geographical area (UGB, county, city, etc.) specified by the user. In addition to emissions for total traffic volume, it is possible to develop emission estimates by vehicle class within this process.

Figure B-1
cER Program Flow Chart



Pollutants

	1	HC	Hydrocarbons (gaseous)
	2	CO	Carbon Monoxide (gaseous)
	3	NOx	Oxides of Nitrogen (gaseous)
	4	CO2	Carbon Dioxide (gaseous)
▲	7	SO4	Sulfate Portion of Exhaust Particulate
	8	OCARBON	Organic Carbon Portion of Diesel Exhaust Particulate
	9	ECARBON	Elemental Carbon Portion of Diesel Exhaust Particulate
	10	GASPM	Total Carbon Portion of Gasoline Exhaust Particulate
PM	11	Lead	Lead Portion of Exhaust Particulate
	12	SO2	Sulfur Dioxide (gaseous)
	13	NH3	Ammonia (gaseous)
	14	Brake	Brake Wear Particulate
▼	15	Tire	Tire Wear Particulate

Emission Types

1	Running	Exhaust Running Emissions
2	Start	Exhaust Engine Start Emissions (trip start)
3	Hot Soak	Evaporative Hot Soak Emissions (trip end)
4	Diurnal	Evaporative Diurnal Emissions (heat rise)
5	Resting	Evaporative Resting Loss Emissions (leaks and seepage)
6	Run Loss	Evaporative Running Loss Emissions
7	Crankcase	Evaporative Crankcase Emissions (blow-by)
8	Refueling	Evaporative Refueling Emissions (fuel displacement and spillage)
9	Brake Wear	Particulate matter from brake component wear Brake wear
10	Tire Wear	Particulate matter from tire wear Tire wear

Roadway Classifications

1	Freeway	High-Speed, Limited-Access Roadways
2	Arterial	Arterial and Collector Roadways
3	Local	Urban Local Roadways
4	Fwy Ramp	Freeway on and off ramps
5	None	Not Applicable

Mobile 6 Speed Bins

Freeway	2.5, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65 mph
Arterial	2.5, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65 mph
Local	12.9 mph
Fwy Ramp	34.6 mph

12/9/03
Ben Stabler, ODOT
Based on Metro's PATA Study Method

User defines the inputs in the Mobile 6 Inputs and R-EM Inputs boxes. The rest of the process is handled by R and Mobile 6.

Depending on the requirements of the user, the Mobile 6 input file may need to be edited.

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