8 MESOSCOPIC ANALYSIS

8.1 Purpose

This APM chapter provides fundamental guidance and overview of an array of methods related to mesoscopic modeling. Mesoscopic methods are rapidly changing based on availability of new tools and data sources, such as the move towards activity based travel demand models. This chapter focuses on methods that have previously been applied in projects involving ODOT and is not intended to be comprehensive for all mesoscopic methods and tools. Other methods not documented in this chapter may be applied, if appropriate, through consultation with TPAU staff.

The purpose of this chapter is to provide an overview of methods and tools available to apply mesoscopic analysis. The information provided in this chapter is intended to provide the user with the information required to understand the general approach for scoping project methodology and understanding the differences between various methods along with limitations and advantages of using each method. For more details on many of the methods in this chapter also refer to NCHRP Report 765.

8.1.1 Overview of Chapter Sections

This chapter covers a broad array of topics related to mesoscopic analysis. Topics included cover:

- Scoping – How to identify approach, tools, and effort based on the analysis needs.
- Subarea Analysis – How to develop subarea models that increase the detail from an existing model.
    - Focusing – General procedures for adding detail and creating a focus area model within a regional model.
    - Windowing – General procedures for selecting an area to "cut" or "window" out into a separate model that can then have additional detail.
- Dynamic Traffic Assignment (DTA) – Analysis considerations and triggers that may lead to analysis that considers traffic routes and travel times that vary by time of day.
- Peak Spreading – General concepts and analysis considerations to identify how congestion spreads from peak periods to larger intervals and the impact on vehicle demand during shoulder periods.

Section 8.1.4 includes references to other chapters of the APM that provide material that may be related to mesoscopic methods covered in this chapter.

8.1.2 Key Definitions

Having a common understanding of the terms in this chapter is necessary for proper implementation of methods and tools. Definitions for terms included in this chapter are included in the Glossary. Selected terms that are needed for fundamental content are shown below.

- **Macroscopic Model**– Aggregate models that have a high-level view of the transportation system and do not include many transportation network details. Macroscopic travel demand models are generally large (potentially regional) in size and focus on general vehicle flows and route choice from one area to another. Streets may be approximated by the average number of lanes, a free-flow speed, and approximate vehicle capacity. Vehicle trips are routed through the network based on algorithms that select paths that minimize the travel time.

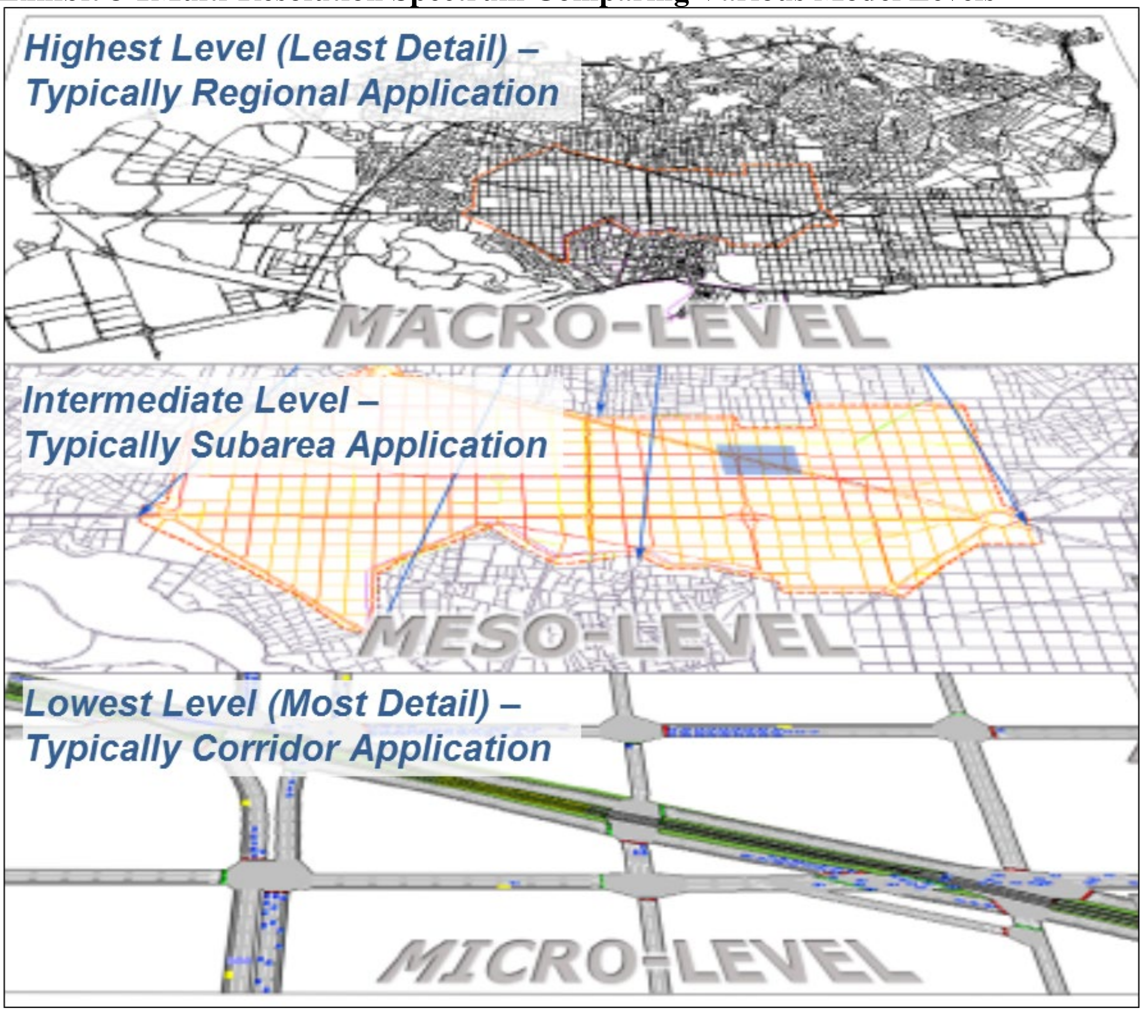
- **Mesoscopic Model** – A hybrid model that includes combinations or approximations of elements from both macroscopic and microscopic models. Mesoscopic models may include a routable network similar to a macroscopic model (with a supplementary origin-destination matrix), while also incorporating more detailed operational elements of the transportation network to better estimate travel time based on traffic operations similar to a microscopic model. Elements from either the macroscopic or microscopic models may be generalized or simplified.

- **Microscopic Model** – Detailed models that are at a fine scale and typically include all streets and components of the transportation system that impact travel. Such elements can include intersection control and striping, pedestrian crossings, transit stops, and even the inclusion of traffic calming measures. Microscopic models typically refer to simulation models that include randomized characteristics and behaviors of an array of drivers and vehicles as they traverse a network. The performance of these models is typically averaged over several "runs" to account for the randomized driver and vehicle characteristics. Unlike macroscopic models, traffic demand values are generally inputs and typically do not result from path choice within the model, therefore, there may not be a predetermined throughput. As a result, assigned traffic volumes at specific locations such as midblock or a turn movement may not match the input demand due to constraints on the network metering flow. For example, queues will build in a microscopic model and only vehicles that can make it through a bottleneck in a given time period will be observed.

- **Multi-Resolution** – The combined framework of an integrated series of models, each built or scaled for the appropriate level of "resolution" and detail given the context for project application and need. The individual model components (resolutions) each can be integrated for a particular project/analysis that benefits from the data analysis and output of the individual tool and level. General levels, or “resolutions”, that may be used to describe models or application that fit a general context include microscopic, mesoscopic, and macroscopic models as shown in Exhibit 8-1.

Appendix 8B provides a user guide for the PTV Vision Suite software which is an example of a multi-resolution tool. The guide is provided to help infrequent users get a quick start in building, importing and exporting networks for analysis.

Exhibit 8-1Multi-Resolution Spectrum Comparing Various Model Levels



8.1.3 Introduction to Mesoscopic Analysis

Transportation analysis methods have traditionally focused on two levels of detail, macroscopic and microscopic. ***Macroscopic*** analysis is concerned with system-wide travel movements; how much travel, of what types, when, how, and by what modes and major routes. Urban, regional, and statewide travel demand models are the primary tools used to do this level of analysis. These tools facilitate the evaluation of the effects of demographics, economics, land use patterns, transportation network configurations, and prices on travel patterns. These models assess how many trips are moving between areas (zones) and along which routes (links). Because they are not built for focused urban area studies they do not typically account for the influences on delay from turning lanes and signal or stop sign controls at intersections. Likewise, macroscopic models provide no information on the location and duration of queuing. Furthermore, they are not calibrated to the level of local streets and points of access to the network (e.g. parking locations).

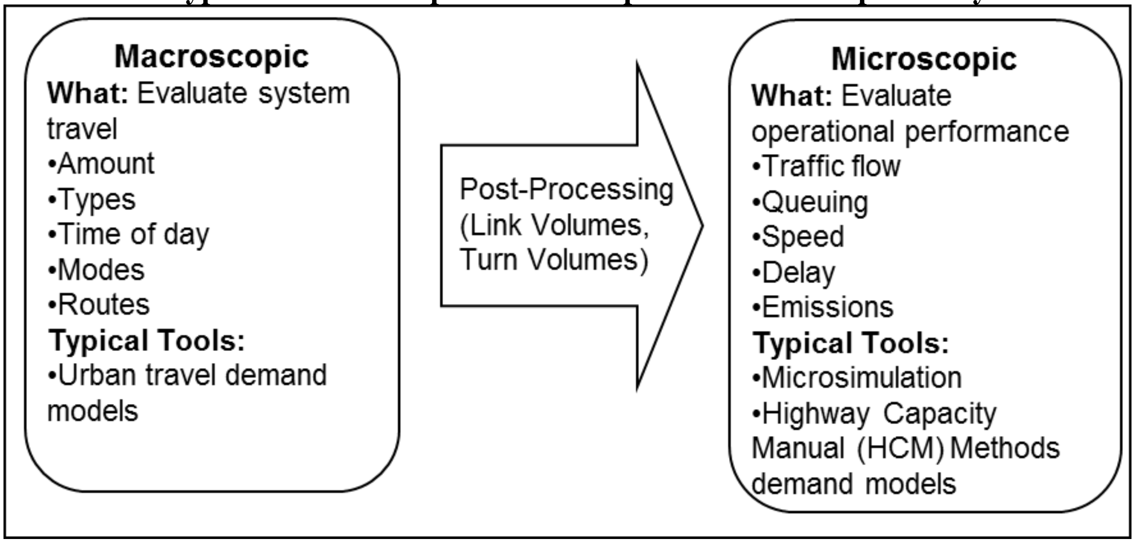
Microscopic analysis is concerned with the operational performance of transportation facilities; traffic flow rates, queuing, speed, and delay. This level of analysis uses micro-simulation models and highway capacity manual methods primarily. These tools facilitate the evaluation of the effects of localized land uses, roadway geometry, and traffic controls on traffic flow characteristics. However, most microsimulation models rely upon fixed post-processed traffic volume inputs from travel demand models to evaluate future year scenarios and are, therefore, only as good as the volumes put into them. Furthermore, project application of microsimulation models typically requires many hours devoted to model development due to the level of detail incorporated in the models. While these models provide a good estimation of traffic operations, they are often not practical to implement as a tool to evaluate or screen a large number of alternatives or a large analysis area.

One major difference between macroscopic and microscopic analysis is that macroscopic models use land use data as the primary input that dictates demand for travel, whereas microscopic use traffic volumes or vehicle trips as the primary input that dictates the demand for travel. The impacts of land use on travel demand are external to microscopic models and assumed to be already accounted for in the microscopic model's traffic volume inputs. Likewise travel costs (e.g. fuel prices, the traveler's value of time, transit fares) are direct inputs to macroscopic models dictating travel mode and route choices. These travel costs and decisions are external to microscopic models, and assumed to be already accounted for in the microscopic model's traffic inputs.

These two levels of analysis (macroscopic and microscopic) are loosely coupled through the transmittal of link and turn volume data and the use of travel demand model post-processing methods. The flow of the data is from macroscopic to microscopic, and there is typically no feedback from microscopic to macroscopic (e.g. queuing calculations do not affect system travel calculations).

The following diagram illustrates these two levels of analysis and their connection.

Exhibit 8-2 Typical Relationship of Macroscopic and Microscopic Analysis



Increasing attention is being given to the combination between the macroscopic and microscopic modeling levels, often referred to as "***mesoscopic***." While the term "mesoscopic" can have various meanings for users in different fields and even to multiple users within the field of transportation, it generally is used to denote a hybrid of microscopic and macroscopic features. Exhibit 8-3 demonstrates the relationship between these three general fields.

Exhibit 8-3 Mesoscopic Overlap between (and Potentially Combining) Macroscopic and Microscopic Modeling Process

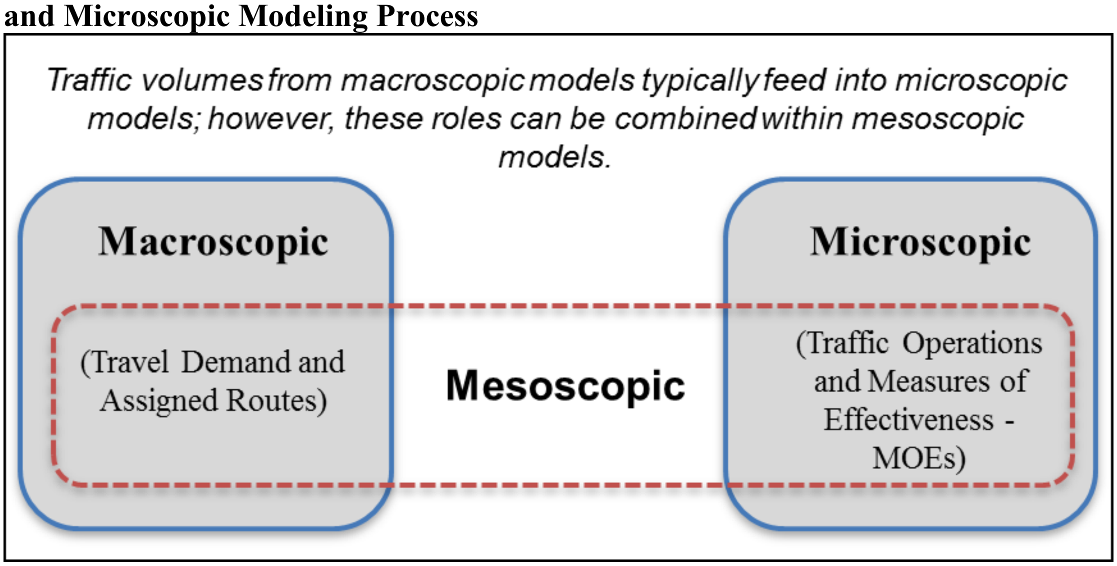


Exhibit 8-4 lists potential examples that summarize key comparisons among typical microscopic, mesoscopic, and microscopic models. These examples are provided for demonstrative purposes and actual characteristics of these models can differ.

Exhibit 8-4 Summary of Typical Differences among Microscopic, Mesoscopic, and Macroscopic Models

	Detail Present		
Model Element	**Macroscopic**	**Mesoscopic (Potential hybrid)**	**Microscopic**
Network Scale (Size)	Region-wide	Varies. Potentially region-wide, but may be smaller, depending on level of network detail and mesoscopic software	Typically a single corridor or small study area
Network Scale (Detail)	Regionally significant routes (generally collector and higher)	Varies. May include all public streets, but could include less depending on network size	All streets and major driveways
Intersection Detail	None (typically a simple node junction of streets without time-penalty and without geometric or control characteristics)	Generally includes types of attributes needed for HCM level analysis (intersection control, lane geometry, basic signal timing, etc.)	Full lane geometry and widths, turn bay lengths, traffic control and striping, signal timing detail for individual phases (if applicable)
Travel Time	Link-based travel times generally rely on volume-delay functions (vdf). Intersection delay is generally ignored or simplified.	Can have a combination of link and intersection travel time, though intersection delay may be less robust than microscopic models	Travel time is based on vehicle interaction and includes acceleration, deceleration, stopped delay, and other associated factors
"Outputs" - Measures of Effectiveness (MOE) / Performance Measures	Vehicle hours of delay, corridor travel time, average distance traveled by users on a link	Provides general MOEs possible in both macro and micro models, without full detail (e.g. queue lengths and impacts) of micro models.	Intersection turn delay, corridor travel time, 95^{th} percentile vehicle queue length, etc.
Routes / Assignment (Is route diversion possible?)	Yes (routes vary based on relative "cost" of all potential routes, typically travel times)	Yes	No (traffic volumes and route paths are typically a fixed input and route options/ diversion are not present)

Needs

Mesoscopic analysis capabilities can help meet emerging analysis needs and overcome limitations of the traditional process and tools (macroscopic forecasts fed into microscopic models). In particular, the following needs can be addressed:

1. Operational Impacts
    - Restricted funding and less interest in making major changes in the roadway system are shifting the focus of planning to system management and leveraging the effects of changes in operations and many small system improvements. In addition, there is increasing interest in modeling operational improvements that improve reliability and reduce incident-related congestion. Macroscopic models are typically not applied in a manner that is precise enough to model the effects of traffic operations or minor improvements. Microscopic models can analyze these effects, but cannot do so at a large-scale systems level. Moreover, microscopic models require a very large amount of data and are impractical to develop for an entire urban road system.
    - The focus on operational improvements and smaller system changes requires the use of more precise performance measures in order to distinguish the relative benefits of alternative choices. Macroscopic models use travel time and speed measures having limited precision (e.g. do not capture the vehicular delays upstream of system bottlenecks). These measures are necessary in order to predict travel patterns, but precision has been limited for reasons of computational tractability and because precision may not have been important for the regional decisions being made. Microscopic models can produce these measures, but only for a relatively small portion of the system.
    - The operational impacts of interactions with other modes (such as bus stops or rail crossings) can impact travel time along a route and thus route choice. For example, the impacts that transit vehicles have on auto travel times are ignored in most macroscopic models (e.g. additional traffic congestion caused by buses on mixed use roadways and vehicular delays occurring at rail crossings). These impacts can be explicitly modeled and evaluated using microscopic models.
2. Congestion Impacts
    - As traffic congestion severity, extent, and duration grow, the travel time and speeds estimated by macroscopic models become less able to reflect actual travel conditions. Macroscopic models have a limited ability to account for congestion on adjacent (downstream) links, as well as within (adjacent lanes) a given roadway segment. Consequently, macroscopic models are less able to account for the effect of traffic congestion on travel patterns. This has been a significant consideration in the Portland metropolitan area for some time, and is starting to become an issue in other areas of the state as well.

    - The effects of severe congestion may not be reliably accounted for by microscopic models. How are the system constrained traffic volume and trip inputs for microscopic models developed for future year scenarios (as the severity, extent, and duration of traffic congestion grows) without the help of macroscopic travel models?
3. Sensitivity/Risk Testing/Alternatives Analysis
    - There is increasing interest in assessing the risks associated with uncertain futures (e.g. amount and distribution of land uses, fuel and other travel costs, government policies, regional economic and funding issues). The assessment of uncertainty and risk requires a more comprehensive analysis than is presently done. In the past, assumptions were made about many factors (such as land use, transportation network changes, etc.) in order to limit the number of alternatives needing to be analyzed. This has been necessary because of the amount of work required to develop models and process outputs from macroscopic models to be input into microscopic models and time required to adequately develop microscopic models.

Mesoscopic modeling has the potential for meeting these emerging needs and overcoming existing limitations by leveraging the strengths of both macroscopic and microscopic modeling:

- Operational performance can be calculated with more detailed metrics than is currently done by macroscopic models in order to account for the effects of smaller changes to the system and to distinguish smaller differences between alternative improvements. The calculations in mesoscopic models are less precise than those of microscopic models; this reduces the data needs and model run-times so that entire regional transportation systems or large portions of transportation systems can be modeled.
- Since mesoscopic models can make more detailed calculations of performance, in some cases they may be a substitute for microscopic models for the purposes of uncertainty and risk analysis. For larger systems with severe congestion issues, a mesoscopic model will allow for realistic results to be generated at a lower detail level but still meet the needs of the project development process. The calculation of the performance measures by a mesoscopic model would reduce the need/use of microscopic models for alternatives testing and greatly increase the number of scenarios that could be analyzed within a given amount of time and resources. Microscopic models would continue to be used for more detailed analysis of a limited number of scenarios.
- Mesoscopic models can provide a mechanism for feeding back better estimates of travel times reflecting very congested conditions to macroscopic modeling processes for forecasting travel demand for successive iterations in the macroscopic models. This might be done by incorporating the mesoscopic model into the macroscopic model, or by using the mesoscopic model as a post-processor of the macroscopic model.

When to Consider Mesoscopic Analysis

Many considerations exist that could lend mesoscopic procedures being applied for an analysis. Some of these considerations for mesoscopic application could include:

- Do a large number of system network alternatives need to be analyzed or screened at a system level? Is it not feasible/cost-effective (or appropriate) to model all alternatives in microscopic analysis? Does macroscopic analysis not provide adequate detail for providing relative comparisons among alternatives?
- Do network alternatives include operational impacts or improvements that may not be captured with a macroscopic model?
- Do network alternatives have the potential to impact system circulation and routing due to the outcome of the resulting traffic operations and flow?
- Does a level of congestion exist that may not be captured with a macroscopic model?

Any of the items listed above may be an indication that mesoscopic analysis would be beneficial for project application. While defined triggers do not exist, generally a mesoscopic approach will provide additional benefit in cases where both macroscopic traits (such as route choice) and microscopic traits (such as traffic operations, performance measures on duration and severity of congestion and queuing) are desired in a hybrid environment.

8.1.4 Related APM Chapters

Several other chapters provide related guidance. These chapters and the relation each has to this chapter are listed here.

- Version 2 Chapter 2: Scoping Projects – Guidance on scoping transportation analysis work. Includes comparisons of analysis tools and guidance on tool selection.
- Version 2 Chapter 3: Transportation System Inventory – Includes information about data collection that may be needed for application of the methods covered in this chapter.
- Version 2 Chapter 5: Developing Existing Year Volumes – Includes information about volume development that may be needed to estimate demand for some of the tools and methods covered in this chapter.
- Version 2 Chapter 6: Future Year Forecasting – Provides information about developing future forecasts and includes subarea assignment methods. The chapter also describes multiple forecasting methods, including use of travel demand models.
- Version 1 Chapter 8: Traffic Simulation Models – Procedures for microsimulation model development and calibration.
- Version 1 Chapter 10: Analyzing Alternatives – Includes information about developing sets of alternatives that may be analyzed or screened using the tools and methods covered in this chapter.

8.2 Subarea Analysis

This section provides an overview of types of subarea analysis and general considerations for application. Two types of subarea analysis, focusing and windowing, are covered in greater detail in following sub-sections.

8.2.1 General Considerations

The analyst has a number of tools and methods available for application. A critical component of any project is first selecting an appropriate tool and then determining how to best apply that tool. In many cases, the best tool available may not be adequately refined for the intended application. In the case of a regional travel demand model, the model may be constructed and calibrated to a regional scale. However, with the appropriate additional refinement, the model (tool) may be applicable to additional uses. Creating a subarea model is a common example of applying model refinement for more rigorous use beyond the original scale of the model.

This subsection describes general subarea refinement and considerations. A ***subarea*** is a specified area that is identified for refined analysis. This may require a model or tool that includes additional detail beyond what is used for areas outside the subarea in order to adequately capture the desired level of analysis. The subarea may be similar to a "study area" identified through the analysis as the general area included in the analysis, but often these areas differ based on the degree of analysis needs and tools present.[1]

Once an analyst is aware of pre-existing models, the decision about model applicability and potential to use the model for another purpose must be made. While this decision process should be coordinated with Transportation Planning Analysis Unit (TPAU) and documented, the following considerations may indicate the potential for applying subarea analysis:

Is the "base model" (agency or regional model) appropriate for further project use?

- Does the model boundary fully include the study area?
- Does the model consider the appropriate time period (hour of day, season, etc.)?
- If land use changes are being investigated, are the scale and type of uses appropriate for the model? Smaller magnitude areas, such as some traffic impact analysis (TIA) for the development review process, may not require land use adjustments in the model if it is being used to forecast background growth. However, larger magnitudes may require land use adjustments or even be beyond the scope of the model. Additional documentation on this matter is provided separately.[2]
- Does the model boundary include key locations outside of the study area that may influence operations within the study area (downstream interchanges, over capacity intersections, etc.)?

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[1] Considerations for identifying subarea boundaries are presented later in this section.
[2] Modeling Procedures Manual for Land Use Changes, TPAU, February 2012.

Is subarea refinement needed for model application?

- Does the model include all transportation facilities relevant to the study? This may include study intersections as well as parallel facilities or alternate routes, which may be needed for gauging traffic diversion.
- Is the zone structure detailed enough for the analysis and are centroid connectors placed in a way that will not impact the outcome of the results?
- Is the model sensitive enough to test the range of alternatives under consideration, such as intersection control and geometry or signal timing changes?
- Is a specific zone or unique land use not adequately captured due to the regional scale of the model?
- Is the zone and centroid connector structure detailed enough to perform Origin-Destination (O-D) matrix estimation procedures if needed?
- What will be the ultimate use of the model data? Do HCM procedures need to be performed on study intersections? Will the model be exported to microsimulation?
- Do other modes of travel need to be considered that are not included in the regional model? For instance, do a significant amount of trucks or heavy vehicles need to analyzed separately and/or account for restricted routes? Are there other modal network elements?
- Is a more realistic assignment needed due to extensive peak period congestion?

The considerations above are intended to serve as a general guide for determining model application potential. However, given project context, other considerations may exist and coordination with TPAU is needed. The following sections explore these general considerations in more detail.

8.2.2 Overview of Focusing and Windowing

Focusing and windowing are two general types of subarea models that are commonly applied. These approaches can be applied for both macroscopic and mesoscopic analysis models. While each of the two methods shares similarities, there are also distinct differences.

Focusing is the practice of adding additional refinement and detail to a model within the structure of that model. The additional resolution may be added to the supply (transportation network) or the demand (zone structure or loading). In either case, the full function of the model is maintained.

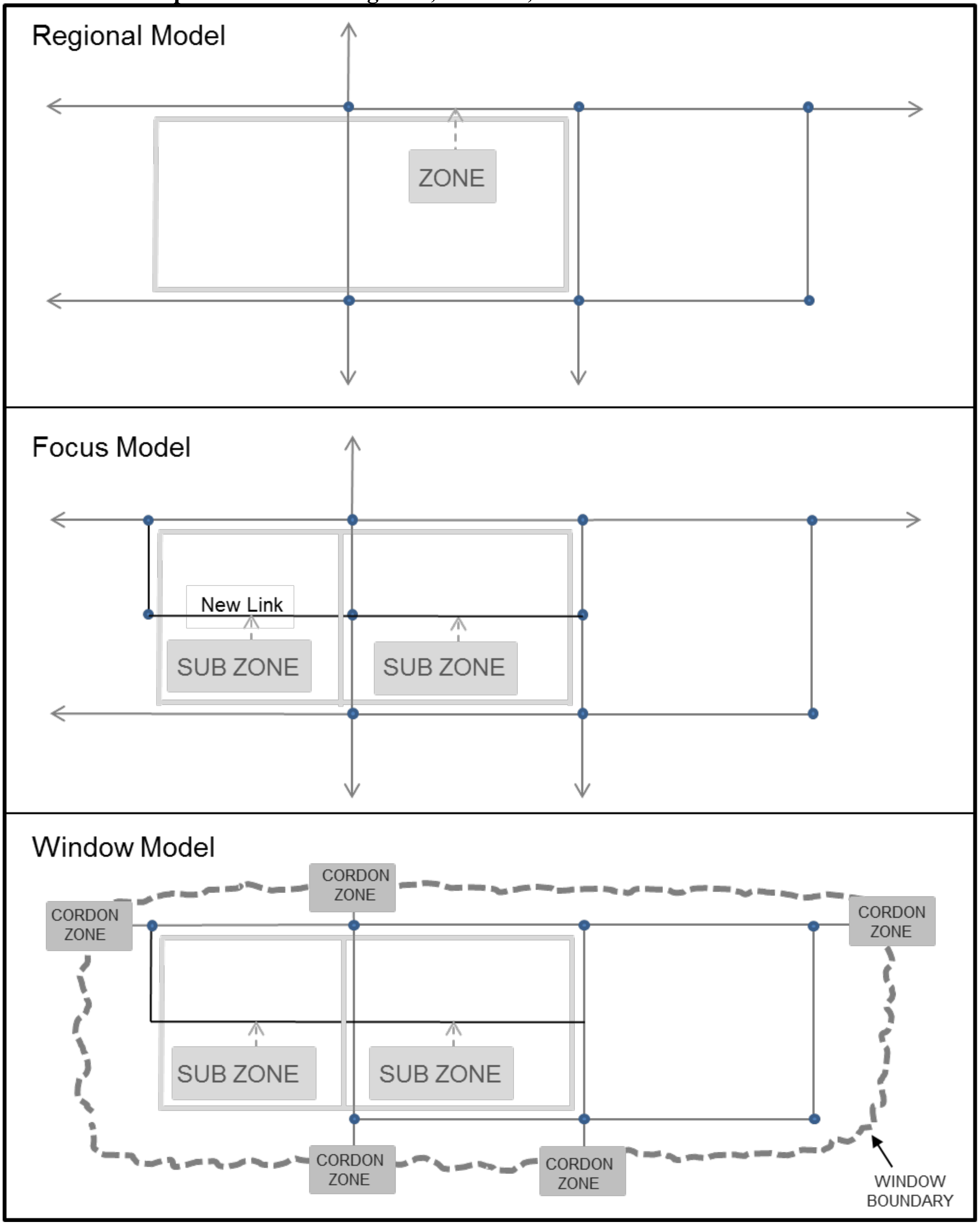
Windowing involves cutting out a portion or component of a model. Often, this will include a "window" of the transportation network in the subarea that then creates cordon (external) areas at the edge of the subarea. Windowing, like focusing, is applied to allow additional refinement or modification. However, because windowed models are separate from the original model, they are not held to the same requirements for consistency[3] and integration with the full model. This allows for testing changes from the original model (such as travel demand intensity or trip assignment technique). Results of the windowed model are specific to the window itself and are not necessarily relevant to the original model. In some cases, the entire model area may be windowed in order to test scenarios (or framework) that differs from the base regional model.

Refer to Appendix 8B Section 1 for guidance on windowing using PTV Visum software. If the model is in the Emme platform, see Section 4.1 for guidance on converting the model network to Visum.

Exhibit 8-5 demonstrates the general differences in network refinement that a focus and window subarea model would add to a base model network.

[3] Coordination with TPAU is necessary to determine if the level of adjustments are appropriate and reasonable for the windowed area model.

Exhibit 8-5 Comparison of Base/Regional, Focused, and Windowed Models



8.2.3 Scoping

The following sections provide an overview of scoping subarea modeling efforts, including general considerations for selecting windowing and focusing methods and level of effort for subarea application.

Tool Selection

In some instances either windowing or focusing may be an appropriate approach for refining the model area. However, in other cases one approach may be preferred due to limitations or flexibilities built into each method. Exhibit 8-6 highlights some situations to guide the analyst in selecting an appropriate methodology.

Exhibit 8-6 Considerations to Guide Selection of Subarea Model Methodology

Consideration	Focusing	Windowing
Alternate Traffic Routes	• If alternate (or parallel) traffic routes exist outside the subarea, they may be affected by non-uniform refinements made to the model within the focus area.	• Routes from the regional model will be fixed and constrained at the location of subarea boundary or cordon “cut” lines (outside the windowed area)
Assignment	• Constrained by base (regional) model	• Adjustments to assignment type and parameters allowed
Demand Intensity	• Constrained by base (regional) model	• Adjustments to demand intensity of zones allowed
Model Size	• Can be applied for any size model	• Applying a “cut” of the model and creating new cordon zones may be desired to reduce run time
Model consistency	• Edits require consistency within the framework of the regional model and running the full 4-step model	• Edits are allowed to deviate from regional model framework, however do not provide the ability to re-run the full 4-step model directly.
Future Work	• May be used for future projects	• Generally can only be used for the subject analysis
Intersection Control	• Typically not available in regional models	• Intersection control through nodal delay-based assignment
Level of Effort	• (Varies – see Exhibit 8-7)	• (Varies – see Exhibit 8-7)
Full 4-Step Model Runs	• Full model could be rerun with the additional detail of focus area	• Model generally reassignment only. A full model run (trip generation, distribution and mode choice) is not performed.
Transit	• Typically not affected in subarea focus model.	• Transit assignment and route functionality may break due to unique nature of coding.

Data

Types of data that are necessary to perform subarea analysis (such as focusing and windowing) may include:

- Traffic volumes – Needed to validate the model traffic volumes, particularly if new network is being added
  - Roadway tube counts
  - Intersection turn counts
  - Truck percentages
- Land use – Provides guidance for refining zone structure to allocate land use or trips to new zones.
  - Zoning map
  - Detailed land use metrics (in size of building and/or number of employees)
  - Aerial photos
- Network geometry – Characteristics needed to reflect infrastructure and control
  - Intersection and corridor geometry (lane use and channelization)
  - Posted speed
  - Capacity
  - Intersection control – type, orientation, signal timing plans, etc.
- Traffic operations – Existing traffic operations for model validation/calibration.
  - speed
  - travel time
- Traffic patterns – What is the distribution and what routes are being used?
  - origin-destination patterns
  - routes

Some data may only be needed depending on the detail of the subarea model (such as intersection control and geometry), while other data may only be needed if the subarea model will be later converted to microsimulation.

Resource Needs

The ability to scale the tool for the analysis is an important benefit of subarea modeling. The degree of effort needed to apply a subarea model can vary greatly based on the amount of detail that is put into refinement of the key model elements. Various model elements that may be refined for subarea analysis are listed in Exhibit 8-7 along with a sample of "low", "medium", and "high" levels of effort. For the purposes of this table, these levels are defined (as approximations) to be:

- Low Effort – Typically completed within a couple hours
- Medium Effort – Can be completed within a day
- High Effort – May require several days or more to complete

Exhibit 8-7 Subarea Scalability to Identify Resource Needs

	Range of Effort (Refinement and Application)		
Consideration	**Low**	**Medium**	**High**
Network Refinements	Add a link in study area or adjust speed/capacity	Review and refine all existing links and link properties for advanced street network detail. Add key missing links.	Review and refine all links in model and add any missing public streets (local, collector, arterial, etc.)
Zone System	Use existing zone system or split a single zone	Split zones (5 or less) in the immediate study area	Split zones (5+) over a broad area that may expand beyond the study area
Connectors	Use existing connectors, add connectors, or adjust placement to be loading to optimal roadway in study area	Review and refine placement and potentially weights of connector loading in general study area	Review and refine placement and weights of connector loading in broader area
Assignment Method (Window only)*	Use existing assignment method. May still require subarea “cut” of windowed area.	Modify assignment method to incorporate other considerations (such as fixed intersection delay by movement)	Implement detailed intersection operations elements that incorporate HCM intersection turn delay.
Intersection Control	No control setting, or simple node type of signalized/unsignalized	Control includes intersection geometry, specific control type and orientation	Control includes detailed type, geometry, and settings such as signal timing
Data Mining	Daily or peak hour link volumes	Peak hour/period link and turn volumes at key locations in study area	Peak hour/period link and turn volumes at locations in and beyond study area (and cordon zones if they exist)
Validation/ Calibration	Check/observe regional links in study area.	Check/observe regional links and additional subarea link network	Check/observe and plot the differences for all link and turn count locations to measure model calibration

Note: *Applies to Window models only since focus area models do not change assignment methods.

8.3 Focusing

The following sections provide an overview of how to apply focusing:

- Process – What steps are involved?
- Potential Issues – What are issues that may occur?
- Calibration – How to know when the model is "ready"?
- Application – When is this tool needed?
- Examples – When has this tool been used?

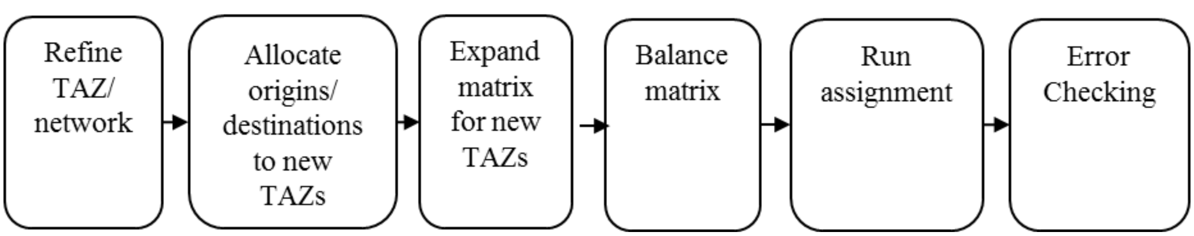
8.3.1 Process

> *While not explicitly listed as a repeated step below, continuous, on-going error checking and quality control are vital components of the model coding and application process. For purposes of simplification, this on-going component is not depicted.*

The following steps, simplified in Exhibit 8-8, are used to apply focusing[4]:

1. **Refine Transportation Analysis Zone (TAZ)/network** - The standard TAZ system and network are refined in the subarea. This may include adding elements that were not included in the base model (such as additional roads), or adjusting elements that were in the base regional model (such as modifying link capacity).
2. **Allocate origins/destinations to new TAZs** - The origins and destinations for the original or "parent" TAZs from the model run are allocated to the disaggregated TAZs using one of several possible weighting schemes (Section 8.4.4).
3. **Expand matrix for new TAZs** - The assignment trip matrix from the model run is expanded to reflect the revised TAZ system.
4. **Balance matrix** - The expanded matrix is balanced using the disaggregated origins and destinations from Step 2.
5. **Run assignment** - A new trip assignment is run with the trip matrix from Step 4 and the refined network.
6. **Error checking** – Compare model output to check for consistency with base model.

Exhibit 8-8 Focusing Process



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[4] *Modeling Procedures Manual for Land Use Changes*, ODOT Transportation Planning Analysis Unit, February 2012.

Potential Issues

The following potential issues may arise with a subarea model that uses focusing:

- Additional detail or street network may attract/detract travel demand from the study area. Creating additional transportation system links in the study area may increase the total capacity, thus attracting additional trips. Conversely, adding additional detail (nodes/intersections, traffic control, etc.) may disproportionately increase the travel time through the study area and detract traffic. These potential issues may indicate that windowing is more appropriate.
- Data may not be readily available to validate the traffic volumes on street network that is vital to the focused area.

8.3.2 Calibration (Model Checking)[5]

> *Analysis Procedure Manual Version 2 Chapter 6 includes additional information on model checks. It is assumed that the subarea models are based on regional travel demand models that have already been subject to a formal calibration and validation process. The following information is provided for calibration of subarea models for project application and may not be appropriate for regional models.*

The calibration process is a critical step to ensure that the focused subarea model is compatible with the base model. If issues arise during the calibration process, it may be indicative that another method (such as windowing) may be more appropriate. The calibration process should generally include the following considerations, at minimum:

- Confirm the focus model is consistent with the base model
  - Is the overall demand matrix sum unchanged? There is risk of modification to the overall matrix demand when splitting the zone structure and creating new TAZ. Any change in overall demand (which may result when splitting zones with internal trips) should be minimal (typically less than one percent, unless documented otherwise).
  - Do links outside the focused area generally retain the same assigned traffic volumes? Significant shifts in traffic volumes may indicate incompatibility with the base model and a need to perform windowing as an alternate approach.
- Confirm the focus model is compatible with the base model
  - For a given screenline, do links within the focus area carry the same total assigned traffic as the base model? If the network was refined, traffic assignment may shift within the focus area, but the overall assigned volumes across a screenline should not significantly differ.
- Confirm the focus model is providing realistic results

[5] The following material includes components of both a validation and calibration process. It is assumed that the regional demand models would have been formally validated and calibrated during model development. The information in this section focuses on the calibration of subarea models for project application.

    - Do the sums of connector volumes for a zone match the total zone demand?
    - Does the routing for traffic into and out of new zones make sense? Common checks include a select zone analysis (Emme traffic assignment software) or a zonal flow bundle analysis (Visum traffic assignment software).
    - Do the routes, origins, and destinations for traffic using a new link make sense? Common checks include a select link analysis (Emme) or a link-based flow bundle analysis (Visum).
- Confirm the model reflects existing traffic data
    - Does the magnitude of resulting traffic demand match base year traffic count data? Differences in data are typically present due to:
        - Difference in model year/period and date of data collection (e.g., average weekday model for year 2010 compared to July 2013 count data).
        - Count data collected from various source and time periods. Assigned traffic volumes in the subarea model must balance (unless there is a connector between locations), so unbalanced count data can lead to incompatibility of the dataset and create more difficulty for the calibration process.
        - The amount of driveway trips related to pass-by and retail use, or the detail of street network included in the subarea model, may not be captured in the regional travel trends present in the regional travel demand model.
    - If assigning multiple vehicle classes, does the traffic demand match classification data?
    - Does the distribution of traffic match O-D patterns anticipated from license plate, Bluetooth, cell-phone, or other data survey means?

8.3.3 Key Considerations (Application and Issues)

> *In general, the level of detail and refinement in any particular element should generally reflect the detail of other model elements.*

The following questions and considerations are intended to help guide decisions regarding application of focus models. In general, the level of detail and refinement in any particular element should generally reflect the detail of other model elements. These considerations are not absolute but are intended to function as a general guidance when developing an approach and methodology.

Study Area Size/Boundary
When selecting an area of the model to focus, consider the following:

- Larger focus areas provide more opportunity to refine the model, but also require additional effort.

- Smaller focus areas may limit the effects of focusing.
- Having a constrained focus area with limited connectivity to surrounding areas helps to retain consistency with the base model assignment.
- A focus area should be adequately large that changes within the focus area do not impact areas outside of the focus area.

Network Link (Street) Refinements

- When refining the attributes of the street network, parameters should be consistent with assumptions made about the rest of the network. For example, streets within the focus area should have compatible capacity to similar streets outside the focus area.
- Is the structure of the focus area street network appropriate for the level of detail that is needed for the analysis? Are key streets missing from the model? These may include facilities that affect circulation as well as locations that require detailed traffic forecasts.
- Are the attributes that are used in the regional model appropriate for the focus area? Models are often calibrated to a regional scale and may not include unique details that reflect specific locations. Attributes such as speed or capacity may need to be refined to better reflect true conditions.

Network Zone Refinements

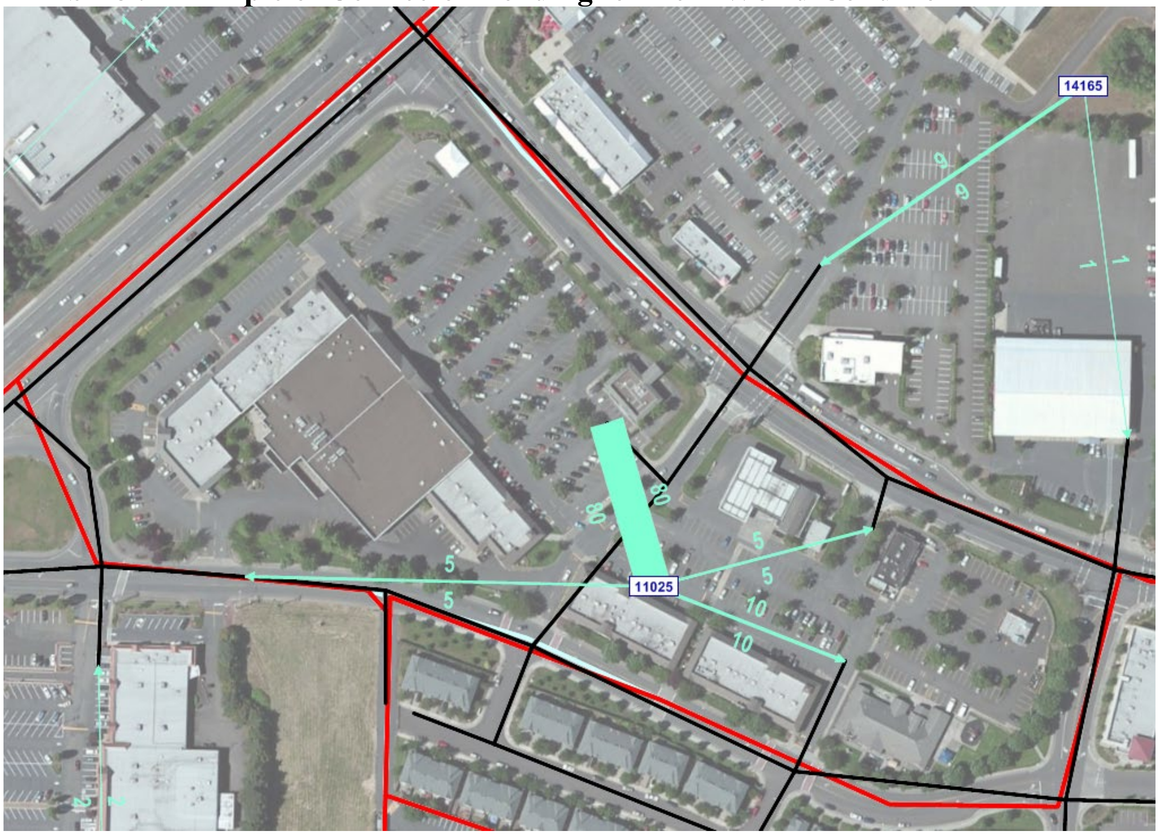
- Can a zone be split based on different land use types? This often can help to allocate the portion of trips from the original zone to the split zones.
- Are there constraints that affect connectivity (such as rail, topography, water, etc.) that drive the need to split a zone to better control loading?

Network Connector Refinements

Depending on the modeling platform, treatment of connectors may be used as a substitute for splitting zones. However, some modeling platforms may not provide the flexibility for multiple connectors per zone with different weighting allocations.

- Location of connector loading should best represent the real-world condition (location of internal streets, driveways, or parking) as is feasible given the model detail. Exhibit 8-9 provides an example of using connector loading to better represent actual network conditions. In this example, each connector for Zone 11025 is placed to represent approximate driveway locations and is given a relative weight based on the amount of trips that are served by the land uses at each driveway. In some cases additional link network and detail may be needed for realistic connector loading.

Exhibit 8-9 Example of Connector Loading for Real-World Condition



- The amount of connectors may need to be increased depending on the magnitude of zone trips and the uniformity of real-world loading throughout the zone. Commercial zones typically have less loading points due to the location of specific (high volume) driveways. Residential zones that may not require specific loading points that represent major driveways but instead multiple connectors that distribute these trips along the edge of the zone as local street circulation would provide.
- The weighting or portion of trips loading to each connector may be set based on the configuration and available data. A common case may be a commercial zone that includes multiple driveways. If traffic counts are available for the driveways, connectors can be weighted to replication these driveways and better reflect actual conditions. In other cases it may make sense to uniformly load (equal weight) connectors across the zone area to distribute demand more evenly – as in the case of a residential zone with uniform house coverage.
- What is the real-world circulation within the zone and should all connectors be used? Is internal circulation possible and is connector (driveway) use based on driveway delay or some other attribute? If so, movement within a zone may occur and trips (in some cases) may not use a given connector and/or connector weights may change. The level of internal circulation also may impact the amount of crossing driveway traffic (e.g., traffic from an eastern driveway heading to the west and traffic from a western driveway heading toward the east, versus all

western driveway traffic heading to the west and all eastern driveway traffic heading to the east).

Intersection Control

- What methods are applied to determine intersection capacity and impedance (delay) in the regional model? If none are applied, application of intersection control is likely beyond the scope of focusing and may be better suited for windowing (which provides more flexibility and deviation from the regional model).
- What level of detail is appropriate given the fidelity of other model elements? Models generally fit into one of the following levels of intersection control:
  - Level 1 – intersection control is ignored
  - Level 2 – some control types are coded (e.g., signalized intersections are flagged) with an equal delay given to all movements
  - Level 3 – all control types are coded and a look up delay is applied for all/some turns. This may consider influences of major and minor street approaches.
  - Level 4 – all control types (and potentially geometric details) are coded and delay is calculated at each intersection movement by a method such as HCM.

Section 8.5.4 (Windowing Key Considerations) includes additional information on application of intersection control and node delay.

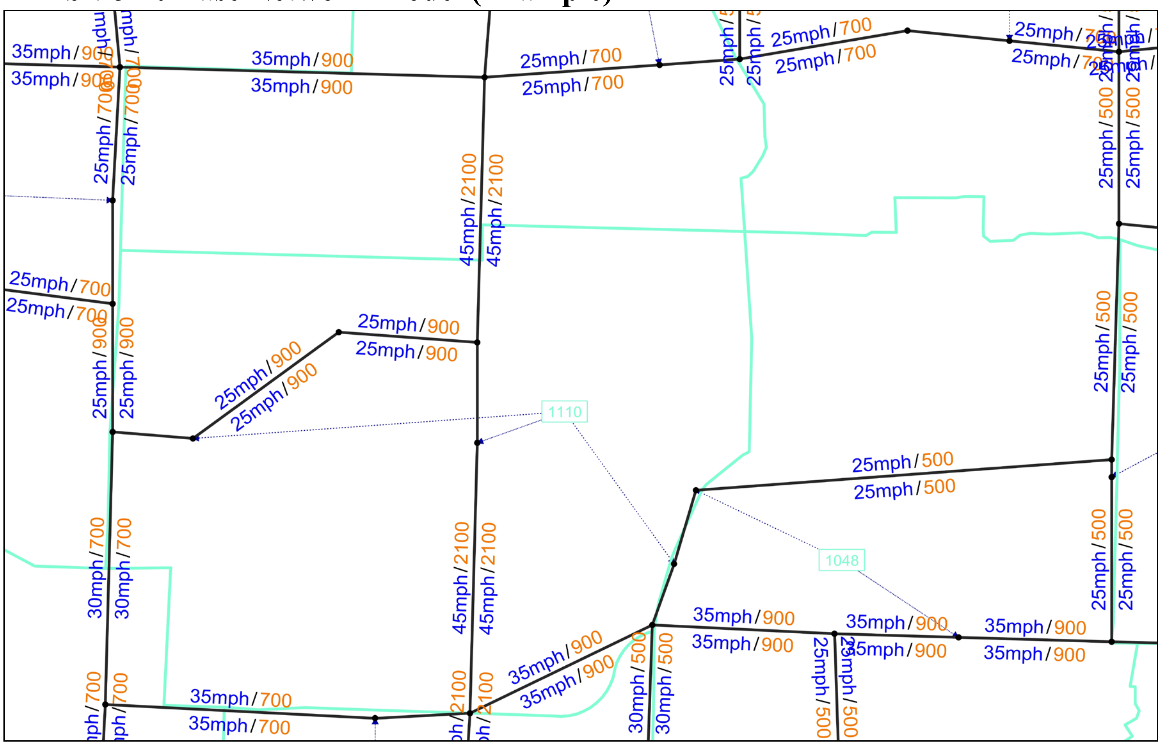
Ramp Meters

- Ramp meters can create bottlenecks that can significantly restrict the throughput based on timing parameters. To reflect this “hard” capacity restriction, a volume delay function that has significantly more delay when over capacity may be an option for emulating a ramp meter.
- Additional solutions for reflecting ramp meter impacts may be available depending on the presence of intersection control elements in the model.

8.3.4 Examples and Scaling

As listed in Exhibit 8-7, the focusing methodology can be applied in varying degrees and scaled to fit the needs of each project and analysis. The following examples demonstrate different scales of application. For reference, Exhibit 8-10 provides a sample of a typical regional base model. This model includes a sparse system of links that represent the major roads (typically collectors and arterials), a zone network, and limited connector loading.

Exhibit 8-10 Base Network Model (Example)



Examples for different scales of applying focusing are shown in Exhibit 8-11 and Exhibit 8-12.

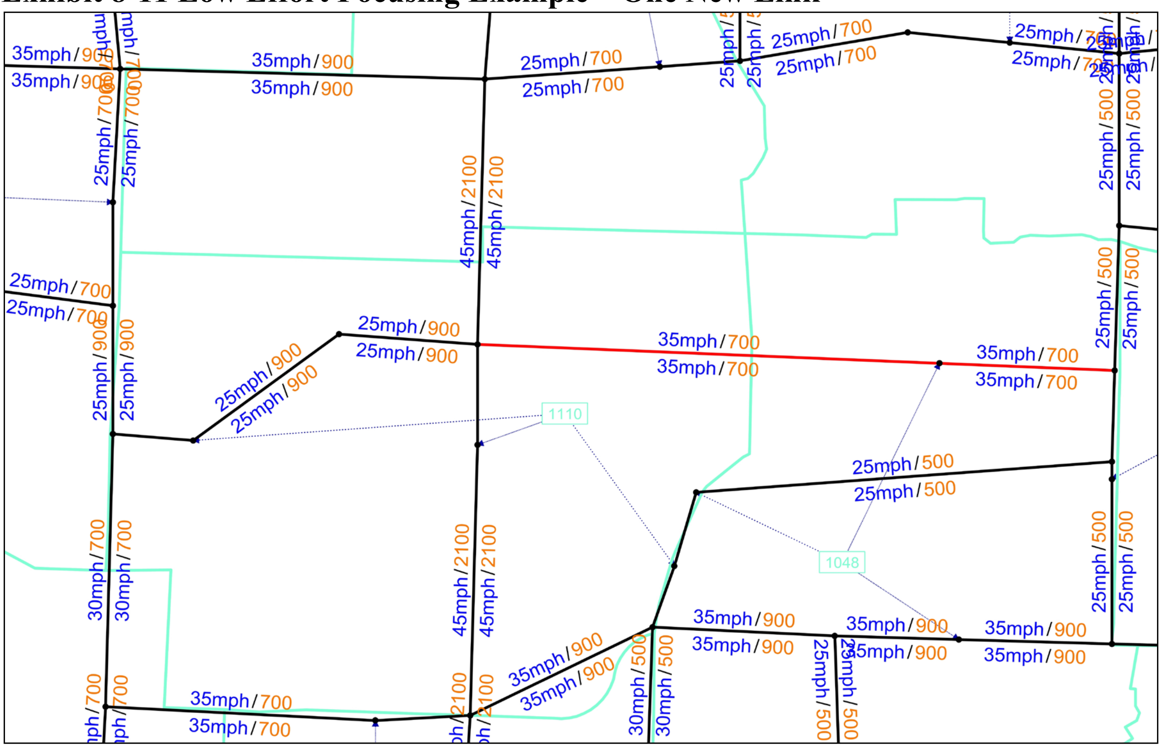
Focus Model Example 1: Low Effort

A low effort application may include making a minor refinement to the travel demand model, including any combination of the following:

- Add a new link or adjust the attributes of a link
- Add connector location or weighting
- Split a zone

Exhibit 8-11 shows an example of adding an additional link and centroid connector to refine the network. The new link (relative to the base network shown in Exhibit 8-10) is shown in red. These two refinements (new link and new centroid) may be all that are needed to focus the subarea model, and represent a minimal, low effort application. Low effort applications may also involve adjustments to the zone system (disaggregation), or minor additional link and centroid connector edits.

Exhibit 8-11 Low Effort Focusing Example – One New Link



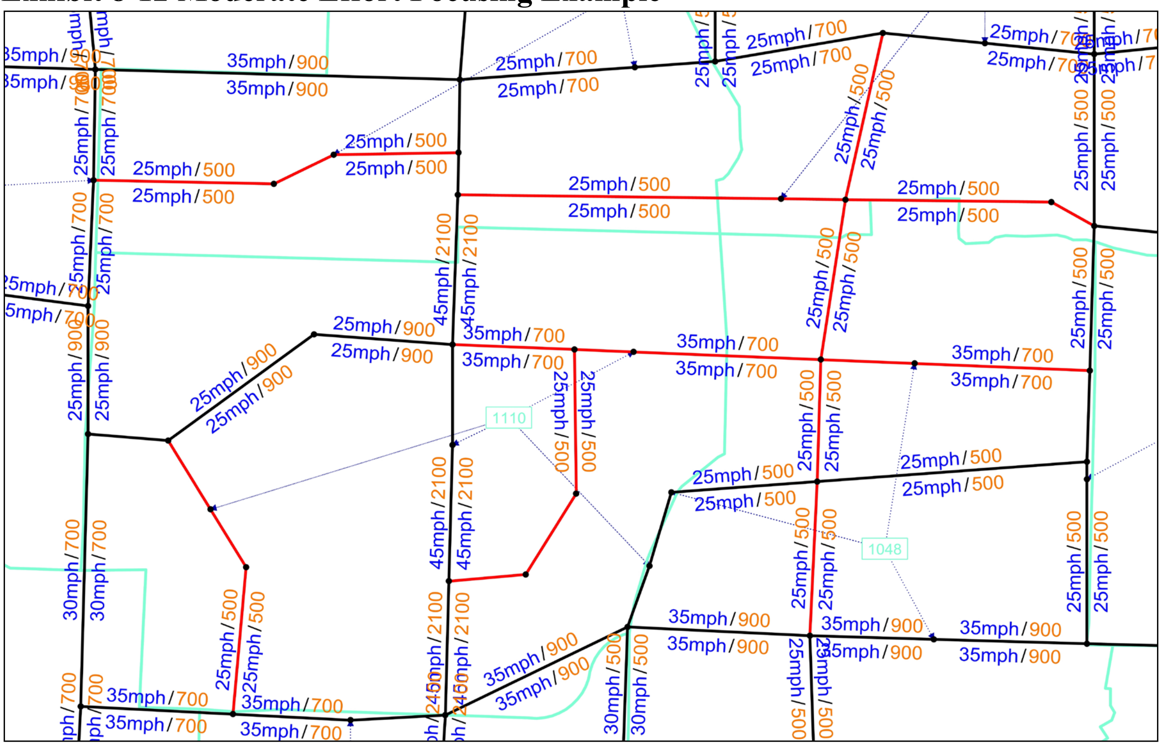
Focus Model Example 2: Moderate Effort

A moderate effort application may include making refinements to several elements in the travel demand model, including any combination of the following:

- Adding several new links or adjust the attributes
- Add connector location or weighting for several zones
- Split several zones

Exhibit 8-12 shows an example of adding several additional links and centroid connectors to refine the network. Similar to the previous example, the new links (relative to the base network shown in Exhibit 8-10) are shown in red. These additional refinements (beyond the level of detail shown in Exhibit 8-11) represent a moderate effort application and would further refine the assignment of traffic in this subarea. Moderate effort applications may also involve adjustments to the zone system (disaggregation).

Exhibit 8-12 Moderate Effort Focusing Example



8.4 Windowing

> *Windowing is primarily intended to be a motor vehicle reassignment exercise to improve traffic circulation routing and analysis within a subarea. It is likely that continuity of certain elements of the full regional model, such as the ability to perform full 4-step model runs and assigning transit, will be broken by windowing a subarea model. If these components are critical for the application, consider performing a focus model or other methods.*

The following sections provide an overview of how to apply windowing:

- Process – What steps are involved?
- Potential Issues – What are issues that may occur?
- Calibration – How to know when the model is "ready"?
- Application – When is this tool needed?
- Examples – When has this tool been used?

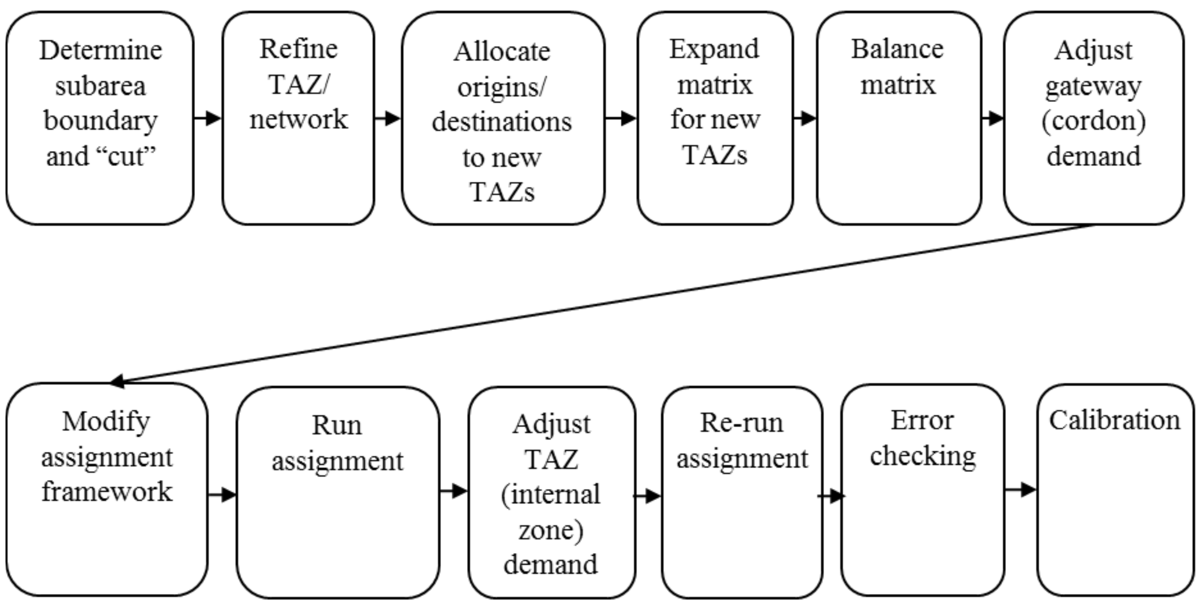
8.4.1 Process

The following steps, simplified in Exhibit 8-13, are used to apply windowing. Note that the windowing process contains more steps than the focusing process shown in Exhibit 8-8. Steps that are also included in the focusing process may have more details in Section 8.4. Additional information, including key considerations and checks, is provided in the following sections.

1. **Determine subarea boundary and "cut"** – Identify locations (links) that will become "cordon" zones with fixed demand from the regional model run. The selection of the boundary is a key decision since demand will be fixed.
2. **Refine TAZ/network** - The standard TAZ system and network are refined in the subarea. This may include adding elements that were not included in the base model (such as additional roads), or adjusting elements that were in the base regional model (such as modifying link capacity).
3. **Allocate origins/destinations to new TAZs** - The origins and destinations for the original or "parent" TAZs from the model run are allocated to the disaggregated TAZs using one of several possible weighting schemes.
4. **Expand matrix for new TAZs** - The assignment trip matrix from the model run is expanded to reflect the revised TAZ system.
5. **Balance matrix** - The expanded matrix is balanced using the disaggregated origins and destinations from Step 3.
6. **Adjust gateway (cordon) demand** – Adjust the demand at the windowed gateways as appropriate for analysis needs (such as adjustment to another analysis year or season).

7. **Modify assignment framework –** Adjust the assignment parameters[6] (such as assignment type and method for determining cost or travel delay), as appropriate, to meet the analysis needs.
8. **Run assignment** - A new trip assignment is run with the trip matrix from Step 5 and the refined network.
9. **Adjust TAZ (internal zone) demand –** Adjust the demand for internal zones as appropriate for analysis needs (such as scenario testing and scaling for additional growth or development). Verify that the resulting demand matches the target values.
10. **Rerun Assignment** - A new trip assignment is run with the updated demand parameters.
11. **Error checking** – Compare model output (such as link and/or turn assignments and general routing patterns between zones) to check for consistency with base model.
12. **Calibration** – Compare model output to data sources and make adjustments to calibrate model.

Exhibit 8-13 Windowing Process



8.4.2 Potential Issues

The following potential issues may arise with a subarea model that uses windowing:

- The subarea needs to be sufficiently large to capture variations in traffic circulation patterns among alternatives. Since the edge of the subarea becomes

[6] While windowing provides some flexibility to add additional detail and refinements that may support using different assignment techniques than the regional model (such as moving from a link-based volume-delay function to an intersection turn-based delay calculation), it is critical to coordinate with TPAU and ODOT regional staff to confirm these methods and assumptions are appropriate for the network detail.

fixed demand, traffic circulation that may be impacted outside the study area is not considered.

- The additional flexibility (“more knobs to turn”) with windowed models can require more care and make them more difficult to calibrate. The iterative process that considers adjustments to the network, demand, assignment parameters, and other elements, often requires that those elements are revisited after subsequent adjustments have been made to other parameters. Conceptually-sound adjustments are critical.

8.4.3 Demand Adjustments

Demand adjustments (scaling or changing the demand for a zone or specific O-D pairs) allow a layer of flexibility not present in focus area models that can be used to account for subarea demand magnitudes and traffic patterns that may not be captured in a regional scale model. While subarea models should typically stay consistent with the regional demand model, there may be cases where demand adjustments are needed. Section 8.5.5 includes additional considerations for demand adjustments.

- Demand adjustments may be needed for a number of reasons (including, but not limited to, adjusting to count data for another analysis period/year, or capturing internal trips ends and driveway counts along a corridor) to represent demand well enough that the model has the ability to adapt to network modifications and alternatives.
- A sample application of a demand adjustment could include the following analysis scenario:
    - The purpose of the analysis is to test a variety of transportation improvements, which include operational improvements such as intersection control and lane configurations.
    - A windowed area model is created that includes a high level of detail for the traffic network in order to capture the operational behavior and impacts in the model. This model uses intersection-level turn delay based on HCM methodology.
    - Traffic circulation in the model depends on the delay calculated for turn movements in the system. In order to capture existing traffic flow patterns, a realistic approximation of the travel demand between zones is needed to produce accurate turn delays in the model.
    - A comparison of the subarea model and traffic count data indicates that some of the gateway (cordon) traffic volumes in the model do not match well with count data.
    - A demand adjustment is performed in order to scale the gateway traffic volume (or other isolated internal demand that is not related to routing errors) closer to actual count data. By having a model demand that reflects actual count data, the model will be able to better account for traffic circulation patterns that result from changes in the transportation system. By better estimating the traffic circulation, the model will also better estimate actual traffic volumes on the road system.

- Demand adjustments typically rely upon having traffic count data that demonstrate the basis for the adjustment. However, it is important to be mindful of daily traffic fluctuations, which may be 10% on a day-to-day basis.
- Demand adjustments (as noted in Section 8.5.4) should only be performed after exhausting other model checks and calibration items related to assignment routing in the model.
- Demand adjustments should not be performed indiscriminately without a conceptual basis for why the adjustments are being made.
- Demand adjustments require existing year count data or similar thresholds to act as constraints to determine the degree of adjustment. Demand adjustments made to future year models should be applied in such a way that the resulting model growth (difference between the original base and future models and differences between the adjusted base and adjusted future models) does not change. Demand adjustments are performed to better fit traffic data and routing behavior in the model, not to influence the growth projected by the model (unless analysis year is changed).

8.4.4 Calibration (Model Checking)

Analysis Procedure Manual Version 2 Chapter 6 includes additional information on model checks.

The calibration process is a critical step to ensure that the focused subarea model is compatible with the base model. If issues arise during the calibration process, it may be indicative that another method (such as focusing) may be more appropriate. The calibration process for windowing is similar to the process used for focusing (Section 8.4.3); however, some key differences exist due to additional allowances and flexibility that the modeler has through the windowing process. The calibration process for windowing should generally include the following considerations, at minimum:

(Before demand adjustments or network refinements)

- Confirm the window model is consistent with the base model
  - Are demands at cordon zones or gateways on the edge of the windowed model consistent with the assigned link volumes at these locations in the base regional model?
  - Do internal TAZ retain their original scale of demand (total trips in and out)?
- Confirm the window model is compatible with the base model
  - Does rerunning the assignment procedure for the windowed area give similar assignment results as the regional base model?

(After network refinements)

- Confirm the window model is providing realistic results

- Do the sums of connector volumes for a zone match the total zone demand?
- Does the routing for traffic into and out of new zones make sense? Common checks include a select zone analysis (Emme) or a zonal flow bundle analysis (Visum).
- Do the routes, origins, and destinations for traffic using a new link make sense? Common checks include a select link analysis (Emme) or a link-based flow bundle analysis (Visum).

- Confirm the model reflects existing traffic data
  - Does the magnitude of resulting traffic demand match base year traffic count data?
  - If assigning multiple vehicle classes, does the traffic demand match classification data?
  - Does the distribution of traffic match O-D patterns anticipated from license plate, Bluetooth, cell-phone, or other data survey means?

(After demand adjustments)

- Confirm the demand adjustments had the intended effect
  - Are adjusted totals for in and out trips by zone consistent with the targets?
  - Does the overall matrix sum change by the intended amount (if applicable)?
  - Do demand levels at zones that weren't intended to change remain the same?
- Confirm the window model is providing realistic results (again)
  - Do the sums of connector volumes for a zone match the total zone demand?
  - Does the routing for traffic into and out of new zones make sense? Common checks include a select zone analysis (Emme) or a zonal flow bundle analysis (Visum).
  - Do the routes, origins, and destinations for traffic using a new link make sense? Common checks include a select link analysis (Emme) or a link-based flow bundle analysis (Visum).

Given the unique characteristics and applications of subarea models, an appropriate level of calibration (e.g., metrics such as R^2 values for observed versus modeled link or turn volumes) for one model may not be sufficient for another model. For that reason it can be difficult to determine when a model is calibrated "enough", since it ultimately depends on how the model is applied and the decisions that will be made with the analysis. However, at a minimum, the above process and qualitative checks should be followed to ensure that due-diligence is performed, though additional checks and actions may be required. In addition, the analyst/modeler should provide documentation that shows that convergence criteria (such as R^2) were tracked through the calibration process.

8.4.5 Key Considerations (Application and Issues)

The following considerations are intended to help guide decisions regarding application of window models. In general, the level of detail and refinement in any particular element should generally reflect the detail of other model elements.
These considerations are not absolute but are intended to function as a general guidance when developing an approach and methodology.

Study Area Size/Boundary
When selecting an area of the model to window, consider the following:

- The boundary of the windowed area creates gateway or cordon zones that have fixed demand based on the assigned link traffic in the regional base model.
- Refinements to the regional base model may be needed before applying the windowed cut in order to refine demand at the cordon zone locations.
- Since demand is fixed at cordon locations, ensure that the model is sufficiently large to test the set of alternatives that will be analyzed. Running a sensitivity test in the regional base model that includes the most extreme network alternative can be used to determine the area of impact and potentially the size of windowed area model that may be needed.
- Since demand is fixed at cordon locations, it is generally beneficial to minimize the number of cordons and select a boundary that has less network redundancy. Constraints to network connectivity (rail, water, extreme topography, etc.) can provide physical boundaries that serve windowed models well.

Network Element Refinements (Links, Zones, Nodes)
When adding refinement to the network elements in a windowed subarea model, many of the same considerations for focusing should also be applied and are provided in Section 8.2.4. Additional considerations that result from the added flexibility that windowing allows:

- Do other attributed need to be considered and coded in the windowed area that may not be included in the regional base model? Unique elements within the windowed area (downtown parking, pedestrian activity, etc.) may be considered and added to the network attributes. These elements may also need to be accounted for in the assignment process.

Demand Adjustments
When applying demand adjustments, consider the following (and items noted in 8.5.3):

- Applying network refinements before demand adjustments aids in error-checking these edits before introducing additional changes (demand).
- What is the demand adjustment trying to achieve and what is the appropriate level of detail to meet this need? Some adjustment scenarios may require simply applying a factor to a single zone, while other adjustment scenarios may include a more elaborate process that considers changes to distribution.
- What type of demand needs to be adjusted? Will all model trips be adjusted, or will adjustments be made to specific internal zones and/or cordons?

- Do the trip length frequencies of the adjusted demand matrices remain similar to the original demand matrices?

Future Year Scenarios

When preparing future year scenarios, consider the following:

- What is the most appropriate method for combining the windowed area network with the future year demand? The most efficient process often includes windowing the future demand matrix and inserting it into the windowed base year model network and then adding additional improvement projects (if any) to reflect the future model road network.
- Were demand adjustments made to the base year model that needs to also be applied to the future year model? Section 8.5.2 provides additional information about conducting demand adjustments and application for future year models.

8.4.6 Examples and Scaling

As listed in Exhibit 8-7, the windowing methodology can be applied in varying degrees and scaled to fit the needs of each project and analysis. The following examples demonstrate different scales of application.

Window Model Example: Astoria Downtown

The Astoria-Warrenton model was windowed to capture potential circulation impacts related to potential traffic control changes in the Astoria downtown area. The base regional model is shown in Exhibit 8-14 and includes Astoria, Warrenton and the surrounding rural areas.

Exhibit 8-14 Astoria Warrenton Regional Model

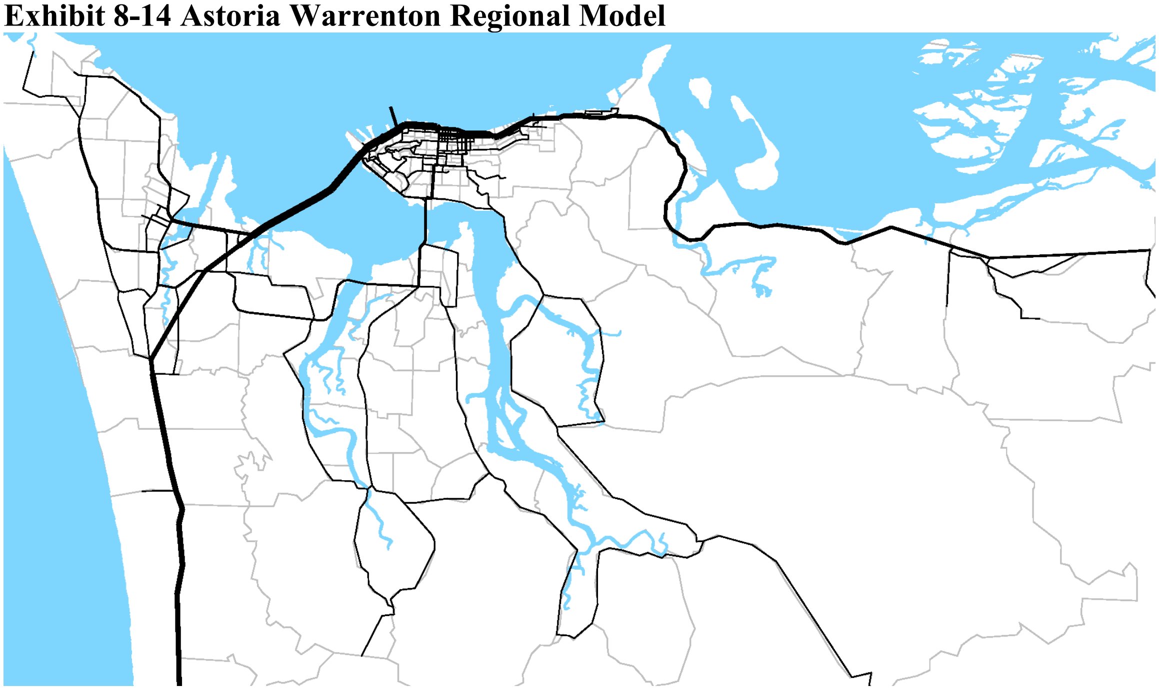
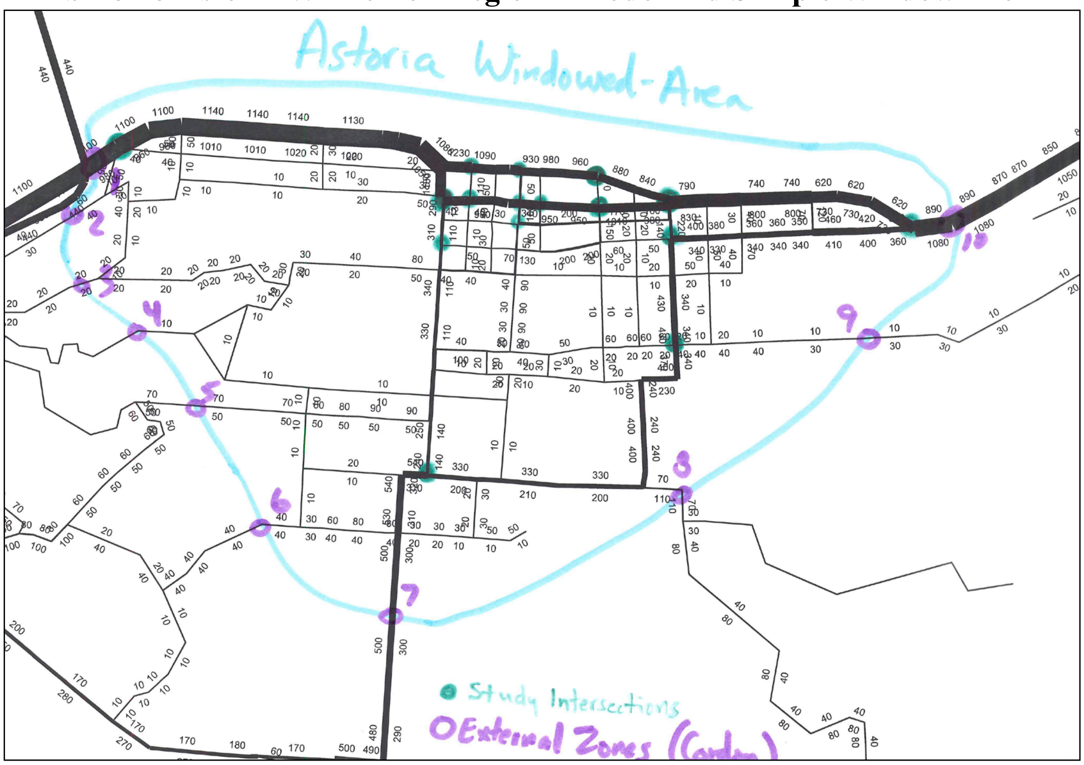


Exhibit 8-15 shows the Astoria downtown area in the regional model, as well as a sketch showing the proposed window boundary and cordon zones. This area was selected to minimize the amount of streets in the regional travel demand model that would be cut, while allowing for a large enough area to sufficiently capture potential traffic circulation changes due to future transportation network alternatives. Specifically, the window boundary was selected to account for and balance the following needs:

- Adequate size to include subset of study intersections and circulation impacts
- Minimize the number of cordon zones (cut base regional links)
- Zone boundaries were retained and not split (windowed matrix retained total trips for internal zones)

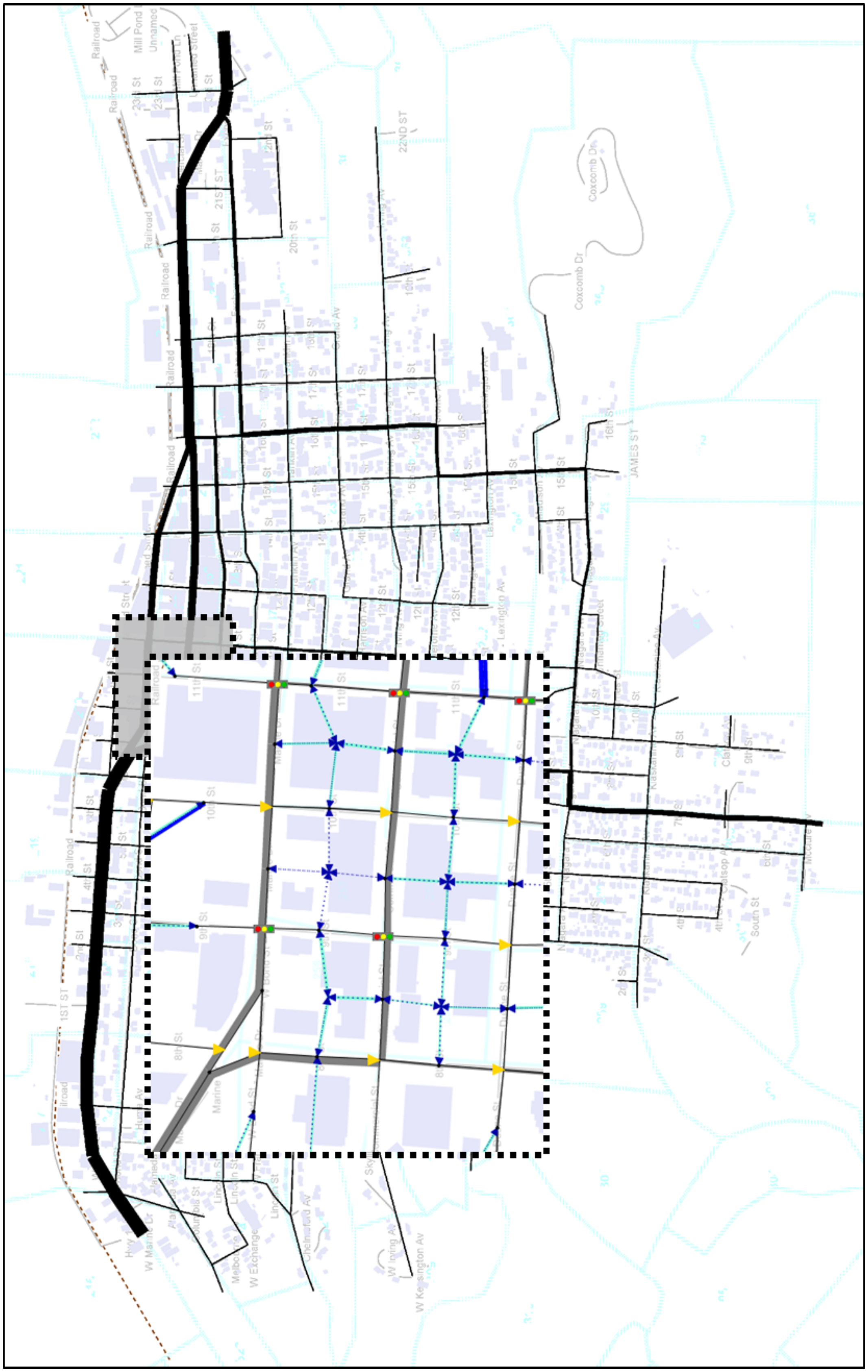
Exhibit 8-15 Astoria Warrenton Regional Model and Sample Window Area



The resulting windowed area model is shown in Exhibit 8-16. The windowed model included the following refinements to capture circulation impacts:

- Assignment – Incorporated HCM intersection delay for intersection turns.
- Link Network – Added all public roadways in windowed area
- Zone Network – Added centroid connectors to reflect major driveways and parking locations.

Exhibit 8-16 Astoria Downtown Windowed Model



8.5 Dynamic Traffic Assignment (DTA)

This section provides an overview of Dynamic Traffic Assignment (DTA) concepts and general considerations for application in Oregon. DTA tools and software packages are still relatively new, emerging tools that have the potential to improve forecasting and analysis and are becoming more widely used around the country. Due to the potential benefits of these tools, they may become more prevalent as they become better known and understood. While this section provides a general overview of DTA, additional information about DTA is provided by the Transportation Research Board[7].

8.5.1 DTA General Concepts

Traditionally, travel demand models have generally included a "static" assignment – one that provides a fixed path (or paths) for each origin-destination (O-D) pair during a given time interval. The time interval is generally the duration of the model period (such as a full day or a one-hour evening peak hour), or may be divided into shorter durations (such as one hour intervals within a day, or 15-minute periods within an hour). Generally, these static models have four common characteristics:

1) The O-D trips for each time interval are a function of input static time-of-day factors that are unrelated to the modeled assignment results. This means that the trips planned for each time interval are largely insensitive to how congestion varies through time.
2) All O-D trips are assumed to be completed during the time interval. That is, the travel time for each O-D pair is less than or equal to the time interval (generally one hour). In the event that a trip exceeds the time interval, demand is still forced through the system, leading to unreasonable demand-to-capacity (d/c) in highly congested networks.
3) The assigned path (or paths) for each O-D pair are not affected by the volumes in earlier time periods. Therefore, preexisting congestion on the roadway (from previous time periods) is ignored.
4) The representation of intersection Level of Service (LOS) is very simple (or non-existent) as the network usually lacks intersection geometry and signal timing. This significantly limits the static assignment model in its usefulness for traffic operations analysis.

Such static assignment models tend to work fairly well as long as recurring congestion is not present in a network with multiple alternatives routes (i.e. a redundant network). In addition, static assignment models are not able to fully capture additional details related to the complex effects of congestion that causes traffic to:

- Divert to another route (spatial spreading),
- Leave earlier or later (during another time period – peak spreading), or
- Travel through the congestion (with a significantly higher realized travel time).

[7] TRB Transportation Research E-Circular E-C153: Dynamic Traffic Assignment: A Primer, Transportation Research Board, Washington DC, June, 2011.

Beyond traditional aggregate trip-based demand models, activity-based demand models (ABM), are a better framework for integration with DTA. ABMs microsimulate a day's worth of travel for each individual in a region, operate at a finer temporal resolution (such as 30 minutes), and include improved models for scheduling trips (both departure and durations). Unlike aggregate trip-based models which output matrices by time period, ABMs output a list of individual trips with departure times. Integrating an ABM with a DTA therefore looks significantly different than integrating with a trip-based model. Currently, ODOT is in the process of developing ABMs.

In addition, static assignment models are not designed for dynamic changes in network capacity related to temporary closures, changes in traffic control, or non-recurrent diversion related to an incident. Other tools are needed for application in these scenarios. To better understand the potential impacts of the above cases, DTA can provide a more comprehensive assessment.

Unlike static models, DTA models allow travel routes to change through time. Traffic that is existing on the system (and its impacts on travel time) is considered, much like a seeding interval for a traffic simulation model. While there are many differences between different DTA platforms, the following general characteristics are common:

- Time-dependent paths; the path through the network is influenced by travel times that vary depending on when travelers arrive at a given network link, as opposed to assuming that travel times are constant throughout the period being simulated.
- Travel routes typically change at shorter intervals than static models (typically minutes instead of hours).
- Network congestion estimates, which are often based on traffic operations, are typically more detailed than a static model to account for travel time difference between routes.
- Vehicles queue on the network and are not forced through over-capacity conditions due to a timer interval constraint. Thus some demand may remain unserved during the analysis period.
- Individual vehicle "simulation" (whether visualized or not) is generally present to account for vehicle interaction and operational impacts.
- Like static assignment, multiclass assignment (including trucks) can be captured in DTA tools, which allow for different path sets and attributes among vehicle classes.
- Transit elements are included in varying degrees based on each DTA tool, but may include the ability to include service information including routes, stop locations, and schedules. Next generation DTA tools are starting to model individual transit persons as well.

DTA models assign demand in a much shorter time interval than static equilibrium traffic assignment models; often demand must be segmented into 15, 10 or even 5 minute time slices. This shorter interval duration is a feature that allows for better reflection of traffic flows, but it is also a requirement that necessitates better trip estimates than typically provided by demand models. Developing the initial set of OD trip tables by time period that are fed into the DTA is an important task that needs to be done with care, and is discussed later in this section.

In mesoscopic modeling, DTA models represent the application that comes closest to achieving the same details that microsimulation models achieve. While microsimulation models maintain more advanced driver behavior algorithms and settings, DTA models usually provide individual vehicle simulation, car-following logic, intersection delay and queuing components, and the ability to introduce vehicle and/or driver profiles, all while maintaining trips to load onto a routable network.

A key differentiator among DTA models is the overall fidelity and detail for which traffic flows are captured along a road. The two types of models are referred to as “link-based” and “lane-based:”

- **Link-Based Models** – Traffic flow along a roadway is analyzed macroscopically, where the total number of lanes is considered as an overall link capacity. Differences among individual lanes (including the amount of traffic demand for an individual lane), interactions among individual vehicles, and friction related to movement and lane changing are not directly modeled.
- **Lane-Based Models** – Traffic flow along a roadway is analyzed for each lane, using car-following algorithms that account for interactions among vehicles and flow differences in each lane. Storage of vehicles related to turn bay lengths and other differences between lanes along a given link may influence operations at the adjacent node/junctions/intersections.

As discussed in later sections, the fundamental differences between these model types should be considered when selecting a DTA tool for project application.

8.5.2 DTA Scoping

The following sections provide an overview of scoping DTA modeling efforts and an introduction to various tools and software packages.

"…DTA models are not the universal cure that can cost-effectively address all types of problems at hand. DTA models take more time and resources to construct and calibrate (as compared with static traffic assignment models) and represent traffic dynamics in a coarser granularity (as compared with microscopic traffic simulation models.) Practitioners are advised to match the choice of modeling approaches to the problem at hand. For long-term planning, for example, the available level of input data required for DTA may not be available, so that one may have to make many assumptions in order to construct such models. If the additional detail and precision in their output data compared to conventional network forecasting is not beneficial for the modeling question in mind, then it may not be worth the additional modeling effort. For a smaller bounded area in which a detailed representation of multiple modes (e.g., auto, transit, pedestrians) and facilities (roadways, parking, crosswalks, etc.) are required, microscopic models may be more appropriate and useful"[1]

[1] TRB Transportation Research E-Circular E-C153: Dynamic Traffic Assignment: A Primer, Transportation Research Board, Washington DC, June 2011.

Tool Selection
Unlike static demand models that typically can achieve similar analysis under different graphical user interface (GUI), DTA models generally have many more fundamental differences related to model structure, network detail, and assignment algorithms. Section 8.5.3 provides an overview of DTA tools and includes additional information comparing key differences among some of the DTA tools and software packages. It is important to consider these fundamental differences when selecting the correct tool (among DTA software or other tools) to address the transportation question.

Data
The general types of data needed to code and calibrate a DTA model are similar to a subarea model (Sections 8.2 through 8.4) and require the following general types of data:

- Network Data – Attributes of the transportation network such as traffic control, lane geometries, and signal timing information.
- Demand Data – Data such as initial O-D trip matrices by time period, land use inventories and/or traffic counts to estimate the level of overall traffic demand.
- Calibration/Validation Data – Data that can be used to compare traffic flows and operations from the model, such as tube or intersection turn counts, and travel time runs along a corridor.

However, the key differences are that DTA traffic datasets (demands, flows, and operations) typically need to address finer-grained resolutions of traffic volume and travel time data over sequential time periods. For instance, data (such as traffic volumes, speeds, etc.) may be needed for individual 15-minute intervals (3:00 to 3:15 p.m., 3:15 to

3:30 p.m., … 6:45 to 7:00 p.m.) rather than a single, aggregated 5:00 to 6:00 p.m. one-hour period. Key differences in the type and resolution of data needs include:

- O-D Trips (travel demand)
  - Finer time resolution trip matrices
  - Trips matrices that will not overload the DTA network (i.e. the overall magnitude of traffic demand is appropriate for the network)
- Traffic Volumes (intersection turn or roadway tube)
  - Flow profiles that cover the modeled time period (which may exceed a simple peak hour)
  - Flow profiles in time intervals of an appropriate resolution to be compared to the DTA model (such as 15-minute periods)
  - Flow profiles at key locations upstream, downstream and/or within bottleneck areas to understand differences in traffic demand and actual supply output
- Traffic Operations
  - Average speed profiles along a corridor (may come from Bluetooth and/or third party vendor speed data such as INRIX or TomTom)
  - Average delay for intersection movements (may be compared to an HCM intersection model)
  - Actual signal timing (such as observed average phase durations and cycle lengths) to develop the network model (traffic control details).
  - Queue lengths to understand the vehicle spacing and jam density

Given the duration and resolution of datasets identified above, it can be difficult (if not cost-prohibitive) to acquire complete data coverage of the model area. For that reason, it is important to strategically make use of existing datasets and focus new data collection efforts on key locations that capture real world behavior and attributes that need to be reflected in the model. The following types of answers should be addressed in model validation and calibration and may guide the collection of data:

- Is the overall magnitude of traffic demand appropriate? If not, then a common correction (for current and short term forecast years) is to adjust the O-D trip matrix to better match traffic counts (see Section 8.5.3) (Check volumes at network entry points and/or screenlines)[8]
- Is the correct routing being reflected in the model? (Check volumes on screenlines and turn movements at key junctions)
- Is the correct volume profile (and peaking) being realized on key network links? (Check volume profiles at key locations as well as upstream/downstream of bottlenecks)
- Is the correct travel time profile being realized on key network links? (Check traffic volumes and determine if delay estimates are being applied appropriately)

[8] There are some DTA model development projects that rely upon activity-based demand, provided in the form of trip lists (simulation output) rather than an ODO matrix.

Resource Needs

Section 8.3.3 reviewed the level of resources needed to apply windowing and subarea models. In many cases a DTA model may be applied as a windowed model. For reference, application of a DTA windowed model will generally fall under the "high" range of effort listed in Exhibit 8-7.

Due to the additional refinements and details available in a DTA model, the time needed to set up a DTA model (like a microsimulation model) is probably best summarized as weeks or months, rather than hours or days.

Since DTA models typically require additional effort to build and calibrate beyond a typical static macroscopic model, it can be helpful to approach the process from the perspective of scoping a microsimulation model. While DTA models may be used for a variety of purposes ranging from developing better demand volumes for microsimulation to using operational measures to screen alternatives, the details and data needed to build and calibrate the models can emulate a microsimulation model. ODOT has developed a process[9] for building Vissim microsimulation models that provides a general structure for how to approach and scope a microsimulation effort. Depending on the DTA application and similarity to a microsimulation model, some of the framework of this approach may be able to provide a generalized resource for a DTA modeling endeavor.

8.5.3 Overview of DTA Tools and Software Packages

There is a wide array of tools available to perform DTA at varying scales and resolution levels. These tools range from enhancements of macroscopic models to application within microsimulation – essentially covering the full spectrum of mesoscopic modeling in terms of network detail and level of effort. The various types of tools available and the range of these tools allows for broad application ranging from enhancing volume development for separate traffic analysis to performing the actual traffic analysis in place of microsimulation. The following section provides an overview of some of tools used in the Portland metropolitan area. This list is not meant to be a review of all the DTA tools on the market; instead it is meant to illustrate the spectrum of DTA tools. Exhibit 8-18 summarizes the DTA tools that have been applied in the Portland metropolitan area.

[9] *Protocol for Vissim Simulation*, Oregon Department of Transportation, June 2011.

The following tools are grouped along the spectrum of mesoscopic modeling, ranging from those closer to macroscopic models to those that are more similar to microscopic models. Each tool has numerous features and fundamental differences that provide opportunities and limitations that ultimately impact the analysis results. This list is grouped for demonstrative purposes only and analysts are encouraged to understand the full abilities and limitations of these tools before project application. Groups closer to macroscopic models would require less detail and resources to use, while those closer to microsimulation would be more data and labor intensive to apply.

DTA tools within **macroscopic framework** (individual vehicles are not modeled):

- Visum Dynamic User Equilibrium (DUE) – A model within PTV's macroscopic Visum model that constrains vehicle flow due to out-link intersection capacity and allows spreading of vehicle demand to adjacent routes. If other routes are at capacity (for a given time period), demand can be spread to originate during adjacent time periods. DUE is a link-based model and does not require coding intersection geometry or signal timing.

DTA tools with **link-based traffic flow** (individual vehicles modeled):

- DynusT – An open-source stand-alone DTA package that models individual vehicles but does not model individual travel lanes. Because of its simplifications in network representation, it can be applied to larger network sizes. See Exhibit 8-18 for additional details.

DTA tools with **lane-based traffic flow** (individual vehicles modeled):

- Dynameq – This stand-alone DTA package developed by INRO models individual vehicles and lanes, includes car-following logic that (due to the lane-based nature) models interactions in a more advanced manner than the link-based models but is more simplified than a microsimulation model. See Exhibit 8-18 for additional details.

DTA tools within **microscopic framework** (individual vehicles modeled)

- Vissim DTA – A model within PTV's Vissim microsimulation package that allows for dynamic routing of individual vehicles. This application makes use of the fine-grained car following logic within the microscopic model.

Exhibit 8-17 Continuum of DTA Tools and Typical Level of Detail

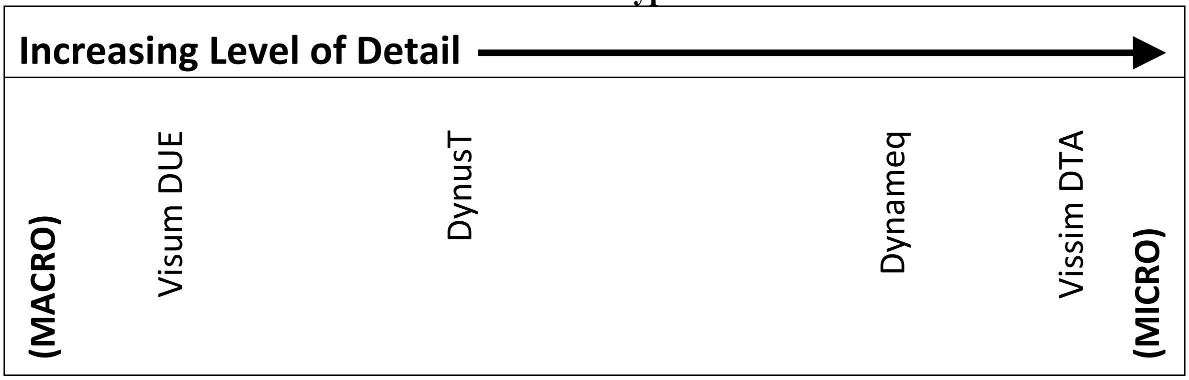


Exhibit 8-18 Comparison of DTA Tools Applied in Portland Metropolitan Area

Element	DynusT	Dynameq
Segment Geometry and Control	**Link**-based (overall capacity of the cross-section is considered)	**Lane**-based (individual capacity for each lane and interaction with adjacent lanes and vehicles are considered)
Intersection Geometry and Control	Intersection turn bays are based on single global distance parameter.	Allows specific lane storage via creation of new links at any change in cross section.
Traffic Signals	Includes general traffic signal settings as well as actuated timing on a cycle by cycle basis.	Includes general traffic signal settings as well as actuated timing on a cycle by cycle basis. (beta feature)
Typical Model Size/ Application	Regional application for major roads is common.	Typically more restrictive model size that may be smaller scale subarea due to increased detail (all streets).
Includes Vehicle Simulation	Vehicles simulated at specific time steps (every 3 seconds or other duration)	Vehicle interaction is simulated for events and calculation is performed when there is a change
Visualization	Synthetic visualization of individual vehicles based on link-level information.	Macro flow (density, speed, etc.) at link level - individual vehicles not shown (but are simulated).
Randomness	Stochastic – allows multiple runs to reflect system variability (similar to microsimulation)	Deterministic model (profiles are applied for characteristics)
Ability to Import and Export Data	Allows network import/export with travel demand models and microsimulation. Direct integration may be difficult since network may be modified based on geometries.	Allows network import/export with travel demand models and microsimulation. Direct integration may be difficult since network may be modified based on geometries.
Output	Data/Measures can be visualized in GUI or raw data exported for processing.	Data/Measures can be visualized in GUI or raw data exported for processing.
Scripting / Application Programming Interface (API)	Custom dynamic-link library (DLL) for ramp metering and signal control; full API planned	Python API
License	Open source without support; support for a fee	Purchase (includes software updates and support)

8.5.4 DTA Calibration

> *Analysis Procedure Manual Version 2 Chapter 6 includes additional information on model checks. Calibration information in section 8.5.4 may also be relevant, particularly when applying a DTA model as a windowed subarea model.*

Model Checking

An important aspect of DTA calibration is finding and fixing network coding problems and performing a model checking process. In the case of a DTA model, miscoding signal timing, approach geometry, intersection connectivity, turn prohibitions, etc. can have major impacts on the simulation. Very often the calibration process requires detailed network coding checks, and network defaults must be revised where they are found to be insufficient to reflect true operations in key locations. In addition, any O-D demand adjustment should be re-done if significant network errors are corrected.

Calibration

In general, the following broad observations are common to DTA model calibration:

- DTA models include more settings and “knobs” to turn (which may or may not be appropriate to adjust) than a traditional static assignment model. This makes the calibration process more complex, costly and time consuming.
- More data are needed than a typical static model (see Section 8.6.2)

Due to the varied level of detail and application of DTA tools, it is important to consider the resolution of the model and what is an appropriate level of calibration. In addition to information provided for calibration subarea models, some strategies for calibrating DTA models include:

- If specific targets are used for traffic volumes and/or travel times, consider thresholds that vary by project priority. Corridors that are the primary focus of the analysis should have the tightest calibration targets while other roads in the model that compose the supporting network may not be as critical. These targets should be developed through coordination with agency staff.
- Signal timing can be a critical element that affects calibration on non-freeway facilities. Spending the time to code signal timing at an appropriate level of detail will facilitate calibration.
- Flow models (relationship of vehicle speed, density and flow) are an important component of freeway segments. Be sure that the settings are reasonable and appropriate for the model area.
- Understand the basis, limitations, and location-dependency of data that were used to develop the model, specifically in regards to if the data represent a total traffic demand or an actual (potentially capacity-restricted) traffic volume that is realized in the network.

- Consider if bottlenecks and capacity constraints are being correctly reflected in resulting flow profiles. Gateway adjustments may be necessary to approximate bottleneck effects.
- Depending on model resolution and purpose, calibration may be sufficient at aggregate levels.
- Review high-level items (such as total volume magnitude of a screenline) and general routing patterns before focusing on network details.
- Check for unserved demand or "lost trips" on the travel network. These are vehicles that cannot actually get on the network or cannot make it from their origin to their destination according to their chosen route because of congestion. Many DTA packages report these trips and the analyst must address them by changing the demand profile or fixing the network.
- O-D demand adjustment may be needed to fit a demand matrix to the network conditions (as observed by traffic counts). However, such action should be approached with caution and should be re-done once the network is error free. . Related guidance for demand adjustments is provided in Section 8.5.3.

Some parameters (such as vehicle flow densities and signal timing) have the potential to greatly influence the model network capacity and the resulting traffic assignment and overall results. These parameters should be verified before focusing on and adjusting gateways or micro-level details for calibration.

8.5.5 Measures of Effectiveness (MOE)

The fundamental nature of DTA models and core differences from traditional static models allows for an expanded set of model data and reportable measures of effectiveness. The increase of available measures reflects the key differences introduced by DTA models in level of detail (such as intersection operations) and changes over time that are typically not available in static models.

The amount of MOE that are available directly through the GUI of the DTA platform may vary by software version and type of DTA model (link-based versus lane-based, see Section 8.5.3). However, additional measures are typically available indirectly by processing raw data that are produced through the model runs. These possibilities leave the analyst with a wide selection of potential MOEs. It is important to select MOEs that are relevant for the decisions being made and are appropriate for the level of detail coded into the model.

Some potential types of MOEs include:
*(Note: additional detail may also be available for individual lanes in lane-based DTA models when denoted with *)*

- MOEs typically produced by a static model
    - Roadway segment (link) traffic volume during a time period *
    - Roadway segment (link) average travel time during a time period *

    - Roadway corridor average travel time during a time period *
    - System MOEs (vehicle hours of delay, etc.)
- MOEs typically produced by a DTA model
    - Available due to additional operation detail
        - Average delay by intersection movement
        - Vehicle queuing or link occupancy (available on a lane basis for lane-based DTA models) *
    - Available due to nature of model simulation (individual vehicles)
        - Reliability metrics related to range of travel time for all vehicles along a corridor during a time period (Exhibit 8-20) *
        - Individual travel time trajectories along a corridor *
    - Available due to differences between time periods
        - Map-based simulation of traffic volumes, occupancy, or other metric shown on a link by link basis (Exhibit 8-19) *
        - Segment or corridor travel time profile (for each hour of the day or model time interval) (Exhibit 8-20)
        - Space-time ("brain scan") heat maps showing changes in travel time, occupancy, speed, etc. along a corridor (Exhibit 8-21) *

> YIELD
>
> *Some MOEs or outputs that are commonly produced using static models (such as model difference plots) may not be as easy to reproduce in DTA packages. The summary of this output may require additional processing rather than being directly available/automated through the model interface.*

The following exhibits demonstrate some of the MOEs that are possible with DTA models.

Exhibit 8-19 DTA MOE Sample 1 – Map-based Shockwave Animation (Regional or Subarea) Shown for Four Sequential Time Periods

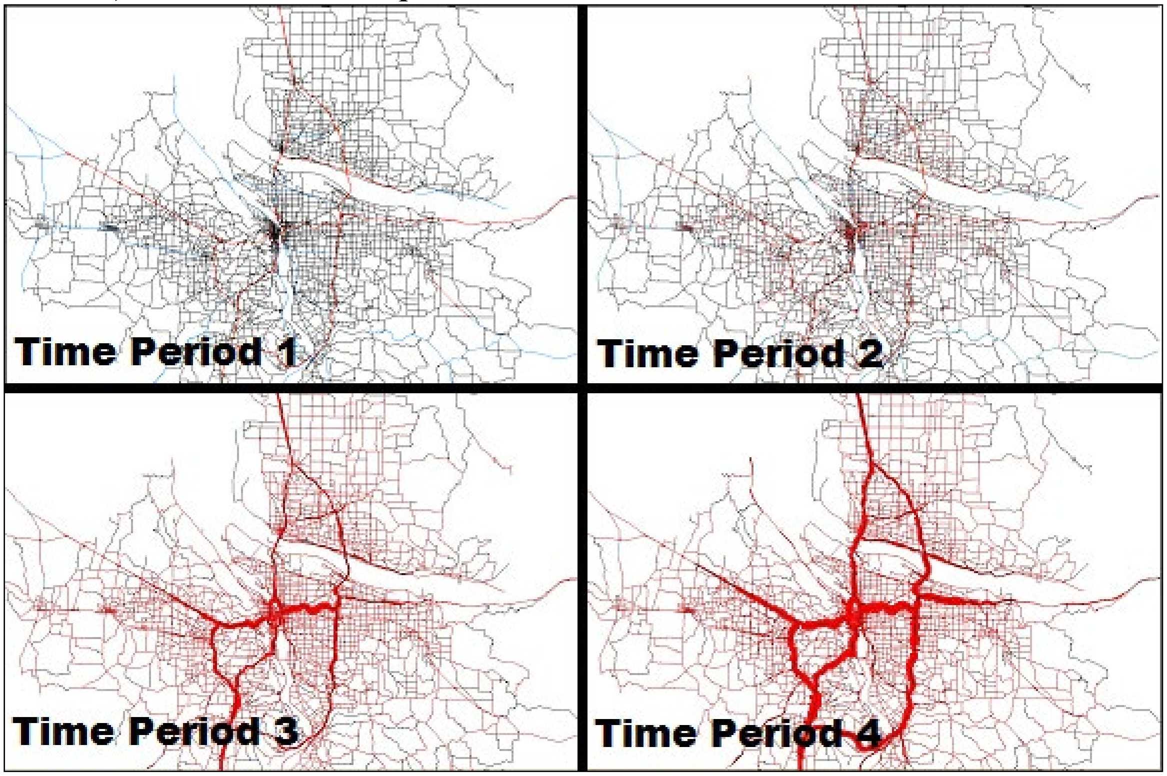


Exhibit 8-20 DTA MOE Sample 2 – Travel Time Profile along a Corridor

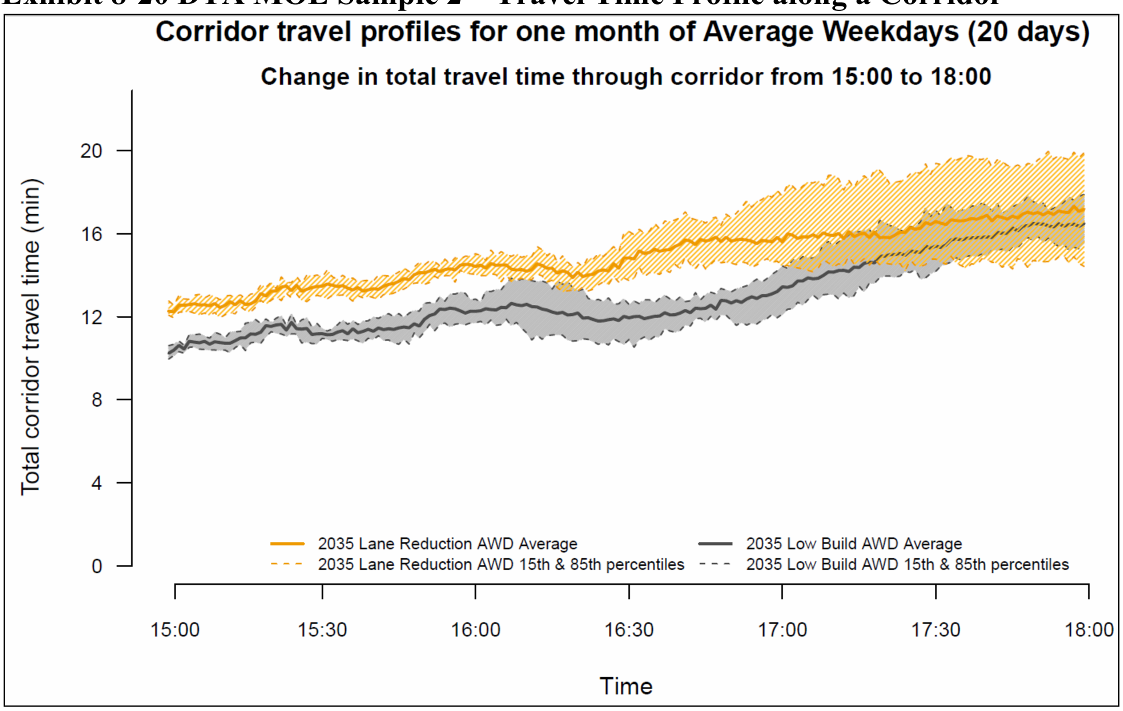
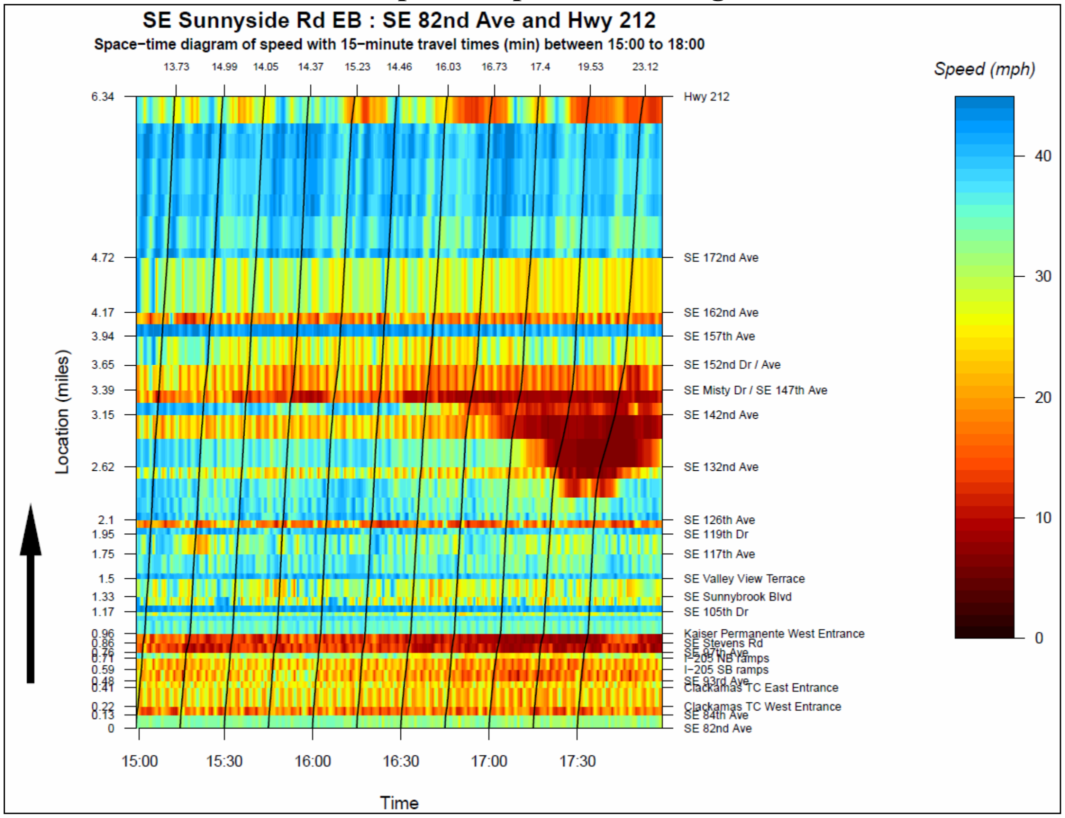


Exhibit 8-21 DTA MOE Sample 3 – Space-time Congestion Plot



8.5.6 Key Considerations (Application and Issues)

The following considerations are intended to help guide decisions regarding application of DTA models. In general, the level of detail and refinement in any particular element should generally reflect the detail of other model elements. Since application of a DTA model may be applied as a windowed subarea model to a regional static model, many of the same considerations for windowing would apply. However, due to the fundamental differences for DTA models (including increased resolution for traffic operations), additional considerations would apply. These considerations are not absolute but are intended to function as a general guidance when developing an approach and methodology.

General considerations related to windowing a DTA subarea from a regional static model (see Section 8.5.5 for additional detail)

- Study Area Size/Boundary
- Network Element Refinements (Links, Zones, Nodes)
- Demand Adjustments
- Future Year Scenarios

The following considerations reflect those that are introduced by DTA models that may not be primary issues when dealing with static models.

- Balancing model refinements with overall purpose - The ultimate purpose of the DTA model will application will vary from project to project and will ultimately guide the level of refinements needed in the model. Some examples of the range of typical applications include:
  - Volume development (may include higher level model)
    - Developing base year alternative volumes for operations analysis
    - Forecasting future year volumes
  - Operations analysis (may include finer resolution and detail)
    - Screening alternatives within the DTA model (relative comparisons)
    - System measures
    - Corridor/Intersection measures

- Understanding Traffic Flow Theory and Operations Concepts - DTA models introduce traffic flow details that are not generally present in static models. These elements may vary from those that are simplified in static models (such as traffic control types), to those that are non-existent in static models (flow model and jam density values). In order to correctly understand and use the models, the analyst needs to have an understanding of traffic flow theory that goes beyond what is generally needed for regional-scale travel demand modeling using static models. Some of these key concepts include:
  - Intersection control and movement priority
  - Traffic signal timing (and realistic settings)
  - Speed/Flow/Density relationships (including jam density[10])

Fundamental knowledge in these areas is needed to correctly code operational elements in the model and to consider the reasonableness of model results.

- While DTA software generally include the ability to import and export data, these abilities, and the differences in the underlying network data models, vary by platform and can make it difficult to transfer data between packages in an efficient manner. For this reason, the analyst should consider these differences when considering application of multi-resolution models and combinations of DTA platforms for project application.
- Applying DTA models for future conditions introduces several other considerations for the future year model:
  - Assumptions for traffic control, specifically future traffic signal timing parameters for existing or proposed traffic signals. In some cases (such as a fixed timed grid network or along a coordinated corridor) it may not be reasonable to assume that signal timing parameters would change in the future. However, depending on the intersection location, ownership, and potential for growth, it may be reasonable to anticipate that traffic signal timing would be updated in the future to reflect changing needs. For example, an intersection on the urban fringe that currently runs free and

[10] Jam densities vary by location and vehicle mix but generally range from a spacing of 25 to 30 feet per vehicle or 175 to 210 vehicles per lane per mile)

has low average splits and cycle lengths may have longer average splits and cycle lengths as demand increases in the future. However, for intersections that are part of a coordinated system, particularly when located along a highway route that maintains a green band, future signal timing modifications may not be as likely. These assumptions should be coordinated with TPAU and/or ODOT Region traffic group.

- Adjusting demand through O-D matrix demand adjustment is problematic for future year models because it assumes the relationships that exist between the seed demand matrices from a regional travel demand model and the traffic counts hold true in the future (see Sections 8.5.3 and 8.6.4)
- Method used for developing traffic analysis volumes. Many factors (such as the type of DTA model used, the amount of data available, the effectiveness of the calibration process, the amount of pre -processing of traffic demand, etc.) will influence the balance of traffic analysis that is performed within the DTA model versus the use of external tools (including HCM or microsimulation).

8.6 Peak Spreading

This section describes the concept of peak spreading and summarizes different analysis methods, needs, and considerations based on location and context (type of study and implications such as short term development impacts for a TIA or long-term regional planning needs). Peak spreading (as described in the following sections) occurs when there is travel demand for a sustained period that exceeds the available capacity of the transportation network. For this reason, peak spreading is unique to congested conditions, and is unlikely to exist for an extended period in a relatively uncongested network.

While peak spreading methods can be used to estimate how traffic routing, assignment, and/or travel time may be influenced by congestion during different periods of the day, the existence of peak spreading may indicate that other facets of the travel estimation (such as trip generation and trip distribution) may need to be reconsidered. As Oregon moves towards activity based models (ABM) and Dynamic Traffic Assignment (DTA) models the integrated abilities of these tools will limit the need for separate peak spreading processes described in this section.

8.6.1 Peak Spreading General Concepts

The following sections provide an introduction and overview of general peak spreading concepts. For the purposes of the following material, it is important to understand the differences between two terms that are commonly used interchangeably but have very different meanings:

- **Travel demand** – the amount of unconstrained traffic that wants to travel on a road or make a turn movement during a specified period of time. An example of traffic demand would be the amount of traffic that a static travel demand model reports wants to use a road in the future. In reality, there may be constraints (such as capacity of a downstream intersection) that prevent this amount of travel demand from being achieved in the real world. However, this demand" can still provide insight for planning purposes. Travel demand is sometimes reported as a ratio to available capacity as demand/capacity (D/C), which can exceed a value of 1.0.
- **Traffic volume** – the amount of traffic that is actually served on a road during a specified period of time. An example of a traffic volume would be the number of cars that are observed travelling in a lane or making a turning movement during a vehicle count data collection. These volumes are the actual amount of vehicles that are able to use the system, given constraints that exist. The traffic volumes may be equal to the travel demand, but in congested conditions the traffic volumes will be less than the travel demand due to constraints (insufficient green

time at the signal, downstream bottlenecks, etc.). Traffic volumes are commonly reported as a ratio to available capacity as volume/capacity (V/C). By definition, these ratios cannot exceed a value of 1.0.

How Travel Demand Models Deal With Time-of-Day

Before defining peak spreading in detail, it is important to understand how travel demand models generate traffic demand forecasts since traffic demand is often revised during peak spreading procedures.

Aggregate trip-based models create time period specific travel demand trip matrices based on static user defined time period factors. These factors usually vary by trip purpose and direction of travel (production to attraction and attraction to production). By applying these time-of-day factors, the estimated daily travel demand is split into time period specific demand. As a result, travel demand models are largely insensitive to peak spreading since the user specifies how demand is spread across the hours of the day.

Activity-based models (ABM), such as those being developed for the Portland metropolitan area regional government (Metro) and ODOT, take a much different approach to modeling time-of-day. ABMs have explicit trip departure time and duration models that operate at the hourly or half-hour time period that are sensitive to a much more comprehensive set of information, including differences in network congestion by time-of-day. As a result, ABMs can produce more reasonable travel demand by time period and are much more able to model peak spreading.

What is Peak Spreading?

Traffic demands and traffic volumes constantly fluctuate based on many factors. While traffic is always changing, traffic analyses generally consider peak traffic conditions to assess the needs of the roadway system. Traffic analyses commonly account for traffic peaks or profiles in three general ways.

1) Annual traffic profile - Daily traffic volumes for a given location may be assessed to determine how they change over the year. These considerations are used to adjust for seasonal factoring, which account for changes in daily traffic demand throughout the year. (see APM Section 5.4 for additional information)
2) Daily traffic profile and “peak hour” occurrence - Traffic volumes by time of day (generally divided into an hour) are considered to determine at what time the traffic is generally highest. These periods are commonly referred to as peak periods and (based on land use and transportation factors[11]) generally occur during a “peak hour” in both the morning and evening periods that correspond to commute patterns. In order to account for this peaking, traffic counts may be conducted during both periods for a traffic impact analysis, such as the 7:00 a.m.

[11] Such as proximity to land uses that may have atypical trip generation peaks (schools, major employment centers with off-peak shift changes) or variable elements of the transportation system (time of day control or meters that influence other network options) that cause routing patterns to change.

to 9:00 a.m. and 4:00 p.m. to 6:00 p.m. periods to identify the peak hour.

3) Traffic peaking during the highest hour and peak 15-minutes[12] – Traffic analysis following HCM procedures further accounts for peak traffic demands during a peak 15-minute period. This is measured as the peak hour factor (PHF), which corresponds to the ratio of: (peak hour volume / (4 * peak 15-minute volume)). A PHF of 1.0 indicates a uniform traffic volume during each 15-minute segment of the peak hour, while lower values indicate a sharp peak (such as a shift change near a major employer or end of school day near a school).

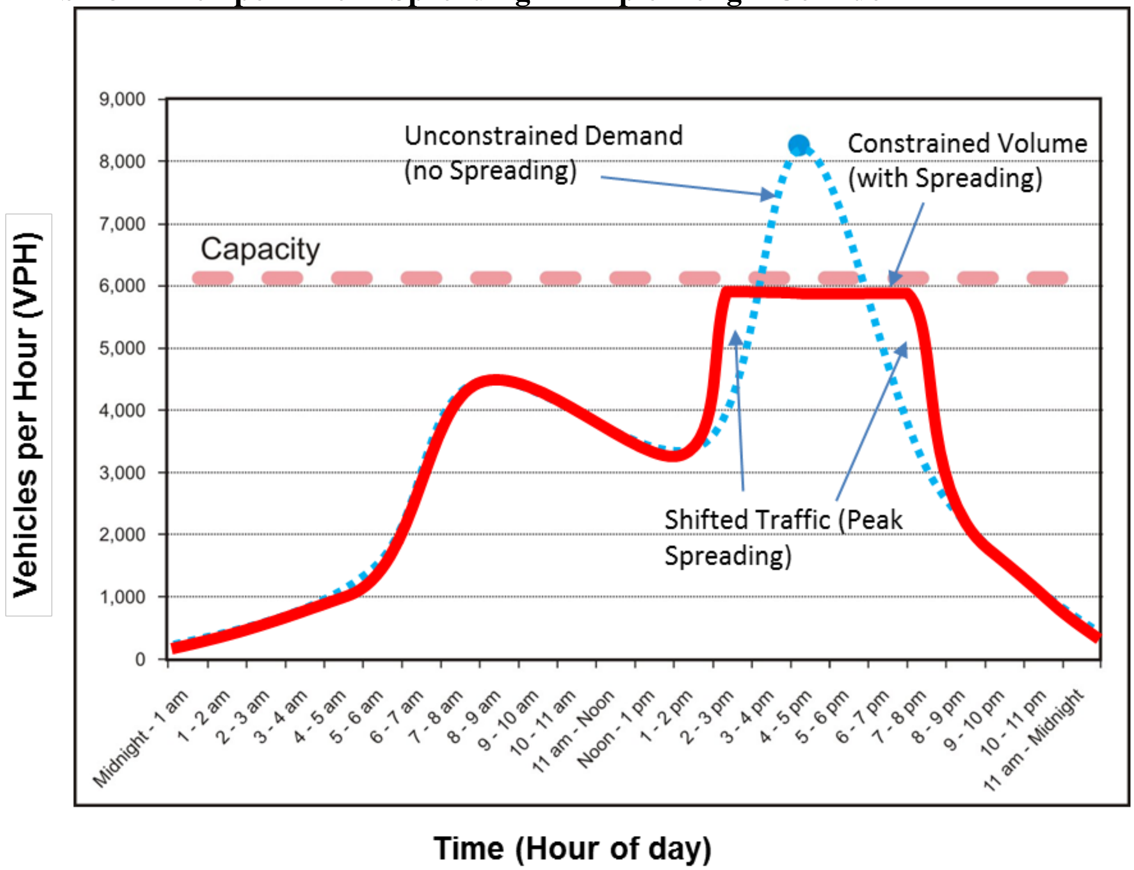
On a smaller scale, the example of a PHF at or near 1.0 is indicative of the general concept of peak spreading within the peak hour. **Peak spreading** is when traffic demand exceeds capacity and the resulting traffic volumes are served over a longer peak duration (temporal spreading) or may shift to other routes (spatial spreading).

Exhibit 8-22 demonstrates temporal peak spreading along a corridor. First, the x-axis represents the hour of the day and the y-axis represents the traffic on the freeway segment. The example includes four primary elements:

- The capacity of the segment is approximately 6,100 vehicles per hour (VPH), represented by a dashed red line.
- The unconstrained traffic demand (shown in dashed blue) is the amount of traffic that wants to travel on the corridor. This demand may be the result of applying a growth factor (resulting from historical trend or travel model forecast to an existing profile. The unconstrained demand is highest around 3 p.m. with a value of 8,200 vehicles. This unconstrained demand is well above the capacity of 6,100 vehicles per hour.
- The constrained traffic volume (shown in solid red) is the amount of traffic that can actually use the corridor given the capacity constraints. The constrained traffic volume does not exceed the capacity of 6,100 vehicles per hour. During early hours of the day and late hours of the night (when traffic demand is low), the traffic volume is the same as the traffic demand. However, when traffic demand exceeds the capacity, the traffic volume is limited at the capacity.
- The peak spreading (shown as the area above the unconstrained demand and below the constrained volume) is traffic volume that is using the system earlier or later than the unconstrained peak in order to be accommodated by the capacity. In this case, some of the traffic volume would occur later (approximately between 6 p.m. to 9 p.m.) due to congestion and longer travel times. In addition, some of this traffic may have desired to use the system between 2:00 p.m. and 5:00 p.m. but may have chosen to plan their route differently to leave later. In addition, the peak spreading shown to occur between 5:00 a.m. and 11:00 a.m. would be caused by traffic that would be leaving earlier to avoid congestion later in the day.

[12] Refer to APM Chapter 3 for additional information regarding traffic counts and congested conditions.

Exhibit 8-22 Temporal Peak Spreading Example along a Corridor

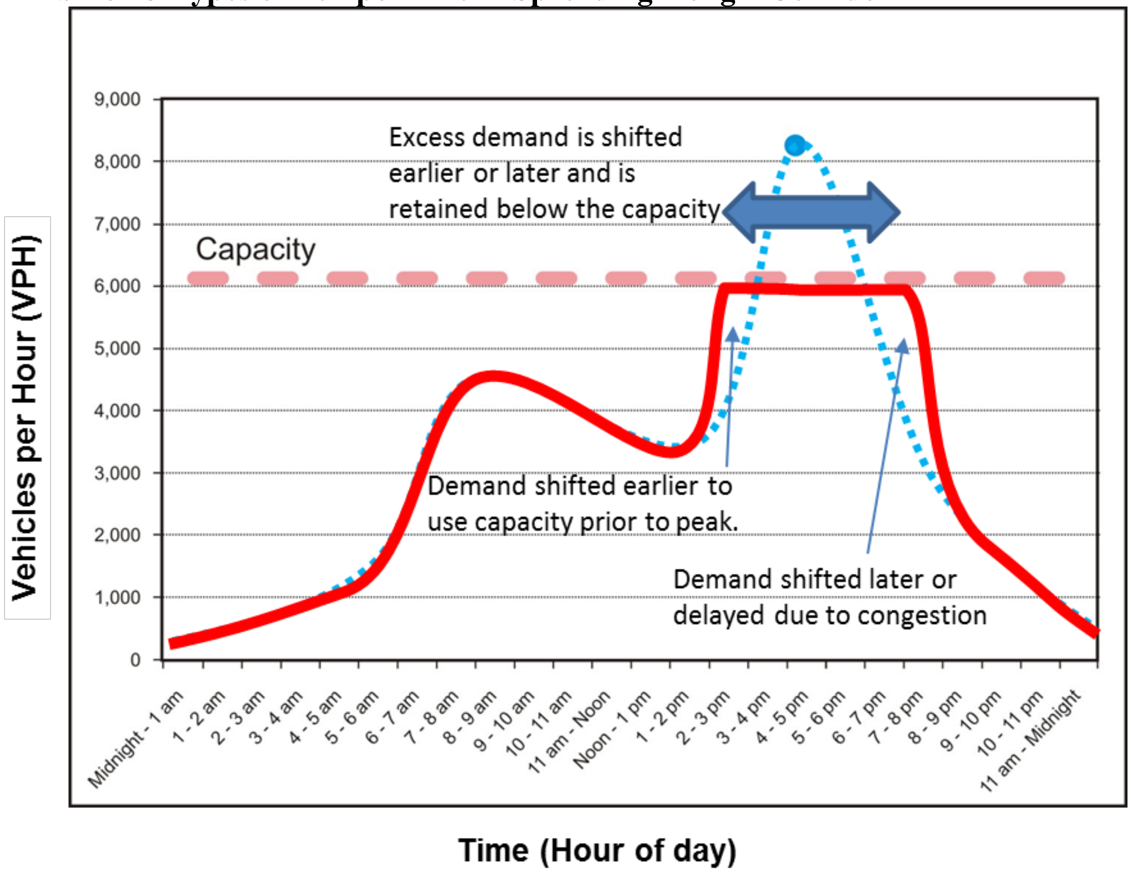


What Causes Peak Spreading?

As demonstrated in Exhibit 8-23, peak spreading is generally caused by one or both of the following conditions related to congested traffic conditions:

- Driver decision making - A driver changes their travel behavior to leave before/after the peak conditions to decrease the overall travel time and avoid waiting longer in congestion.
- Bottleneck capacity - A driver does not change their travel behavior and leaves at the desired time to start their trip. However, congestion prevents the driver from completing their trip in a timely manner and they do not reach a downstream location until later due to upstream bottlenecks.

Exhibit 8-23 Types of Temporal Peak Spreading along a Corridor



Why Does Peak Spreading Matter?

Peak spreading as an outcome of congested traffic conditions can influence the amount and distribution of actual traffic on the system. In some cases, the traffic volumes may be less than the travel demand that was projected (during the peak period), but in other cases the traffic volumes may be greater than the projected travel demand due to the effects of peak spreading. In cases where actual traffic volumes are required for an analysis (which is the majority of all traffic analysis), and there is potential for congestion and peak spreading, considerations for peak spreading are important to ensure that findings are reasonable.

In particular, peak spreading considerations are critical for the following use cases:

- Realistic operational analysis (including microsimulation analysis) – Realistic traffic demands are necessary to produce realistic traffic operations results. In order to derive more realistic operations (such as v/c or LOS), appropriate consideration needs to be taken for other network elements and behavior that may influence the traffic demand. Microsimulation models generally function poorly (and may reach a gridlock state) when estimates of O-D trips are not reasonable to account for upstream metering or capacity constraints. In addition, by not correctly accounting for peak spreading, the analysis may lead to unrealistic conditions, misidentification of traffic impacts and queues, and poor design decisions.

- Understanding duration of congestion (and implications of potential improvements) – As new performance measures and policies are explored, it is critical to have a better understanding of what congested conditions will result. By portraying the actual conditions that people will experience, analysts and decision-makers will have a better context for choices related to transportation improvements and policy needs. This consideration will also provide a means for assessing the implications for potential improvements outside the traditional design hour case.

8.6.2 Peak Spreading Scoping

The following sections provide an overview of scoping peak spreading considerations.

> *Peak spreading analysis and approach depends highly on the preexisting tools (such as the type of travel demand and assignment model) that exist for a location as well as the level of detail needed. Some sketch level analysis may be completed in a matter of hours while more in-depth questions may require additional travel surveys and/or (further) development of a travel demand model.*

Identifying Analysis Needs

When analyzing congested conditions, peak spreading may need to be accounted for in the following conditions:

- Developing travel demand volumes for microsimulation
- Determining peak hour factors for future intersection capacity analysis
- Evaluating compliance with OHP mobility targets and possibly identifying alternate mobility targets

Tool Selection

Ultimately, the tools and methods available to assess peak spreading will vary greatly for each unique application based on a variety of factors, including:

- Purpose of the analysis
  - What questions are being asked and what level of detail and precision is needed? Having a sketch level estimate of congestion duration at one location is much different than producing peak period travel volumes along a corridor for microsimulation analysis.
- Location and context
  - Single road location versus network level demand
  - Commuter travel base that may adjust travel patterns and driver behavior versus recreational trips that may not have information (the knowledge of regular occurrence) to change travel behavior.
- Availability of existing data sources (see Data section)

- Availability of existing modeling tools (travel demand models or other tools)

Exhibit 8-24 provides an overview of peak spreading tools and methods that are covered in additional detail in the following section.

Exhibit 8-24 Overview of Peak Spreading Tools and Methods

Element	Cursory Method (No Model)	Travel Demand Model (OSUM[1]/ JEMnR[2])	Metro Hours of Congestion (HOC)	Metro Peak Spreading	DTA
Area	Areas without models	Urban areas with models (outside Portland)	Portland region	Portland region and other OSUM/ JEMnR models	Portland region
Location Scope	Manually applied on link by link basis	Systematic for model area	Systematic for model area	Systematic for model area	Systematic for model area
Data Needed	Existing traffic counts and profile	Depends on application and post-processing	Depends on application and post-processing	Depends on application and post-processing	Depends on application and post-processing. See Section 8.6.2
Output	Scaled volume profile for a location	With additional processing - regional matrix and systematic link level travel demand by hour	Systematic link level travel demand by hour	Regional hourly demand matrix from 2-7 p.m. that can be assigned	Link by link or O-D pair travel time for time intervals.

[1] Oregon Small Urban Models (OSUM) - Population under 50,000
[2] Joint Estimated Model in R (JEMnR) Population over 50,000 (MPOs)

Data

The following types of data may be useful or necessary to conduct peak spreading analysis:

- Existing travel profiles – existing profiles can provide some insight into how peak spreading currently occurs or could develop given additional traffic growth or transportation network changes.
- Bottleneck data – data that indicate the maximum capacity for bottlenecks such as intersections. Saturation flow studies may be needed to determine actual capacities.
- Travel survey – Driver decision making has the potential to influence peak spreading characteristics. The decisions people make related to how much congestion they are willing to endure, the flexibility of their schedule, and the likelihood to leave earlier or later to avoid congestion can all affect the degree of peak spreading.

- Travel time data – The collection of existing travel time data may be used to calculate a travel time index (TTI) or other measure to better understand existing congestions levels (the degree to which travel time is impacted by existing congestion) and consider when estimating driver sensitivity and the future potential for peak spreading.
- Seasonal count data – In absence of specific data about the share of system users that are aware of recurrent system conditions (such as commuters) and those that are not (such as recreational travelers), a comparison of seasonal count data may provide insight into the portion of travelers that are seasonal users. These data can be used to inform assumptions about whether trips would occur at other periods in the presence of congestion. (See Section 8.7.3).

8.6.3 Peak Spreading Application and Procedures

The following sections provide an overview of tools and methods available to analyze peak spreading. Each tool is location-based and therefore options and methods may be limited. In all cases, it is appropriate to coordinate with TPAU or Region 1 Traffic staff to ensure that the method and application is appropriate based on the analysis requirements. In some cases existing tools and data may limit the degree and certainty of peak spreading analysis.

Areas without Travel Demand Models (Cursory Method)

> *The following section provides an overview of a cursory method to estimate peak spreading in the absence of a travel demand model. While this method can provide useful estimation on peak spreading potential, locations that are projected to be congested to the degree that trip generation, distribution, or route choice are affected may require a travel demand model to better assess this impacts.*

At a cursory level, peak spreading can be assessed for locations that do not have a travel demand model. The application may vary based on the specific location, context or purpose of the analysis (such as short-term analysis or long-range planning needs), and availability of data. However, the general process would be the same. While additional processing and adjustments may be needed and applied, the following method is intended to be applied at a cursory level as an informative approximation of peak spreading.

To manually assess peak spreading, three elements are needed to first develop the un-spread profile, including:

- **Reference traffic volume at location to be analyzed** – This may be an existing traffic count or a projected future traffic volume, typically for a peak hour. This value is needed to determine how to appropriately scale the traffic profile.
- **Traffic profile at a generally representative location** – This may be data from an ATR or data collected from a multi-hour (typically 16-hour or daily) traffic count. The location would optimally be at the same location that is studied for the

effects of peak spreading. However, it may be determined that other locations may be representative (or may be all that is available) and may be sufficient for analysis. Other representative locations would typically be along the same corridor either upstream or downstream of the analysis location. Depending on the use of the cursory analysis, other locations may be considered.

- **Relative comparison (or scaling factor) to adjust ("fit") the traffic volume to the representative location on the profile** – A factor to convert the traffic profile to the profile for the analysis condition is needed. This factor is derived from the following method and will generally vary by location:
    - **Reference volume / Profile volume during period = Profile Factor** For a like time period (such as 5-6 p.m.) (Exhibit 8-25):
        - **For same location -** This factor may be equal or near 1.0 depending on when the profile data and reference data were collected. However other values may result from impacts such as seasonal factors or annual growth.
        - **For different location -** This factor may be more or less than 1.0 depending on where the data were collected and the relative difference between the two locations (e.g., the profile data may be located upstream of the study location in an area that generally has higher traffic volumes). Like data collected from the same location, variability also may result from impacts such as seasonal factors or annual growth.

Exhibit 8-25 Profile Factor Calculation

$$\textbf{Profile Factor} = \textbf{Volume}_{\textbf{(Reference)}} / \textbf{Volume}_{\textbf{(Profile)}}$$

Profile Factor: Scalar factor that will be applied to each hour of the existing profile to achieve the demand profile, which is representative of another location or another analysis period (or year)
Volume $_{\textbf{(Reference)}}$: Volume that represents the analysis volume (peak count or post-processed) for a given time reference time period. This may be the 30HV traffic volume
Volume $_{\textbf{(Profile)}}$: Volume that is indicated in the daily profile during the same reference time period as the Volume $_{\text{(Reference)}}$.

In addition, a general assumption about spreading behavior is needed to determine how the excess demand will be spread:

- **Capacity or maximum traffic flow that can be served –** At the location being analyzed, determine the maximum traffic flow. This may be based on an HCM intersection or other types of capacity analysis.
- **Seasonal data/user system familiarity, or assumptions related to the propensity for drivers to shift earlier, later, or not at all –** Roadway context,

location, and fluctuation in seasonal demands have an influence on peak spreading. The decisions made by a traveler (destination, route choice, and time of departure) have the potential to greatly influence the observed peak spreading trends. The outcomes of these decisions can vary greatly based on the characteristics of the travelers, particularly with respect to how familiar the traveler is with the system condition and their level of flexibility. Commuters or other drivers that know the system conditions may choose to leave earlier or later, or may select a different route, based on their expectation of the system condition. This could include unfamiliar drivers if they have access to traveler information on congested conditions. Thus, they may tend to make peaking spread both earlier and later. However, trips made by users that are not familiar with the system (such as regional/recreational trips) may not have the ability to leave at a different time (being committed to a longer regional or interstate trip) or may not be aware of the local conditions before committing to a route. These users would tend to cause peak spreading to occur with a bias towards later. Therefore, the types of drivers on the system and the mix of seasonal and daily users can have an influence on how peak spreading occurs. Related discussion about data is provided in Section 8.7.2. In the absence of other data, the following spreading trends could be applied based on the traffic user:

- Commuters – Assume that these users that are familiar with the reoccurring system conditions would be evenly likely to change their daily behavior to leave before and after the peak period - half of the travelers would leave before the peak and the remaining half would leave after the peak.
- Recreational Users (Portion derived from seasonal data) – Assume that these users, which are not familiar with the reoccurring system conditions, would not spread to other periods (i.e., these users would not leave before or after the peak period in order to reduce their overall travel time).

To manually apply the cursory method, the following two steps are needed:

1) Determine the projected (un-spread) traffic profile (each hour) of the profile
2) Determine the method used to develop the adjusted (spread) traffic profile by the following method::
    a. No shifting - Trips leave at original times, but take longer to complete due to congestion. (Trips over capacity will be shifted to later period of arrival)

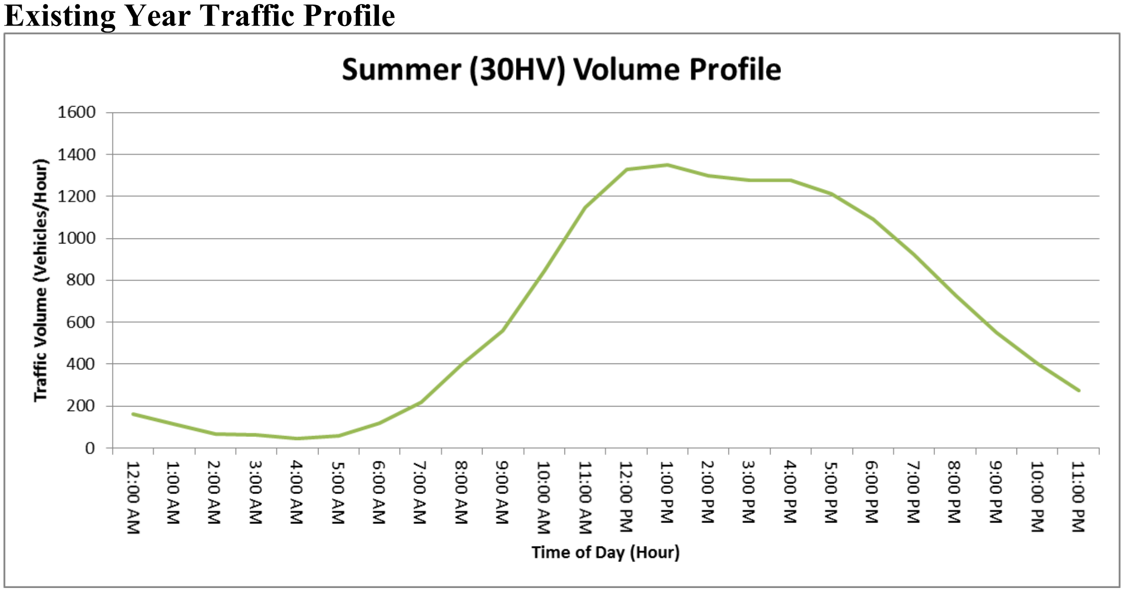
b. Shifting – A share of commuter or other users may shift their trip-making to an earlier and/or later period. (Determine portion to shift)
    i. Identify the portion of trips that will be shifted earlier or later based on the familiarity with the system.
    ii. Based on the split of excess demand that will be shifted earlier and later than the peak, identify when this period occurs. This will serve as the "divide" where excess demand is shifted before or after the peak.

Example 8-1 Cursory Method for Estimating Peak Spreading (To Determine Duration of Congestion)

In this example, the Cursory Method is applied to determine the duration of "congestion" at the US 101/ D River intersection in Lincoln City. This example assesses the southbound direction in the peak summer month (August). The duration of congestion, accounting for peak spreading, is estimated using the following steps:

- **Step 1: Determine the base year volume profile.** An Automatic Traffic Recorder (ATR) exists near the study intersection (D River Wayside ATR) and used to determine the base year volume profile. To determine the summer volume profile, each hourly volume is averaged for the entire month of August. The resulting profile is shown below.

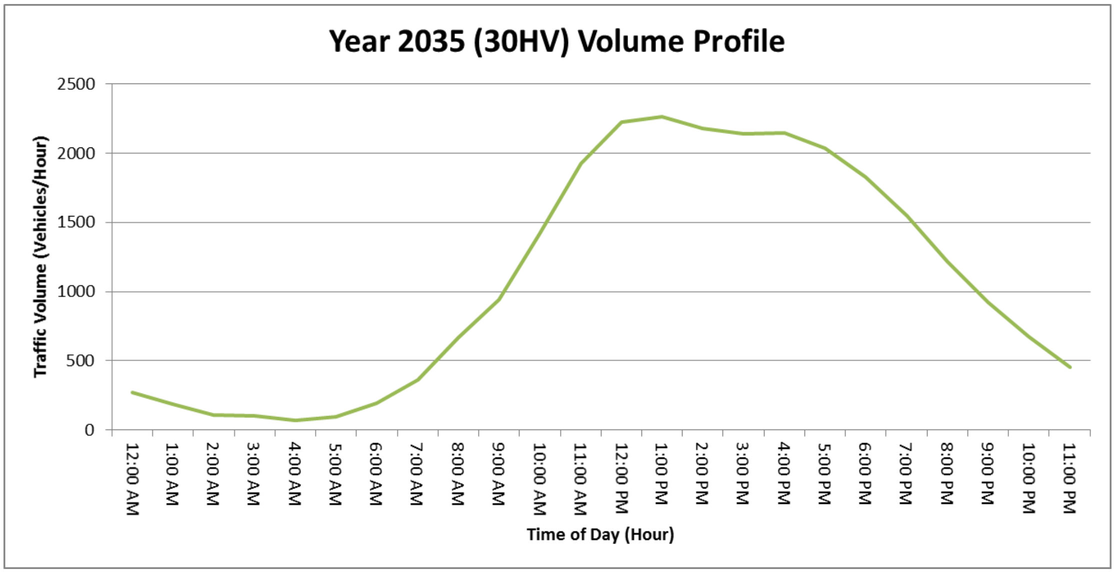
Existing Year Traffic Profile



- **Step 2: Factor the volume profile to the year 2035 p.m. peak hour volumes.** Through the forecasting process, the resulting year 2035 p.m. peak hour volume for the southbound approach is 2,145 vehicles/hour; the peak hour is 4 p.m. The corresponding base year volume at 4 p.m. (determined in Step 1) is 1,279 vehicles/hour. The resulting factor is 1.68 (i.e., 2145/1279). To determine the

2035 volume profile, each hour of the base year volume profile is multiplied by 1.68. The resulting year 2035 volume profile is shown below.

Factored Future Year Unconstrained Demand Profile



- **Step 3: Determine capacity constraint.** Through HCM analysis (e.g., Synchro HCM report), the southbound mainline approach capacity is 2,091 vehicles/hour. The same value of capacity is assumed for each hour of the 24-hour volume profile.

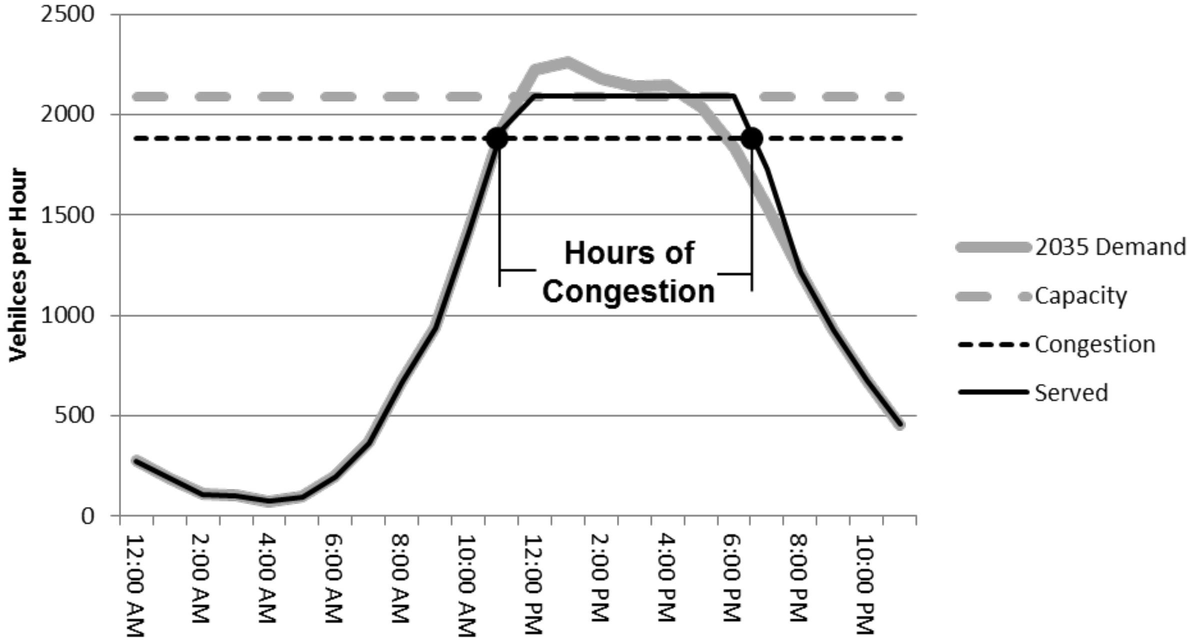
- **Step 4: Apply Peak Spreading by Shifting Demand to Determine the Volume Served.** First, for this analysis, it was assumed that due to the high amount of recreational traffic during the seasonal peak that no trips would shift before the peak. Therefore, all peak spreading would occur by shifting to a later period. This exercise included comparing each projected (unconstrained) hourly demand to the capacity. When an hourly volume exceeds capacity, the difference is added to the demand of the next hour. After shifting demand, demand is capped at capacity (2,091 vehicles/hour in this example). The following table shows the original demand projected for each hour as well as the resulting shifted capacity. Time periods where the ultimate volume is different than the original demand are shaded.

Shifted Volume Constrained by Capacity

Time	Demand	Capacity	Volume
12:00 AM	275	2091	275
1:00 AM	189	2091	189
2:00 AM	110	2091	110
3:00 AM	103	2091	103
4:00 AM	73	2091	73
5:00 AM	95	2091	95
6:00 AM	197	2091	197
7:00 AM	365	2091	365
8:00 AM	671	2091	671
9:00 AM	940	2091	940
10:00 AM	1416	2091	1416
11:00 AM	1927	2091	1927
12:00 PM	2226	2091	2091
1:00 PM	2263	2091	2091
2:00 PM	2178	2091	2091
3:00 PM	2140	2091	2091
4:00 PM	2145	2091	2091
5:00 PM	2036	2091	2091
6:00 PM	1831	2091	2091
7:00 PM	1549	2091	1731
8:00 PM	1219	2091	1219
9:00 PM	925	2091	925
10:00 PM	676	2091	676
11:00 PM	457	2091	457

- **Step 5: Determine "congestion."** Congestion can be defined many ways, but in this example, congestion is assumed as volume/capacity (v/c) of 0.90 or higher. To determine the equivalent volume at which the approach becomes congested, the v/c ratio is multiplied by capacity: 0.90*2,091 = 1,882 vehicles/hour.
- **Step 6: Determine hours of congestion.** For 8 hours of the day (11 a.m. to 7 p.m.) the volume of the southbound approach exceeds 1,882 vehicles/hour. This information is summarized in the figure below.

Cursory Method for Estimating Peak Spreading



Areas with Travel Demand Models (excluding the Portland Metropolitan Area)

Travel demand models have been developed for a number of areas around the state.[13] These models generally fit into one of two categories, each with distinctions that may provide ability to estimate peak spreading.

- Oregon Small Urban Models (OSUM) - Population under 50,000
- Joint Estimated Model in R (JEMnR) Population over 50,000 (MPOs)[14]

The following sections provide an overview of peak spreading available with each type of model. These methods could be applied systematically over the entire model area. Additional post-processing and refinements that incorporate more real-world data (such as spot location use of actual traffic profile data) and/or use of subarea modeling methods could provide information for peak spreading and traffic profiles on other network locations.

In addition, there is the potential that Metro’s methods for pre-processing the trip table (shifting the demand of O-D pairs to other adjacent time periods based on a TTI ratio), described later in this section, could be applied to these other models with additional effort and coordination. In these urban areas, the modeler would need to identify whether there is systematic peak spreading, or if spreading is limited to a specific corridor through investigation of the variability of the TTI. This endeavor (and travel time data collection) would require further discussion and scoping with TPAU and Region traffic to determine the extent of the analysis based on the unique characteristics of the urban area. Application of this method would require development of a TTI ratio based on a perceived accepted maximum level of congestion (and travel delay) that currently occurs.

The following sections provide a general overview of the model tools and abilities. Coordination with TPAU modeling staff is critical to ensure appropriate use of the individual modeling tools based on issues related to model age, data sources, and calibration.

OSUM

The OSUM models can produce hourly trip matrices based on static input factors that can be assigned for each hour of the day. These trip matrices provide the ability to determine raw, model level demand profiles for links in the transportation model network. Additional post processing of these demands using real-world traffic data (depending on analysis need) has the potential to readily provide information about peak spreading. A key limitation for this method is that reliability would be a question for time periods that haven't been validated (e.g., 10 p.m. to 11 p.m.). Metro’s method of pre-processing the

[13] For more information: https://www.oregon.gov/ODOT/Planning/Pages/Technical-Tools.aspx

[14] The Eugene-Springfield travel demand model is not a JEMnR model, but it shares many of the same features as it relates to modeling time-of-day and (the lack of) sensitivity to peak spreading.

trip table (shifting individual demand of OD pairs to adjacent time periods) may be an option, as noted in the previous section.

JEMnR (MPO)

The JEMnR model by default does not produce hourly matrices. Instead, the model is typically set up for the daily, a.m., and p.m. peak periods. It may however be set up for different time periods if desired. To develop matrices for other time periods, static input factors would be needed to split the daily person trip matrices by time-of-day and direction. Separate factors are used for each trip purpose. Once individual matrices were developed, the tool could be applied in a similar method as the OSUM models – with assignment of individual time periods and additional post-processing (using real-world traffic data), as needed, based on specific application needs. Metro's method of pre-processing the trip table (shifting individual demand of O-D pairs to adjacent time periods) may be an option, as noted in the previous section.

Portland Metropolitan Region

There are two recent tools that have been developed to analyze peak spreading in the Portland metropolitan region. A summary of each of these tools is presented in the following section, but additional documentation for each tool may be available[15].

Hours of Congestion (HOC) Tool [Interim Method]

ODOT Region 1 developed this tool as an interim method to assess the duration of congestion in the Portland region. The following excerpts summarize the purpose and methods used to develop the tool. Additional documentation is available from ODOT.

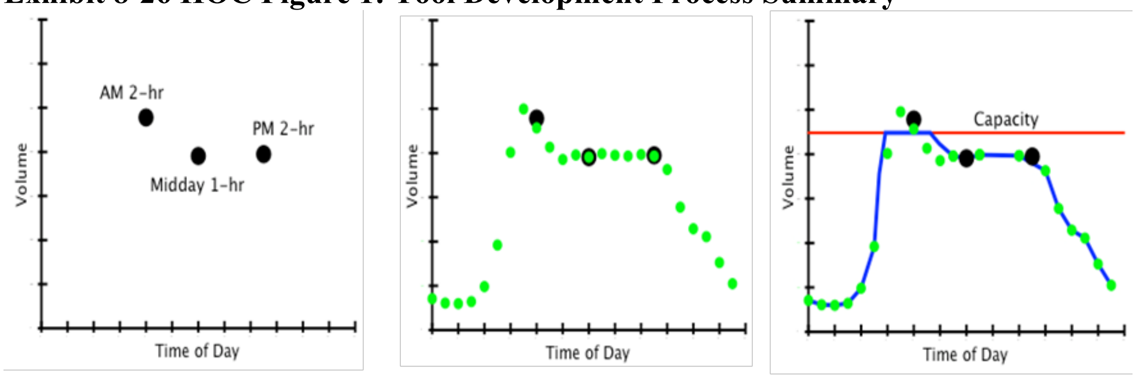
The tool is in the form of a spreadsheet that imports and processes data from the travel demand model to calculate hourly demand for every link in the model. The following excerpts from the documentation provide an overview of the procedures used by the tool:

> "The purpose of this study was to develop a method to address peak hour spreading given the limitations of a traditional four-step travel demand model. This was accomplished by using a link-based approach that post-processes travel demand model outputs to generate peak-spreading measures at the link level. The link based approach is viewed as an interim method for addressing hours of congestion where a more robust method would adjust the travel demand model trip tables. However, the link based approach is viewed as a reasonable estimate that will allow the congested hours on freeways and arterial roadways in the Portland metropolitan area to be approximated for purposes of policy discussions and project prioritization.
>
> Hours of Congestion Application

[15] For additional information, contact ODOT Region 1 Traffic Unit for the Hours of Congestion study or Metro's Transportation Research and Modeling Services for information related to regional model peak spreading.

To capture peak spreading on a corridor with a link based approach, traffic volumes produced from a travel demand model need to be post-processed to reveal an hourly volume profile. For this study, an application was developed that accomplishes this process in three basic steps, as shown in Figure 1 [Exhibit 8-26]. The first step involves gathering Metro's model data for the AM, midday, and PM peak periods. Next, the model data are used to estimate Average Daily Traffic (ADT) and hourly traffic volumes for the entire 24-hour period. Finally, the hourly volumes are compared to the link capacity and, where volumes exceed capacity, peak spreading is applied to spread the volume into shoulder hours.

Exhibit 8-26 HOC Figure 1: Tool Development Process Summary



Step 1: Metro Model Data   Step 2: Hourly Estimation   Step 3: Apply Peak Spreading

Methods
To determine the congested hours on roadways in the Portland metropolitan area using the link based approach described above, a data mining effort was undertaken to build the Hours of Congestion application based on observed traffic characteristics in the Portland area. The following sections describe the four major components of the data mining.

Data Collection
Data for ODOT facilities in the Portland area were collected for the most recent four years from PORTAL, ODOT Automated Traffic Recorders (ATRs), available 24-hour tube counts, and TriMet GPS bus travel time records. Reality checks and data quality screenings were performed on the PORTAL, ATR and tube-count data to remove data from outside the area of interest, incomplete or suspect data, and/or data that did not meet data quality diagnostics. For an example, of the original 665 PORTAL detector locations, 455 remained in the database after the data screening and quality checks were performed.

Volume Profile Analysis
Metro's regional travel demand model provides forecasts for a 2-hour AM period, a 1-hour midday period, and a 2-hour PM period. Daily traffic volumes are not directly forecasted. To estimate a 24-hour vehicle volume profile, regression analysis was conducted to first develop estimation factors for the total daily volume (ADT). With the predicted daily volumes and the peak period volume

forecasts, a 24-hour volume curve was estimated to represent an "unconstrained"[16] forecast for each link.

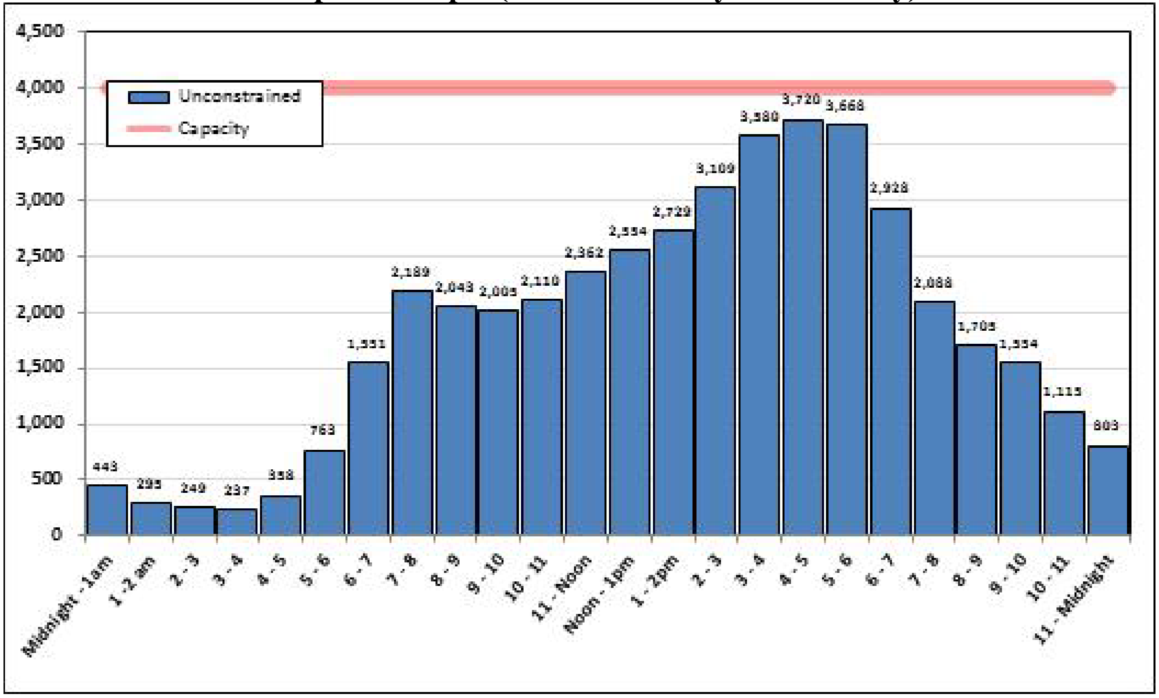
Peak Spreading Analysis
To develop an application that can spread excess volumes in peak periods, existing peak spreading in the Portland area was investigated in the PORTAL traffic volume database. Traffic volume data were examined to essentially identify congested vs. uncongested traffic flow days at locations where peak spreading was found to occur. At these locations, AM and PM peak periods were examined to determine how spreading occurs (i.e., which direction traffic shifts relative to the peak hour). These volume shifting factors were then used in the Hours of Congestion application to adjust 24-hour profiles when demand was forecasted to be above capacity. This shifting of traffic volume is an important distinction, as total daily traffic volume is conserved whereas some methods used by other agencies for similar efforts "trim" peak period volumes and do not maintain ADT.

Congestion Threshold Analysis
Review of Hours of Congestion analysis compared to speed data in the PORTAL system found that the congestion threshold (where vehicle speeds are significantly reduced from free-flow speed) may be well below the ODOT mobility standard, which is essentially where volume reaches capacity. An evaluation of speed congestion information compared to link v/c estimates was conducted, which found that a v/c ratio of 0.80 (instead of 1.00) would be a reasonable threshold for congestion. Therefore, the Hours of Congestion application was built to track both how many hours exceed a v/c ratio of 0.80 and how many hours reach a v/c ratio of 1.0."

The output of the Hours of Congestion tool is link-level traffic volumes for each hour of the day as shown in Exhibit 8-27. This example demonstrates a case where the link demand during the evening peak approaches the link capacity (4,000 vph) shown by the red line but does not reach the capacity. If the demand had exceeded the capacity, the tool would process the demand to the shoulder periods.

[16] It should be noted that while Metro's model does not provide temporal spreading of the traffic volumes in the peak periods when congestion occurs, it does spatially spread volumes to parallel corridors when possible to balance travel times in the system.

Exhibit 8-27 HOC Output Example (Link Volume by Hour of Day)



<u>Metro Travel Demand Model with Peak Spreading</u>

Metro has developed a methodology for pre-processing raw demand volumes from the static travel demand model to feed into dynamic traffic assignment (DTA). The output of the tool is an adjusted origin-destination matrix for each hour between 2:00 p.m. to 7:00 p.m. The following text is an excerpt for Metro's tool documentation, which is distributed with other travel demand model assignment tools[17]:

> "Metro's peak spreading algorithm is a method for measuring congestion through a travel time index (TTI), which is simply *travel time / free flow travel time*. For example, if the free flow travel time between an O-D pair is 10 minutes and the peak period travel time is 15 minutes, then the O-D pair has a TTI of 1.5 (15 minutes / 10 minutes).
>
> A proxy 'threshold' for congestion is based on the highest TTI corridor in our region within Existing Year (2010) regional model--I-5 NB from 5pm to 6pm. It's a corridor that currently experiences a good deal of peak spreading, which is represented in the relatively long congested peak (3pm – 6:30pm or later on most work nights). The TTI for this corridor is 1.6, and establishes a threshold for comparing all other congestion against. It is assumed that travelers are willing to accept congestion up to a TTI of 1.6 before they begin peak spreading.[18]
>
> The TTI threshold is used to adjust future year demand for each hour in the PM peak period. Since congestion is widely prevalent in the future, the peak period is

[17] Contact Metro's Transportation Research and Modeling Services for additional information.
[18] Application of this methodology to areas outside of the Portland metropolitan region would require assumptions about an appropriate TTI to use.

measured from 3pm-6pm. Hour-long shoulder periods are also produced, resulting in a full 5 hours of PM peak period trip tables (2pm-7pm).

To begin the peak spreading algorithm, a 5pm-6pm (peak of the peak) hourly static assignment is run, and the TTI for each O-D pair is then calculated. For each O-D pair in which the TTI exceeds the TTI threshold (1.6), trips are removed based on how much the TTI exceeds the threshold. For example, if an O-D pair has a 2.0 TTI, and the TTI threshold is 1.6, the difference is 0.4. This number is 25% above the TTI threshold (0.4 / 1.6), therefore 25% of the trips from this O-D pair are removed from the 5pm-6pm trip tables (SOV and HOV only) [Note that latent demand for other O-D pairs may potentially be reassigned to links belonging to paths and O-D pairs that were adjusted][19].

The trips that are removed from the 5pm-6pm hour are added to the 4pm-5pm and 6pm-7pm trip tables. For each of these hours, the above process is repeated: Produce hourly static assignments with the new trip tables, calculate the O-D TTIs, and remove excess trips based on the TTI-to-threshold ratio. The excess trips get added to the next shoulder hour (e.g., 3pm-4pm for the 4pm-5pm hour). The process is continued on through every hour of the 5-hour PM peak period.

There are a few additional rules that are observed during the process, such as never removing more than 50% of the trips in an O-D pair for the 5pm-6pm hour and never reducing the O-D trips in subsequent shoulder hours to values less than the final 5pm-6pm peak spread tables.

The final result is a set of hourly trip tables encompassing the 2pm-7pm time period, with O-D pairs reflecting different degrees of peak spreading depending on the initial amount of 'congestion' (i.e., comparison against the TTI threshold) measured during each hour."

Additional frequently asked questions for Metro's peak spreading methodology are available in Appendix 8A.

8.6.4 Key Considerations for Peak Spreading Application

Policy and Performance Measures

While accounting for peak spreading generally improves the reasonableness of traffic volumes, it may not be compatible with some performance measures and policies that are based on those performance measures. For example, mobility targets in the Portland region are based on V/C ratios, which for some locations (such as a Town Center) exceed

[19] The spreading is applied to the O-D matrix itself and not the assigned link volume. Therefore, after the O-D matrix has been adjusted it will need to be reassigned. The reassignment may result in different paths than the original assignment and (while the demand for the original O-D pairs using a link will be reduced) other latent demand from other O-D pairs may shift to the link that was originally over capacity. Therefore, reducing all O-D pairs assigned to a link by 25% may not ultimately result in a 25% demand reduction.

1.0. These policies are based on traditional tools that do not fully account for limitations related to peak spreading and capacity constraints within congested systems. Peak spreading methods have the potential to greatly improve the reasonableness of reported measures; however, it is important to understand the limitations and differences between policy measures and the tools that are used to analyze them.

Existing and Future Year Methods
Projecting peak spreading for future year conditions adds another aspect of uncertainty. Given limited resources and data, one approach may be to scale an existing demand profile to a forecasted future magnitude. However, assuming that existing year demand profiles (shape, not magnitude) are similar in the future may be affected by the following:

- Location of future growth areas and travel patterns on the facility
- Traveler decision making based on future changes to society and technology
- Future conditions on other areas of the travel network, including upstream/downstream bottlenecks and adjacent routes

Appendix 8A – Peak Spreading Procedure

Appendix 8B – PTV Vision Software Network Setup Guide