# Contents

# List of Figures

# List of Tables

# 1.0 Executive Summary

The purpose of the Alternative Traffic Assignment Methods Study was to investigate alternative traffic assignment methods that can be used for various applications in ODOT TPAU's transport models and those of its OMSC partner agencies. The investigation was limited to traffic assignment only, and did not include transit assignment or other model components.

The study consisted of the following main steps:

- Step 1 – Identify Alternative Assignment Methods
- Step 2 – Evaluate Assignment Methods
- Step 3 – Investigate Assignment-Related Topics

Input was obtained from the study working group on the assignment method objectives, the alternative methods to be evaluated and the evaluation criteria to be used, and assignment-related topics. The group consisted of staff from ODOT TPAU, ODOT Region 1, Oregon Metro, the Mid-Willamette Valley COG, and the Bend MPO.

## *1.1 Assignment Methods*

The primary components of traffic assignment models are a route choice model and a network flow model. A route choice model determines the trip-maker's path selection between origin and destination zones. These models can be classified according to the method of route choice (deterministic or stochastic), the treatment of time (static or dynamic), and the level of vehicle aggregation (microscopic, macroscopic, and mesoscopic). Network flow models define how links and nodes perform under congested conditions. Static network flow models assume that route flows propagate instantaneously through the network. Dynamic flow models move traffic through the network in time slices or distinctive time periods. Microscopic flow models consider vehicles separately and simulate specific characteristics of driver behavior. Mesoscopic flow models are hybrids of macroscopic and microscopic models.

Several of the more frequently found combinations of these model dimensions are:

- Static, macroscopic
- Dynamic, macroscopic
- Dynamic, microscopic or mesoscopic

All of these are equilibrium assignment methods in which demand is distributed according to Wardrop's first principle which states, “Every road user selects his route in such a way that the travel time on all alternative routes is the same, and that switching to a different route would increase personal travel time."

## *1.2 Evaluation of Assignment Methods*

The assignment method objectives defined by the study working group describe the desired properties and capabilities of the assignment methods as well as the types of applications the methods are to be used for. Evaluation criteria were defined that would allow the objectives to be reflected in the comparison of the alternative methods. The criteria were applied to the three assignment methods listed above:

- Method 1 – Static, macroscopic assignment
- Method 2 – Dynamic, macroscopic assignment
- Method 3 – Dynamic, microscopic/mesoscopic assignment

Ratings of “low”, “medium”, or “high” were assigned for each criterion.

The evaluation was not intended to rank the methods to identify a “best” method, but rather to to establish a general framework for considering the advantages and disadvantages of the methods. If there is interest in determining which method may be the most appropriate for a particular urban area, travel demand forecasting model, or model application, the methods can be quantitatively ranked by using a combination of weights and numeric scores for the criteria to develop a weighted total score for each method. A summary of the evaluation results is shown below.

**Assignment Method Rating Summary**

| Rating | Method 1<br>Static, Macro | Method 2<br>Dynamic, Macro | Method 3<br>Dynamic, Micro/Meso |
|---|---|---|---|
| Low | 28<br>60.9% | 10<br>21.7% | 10<br>21.7% |
| Medium | 9<br>19.6% | 33<br>71.7% | 15<br>32.6% |
| High | 9<br>19.6% | 3<br>6.5% | 21<br>45.7% |
| Total No. of Criteria | 46<br>(100%) | 46<br>(100%) | 46<br>(100%) |

Reading across the diagonal of the table, it can be seen that overall, Method 1 received the highest number of "low" ratings, Method 2 had the highest number of "medium" ratings, and Method 3 received the largest number of "high" ratings. The main reasons that Methods 2 and 3 rated relatively well compared to Method 1 are:

- Better accuracy of link traffic flows;
- Better representation of travel times/speeds;
- More realistic estimation of intersection delay;
- Higher levels of temporal resolution;
- More realistic representation of traffic operations characteristics;
- Ability to represent peak spreading;
- More accurate estimation of the effects of capacity improvements;
- Ability to reflect the effects of small-scale improvements, such as TSMO-type improvements; and
- Better ability to support project selection.

These advantages are primarily related to the more realistic representation of network response to congestion (in terms of delay), the higher level of temporal resolution and, in the case of Method 3, the higher network resolution. The higher overall rating for Method 3 compared Method 2 is also largely accounted for by the greater advantages of Method 3 in these areas.

There are several criteria, however, for which Methods 2 and 3 were rated lower than Method 1. This is related to the following disadvantages of Methods 2 and 3:

- Larger implementation and maintenance time requirements;
- Larger data collection time requirement;
- Less intuitive understanding of the assignment method processes;
- Greater difficulty in interpreting the cause-effect relationships in the assignment outputs;
- Higher level of staff expertise for application and maintenance; and
- Lower degree of assignment convergence.

All of these disadvantages, except the last one, are due to the greater complexity of Methods 2 and 3. The lower degree of assignment convergence is related to the constrained physical capacities used in the these methods compared to the continuous VDFs used in Method 1, which result in the spillover of traffic to adjacent time periods if capacity is exceeded. Also with Methods 2 and 3, fractional vehicles are used in the assignment which reduces the level of convergence possible compared to Method 1, which uses whole vehicles.

## *1.3 Assignment-Related Topics*

Specific topics related to the implementation and use of the assignment methods were identified for investigation by the study working group. The focus of the investigation was on static assignment topics because this will likely be the main method used by ODOT and its partner agencies within the near-term. Brief highlights for each topic are summarized below.

### *Static, Macroscopic Assignment Topics*

<u>Alternative Forms of Volume Delay Functions (VDFs)</u> - The most commonly used VDFs are the Bureau of Public Roads (BPR) function, Davidson's delay model, the Akcelik function, and the conical delay model.

Incorporation of Node-Based Delay in VDFs – Potential advantages of VDFs that include an intersection delay component are more accurate estimation of link traffic flows and travel times/speeds, more accurate estimation of intersection delay, and better representation of the effects of capacity improvements.

Calibration of VDFs – In a study conducted by Florida A&M University - Florida State University, traffic volume and speed data from the Florida Department of Transportation's traffic monitoring stations and statewide transportation engineering warehouse were used to calibrate four types of VDFs across four facility types and three area types.

Representation of Truck Volumes in VDFs - The travel time functions of trucks and cars are not identical, and furthermore depend on not only traffic volume, but traffic composition as well. Thus, there is a need for travel time functions that consider both the volume and proportion of trucks in the traffic stream.

Representation of Network Capacity - The treatment of network capacity varies according to assignment method used. Capacities can be more realistically represented with the dynamic, macroscopic method, providing more accurate and detailed information about capacity improvements compared to the static, macroscopic method. Capacities are an output, not an input, of dynamic, microscopic/mesoscopic models.

Generalized Cost Assignment

Generalized cost assignment attempts to more realistically represent the traveler's path decision-making process by including other factors in addition to travel time. Since the generalized cost for a specific link must be expressed as a single value, all of the factors not measured in monetary units must be converted to a constant dollar amount.

## *Dynamic, Macroscopic Assignment Topics*

### Calibration of Dynamic Traffic Assignment (DTA) Models

DTA model results are influenced primarily by the model network, input demand, and the type of queuing model used. Once it has been confirmed that the input demand is reasonable, a multi-step process is followed to calibrate the model to produce estimates of network operating characteristics such as link flows and queue lengths.

### Level of Network Disaggregation

DTA model networks are generally more data-intensive than static model networks. For example, DTA requires information on the number of lanes on each link, the presence of acceleration–deceleration lanes and turn bays, and lane connectivity.

### Level of Time Resolution

One of the main advantages of DTA models compared to static models is that the higher level of temporal resolution allows a more realistic representation of network response to congestion, in terms of delay. Therefore, relatively short time periods for assignment are used, typically ranging from five to 15 minutes.

## *Dynamic, Microscopic/Mesoscopic Assignment Topics*

### Calibration of Microsimulation Models

Calibration of a microsimulation model is the adjustment of parameters to improve the model's ability to reproduce local driver behavior and traffic performance characteristics. Every microsimulation software program comes with a set of user-adjustable parameters for calibrating the model to local conditions.

### Size of the Modeling Problem

The additional cost of developing microsimulation models tends to limit their use to a subregional level. In a study of best practices in microsimulation, it was estimated that mesoscopic simulation models tend to cost an order of magnitude (i.e., ten times) more to develop than macroscopic models.[1] On a similar scale, microscopic simulation models tend to cost an additional order of magnitude more to develop than mesoscopic models.

## *General Assignment Topics*

Development of Multi-Resolution Modeling Networks

Multi-resolution modeling (MRM) is the integration of macroscopic, mesoscopic, and microscopic models for the purpose of analyzing transportation projects at different levels of detail by enabling data to be shared across modeling platforms. The objectives in the development of networks at each modeling scale are maintaining consistency between the networks, accuracy, and minimization of effort.

Consideration of Travel Time Reliability in Traffic Assignment

Typically in the traffic assignment process, it is assumed that travelers only consider average travel time when making route choice decisions. However, many empirical studies have shown that travelers also take travel time reliability into consideration when making trip decisions. As a result, the identified optimal paths from traditional models may fail to represent most travelers' risk averse behaviors.

Cost Effectiveness of Dynamic vs. Static Assignment Methods

If congestion can be expected to be low then there is little added value in a detailed accounting of it in the model system. Given that without congestion there is only limited physical connection between the network conditions of different time slices, static network assignment may be fully adequate.

[1] Best Practices in the Use of Micro Simulation Models, American Association of State Highway and Transportation Officials (AASHTO), 2010.

Use of Demand Adjustment Procedures

Demand adjustment is a procedure used to update a seed origin-destination matrix using traffic counts. This procedure is most often applied to adjust base year trip matrices to better fit existing conditions, as reflected in the count data.

# 2.0 Introduction

The purpose of the Alternative Traffic Assignment Methods Study was to investigate alternative traffic assignment methods that can be used for various applications in ODOT TPAU's transport models and those of its OMSC partner agencies. The investigation was limited to traffic assignment only, and did not include transit assignment or other model components.

The study consisted of the following main steps:

- Step 1 – Identify Alternative Assignment Methods
- Step 2 – Evaluate Assignment Methods
- Step 3 – Investigate Assignment-Related Topics

At an initial meeting of the study working group, a list of assignment method objectives was identified. The working group consisted of staff from ODOT TPAU, ODOT Region 1, Oregon Metro, the Mid-Willamette Valley COG, and the Bend MPO. The objectives were used as a guide for the identification of alternative assignment methods, based on a literature review of currently-used methods.

The alternative methods were reviewed at a second working group meeting to determine the methods to be evaluated in Step 2, as well as a proposed set of evaluation criteria reflecting the assignment method objectives. Suggested assignment-related topics to be investigated in Step 3 were also reviewed at the meeting.

In Step 2 of the study, the assignment methods were evaluated using the criteria defined in Step 1. The evaluation was done by assigning ratings of "low", "medium", or "high" to the alternatives for each of the evaluation criteria.

Specific topics related to the implementation of the assignment methods were investigated in Step 3 of the study.

This report is organized according to the following sections:

- Section 1: Assignment Methods – General discussion of assignment model components and the categories of assignment methods.
- Section 2: Evaluation of Assignment Methods – Description of the assignment method objectives and evaluation criteria, evaluation procedure, and evaluation results.
- Section 3: Assignment-Related Topics – General discussion of topics related to implementation of the assignment methods.

# 3.0 Assignment Methods

## *3.1 Assignment Model Components*

The primary components of traffic assignment models are a route choice model and a network flow model.

### *Route Choice Models*

A route choice model determines the trip-maker's path selection between origin and destination zones. The choice of a route is based on the route's properties, typically cost in the form of travel time.

Route choice models can be classified according to the method of route choice, the treatment of time, and the level of vehicle aggregation. Deterministic route choice models assume that the trip-maker selects a path that has the minimum cost as defined in the model, i.e., no route with higher than the minimum cost is used. Stochastic route choice models are discrete choice models that specify the probability that a specific route will be chosen. This approach accounts for unobserved factors related to route choice, such as travelers' subjective perceptions about a preferred route. Often this is accomplished through the use of random utility theory, and results in the choice of routes that can have higher than minimum cost in the model.

Static and dynamic route choice models differ in the way they treat time. Static route choice models do not account for time, neither when evaluating route costs nor when predicting route choice. Travel times are derived from the instantaneous network conditions at the time of starting a trip. Dynamic route choice models account for the time dependence of travel times and predict, accordingly, time-dependent route choice. The experienced network conditions depend on when a vehicle has reached a particular point in the network.

The level of vehicle aggregation in route choice models varies between microscopic, macroscopic, and mesoscopic. Microscopic route choice models define discrete route choices by individual vehicle. Macroscopic models distribute vehicle flows across alternative routes.

Typically, this is done deterministically, with flows concentrated on routes of minimum cost. The level of aggregation in mesoscopic models is between that of microscopic and macroscopic, in which vehicles are grouped into packets, for which a single common route is selected.

### *Network Flow Models*

Network flow models define how links and nodes perform under congested conditions. Static network flow models assume that route flows propagate instantaneously through the network and use VDFs to compute travel times. Travel times are considered an explicit function of link flow rather than an implicit result of traffic flow propagation; thus, link flows are not constrained to capacities. In practice, nearly all static flow models are macroscopic and deterministic.

Dynamic flow models are fundamentally different than static flow models in that they move traffic through the network in time slices or distinctive time periods and estimate travel times based on traffic flow theory. Macroscopic flow models use speed-density relationships in the form of a fundamental diagram to model traffic flow. In these models, flow can never exceed capacity, so that queues build up and can spill over between time periods. Simple models assume vertical queues without any physical length, while more complex models reflect horizontal queues. In addition, macroscopic flow models include node models that restrict the flow of traffic to determine the severity and direction of congestion at intersections.

Instead of using fundamental diagrams and macroscopic flow theory, microscopic network flow models consider vehicles separately. These models simulate car-following behavior, gap acceptance, speed adaptation, ramp merging, lane-changing, and overtaking behavior. They require a high level of detail, but are able to represent the behavior of each vehicle.

Mesoscopic flow models are hybrids of macroscopic and microscopic models. They are based on macroscopic traffic flow theory, but propagate individual vehicles or packets of vehicles through the network. The strength of this approach is that it relies on robust macroscopic flow theory, while at the same time retaining information on individual vehicles (e.g., route selection and vehicle class).

## *3.2 Categories of Assignment Methods*

The main criterion for classifying network assignment models is the representation of time. The following categories define the range of assignment models resulting from the combination of different types route choice and network flow models:

- The combination of a static route choice model and a static network flow model results in the typical assignment model used to implement the fourth stage of a traditional four-step model. Nearly all of these models are macroscopic and deterministic.
- The combination of a dynamic route choice model and a dynamic network flow model results in a dynamic traffic assignment (DTA) model. Common subcategories of DTA's consist of combinations of macroscopic route choice/macroscopic network flow models and microscopic route choice/micro or mesoscopic flow models.
- Intermediate approaches exist that simplify the dynamic route choice and dynamic network flow processes by specifying a static assignment for a series of time slices and using simplified dynamic coupling procedures to simulate the carry-over of vehicle queues from one time slice to the next. An example of this approach is the dynamic user equilibrium (DUE) assignment method.

Several of the more frequently found combinations of these model dimensions are:

- Static, macroscopic
- Dynamic, macroscopic
- Dynamic, microscopic or mesoscopic

All of these are equilibrium assignment methods. A second class of methods performs non-equilibrium, stochastic assignment, in which routes are selected probabilistically rather than strictly according to travel time minimization. These methods are not widely used and have several difficulties for use in strategic planning and implementation. Therefore, they were not further investigated as a part of this study.

With all equilibrium assignment methods, demand is distributed according to Wardrop's first principle which states, “Every road user selects his route in such a way that the travel time on all alternative routes is the same, and that switching to a different route would increase personal travel time." The dynamic equilibrium assignment methods extend this idea to include all departure time slices or distinctive time periods considered in the evaluation of the traffic assignment.

The state of equilibrium is achieved through a multi-step iteration process where flows are shifted between alternative set of paths/routes based various mathematical models. Thus, the objective of all equilibrium assignment methods is the same - equilibration of travel times/generalized costs on alternate routes for all origin-destination zone pairs in the network. However, the algorithms applied for this objective may differ.

### *Static, Macroscopic Assignment*

There are three commonly-used static, macroscopic assignment procedures. These are:

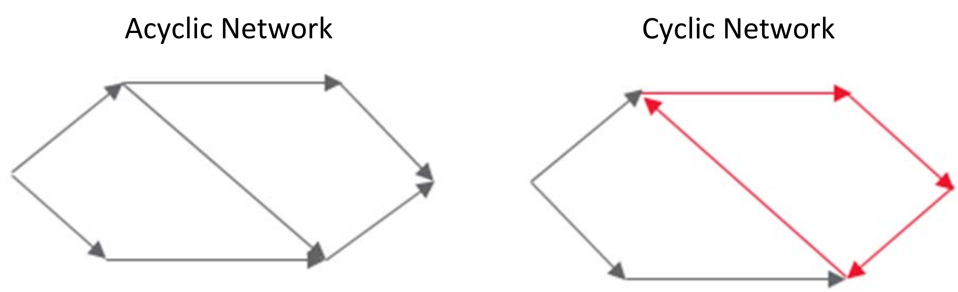
- Link-based
- Path-based
- Bush (origin)-based

With the link-based procedure, an initial all-or-nothing assignment is followed by assignment iterations in which the impedance for several shortest routes between each zone pair are estimated from the impedance associated with the current volume and the impedance from the previous iteration. Route flows are balanced by updating link flows with a method of successive averages. This process continues until the stopping criteria of maximum iterations or convergence is satisfied. This procedure is also referred to as the Frank-Wolfe assignment method.

The path-based procedure starts with an all-or-nothing or incremental assignment, followed by iterative assignments in which shortest paths are searched between each zone pair to augment the existing path set. In the inner loop of each iteration, two or more routes on an O-D pair are brought into a state of equilibrium by shifting vehicles based on the difference in path impedance or generalized cost. The outer loop then checks if there are new routes with lower impedance, based on the current network state. This process continues until the stopping criteria of maximum iterations or convergence measure are satisfied.

In the general framework for the bush-based procedure, flows from one origin are moved using a special structure called a bush. A bush is a subnetwork of the original network rooted at a given origin. It is acyclic, i.e., it does not contain loops or cycles, and has the property of allowing every node to be reached that was reachable in the original network.

**Figure 1 – Acyclic and Cyclic Networks**




Source: PTV Group, Traffic Assignments in Visum, 2017

Each bush is initialized with a shortest path tree rooted at the origin that is created with an all-or-nothing assignment. In subsequent iterations, the bush is modified by traversing the network and adding efficient links and removing unused (zero flow) links. A link without flow is not removed if the connectivity of the bush would be broken, and a new link is only admitted if it does not create a cycle.

### *Dynamic, Macroscopic Assignment*

Dynamic, macroscopic assignment is fundamentally different from static assignment in the following ways:

- Traffic flows are dynamically propagated through the network in different time slices rather than statically on all parts of the network at the same time.

- Queues and spillovers between time periods are explicitly represented.
- Link delays are modeled based on a fundamental diagram rather than VDFs.
- Intersection delays are calculated using a queue dissipation model.
- Intersection and link capacities are based on physical constraints, with volume-to-capacity ratios never exceeding 1.0.

As with static assignment, this assignment approach is iterative, with the number of iterations and convergence gap used as stopping criteria.

### *Dynamic, Microscopic/Mesoscopic Assignment*

Dynamic, microscopic assignment is a simulation-based procedure that accounts for node impedances and allows modeling of the forming and dissolving of queues over time by simulating time-varying network flows. The supply and demand may be varied over time as well. The network is loaded with demand based on a simulation, which means that individual vehicles are simulated and a simple car following model is applied to have the vehicles follow the paths they are assigned. The assignment is an iterative procedure that includes the following steps: 1) route search; 2) redistribution of path flows; and 3) network loading. These steps are repeated until a relative gap or the maximum number of iterations is reached. Microscopic assignment requires a network with intersection geometries and control data defined. The intersection geometry defines the lanes and turns a vehicle uses during the simulation to follow the route it is assigned. Along with the intersection control data, geometry forms the basis for calculating wait times at the intersection and on its upstream links.

Dynamic, mesoscopic assignment is a variation of the microscopic assignment method, in which vehicle groups, rather than individual vehicles, are moved through the network according to aggregate speed/density relationships.

Examples of software packages containing these types of equilibrium assignment methods are shown below. Most of the packages offer multiple assignment methods.

**Table 1 – Equilibrium Assignment Software Packages**

| Software | Static, Macroscopic | Dynamic, Macroscopic | Dynamic | |
|---|---|---|---|---|
| | | | Mesoscopic | Microscopic |
| Aimsun | √ | √ | √ | |
| Cube - Avenue | | | √ | |
| Cube - Voyager | √ | | | |
| Dynameq | | | | √ |
| DynusT | | | √ | |
| Emme | √ | | | |
| TransCAD | √ | √ | | |
| TransModeler | | √ | | √ |
| Visum | √ | √ | √ | |

# 4.0 Evaluation of Assignment Methods

## *4.1 Assignment Method Objectives and Evaluation Criteria*

The assignment method objectives defined by the study working group describe the desired properties and capabilities of the assignment methods as well as the types of applications the methods are to be used for. Evaluation criteria were defined that would allow the objectives to be reflected in the comparison of the alternative methods. These are listed below.

**Table 2 – Assignment Method Objectives and Evaluation Criteria**

| Assignment Method Objective | Evaluation Criteria |
|---|---|
| | |
| **I. Desired Properties and Capabilities** | |
| | |
| **A. General Properties and Capabilities** | |
| | |
| 1. Accurate estimation of link traffic flows | a. Accurate estimation of traffic flows by vehicle class, facility type, and V/C level |
| 2. Reasonable representation of travel times/speeds | a. Reasonable representation of travel times/speeds by vehicle class, facility type, and V/C level<br>b. Reasonable representation of zone-to-zone travel times by vehicle class and time period |
| 3. Reasonable model run times | a. Minimization of run time, assuming a representative network[2] |
| 4. Reasonable level of effort for implementation and calibration | a. Minimization of implementation, assuming a representative network<br>b. Minimization of calibration time, assuming a representative network |
| 5. Reasonable input data requirements | a. All data readily available from existing sources<br>b. Minimization of data collection time for initial implementation of method, assuming a representative network |
| 6. Reasonable level of staff skills and staff time required for application and | a. Method can be applied by entry-level modeling staff (1-2 years experience)[3] |

[2] Roughly 20,000 links and 1,500 zones.

| Assignment Method Objective | Evaluation Criteria |
|---|---|
| | |
| maintenance | b. Minimization of time requirement for typical application, assuming a representative network[4]<br>c. Minimization of annual maintenance time requirement, assuming a representative network |
| 7. Robust outputs | a. Ability of reflect uncertainty<br>b. Reasonable marginal impact of variable values on assignment results |
| 8. Transparency/understandability of method | a. Ability to intuitively understand assignment method processes<br>b. Ability to interpret cause-effect relationships in assignment outputs |
| 9. Flexibility and extendibility of method | a. Ability to adapt method to changing future conditions that may affect travel behavior or transportation system operations |
| | |
| **B. Specific Properties and Capabilities** | |
| | |
| 1. Convergence of network flows | a. Degree of convergence<br>b. Rate of convergence |
| 2. Compatibility with applicable model form | a. Consistency with applicable model and potential to enhance usefulness of model |
| 3. Realistic estimation of intersection delay | a. Accuracy of estimated delays by traffic movement<br>b. Accuracy of estimated delays for all V/C ranges |
| 4. Multiple levels of output resolution | a. Levels of temporal resolution<br>b. Levels of network resolution |
| 5. Representation of new technologies (e.g., shared mobility) | Same as objective |
| 6. Representation of traffic operations characteristics (e.g., intersection spillback, queuing, and lane overflows) | Same as objective |
| 7. Representation of peak spreading | Same as objective |
| | |

[3] Application includes data collection, network coding, assignment method application, and interpretation and reporting of results.
[4] Typical application would be an assignment to reflect minor network modifications.

| Assignment Method Objective | Evaluation Criteria |
|---|---|
| | |
| **II. Applications** | |
| | |
| **A. Scenario Testing** | |
| | |
| 1. Road capacity improvements | a. Reasonableness of response to capacity improvements<br>b. Ability to reflect effects of small-scale capacity improvements<br>c. Ability to represent effects of capacity improvements on both travel time and traffic operations |
| 2. Road pricing schemes | a. Reasonableness of response to pricing schemes<br>b. Range of pricing schemes that can be represented<br>c. Ability to support representation of pricing effects in travel demand model |
| 3. TSMO strategies | a. Ability to reflect effects of small-scale TSMO strategies<br>b. Ability to represent effects of TSMO strategies on both travel time and traffic operations |
| | |
| **B. Planning and Analysis Support** | |
| | |
| 1. GHG reduction and air quality analysis | a. Accuracy of outputs used in GHG reduction/AQ analysis<br>b. Number of assignment outputs that can be used for GHG reduction/AQ analysis |
| 2. Regional scenario planning | a. B/C of implementing/applying method for regional scenario planning |
| 3. Performance measure calculation | a. Ability to produce performance measure outputs for large, medium, and small-scale improvements |
| 4. Project selection | a. Ability to support project selection |
| 5. Subarea planning | a. Minimization of effort to implement/apply method for subarea planning<br>b. Ability to reflect both capacity and operational effects of improvements for subarea planning<br>c. Ability to reflect effects of large, medium, |

| Assignment Method Objective | Evaluation Criteria |
|---|---|
| | |
| | and small-scale improvements for subarea planning |
| 6. Policy analysis (e.g., related to TPR) | a. B/C of implementing/applying method for policy analysis<br>b. Range of policies that can be represented |
| 7. B/C analysis of transportation improvements (large, medium, and small-scale) | a. Number and accuracy of outputs that can be used for estimating benefits (travel time savings, traffic operations benefits)<br>b. Number and accuracy of outputs that can be used for cost estimation (i.e., travel delay, facility sizing) |

## *4.2 Assignment Method Evaluation Results*

The evaluation criteria were applied to the three assignment methods discussed in the previous section – static/macroscopic, dynamic/macroscopic assignment, and dynamic/microscopic or mesoscopic assignment. The methods were were evaluated by assigning a rating of "low", "medium", or "high" for each criterion, indicating the general degree to which the methods satisfied the criteria in absolute or relative terms. The absolute assessment considered how well a method satisfies the criteria on its own merits, while the relative assessment reflected how well the method satisfies the criteria compared to the other methods. The evaluation results are presented in detail in Appendix A. For each criterion, the ratings for the methods are listed, together with notes on the rating rationale and characteristics of the methods.

The evaluation was not intended to rank the methods to identify a "best" method, but rather to to establish a general framework for considering the advantages and disadvantages of the methods. If there is interest in determining which method may be the most appropriate for a particular urban area, travel demand forecasting model, or model application, the methods can be quantitatively ranked by using a combination of weights and numeric scores for the criteria to develop a weighted total score for each method. As documented in Technical Memorandum #3 for this study, this approach was used to evaluate three specific assignment methods for use in the Southern Oregon ABM. Excerpts from Technical Memorandum #3, including the evaluation results, are included in Appendix B.

For purposes of discussing the evaluation, the methods are labeled in the following manner:

- Method 1 – Static, macroscopic assignment
- Method 2 – Dynamic, macroscopic assignment
- Method 3 – Dynamic, microscopic/mesoscopic assignment

A summary of the evaluation is shown in Table 3.

**Table 3 – Assignment Method Rating Summary**

| **Rating** | **Method 1** Static, Macro | **Method 2** Dynamic, Macro | **Method 3** Dynamic, Micro/Meso |
|---|---|---|---|
| Low | 28<br>60.9% | 10<br>21.7% | 10<br>21.7% |
| Medium | 9<br>19.6% | 33<br>71.7% | 15<br>32.6% |
| High | 9<br>19.6% | 3<br>6.5% | 21<br>45.7% |
| Total No. of Criteria | 46<br>(100%) | 46<br>(100%) | 46<br>(100%) |

Reading across the diagonal of the table, it can be seen that overall, Method 1 received the highest number of "low" ratings, Method 2 had the highest number of "medium" ratings, and Method 3 received the largest number of "high" ratings. The main reasons that Methods 2 and 3 rated relatively well compared to Method 1 are:

- Better accuracy of link traffic flows;
- Better representation of travel times/speeds;
- More realistic estimation of intersection delay;
- Higher levels of temporal resolution;
- More realistic representation of traffic operations characteristics;
- Ability to represent peak spreading;
- More accurate estimation of the effects of capacity improvements;
- Ability to reflect the effects of small-scale improvements, such as TSMO-type improvements; and

- Better ability to support project selection.

These advantages are primarily related to the more realistic representation of network response to congestion (in terms of delay), the higher level of temporal resolution and, in the case of Method 3, the higher network resolution. The higher overall rating for Method 3 compared Method 2 is also largely accounted for by the advantages of Method 3 in these areas.

There are several criteria, however, for which Methods 2 and 3 were rated lower than Method 1. This is related to the following disadvantages of Methods 2 and 3:

- Larger implementation and maintenance time requirements;
- Larger data collection time requirement;
- Less intuitive understanding of the assignment method processes;
- Greater difficulty in interpreting the cause-effect relationships in the assignment outputs;
- Higher level of staff expertise for application and maintenance; and
- Lower degree of assignment convergence.

All of these disadvantages, except the last one, are due to the greater complexity of Methods 2 and 3. The lower degree of assignment convergence is related to the constrained physical capacities used in the these methods compared to the continuous VDFs used in Method 1, which result in the spillover of traffic to adjacent time periods if capacity is exceeded. Also with Methods 2 and 3, fractional vehicles are used in the assignment which reduces the level of convergence possible compared to Method 1, which uses whole vehicles.

# 5.0 Assignment-Related Topics

Specific topics related to the implementation and use of the assignment methods were identified for investigation by the study working group. The focus of the investigation was on static assignment topics because this will likely be the main method used by ODOT and its partner agencies within the near-term. A brief discussion of each of the topics is provided below.

## *5.1 Static, Macroscopic Assignment Topics*

### *Volume Delay Functions*

The following VDF-related topics for the static assignment method were identified by the working group:

- Alternative forms of VDFs
- Incorporation of node-based delay in VDFs
- Calibration of VDF parameter values
- Representation of truck volumes in VDFs
- Representation of network capacity

#### Alternative Forms of VDFs

The most commonly used VDFs are the Bureau of Public Roads (BPR) function, Davidson's delay model, the Akcelik function, and the conical delay model. These functions are presented in Figure 2.

**Figure 2 – Alternative VDFs**

**BPR**

$$u = \frac{u_0}{\left[1.0 + \alpha (x)^{\beta}\right]}$$

**Conical**

$$u = \frac{u_0}{\left[2 + \sqrt{\beta^2 (1-x)^2 + \alpha^2} - \beta(1-x) - \alpha\right]}$$

$$\text{where, } \alpha = \frac{\beta - 0.5}{\beta - 1} \quad \text{and} \quad \beta > 1$$

**Modified Davidson**

$$u = \begin{cases} \dfrac{u_0}{1 + \dfrac{Jx}{(1-x)}}, & \text{for } x \le \mu \quad (i) \\[2ex] \dfrac{u_0}{1 + \dfrac{J\mu}{(1-\mu)} + \dfrac{J(x-\mu)}{(1-\mu)^2}}, & \text{for } x > \mu \quad (ii) \end{cases}$$

**Akcelik**

$$u = \frac{u_0}{\left(1 + 0.25 u_0 \left[(x-1) + \sqrt{(x-1)^2 + 8\tau \frac{x}{u_0 c}}\right]\right)}$$

Source: "*Calibration and Evaluation of Link Congestion Functions: Applying Intrinsic Sensitivity of Link Speed as a Practical Consideration to Heterogeneous Facility Types within Urban Network*," Journal of Transportation Technologies, 4, 2014.

The terms in the expressions in Figure 2 are:

| | | |
|---|---|---|
| $u_0$ | = | free flow speed; |
| u | = | operating speed; |
| $c$ | = | capacity; |
| $x$ | = | v/c ratio; and |
| $\alpha, \beta, \mu, J, \tau$ | = | parameters to be calibrated |

The BPR function is one of the oldest and most widely used VDFs in travel demand models in the U.S. because of its simple mathematical form and minimum data requirements. It has a number of limitations, however, including the lack of representation of operating conditions and lack of accounting for facility characteristics, such as signalization on arterials.

The conical function was developed to overcome the drawbacks associated with high $\beta$ exponent values in the BPR function, which can reduce the rate of convergence by giving undue penalties to overloaded links during the first few iterations of an equilibrium assignment and cause numerical problems, such as overflow conditions and loss of precision. Additionally, for links with volumes that are far below capacity, BPR functions with high $\beta$ values yield free-flow speeds that do not match those of actual traffic volumes.

Two versions of the Davidson function are shown in Figure 2. The first version, which is the original function, became popular because of its flexibility and ability to handle a wide range of traffic conditions and environments. The parameter $J$ is associated with the land use or area type surrounding the highway link. This function has a serious flaw, however, because it cannot define a travel time if link volumes exceed capacity. Therefore, a second version of this function was developed which allows for link oversaturation.

The Akcelik function is a form of the Davidson function that attempts to encompass intersection delay. It can improve the modeling of link travel speed when a significant portion of the travel time is comprised of intersection delay. This delay is captured by the parameter $\tau$. Lower values of $\tau$ are recommended for freeways and coordinated signal systems, while higher values are used for arterial roads without signal coordination. It has been reported that this function also produces better convergence and more realistic speed estimates under congested conditions.

## Incorporation of Node-Based Delay in VDFs

Most forms of VDFs currently in use do not directly reflect the intersection delay component of travel time along interrupted flow facilities. Some functions, however, incorporate both a link travel time component and intersection delay component in an attempt to more realistically represent all elements of travel time on interrupted flow roadway segments. The intersection component estimates delay as a function of volume and specific intersection characteristics such as capacity, green time ratio, cycle length, and the presence/absence of signal coordination.

Based on the evaluation criteria presented in the previous section, the main advantages of VDFs that include an intersection delay component compared to those that do not are:

- More accurate estimation of link traffic flows and travel times/speeds.
- More accurate estimation of intersection delay.
- Better representation of the effects of capacity improvements.

The primary disadvantage of this method compared to the link travel time only method is the additional data collection and implementation required to represent intersections in the model network.

### Calibration of VDFs

The calibration of VDFs involves the use of observed traffic volume and speed/travel time data to adjust the coefficients and free flow speed and capacity values within the functions to fit the data. An example of this is a study conducted by Florida A&M University - Florida State University to calibrate the four types of VDFs described above – the BPR function, Davidson's delay model, the Akcelik function, and the conical delay model.

In this study, traffic volume and speed data from the Florida Department of Transportation's traffic monitoring stations and statewide transportation engineering warehouse were used to calibrate the functions across four facility types (freeway, toll road, HOV/HOT lanes, and arterial) and three area types (urban, residential, and rural).

Free-flow speeds were estimated for uninterrupted flow facilities based on the average speeds of vehicles under low flow conditions of density less than 10 passenger cars per hour per mile per lane (pc/h/ln). For interrupted flow facilities, vehicles were considered to be free-flowing if the headway to the vehicle ahead was eight seconds or more and the headway to the vehicle behind was five seconds or more. Practical capacities were estimated as the 99th percentile flow in pc/h/ln rather than maximum hourly flow to exclude outliers. The estimated free flow speeds and capacities are shown in Table 4.

**Table 4 – Estimated Florida Free-Flow Speeds and Capacities**

| Facility Type | Area Type | Number of Sites | Sample size | Speed Limit (mph) | Mean FFS (mph) | $q_{max}$(pc/h/ln) | Capacity (pc/h/ln) |
|---|---|---|---|---|---|---|---|
| Freeway | Urban | 3 | 6810 | 55 | 64.671 | 1891 | 1686 |
| Freeway | Urban | 6 | 13081 | 65 | 66.790 | 2384 | 2027 |
| Freeway | Residential | 3 | 12083 | 55 | 60.537 | 1632 | 1418 |
| Freeway | Residential | 4 | 14115 | 65 | 67.783 | 2108 | 1887 |
| Freeway | Residential | 17 | 71033 | 70 | 71.131 | 2435 | 1722 |
| Freeway | Rural | 4 | 14115 | 65 | 67.783 | 2108 | 1878 |
| Freeway | Rural | 17 | 71033 | 70 | 71.131 | 2435 | 1742 |
| Toll road | Urban | 2 | 24104 | 60 | 64.324 | 1916 | 1748 |
| Toll road | Urban | 3 | 35586 | 65 | 68.503 | 2315 | 1938 |
| Toll road | Residential | 2 | 33872 | 55 | 63.324 | 2235 | 2074 |
| Toll road | Residential | 2 | 52570 | 65 | 71.441 | 1877 | 1741 |
| Toll road | Residential | 2 | 36288 | 70 | 74.031 | 2183 | 2025 |
| Toll road | Rural | 2 | 54210 | 65 | 73.720 | 1802 | 1772 |
| Toll road | Rural | 4 | 68446 | 70 | 75.627 | 2377 | 2205 |
| HOV/HOT | Urban | 1 | 18445 | 65 | 71.116 | 1917 | 1857 |
| HOV/HOT | Residential | 2 | 15367 | 65 | 70.451 | 1823 | 1702 |
| Arterial | Urban | 4 | 16015 | 30 | 34.609 | 984 | 846 |
| Arterial | Urban | 3 | 10046 | 45 | 52.046 | 969 | 825 |
| Arterial | Residential | 4 | 12125 | 35 | 41.920 | 936 | 884 |

Source: "*Calibration and Evaluation of Link Congestion Functions: Applying Intrinsic Sensitivity of Link Speed as a Practical Consideration to Heterogeneous Facility Types within Urban Network*," Journal of Transportation Technologies, 4, 2014.

The coefficients for each of the VDFs were statistically calibrated using the traffic volume and speed data. The estimated coefficients are shown in Table 5.

**Table 5 – Estimated Florida VDF Coefficients**

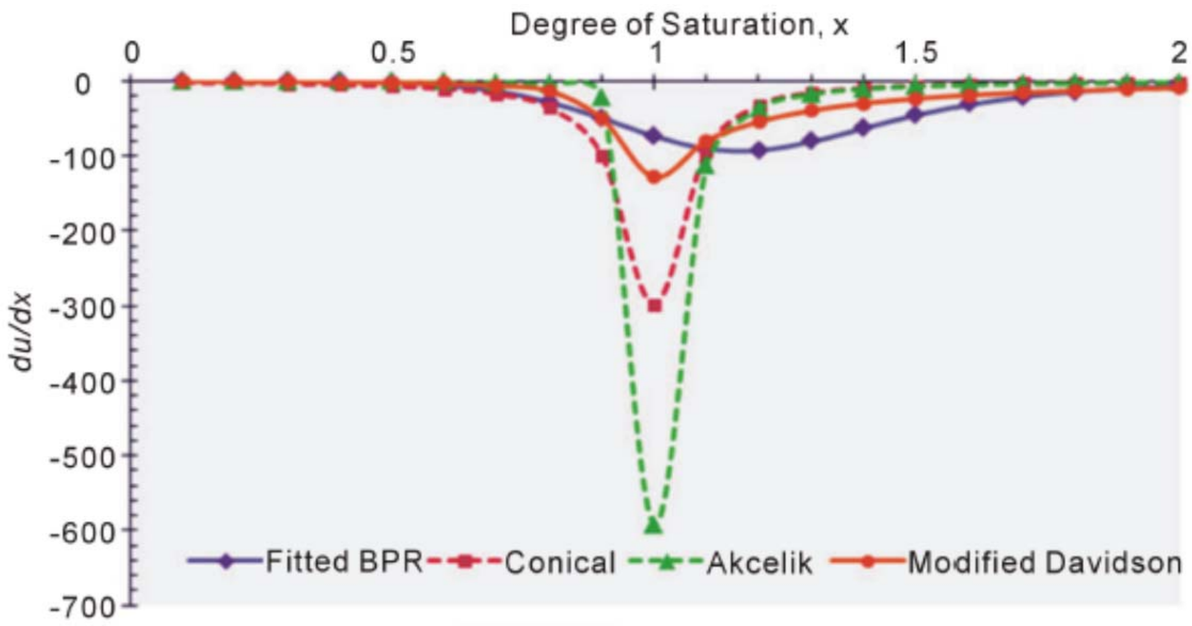
| | | Facility and Area Type | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Freeways/Expressways | | | Toll Roads | | | HOV/HOT Lanes | | Signalized Arterials | |
| **Function** | **Parameters** | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 1 | 2 |
| Fitted BPR | $\alpha$ | 0.263 | 0.286 | 0.15 | 0.162 | 0.25 | 0.32 | 0.32 | 0.33 | 0.24 | 0.26 |
| | $\beta$ | 6.869 | 5.091 | 5.61 | 6.34 | 7.9 | 6.71 | 8.4 | 8.6 | 7.50 | 8.20 |
| Conical | $\beta$ | 18.390 | 18.39 | 15.06 | 18.39 | 15.064 | 15.064 | 18.55 | 18.7 | 18.8 | 18.8 |
| | $\alpha$ | 1.029 | 1.029 | 1.04 | 1.029 | 1.036 | 1.036 | 1.028 | 1.028 | 1.03 | 1.03 |
| Modified Davidson | $J$ | 0.009 | 0.0092 | 0.0099 | 0.008 | 0.0099 | 0.0099 | 0.009 | 0.0089 | 0.01 | 0.01 |
| | $\mu$ | 0.950 | 0.949 | 0.951 | 0.94 | 0.952 | 0.940 | 0.95 | 0.947 | 0.95 | 0.95 |
| Akcelik | $\tau$ | 0.100 | 0.101 | 0.099 | 0.11 | 0.098 | 0.097 | 0.09 | 0.08 | 0.10 | 0.10 |

Source: "*Calibration and Evaluation of Link Congestion Functions: Applying Intrinsic Sensitivity of Link Speed as a Practical Consideration to Heterogeneous Facility Types within Urban Network*," Journal of Transportation Technologies, 4, 2014.

Several important findings of the study were:

- VDFs perform differently given different facility types. Therefore, selection of a VDF for a particular facility type and area type needs to be based on an understanding of network performance under different congestion levels and traffic controls.
- The effect of a change in congestion, near or at capacity, will have different impacts on travel speed for a freeway link compared to a signalized arterial link. Speed tends to deteriorate faster on shorter links (urban signalized arterials) than on longer links (uninterrupted flow facilities such as freeways and expressways) when demand is close to capacity.
- The rate of speed change varies by congestion level. When demand is lower than capacity (up to v/c = 0.7), the slopes of the VDFs remain fairly constant, but become steeper as demand approaches capacity. Near capacity, this relationship varies by the type of VDF (see Figure 3).

**Figure 3 – Florida Speed Change vs. Congestion Level**




Source: "*Calibration and Evaluation of Link Congestion Functions: Applying Intrinsic Sensitivity of Link Speed as a Practical Consideration to Heterogeneous Facility Types within Urban Network*," Journal of Transportation Technologies, 4, 2014.

## Representation of Truck Volumes in VDFs

The representation of truck volumes in VDFs can be considered more generally as how to accurately estimate travel speeds for heterogeneous traffic flows. Vehicles exhibit a wide variety of operational and driver characteristics and thus constitute a heterogeneous user population. Based on their physical dimensions, weights, intended uses, and dynamic characteristics, these vehicles can be classified as passenger cars, light trucks, heavy trucks, buses, etc. Trucks, in particular, have very different travel speeds, operational characteristics, sizes, and headways compared to cars. Mixing cars and trucks on the freeway results in larger delays because heterogeneous vehicle types share the same road space. Faster moving cars may experience sight interference and increased lane changing, and trucks slow down the traffic stream because of their limited acceleration and deceleration capabilities. Therefore, the travel time functions of trucks and cars are not identical, and furthermore depend not only on traffic volume, but traffic composition as well.

Commonly-used travel time functions, such as the BPR formula, do not account for heterogeneity in traffic flows. In addition, the technique of converting all vehicle types into a single class using a passenger car unit (PCU) factor does not reflect the operational differences between these types. Thus, there is a need for travel time functions that consider both the volume and proportion of trucks in the traffic stream.

Such functions were developed based on data from a microscopic traffic simulation for a freeway segment in southern California.[5] BPR-type functions were estimated for three vehicle classes: cars, light trucks, and heavy trucks. For the car and light truck functions, a variable reflecting the proportion of the other vehicle classes was included. This variable was not included in the heavy truck function because it was found that the effect of the proportions of the other vehicle classes was not a key determinant of heavy truck travel time. The functions for the car and light truck classes were piecewise, i.e., different functions were applied depending on the proportion of cars in the traffic stream. For conditions where the percentage of cars was above a specific value, the functions containing the proportionality term were applied. In cases where the percentage was below this value, the standard BPR function was applied. This was done because it was found that for traffic streams with a relatively low proportion of cars, the composition of traffic was not as significant variable.

The study revealed that traffic composition plays a significant role in the determination of travel times. Furthermore, the specification of separate functions by vehicle class and the introduction of the proportionality term significantly improved the accuracy of the travel time estimates.

## Representation of Network Capacity

The treatment of network capacity varies according to assignment method used. The static, macroscopic assignment method (Method 1 in Section 4.2) is typically used if detailed assignment output is not needed for analysis purposes. An example of this would be the use of

[5] Estimating Link Travel Time Functions for Heterogeneous Traffic Flows on Freeways, *Department of Civil and Environmental Engineering, National University of Singapore and Institute of Transportation Studies, University of California, Berkeley,* 2016.

link volumes for estimating the scale of future capacity improvements (number of lanes) for higher-level roadways. For this purpose, network capacity may be represented at the link level only, either in terms of directional capacity or capacity per lane. Typically, different capacities are used by facility type and area type to roughly approximate the varying effects of roadway geometry and traffic operating characteristics on capacity. Intersection capacity at controlled intersections (signals and stop signs) is implicitly represented in the link capacity as a way to include intersection delay in the travel time calculation. If a higher level of accuracy and detail is required in the assignment results, intersection capacity can be reflected separately from link capacity in the type of node-based VDFs described earlier.

Network capacity can be more realistically represented using the dynamic, macroscopic assignment method (Method 2 in Section 4.2). Use of this method would be more appropriate than Method 1 if more accurate, detailed answers to questions about future traffic flows and traffic operations are needed. Some of the advantages of Method 2 are:

- More reasonable response to capacity improvements in highly-congested networks due to a cap on capacity.
- Ability to reflect the effects of smaller-scale capacity improvements (e.g., addition of intersection turn lanes).
- Ability to describe the effects of capacity improvements on both travel time and traffic operations.

The latter two advantages are related to the capability of estimating intersection queuing and queuing delay with Method 2.

The capacities used in Method 2 are more realistic because they are physical capacities rather than abstractions of capacities as in Method 1. Thus, the capacity settings for Method 2 must adhere to the fundamental diagram of traffic flow at the link level and the physical turn/link exit capacities of intersections. This allows the correct calculation and representation of queues in the network. The link capacity is used as a cap for the calculation of link travel time. For link flows less than capacity, travel time is treated as free flow. Once the flow reaches capacity, the travel time is calculated based on a speed-density relationship. The same is true for intersection capacities, where a delay model is used to calculate delays and queues once flows reach capacity.

Dynamic, microscopic/mesoscopic assignment (Method 3 in Section 4.2) provides the most accurate, detailed information about future traffic flows and traffic operations. It is typically used for the analysis of specific corridors or individual locations along corridors rather than system-level analysis due to the large number of detailed inputs required. Because individual vehicle movements are simulated, capacity is an output of the assignment, rather than an input.

### *Generalized Cost Assignment*

Generalized cost assignment attempts to more realistically represent the traveler's path decision-making process by including other factors in addition to travel time. Examples of these factors are tolls, vehicle operating costs, travel time reliability, emissions, and comfort/convenience. Since the generalized cost for a specific link must be expressed as a single value, all of the factors not measured in monetary units must be converted to a constant dollar amount.

An example of this is link travel time, which is converted to dollars using an assumed value of time (VOT). The VOT can be represented in terms of dollars per hour or dollars per minute. In many models, different VOTs are assumed by trip purpose and/or vehicle class. Typically a higher VOT is assigned to the work trip purposes compared to the non-work purposes. Similarly, a higher VOT is assumed for the truck vehicle class than the auto classes. The factors used to convert the non-monetary components of a generalized cost function into dollar amounts can be derived using stated or revealed preference surveys or estimated in the model calibration process.

A simple generalized cost function comprised of travel time, tolls, and operating cost would be expressed as:

*Generalized Cost = Travel Time * VOT + Toll Cost + Vehicle Operating Cost*

## *Use of Demand Adjustment Procedures*

Demand adjustment is a procedure used to update a seed origin-destination matrix using traffic counts. This procedure is most often applied to adjust a base year trip matrix to better fit existing conditions, as reflected in the count data. In the case where the seed matrix is a demand matrix produced by a travel demand forecasting model, the demand matrix can be compared to the adjusted matrix to indicate where potential adjustments may be needed within the model.

Demand adjustment procedures are available within most travel demand modeling software packages, such as Emme and Visum. In Visum, the matrix estimation problem is based on an entropy maximization formulation which incorporates an input count data set and additional constraints that may be selected by the user. In Emme, a gradient method is used which minimizes the differences between link volumes from the model and link counts, while ensuring that the demand matrix is not changed more than necessary.

In applying a demand adjustment procedure, there are some important practical considerations:

1. Based on the general formulation of the O-D estimation problem, it is possible to obtain an infinite number of matrices that will reproduce the counted volumes. As a result, it is recommended that the seed matrix should be from a source that reflects causal travel flow relationships (for example, a travel demand forecasting model), so that the resulting matrix reflects these relationships. Simply using a unit matrix to produce a trip table fitted to observed counts is bad practice and should be avoided.[6]
2. The procedure will adjust the demand matrix to better reflect the observed volumes. It should only be applied if all other data which are used for the assignment have been extensively validated. The procedure will attempt to compensate any remaining error in

[6] Visum Traffic Assignments, PTV, 2017.

the network coding, volume delay functions, or observed volumes by modifying the demand matrix. This, of course, will not correct the error, but just add another error.[7]

3. The selection of count links is very important. The count links should cover the network sufficiently so that most trips will be counted at least once and should not have a large number of local (intrazonal) trips, since these will not be accounted for in the assignment. Care should also be taken when the count links are close to important centroid connectors, since centroids are aggregated abstract trip ends which do not represent true origins and destinations.

4. The matrix adjustment seeks to minimize the error rather than eliminate it. As a result, the procedure should not be used to over-fit the demand matrix to observed counts to obtain a perfect or near-perfect fit. It should be recognized that there are always possible inconsistencies in the counts since they may have been taken on different days or may be non-representative due to traffic incidents, upstream bottlenecks, etc.

5. After the adjustment, the demand matrix and adjusted matrix should be carefully compared in order to identify possible distortions. Typical checks include:

    - Comparing the matrix totals;
    - Plotting before/after trip length frequency distributions;
    - Comparing before/after matrix row and column totals; and
    - Examination of scatter plots to identify matrix cells with large before/after trip differences

    In general, the changes in demand should be small and unsystematic. Large or systematic changes almost always indicate a problem in the input data.

[7] DEMANDJ: A Macro for Demand Matrix Adjustment Using Observed Volumes, Inro, 1990.

## 5.2 Dynamic, Macroscopic Assignment Topics

### Calibration of DTA Models

DTA model results are influenced primarily by the model network, input demand, and the type of queuing model used. Once it has been determined that the input demand is a reasonable representation of trip making in the model area, calibration of the model typically comprises the following steps:

1. In the initial assignment, link capacities only are used, reflecting relatively unconstrained network capacity conditions.
2. Initially, vertical queuing only is applied; i.e., spillback queuing is not modeled.
3. Volume flow plots by v/c level are created for each time interval.
4. The plots are reviewed to determine the reasonableness of traffic flows and congestion points in the network.
5. For locations having unreasonable bottlenecks, the capacities, number of lanes, and speeds are adjusted as needed.
6. Once reasonable link flows are achieved using link capacities only in the model, other capacity constraints are added to the network, such as link exit capacities, followed by turn capacities where needed.
7. The assignment is rerun and volume flow plots are produced.
8. The plots are reviewed for reasonableness and the added capacity constraints are adjusted as needed.
9. Once reasonable link flows are achieved with the added constraints, the spillback queuing model feature is implemented.

## *Level of Network Disaggregation*

DTA model networks are generally more data-intensive than static model networks. For example, although both types of models work on an areawide network, DTA requires more network detail, including the number of lanes on each link, the presence of acceleration–deceleration lanes and turn bays, and lane connectivity.

The network can be based on an existing static model network, GIS files, online maps, or aerial photos. If an existing static model network is used, it must be upgraded to include at least the basic DTA requirements. Such an upgrade can be time-consuming, depending on the spatial extent and density of the network and the level of detail in the static model network. This may also include refining the network topology to better reflect the true alignment of the roadways. Links may be further divided into segments to capture variations in roadway cross-section geometry. Additional work may be involved in defining all allowed and prohibited lane movements at link and segment boundaries.

In contrast to some static models, the geometry and flow characteristics of zone connectors have more significance in DTA models, and should therefore be modeled as real physical roadways. In particular, connectors should not be located close to major intersections as is sometimes the case in static models, and if this is true, they should be moved to mid-block locations or distributed on the link in a manner that corresponds to actual network access/egress locations.

## *Level of Time Resolution*

One of the main advantages of DTA models compared to static models is that the higher level of temporal resolution allows a more realistic representation of network response to congestion, in terms of delay. Theoretically, the higher the level of resolution, the better the calibrated model will represent real-world conditions. Therefore, relatively short time periods are used, typically ranging from five to 15 minutes. Another factor to be considered in defining the time period length is the particular purpose that the model output will be used for. Analyses for which more accurate, detailed estimates of travel times, speeds, and network operating conditions are needed will require higher levels of temporal resolution. This need, however, must be balanced against the computational efficiency of the model. Depending on the spatial extent of the network, the run time for DTA assignments can be significantly longer than that for static models.

Time-dependent trip tables are typically used as the demand inputs to DTA models. Trip patterns can vary across origins, destinations, and departure times. The most common method for capturing these variations is through a series of trip tables, each containing information about the trip departures within a relatively short time interval. The most convenient source of existing trip tables are those produced by travel forecasting models. Most planning agencies have O-D tables for different periods in the day (e.g., a.m. peak, p.m. peak, and off-peak). If hourly factors are available for the time period of interest, these can be used to derive a temporal profile to disaggregate the existing tables into finer time resolutions (e.g., 15-minute tables).

## *5.3 Dynamic, Microscopic/Mesoscopic Assignment Topics*

### *Calibration of Microsimulation Models*

Following the development of a base microsimulation model, calibration is necessary so that it will accurately predict traffic performance. This involves the adjustment of parameters to improve the model's ability to reproduce local driver behavior and traffic performance characteristics. Calibration is performed on various components of the overall model.

Every microsimulation software program comes with a set of user-adjustable parameters for model calibration. The objective of calibration is to find the set of parameter values that best reproduces local traffic conditions.

For convenience, software developers provide suggested default values for the model parameters. It is unlikely, however, that a model will be able to produce accurate results for a local area using only the default values. Therefore, calibration tests should always be performed.

The *Traffic Analysis Toolbox Volume III*[8] recommends dividing the parameters into two basic categories:

- Parameters that the user is certain about and does not wish to adjust; and
- Parameters that the user is less certain about and willing to adjust.

This is done because there are potentially hundreds of model parameters, each of which impacts the simulation results in a manner that is often highly correlated with the others.

The adjustable parameters can be further subdivided into those that directly impact capacity (such as mean headway) and those that directly impact route choice. The capacity parameters are calibrated first, followed by the route choice parameters. The parameters can also be subdivided into those that affect the simulation on a global basis vs. those that have a more localized effect. The global parameters are calibrated first, and then the local link-specific parameters are used to fine-tune the results.

The *Traffic Analysis Toolbox Volume III* also recommends that the model should be calibrated in the following order:

1. Capacity calibration: An initial calibration is performed to identify the values of the capacity parameters that cause the model to best reproduce observed traffic capacities in the field. A global calibration is performed first, followed by link-specific fine tuning.

2. Route choice calibration: If route choice is an option within modeled network, then route choice calibration will be important. In this case, a second calibration process is performed, but this time with the route choice parameters. A global calibration is performed first, followed by link-specific fine-tuning.

3. System performance calibration: Overall model estimates of system performance (travel times and queues) are compared to field-measured travel times and queues.

[8] Traffic Analysis Toolbox Volume III: Guidelines for Applying Microsimulation Modeling Software, Federal Highway Administration, 2004.

Fine-tuning adjustments are then made to enable the model to better match the field measurements.

As an example, the capacity calibration step would be performed as follows:

1. Collect field measurements of capacity, such as queue discharge rates for non-signalized facilities and saturation flow rates for signalized intersections.
2. Obtain model estimates of capacity.
3. Select the calibration parameters, such as mean following headway and driver reaction time for freeways and startup lost time and queue discharge headway for signalized intersections.
4. Set the calibration objective function (e.g., mean square error) for measurement of the difference between observed and modeled capacities.
5. Perform a search for the optimal parameter values that minimize the objective function.
6. Fine-tune the calibration once the optimal global capacity parameter values have been identified.

### *Size of the Modeling Problem*

Among other questions related to the appropriate type of model for a particular type of analysis is the practical scope of the modeling problem. For microsimulation modeling, the answer to this question has significant implications for level of effort required in developing, applying, and maintaining the model. For example, in a study of best practices in microsimulation by the American Association of State Highway and Transportation Officials (AASHTO), it was estimated that mesoscopic simulation models tend to cost an order of magnitude (i.e., ten times) more to develop than macroscopic models.[9] On a similar scale, microscopic simulation models tend to cost an additional order of magnitude more to develop than mesoscopic models on a per-link basis.

[9] Best Practices in the Use of Micro Simulation Models, American Association of State Highway and Transportation Officials (AASHTO), 2010.

This tends to limit the use of microsimulation models to a subregional level. In a national survey of microsimulation practitioners conducted in the same study, it was found that a majority (64%) of the simulation studies were conducted at the corridor or subarea level. Only 27% of the projects were conducted at the regional level. This highlights the difficulties in applying a microscopic simulation tool at a regional level.

Thus, microsimulation is helpful in modeling travel in corridors, but may be less so for regional studies. The size of the network, temporal scale, and travel demand load determine to a large extent the class of simulation models that can produce adequate results. Network size is based on the number of links, nodes, and O-D pairings. The AASHTO best practices study indicates that mesoscopic and DTA models are better equipped to handle large-scale projects, generally those with 15,000 links, 5,000 nodes, 1,000 O-D pairs, and 1,000,000 vehicles. Conversely, microscopic simulation models, to be cost-effective, are typically confined to an area significantly less than regional in size. This is generally on a scale of 50 to 200 nodes and tens of thousands of vehicles, although multi-threading and parallel computing can stretch the simulation model's area of analysis much larger. Table 6 contains information from the study summarizing the applicability of various simulation approaches, including microsimulation, with regard to the geographic and network sizes of the modeling area, length of the analysis time period, and demand level.

**Table 6 – General Applicability of Simulation Approaches**

| Criteria | | Applicability | | |
|---|---|---|---|---|
| | | Macroscopic Simulation | Mesoscopic Simulation | Microscopic Simulation |
| | | | | |
| Geographic Size | Regional | Yes | Possibly | Not common |
| | Corridor | Yes | Yes | Possibly |
| | Subarea | Possibly | Yes | Yes |
| | | | | |
| Network Size* | Large | Yes | Possibly | Not common |
| | Medium | Yes | Yes | Possibly |
| | Small | Yes | Yes | Yes |
| | | | | |
| Time Period Length | 24 hours | Yes | Possibly | Not common |
| | Six hours | Yes | Yes | Possibly |
| | Peak period | Yes | Yes | Yes |
| | Peak hour | Possibly | Yes | Yes |
| | | | | |
| Demand Level** | Large | Yes | Possibly | Not common |
| | Medium | Yes | Yes | Possibly |
| | Small | Yes | Yes | Yes |

* Large: > 10,000 links, > 3,000 nodes, > 1,000 zones
Small: < 1,000 links, < 400 nodes, < 100 zones
** Large: >1,000,000 vehicles
Small: < 200,000 vehicles

Source: "*Best Practices in the Use of Micro Simulation Models",* American Association of State Highway and Transportation Officials (AASHTO), 2010.

## *5.4 General Assignment Topics*

### *Development of Multi-Resolution Modeling Networks*

While current macroscopic, mesoscopic, and microscopic modeling approaches have proven their value in analyzing and planning traffic infrastructure and control, they have also shown limitations in their applicability, most of which are inherent in the nature of the models. Microscopic models have proven to be difficult and time consuming to calibrate and difficult to apply because of their richness in parameters and their dependency on large sets of fine grained input data. Macroscopic models are more geared to long-term planning but do not capture the temporal and spatial distribution of traffic during peak hours including daily operational traffic management strategies. Mesoscopic models have shown their ability to accurately model dynamics in traffic demand, but still lack the fidelity to analyze individual vehicles or corridors on a lane by lane basis. Multi-resolution modeling (MRM) is the integration of macroscopic, mesoscopic, and microscopic models for the purpose of analyzing transportation projects at different levels of detail by enabling data to be shared across modeling platforms.[10]

The networks used at each modeling level differ in their scope, level of detail, and types of input data. Typically, the scope or size of the modeling area decreases from the macro level to the micro level, while the level of network detail increases. Corresponding to the greater detail, additional data is needed for the mesoscopic and microscopic model networks. This includes information about roadway geometry and physical characteristics, as well as signal locations, timings, and control.

The objectives in the development of networks at each modeling level are maintaining consistency between the networks, accuracy, and minimization of effort. To maintain consistency and minimize the level of effort, most model integrations are done directly using macroscopic regional travel forecasting models as a starting point. Many of the modeling software platforms, such as TransModeler, have capabilities to facilitate this process. This includes translation of the network structure (links, nodes, and TAZs) into the required format, as well as the transfer basic network attributes, such as the number of lanes, free-flow speed, and capacity.

Even with an automated conversion process, however, the resulting model must be checked for accuracy and built upon to produce the final model. For example, the original network coded in the macroscopic model may have errors and inconsistencies that do not affect that model's results, but could lead to inaccurate results or errors when running more detailed models. Examples of this are ramp locations and lengths, centroid connector locations, and capacities.

---

[10] Multi-Resolution Model Integration, Center for International Intelligent Transportation Research, Texas Transportation Institute, 2010.

These errors and inconsistencies need to be resolved before using the network as an input to the more detailed models.

In addition, more detailed network attributes and other parameters need to be added when converting a network from a macroscopic model to a mesoscopic or microscopic simulation tool. Real-world sources of this data include data collected using ITS devices, third party vendors, conventional data collection, surveys, and data from agencies responsible for traffic signal control. Further fine-tuning can be done by running the new model after conversion.

### *Consideration of Travel Time Reliability in Traffic Assignment*

Typically in the traffic assignment process, it is assumed that travelers are risk-neutral and only consider average travel time when making route choice decisions. Further, it is assumed that travelers always select the route with minimum travel time between specified origins and destinations, regardless of how variable travel times may be.

However, many empirical studies have shown that travelers also take travel time reliability into consideration when making trip decisions. In fact, under some circumstances, they may place more weight on their knowledge of travel time variation, which is gradually built up based on their past experiences. As a result, the identified optimal paths from traditional models may fail to represent most travelers' risk averse behaviors.

There is no consensus on how reliability should be reflected in deterministic assignment models. One measure is based on the ratio of mean travel time per unit of distance to the standard deviation of mean travel time per unit of distance, with a higher ratio indicating a less reliable trip. A second approach measures reliability as a proportion of success or failure against pre-established thresholds, such as the proportion of trips with a delay less than a predefined threshold.

Another approach was developed in a study in which stated and revealed preference survey data was used to associate travel time reliability with the distribution of travel time. It was assumed that travelers will pay to reduce entropy, which was calculated as a function of the mean and standard deviation of the travel time distribution. The value of entropy was represented in dollars per unit of entropy.

There is greater potential for reflecting reliability in traffic assignment using dynamic rather than static assignment methods. This is because DTA and traffic microsimulation tools explicitly include travel time variability, whereas static assignment can only predict average travel times.

### *Cost Effectiveness of Dynamic vs. Static Assignment Methods*

In determining whether the development of a dynamic traffic assignment model is a worthwhile investment for an urban area or particular project application, the cost and benefits of the model must be considered. As described earlier, one of the largest benefits of dynamic models compared to static models is the more realistic representation of traffic operating conditions, such as travel times, speeds, and intersection queue lengths. Depending on the size of the modeling area, however, the costs of developing and maintaining these models can be substantial, particularly with regard to data preparation, network development, and model calibration.

One of the key factors to be considered in weighing the benefits vs. costs of a dynamic assignment model is the expected level of congestion in the network. This is particularly important if there is interested in studying the effects of congestion-mitigating measures. If congestion can be expected to be low then there is little added value in accounting for it in the model system. This in turn means that detailed representation of congestion in the network assignment is not important. Given that without congestion there is only limited physical connection between the network conditions of different time slices, static network assignment may be fully adequate. If congestion is not expected to be negligible, however, a network assignment method that captures spatio-temporal congestion dynamics may be needed.

An example of the need for a dynamic model is in the examination of the effects of an ITS measure. Since the introduction of this type of measure primarily comes with the intention to provide congestion relief, the network assignment must be able to describe the build-up and dissipation of congestion. Beyond this, the benefits of ITS are strongly dependent on information availability (e.g., who receives the real-time congestion information), technical equipment (who will then follow a recommended path), representation of time (where are travelers at the moment of an incident), and individual traveler characteristics (who is willing and/or capable to at all react to a congestion warning). Apart from time and congestion, a detailed representation of vehicle types, vehicle equipment, and drivers may become necessary. Examples of traffic control measures that fall under the ITS umbrella are traffic responsive signals, dynamic allocation of HOV lanes, and variable speed limits. Vehicle-to-vehicle and vehicle-to-infrastructure communication may also need to be accounted for. These measures require a representation of vehicles and infrastructure at the level of detailed vehicle movements and therefore require a disaggregate representation of network flows.[11]

[11] Evaluation Methods for Calculating Traffic Assignment and Travel Times in Congested Urban Areas with Strategic Transport Models, Institute of Transport Economics, Norwegian Centre for Transport Research, 2014.

# 6.0 Conclusions

Three alternative assignment methods were evaluated for potential future use in ODOT TPAU's transport model's and those of its OMSC partner agencies – static/macroscopic (Method 1), dynamic/macroscopic (Method 2), and dynamic/microscopic or mesoscopic (Method 3). The methods were evaluated using a set of objectives and evaluation criteria defining the desired properties and capabilities of the assignment methods as well as the types of applications the methods can be used for. The evaluation was not intended to rank the methods to identify a "best" method, but rather to to establish a general framework for considering the advantages and disadvantages of the methods.

Overall, Methods 2 and 3 were rated more highly than Method 1. This is primarily related to the more realistic representation of network response to congestion (in terms of delay), the higher level of temporal resolution and, in the case of Method 3, the higher network resolution. The higher rating for Method 3 compared to Method 2 is also largely accounted for by the greater advantages of Method 3 in these areas. Methods 2 and 3 were rated lower than Method 1 for several of the criteria, however, primarily due to their greater complexity.

Several general criteria recommended in the *Traffic Analysis Toolbox Volume I: Traffic Analysis Tools Primer*[12] can be used to guide decision-making about the most appropriate assignment method to use for a particular application or study. These are:

1. Ability to analyze the appropriate geographic scope or study area for the analysis, such as an isolated intersection, single roadway, corridor, or network.
2. Capability of modeling various facility types, such as freeways, HOV lanes, ramps, arterials, toll plazas, etc.
3. Ability to analyze various vehicle types (e.g. autos vs. trucks).

---

[12] Traffic Analysis Toolbox Volume I: Traffic Analysis Tools Primer, FHWA, 2004.

4. Ability to analyze various traffic management strategies and applications, such as ramp metering, signal coordination, incident management, etc.

5. Ability to estimate traveler responses to traffic management strategies, such as route diversion and departure time choice.

6. Ability to directly produce and output performance measures, such as efficiency (throughput and volumes) and mobility (travel times, speeds, and queue lengths).

7. Cost-effectiveness, mainly from a management or operational perspective, including software cost, level of effort required, ease of use, hardware requirements, data requirements, etc.

Specific topics related to each of the assignment methods were investigated, as well as several general assignment-related topics. Because it is likely that ODOT and its partner agencies will continue to use static assignment in their models over the next several years, several of the static assignment topics that could be further investigated in the near future are:

- Alternative forms of VDFs
- Incorporation of node-based delay in VDFs
- Calibration of parameter values of VDFs
- Representation of truck volumes in VDFs
- Generalized cost assignment

As the need for dynamic assignment grows in the future, several of the dynamic assignment topics that could be further investigated are:

- Calibration of DTA and microsimulation models
- Level of network disaggregation
- Level of time resolution

General assignment topics for additional investigation include:

- Development of multi-resolution networks

- Consideration of travel time reliability in assignment
- Contacting other agencies about the assignment methods they are using

# Glossary

**Acyclic network** — A network that does not contain loops or cycles.

**BPR function** — A volume-delay function originally developed by the federal Bureau of Public Roads. It is one of the oldest and widely used volume-delay functions.

**Bush network** — A subnetwork of a larger network rooted at a given origin.

**DTA** — Dynamic traffic assignment

**Fundamental diagram** — A diagram that describes the relationship between traffic flow, density, and speed.

**Generalized cost** — In traffic assignment, the total monetized value of the various factors considered by travelers in route choice.

**Mesoscopic model** — A hybrid of macroscopic and microscopic models.

**Multi-resolution modeling** — The integration of macroscopic, mesoscopic, and microscopic models for the purpose of analyzing transportation projects at different levels of detail by enabling data to be shared across modeling platforms.

**Network flow model** — A component of all traffic assignment models used to define how network links and nodes perform under congested traffic conditions. In static network flow models, the assignment is based on travel times computed using volume-delay functions.

**Node-based delay** — Delay that occurs at intersections due to traffic control and conflicting traffic volumes

**OMSC** — Oregon Modeling Steering Committee

**Route choice model** — A component of all traffic assignment models used to determine the trip-maker's path selection between origin and destination zones.

| | |
|---|---|
| **Traffic equilibrium** | A network state in which travel time on all alternative routes is the same, and route switching would cause an increase in travel time. |
| **Trip end** | In traffic assignment, a trip origin or destination. By definition, every trip has two trip ends. |
| **TSMO** | Transportation Systems Management and Operations |
| **VDF** | Volume delay function. Used in static traffic assignment methods for the estimation of uncongested and congested travel times. |
| **Vertical queue** | A traffic queue represented as a queue without any physical length. |
| **VOT** | Value of time |

# Appendix A

Assignment Method Evaluation Results

**Table A-1 – Assignment Method Evaluation Results**

| Assignment Method Objectives and Evaluation Criteria | **Method 1** Static, Macro | **Method 2** Dynamic, Macro | **Method 3** Dynamic, Micro/Meso | Notes |
|---|---|---|---|---|
| | | | | |
| **I. Desired Properties and Capabilities** | | | | |
| | | | | |
| **A. General Properties and Capabilities** | | | | |
| | | | | |
| Objective 1: Accurate estimation of link traffic flows | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) Accurate estimation of link traffic flows by vehicle class, facility type, and V/C level | Low | Medium | High | 1. In general, the main determinant of assignment accuracy is the accuracy of the demand matrix, not the assignment method used.<br>2. Accurate estimation of traffic flows is more difficult with congested networks. Method 1 performs more poorly in this case than Methods 2 or 3.<br>3. While capacity is an input for the Methods 1 and 2, it is an output of Method 3; i.e., maximum flow rates are calculated based on the physical network characteristics and demand.<br>4. Method 2 does not fully consider the effects of signal timing and opposing traffic flows at intersections, so estimates of link traffic flows are not as accurate as with Method 3. |
| | | | | |
| Objective 2: Reasonable representation of travel times/speeds | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) Reasonable representation of link travel times/speeds by vehicle class, facility type, and V/C level | Low | Medium | Medium | 1. Method 2 produces better estimates of link travel times/speeds than Method 1 because traffic flows are propagated through the network based on the fundamental diagram and shock wave theory. With these, the effects of downstream congestion can be accounted for.<br>2. The same is true for Method 3, which uses a car following model to simulate traffic propagation. With this method, physical link features and traffic flow characteristics determine capacity.<br>3. Method 1 is only a snapshot of traffic flow, with no reflection of dynamic traffic flow. |
| b) Reasonable representation of zone-to-zone travel times by vehicle class and time period | Low | Medium | Medium | See notes for Criterion a) |
| | | | | |
| Objective 3: Reasonable model run times | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) Minimization of run time, assuming a representative network[13] | High | Low | Medium | 1. Methods 2 and 3 are generally both slower than Method 1. |

[13] Roughly 20,000 links and 1,500 zones.

| **Assignment Method Objectives and Evaluation Criteria** | **Method 1** Static, Macro | **Method 2** Dynamic, Macro | **Method 3** Dynamic, Micro/Meso | **Notes** |
|---|---|---|---|---|
| | | | | |
| | | | | |
| Objective 4: Reasonable level of effort for implementation and calibration | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) Minimization of implementation time, assuming a representative network | Medium | Medium | Low | 1. No additional coding time is required for Method 2 compared to Method 1, but coding must be more accurate, so the implementation time is slightly higher.<br>2. Although link coding with Method 3 is similar to Methods 1 and 2, it requires the coding of geometric details and signal timings for intersections, so the time requirement is higher. |
| b) Minimization of calibration time, assuming a representative network | Medium | High | High | 1. Methods 2 and 3 have slightly lower calibration time requirements compared to Method 1, because there is very little to calibrate.<br>2. Speed-density relationships can be calibrated with Methods 2 and 3, but this is not typically done because speed-density data for local modeling areas is difficult to obtain.<br>3. If the network coding is accurate, the speed-density relationships with Methods 2 and 3 generally work well.<br>4. Method 1 takes longer to calibrate because capacities are abstract approximations, which require the adjustment of VDF parameters.<br>5. With Method 3, network capacities are an output, not an input, as with Methods 1 and 2.<br>6. In general, the amount of calibration time varies with level of detail required. |
| | | | | |
| Objective 5: Reasonable input data requirements | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) All data readily available from existing sources (e.g., ODOT or local agencies' files, Google Earth, etc.) | High | High | High | 1. The required input data for each method are available from existing sources. |
| b) Minimization of data collection time for initial implementation of method, assuming a representative network | High | Medium | Low | 1. Method 2 has a higher time requirement than Method 1 because information on intersection green splits is needed.<br>2. Method 3 has a higher time requirement than Method 2 because more intersection data is required, such as geometry, phasing plans, cycle lengths, etc. |
| | | | | |
| Objective 6: Reasonable level of staff skills and staff time required for application and maintenance | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |

| Assignment Method Objectives and Evaluation Criteria | Method 1 Static, Macro | Method 2 Dynamic, Macro | Method 3 Dynamic, Micro/Meso | Notes |
|---|---|---|---|---|
| | | | | |
| a) Method can be applied by entry-level modeling staff (1-2 years of experience)[14] | High | Low | Medium | 1. A higher level of staff experience is required for Method 2, because the user should have some understanding of the fundamental diagram and shock wave theory.<br>2. Method 3 requires less staff experience than Method 2, because there is not as much theory – it is simply the simulation of individual vehicles on the network. |
| b) Minimization of time required for typical application, assuming a representative network[15] | High | High | High | 1. Method 2 generally takes the longest to run, followed by Method 3. The run time requirement for all methods is relatively quick, however, so this is not a major issue. |
| c) Minimization of annual maintenance time requirement, assuming a representative network | High | Medium | Low | 1. Annual maintenance time differences are related to the same factors as the initial implementation time requirements - see comments for Criterion 5.b). |
| | | | | |
| Objective 7: Robust outputs | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) Ability to reflect uncertainty (e.g., natural variability of travel times) | Low | Medium | Medium | 1. Method 2 may be slightly more robust than Method 1 if it contains a probit calculation to reflect travel time variance and varying perceptions of the value of travel time.<br>2. Method 3 is slightly more robust than Method 1 because random seeds can be used to do multiple assignments, with the averaging of results. |
| b) Reasonable marginal impact of input variable values (e.g., value of time) on assignment results | Low | Medium | Medium | 1. Methods 2 and 3 respond more reasonably than Method 1 because V/C ratios cannot exceed 1.0.<br>2. This assumes that reasonable values are used for wave speed, car following parameters, etc. with Methods 2 and 3. |
| | | | | |
| Objective 8: Transparency/understandability of method | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) Ability to intuitively understand assignment method processes | High | Low | Medium | See notes for Criteria 6.a). |
| b) Ability to interpret cause-effect relationships in assignment outputs | High | Low | Low | 1. Interpretation of assignment outputs with Methods 2 and 3 may be more complicated than with Method 1 because of the time dimension and use of "hard" capacities.<br>2. Methods 2 and 3 are more closely linked with real traffic operations cause-effect relationships, which are more complex than the VDFs used with Method 1. |
| | | | | |
| Objective 9: Flexibility and extendibility of method | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) Ability to adapt method to changing future conditions that may | Low | Medium | High | 1. Method 3 is more adaptable than Methods 1 or 2 because of the more detailed network |

[14] Application includes data collection, network coding, assignment method application, and interpretation and reporting of results.
[15] A typical application would be an assignment to reflect minor network modifications.

| Assignment Method Objectives and Evaluation Criteria | Method 1 Static, Macro | Method 2 Dynamic, Macro | Method 3 Dynamic, Micro/Meso | Notes |
|---|---|---|---|---|
| | | | | |
| affect travel behavior or transportation system operations | | | | representation (the higher level of network abstraction with Methods 1 and 2 results in less flexibility).<br>2. Comparison of the methods using this criterion also depends on the nature of changing future conditions. |
| | | | | |
| **B. Specific Properties and Capabilities** | | | | |
| | | | | |
| Objective 1: Convergence of network flows | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) Degree of convergence | High | Medium | Medium | 1. Method 1 achieves the best degree of convergence, because it is based on smooth VDFs.<br>2. With Methods 2 and 3, capacity is the physical capacity of the roadway, with traffic spilling over to adjacent links and time periods if capacity is exceeded. So the degree of convergence isn't as close.<br>3. The degree of convergence with Method 3 is also lower because whole vehicles are required, while with Methods 1 and 2, assignments can be done with fractional vehicles. |
| b) Rate of convergence | Medium | Low | Low | 1. The rate of convergence is slowest with Method 2 if MSA is used for volume balancing between iterations.<br>2. With Method 3, cost proportional balancing can be used if available, which is a faster than MSA. |
| | | | | |
| Objective 2: Compatibility with applicable model form | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) Consistency with applicable model and potential to enhance usefulness of model | Low | Low | High | 1. For activity-based models, Method 3's dynamic skimming can take advantage time-of-day capabilities. This distinction is only meaningful, however, if there are significant levels of congestion in the network. While current congestion levels may be relatively low in the modeling area, future congestion will likely be higher.<br>2. For activity-based models, the heterogeneity of traveler characteristics represented in the trip lists activity-based models is lost with the aggregation of demand with Methods 1 and 2. This can be preserved with Method 3 because trip assignment is agent-based. |
| | | | | |
| Objective 3: Realistic estimation of intersection delay | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) Accuracy of estimated delays by traffic movement | Low | Medium | High | 1. Method 2 produces better estimates of delay than Method 1 because it includes queuing delays. It does not consider opposing traffic volumes, however. |

| Assignment Method Objectives and Evaluation Criteria | **Method 1** Static, Macro | **Method 2** Dynamic, Macro | **Method 3** Dynamic, Micro/Meso | Notes |
|---|---|---|---|---|
| | | | | |
| | | | | 2. Delay estimates are the best with Method 3 because both queuing delays and opposing volumes are reflected. |
| b) Accuracy of estimated delays for all V/C ranges | Low | Medium | High | 1. The accuracy of estimated delays for higher V/C ranges is better with Methods 2 and 3, because there is a cap on capacity. Method 1 does not have cap, so delay estimates for high V/C ratios are not realistic. |
| Objective 4: Multiple levels of output resolution | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) Levels of temporal resolution | Low | Medium | High | 1. Method 1 has no temporal resolution within a given time period (e.g., PM peak hour).<br>2. Varying levels of resolution can be represented with Method 2, depending on the user's preference.<br>3. Method 3 is an agent-based approach with no fixed time intervals, so it has the highest level of resolution. |
| b) Levels of network resolution | Low | Low | High | 1. Methods 1 and 2 have the same level of network resolution.<br>2. Method 3 has more intersection detail, reflecting both geometry and signal timing. |
| | | | | |
| Objective 5: Representation of new technologies (e.g., shared mobility) | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| *(Criterion same as objective)* | Low | Medium | High | See notes for Criterion I.A.9.a). |
| | | | | |
| Objective 6: Representation of traffic operations characteristics (e.g., intersection spillback, queuing, and lane overflows) | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| *(Criterion same as objective)* | Low | Low | High | 1. Method 2 considers spillback, but not finer details, such as signal timing or opposing traffic flows. There is also no accounting of lane-to-lane traffic movements.<br>2. Method 3 performs complete intersection simulation. |
| | | | | |
| Objective 7: Representation of peak spreading | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| *(Criterion same as objective)* | Low | Medium | High | 1. Method 1 is based on fixed demand per time period and individual link capacities.<br>2. Method 2 considers the entire network capacity as a constraint, resulting in peak spreading for |

| Assignment Method Objectives and Evaluation Criteria | Method 1<br>Static,<br>Macro | Method 2<br>Dynamic,<br>Macro | Method 3<br>Dynamic,<br>Micro/Meso | Notes |
|---|---|---|---|---|
| | | | | |
| | | | | high V/C levels.<br>3. User-coded turning movement capacities are not used with Method 3. Capacities are calculated and treated as outputs rather than inputs. |
| | | | | |
| **II. Applications** | | | | |
| | | | | |
| **A. Scenario Testing** | | | | |
| | | | | |
| Objective 1: Road capacity improvements | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) Reasonableness of response to capacity improvements | Low | Medium | Medium | 1. Method 1 can have an exaggerated response to capacity improvements in highly congested networks due to the lack of a cap on capacity, which results in V/C ratios of greater than one and unrealistically high travel times.<br>2. Methods 1 and 2 avoid this problem by having a cap on capacity. |
| b) Ability to reflect effects of small-scale capacity improvements (e.g., addition of intersection turn lanes) | Low | Medium | High | 1. Method 2 reflects the effects of intersection improvements better than Method 1 because it includes queuing delay.<br>2. Method 3 allows the smallest scale improvements to be tested, because the simulation of individual vehicles results in more accurate travel time estimation. |
| c) Ability to represent effects of capacity improvements on both travel time and traffic operations | Low | Medium | High | 1. Method 2 reflects the effects of improvements on intersection queuing; Method 1 does not.<br>2. Method 3 provides the most complete representation of travel time and traffic operations through consideration of signal timing, offsets, and coordination. |
| | | | | |
| Objective 2: Road pricing schemes | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) Reasonableness of response to pricing schemes | Medium | Medium | High | 1. Generalized cost can be represented with all of the methods and the value of time is an exogenous input.<br>2. Method 3 can take advantage of information on individual traveler characteristics produced by ABMs and other agent-based travel models, such as income level and vehicle type, which may affect traveler response to different pricing schemes. |
| b) Range of pricing schemes that can be represented | Low | Low | Low | 1. Method 1 can support/generate input toll matrices (to travel demand models), while Methods 2 and 3 cannot.<br>2. Time-varying tolls can be represented with Method 2, but the tolls are fixed - i.e., toll levels do not respond to the level of delay, as with managed lanes. |
| c) Ability to support representation of pricing effects in travel demand model | Low | Medium | Medium | 1. Method 2 can include a departure time choice model, which allows time-varying tolls to be input to the peak spreading component of the travel demand model. |

| Assignment Method Objectives and Evaluation Criteria | Method 1<br>Static,<br>Macro | Method 2<br>Dynamic,<br>Macro | Method 3<br>Dynamic,<br>Micro/Meso | Notes |
|---|---|---|---|---|
| | | | | |
| | | | | 2. Method 3 can feed dynamic skims back into travel demand models, unlike Method 2. Therefore, Method 3 is more flexible for time-of-day modeling, which is a component of many ABMs. |
| | | | | |
| Objective 3: TSMO strategies | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) Ability to reflect effects of small-scale TSMO strategies | Low | Medium | High | See comments for Criteria 1.b) |
| b) Ability to represent effects of TSMO strategies on both travel time and traffic operations | Low | Medium | High | See comments for Criteria 1.c) |
| | | | | |
| **B. Planning and Analysis Support** | | | | |
| | | | | |
| Objective 1: GHG reduction and air quality analysis | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) Accuracy of outputs used in GHG reduction/AQ analysis | Low | Medium | Medium | 1. Speed is the primary assignment model output used in GHG reduction/air quality analysis.<br>2. Method 1 doesn't produce real speed estimates, but shadow speeds, because they are not based on real capacities.<br>3. Methods 2 and 3 provide better speed estimates than Method 1, but neither method accounts for acceleration or deceleration. |
| b) Number of assignment outputs that can be used for GHG reduction/AQ analysis | Medium | Medium | Medium | Speeds are the primary output available from all methods. |
| | | | | |
| Objective 2: Regional scenario planning | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) Benefit/cost of implementing/applying assignment method for regional scenario planning | Medium | Medium | Low | 1. The main contribution of assignment models for regional scenario planning is peak spreading modeling.<br>2. Peak spreading modeling using Method 2 can be done with the same network coding as for Method 1.<br>3. Method 3 requires more coding time if intersections are involved, so it is probably not worth the effort for regional scenario planning. |
| | | | | |
| Objective 3: Performance measure calculation | | | | |
| | | | | |
| *Criteria:* | | | | |

| **Assignment Method Objectives and Evaluation Criteria** | **Method 1** Static, Macro | **Method 2** Dynamic, Macro | **Method 3** Dynamic, Micro/Meso | **Notes** |
|---|---|---|---|---|
| | | | | |
| | | | | |
| a) Ability to produce performance measure outputs for large, medium, and small-scale improvements | Low | Low | Medium | 1. The range of improvements is slightly larger for Method 2 than Method 1.<br>2. Improvements such as signal coordination can be better tested with Method 3. |
| | | | | |
| Objective 4: Objective: Project selection | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) Ability to support project selection | Low | Medium | High | 1. A more complete representation of project impacts is possible with Methods 2 and 3 compared to Method 1, allowing for better project evaluation. An example of this is reflecting the effects of intersection improvements on upstream locations, which cannot be done with Method 1.<br>2. More accurate speed/travel time and queuing estimates are possible with Methods 2 and 3 than Method 1. |
| | | | | |
| Objective 5: Subarea planning | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) Minimization of effort to implement/apply method for subarea planning | Medium | Medium | Low | |
| b) Ability to reflect both capacity and operational effects of improvements for subarea planning | Low | Medium | High | |
| c) Ability to reflect effects of large, medium, and small-scale improvements for subarea planning | Low | Medium | High | |
| | | | | |
| Objective 6: Policy analysis (e.g., related to TPR) | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) Benefit/cost of implementing/applying assignment method for policy analysis | Medium | Medium | Low | |
| b) Range of policies that can be represented | Medium | Medium | Medium | |
| | | | | |
| Objective 7: Benefit/cost analysis of transportation improvements (large, medium, and small-scale) | | | | |
| | | | | |
| *Criteria:* | | | | |
| | | | | |
| a) Number and accuracy of outputs that can be used for | Low | Medium | Medium | 1. The travel time savings (benefits) of improvements related to queuing can be reflected in |

| Assignment Method Objectives and Evaluation Criteria | **Method 1** Static, Macro | **Method 2** Dynamic, Macro | **Method 3** Dynamic, Micro/Meso | Notes |
|---|---|---|---|---|
| | | | | |
| estimating benefits (travel time savings, traffic operations benefits) | | | | Methods 2 and 3, but not Method 1. |
| b) Number and accuracy of outputs that can be used for cost estimation (i.e., travel delay, facility sizing) | Low | Medium | Medium | 1. Facility sizing requires the use of "hard" capacities in assignment, such as with Methods 2 and 3, to reflect queuing storage requirements. |

# Appendix B

Evaluation of Assignment Methods for Southern Oregon ABM

Three assignment methods presented by PTV at training sessions held on December 6-7, 2016 were selected for evaluation by TPAU using a set of criteria corresponding to the assignment method objectives developed by the study working group. The evaluation was done to identify an assignment method to use in TPAU's Southern Oregon Activity-Based Model (SOABM).

The Visum assignment methods presented by PTV fall under two main categories – equilibrium and non-equilibrium. Three types of equilibrium methods were presented in the training session. These are:

- Static assignment
- Macroscopic dynamic assignment
- Simulation-based dynamic assignment

Visum contains three static assignment procedures – link-based Loshe, path-based, and bush (origin)-based LUCE. For the evaluation, the bush-based LUCE procedure was selected for evaluation because it has a faster running time than the other static methods. A variation of this method was included, which estimates delay for both links and nodes, rather than links only. To represent the complete range of methods in the evaluation, the macroscopic dynamic (DUE) method and simulation-based dynamic (SBA) method were also selected.

The same objectives and criteria described in Section 4.1 were used for the evaluation. To rank the alternative methods, a methodology was applied in which raw scores were assigned to each method for each of the criteria. The scores reflect the degree of positive or negative difference between the alternative method and the "base" method, which is the static link-based assignment method with BPR VDFs currently used by TPAU. The differences are expressed numerically on a scale of -10 to +10, with a score of zero representing no difference and scores of -10 or +10 representing the maximum degree of negative or positive difference.

Two sets of weights were applied to the raw scores to calculate weighted total scores for each alternative. Weights for the objectives were developed to establish the relative importance of each objective. Criterion weights were developed to reflect the importance of one criterion vs. another in cases where there was more than one criterion per objective. The sum of the objective weights was 100. The sum of the criterion weights was 10 for each objective. A weighted score for each criterion was calculated as:

Weighted Criterion Score = Raw Criterion Score*Objective Weight*(Criterion Weight/10)

A total weighted score for each alternative was then calculated as the sum of the weighted criterion scores.

A summary of the evaluation results are shown Table B-1 below. Detailed results are shown in Table B-2.

**Table B-1**
**Summary of Assignment Methods Evaluation for Southern Oregon ABM**

| Method | Total Raw Score | | Total Weighted Score | |
|---|---|---|---|---|
| | Score | Rank | Score | Rank |
| | | | | |
| SBA | 76 | 1 | 183 | 1 |
| DUE | 53 | 2 | 129 | 2 |
| Static - Luce w/ node and link-based delay | 21 | 3 | 48 | 3 |
| Static – Luce w/ link-based delay only | 0 | 4 | 0 | 4 |

**Table B-2 – Results of Assignment Method Evaluation for Southern Oregon ABM**

| Evaluation Criteria | Raw Scores (Relative to BPR method) | | | | Weights | | Weighted Scores | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | LUCE | Mid-block & node | DUE | SBA | Objective Weights | Criterion Weights | LUCE | Mid-block & node | DUE | SBA |
| **Answer** | **0** | **21** | **53** | **76** | **100** | | **0** | **48** | **129** | **183** |
| | | | | | | | | | | |
| **I. Desired Properties and Capabilities** | | | | | | | | | | |
| | | | | | | | | | | |
| **A. General Properties and Capabilities** | | | | | | | | | | |
| | | | | | | | | | | |
| 1. Objective: Accurate estimation of link traffic flows | | | | | 4.13436693 | | | | | |
| | | | | | | | | | | |
| *Criteria:* | | | | | | | | | | |
| | | | | | | | | | | |
| a) Accurate estimation of link traffic flows by vehicle class, facility type, and V/C level | 0 | 1 | 2 | 4 | | 10 | 0 | 4 | 8 | 17 |
| 2. Objective: Reasonable representation of travel times/speeds | | | | | 6.45994832 | | | | | |
| | | | | | | | | | | |
| *Criteria:* | | | | | | | | | | |
| | | | | | | | | | | |
| a) Reasonable representation of link travel times/speeds by vehicle class, facility type, and V/C level | 0 | 2 | 4 | 4 | | 8 | 0 | 10 | 21 | 21 |
| b) Reasonable representation of zone-to-zone travel times by vehicle class and time period | 0 | 2 | 4 | 4 | | 2 | 0 | 3 | 5 | 5 |
| 3. Objective: Reasonable model run times | | | | | 1.80878553 | | | | | |
| | | | | | | | | | | |
| *Criteria:* | | | | | | | | | | |
| | | | | | | | | | | |
| a) Run time for SOABM network[1] | 0 | -1 | -5 | -3 | | 10 | 0 | -2 | -9 | -5 |
| 4. Objective: Reasonable level of effort for implementation and calibration | | | | | 5.29715762 | | | | | |
| | | | | | | | | | | |
| *Criteria:* | | | | | | | | | | |
| | | | | | | | | | | |
| a) Implementation time for SOABM network | 0 | -2 | -4 | -6 | | 5 | 0 | -5 | -11 | -16 |
| b) Calibration time for SOABM network | 0 | 1 | 1 | 1 | | 5 | 0 | 3 | 3 | 3 |
| 5. Objective: Reasonable input data requirements | | | | | 5.94315245 | | | | | |
| | | | | | | | | | | |
| *Criteria:* | | | | | | | | | | |
| | | | | | | | | | | |
| a) All data readily available from existing sources (e.g., ODOT or local jurisdictions' files, Google Earth, etc.) | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |

| Evaluation Criteria | Raw Scores (Relative to BPR method) | | | | Weights | | Weighted Scores | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | LUCE | Mid-block & node | DUE | SBA | Objective Weights | Criterion Weights | LUCE | Mid-block & node | DUE | SBA |
| b) Data collection time for initial implementation of method for SOABM network | 0 | -2 | -5 | -8 | | 10 | 0 | -12 | -30 | -48 |
| 6. Objective: Reasonable level of staff skills and staff time required for application and maintenance | | | | | 4.65116279 | | | | | |
| | | | | | | | | | | |
| *Criteria:* | | | | | | | | | | |
| | | | | | | | | | | |
| a) Method can be applied by entry-level modeling staff (1-2 years of experience)[2] | 0 | -1 | -5 | -3 | | 6 | 0 | -3 | -14 | -8 |
| b) Time requirement for typical application of SOABM[3] | 0 | 0 | -1 | -1 | | 3 | 0 | 0 | -1 | -1 |
| c) Annual maintenance time requirement for SOABM network | 0 | -1 | -2 | -5 | | 1 | 0 | 0 | -1 | -2 |
| 7. Objective: Robust outputs | | | | | 3.61757106 | | | | | |
| | | | | | | | | | | |
| *Criteria:* | | | | | | | | | | |
| | | | | | | | | | | |
| a) Ability to reflect uncertainty (e.g., natural variability of travel times) | 0 | 0 | 1 | 1 | | 4 | 0 | 0 | 1 | 1 |
| b) Reasonable marginal impact of input variable values (e.g., value of time) on assignment results | 0 | 0 | 2 | 2 | | 6 | 0 | 0 | 4 | 4 |
| 8. Objective: Transparency/understandability of method | | | | | 2.97157623 | | | | | |
| | | | | | | | | | | |
| *Criteria:* | | | | | | | | | | |
| | | | | | | | | | | |
| a) Ability to intuitively understand assignment method processes | 0 | 0 | -5 | -3 | | 5 | 0 | 0 | -7 | -4 |
| b) Ability to interpret cause-effect relationships in assignment outputs | 0 | 0 | -3 | -4 | | 5 | 0 | 0 | -4 | -6 |
| 9. Objective: Flexibility and extendibility of method | | | | | 2.3255814 | | | | | |
| | | | | | | | | | | |
| *Criteria:* | | | | | | | | | | |
| | | | | | | | | | | |
| a) Ability to adapt method to changing future conditions that may affect travel behavior or transportation system operations | 0 | 5 | 0 | 3 | | 10 | 0 | 12 | 0 | 7 |
| **B. Specific Properties and Capabilities** | | | | | | | | | | |
| | | | | | | | | | | |
| 1. Objective: Convergence of network flows | | | | | 5.29715762 | | | | | |
| | | | | | | | | | | |
| *Criteria:* | | | | | | | | | | |
| | | | | | | | | | | |
| a) Degree of convergence | 0 | 0 | -3 | -5 | | 10 | 0 | 0 | -16 | -26 |
| b) Rate of convergence | 0 | 0 | -2 | -1 | | 0 | 0 | 0 | 0 | 0 |
| 2. Objective: Compatibility with SOABM model form | | | | | 0.7751938 | | | | | |

| Evaluation Criteria | Raw Scores (Relative to BPR method) | | | | Weights | | Weighted Scores | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | LUCE | Mid-block & node | DUE | SBA | Objective Weights | Criterion Weights | LUCE | Mid-block & node | DUE | SBA |
| | | | | | | | | | | |
| *Criteria:* | | | | | | | | | | |
| | | | | | | | | | | |
| a) Consistency with SOABM and potential to enhance usefulness of model | 0 | 0 | 0 | 0 | | 10 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | |
| 3. Objective: Realistic estimation of intersection delay | | | | | 4.65116279 | | | | | |
| | | | | | | | | | | |
| *Criteria:* | | | | | | | | | | |
| | | | | | | | | | | |
| a) Accuracy of estimated delays by traffic movement | 0 | 2 | 3 | 6 | | 5 | 0 | 5 | 7 | 14 |
| b) Accuracy of estimated delays for all V/C ranges | 0 | 2 | 3 | 6 | | 5 | 0 | 5 | 7 | 14 |
| 4. Objective: Multiple levels of output resolution | | | | | 5.94315245 | | | | | |
| | | | | | | | | | | |
| *Criteria:* | | | | | | | | | | |
| | | | | | | | | | | |
| a) Levels of temporal resolution | 0 | 0 | 4 | 7 | | 7 | 0 | 0 | 17 | 29 |
| b) Levels of network resolution | 0 | 0 | 0 | 2 | | 3 | 0 | 0 | 0 | 4 |
| 5. Objective: Representation of new technologies (e.g., shared mobility) – see Objective I.A.9 | N/A | N/A | N/A | N/A | | | | | | |
| 6. Objective: Representation of traffic operations characteristics (e.g., intersection spillback, queuing, and lane overflows) | | | | | 3.48837209 | | | | | |
| *Criteria:* | | | | | | | | | | |
| | | | | | | | | | | |
| *(Criterion same as objective)* | 0 | 1 | 2 | 7 | | 10 | 0 | 3 | 7 | 24 |
| 7. Objective: Representation of peak spreading | | | | | 4.65116279 | | | | | |
| | | | | | | | | | | |
| *Criteria:* | | | | | | | | | | |
| | | | | | | | | | | |
| *(Criterion same as objective)* | 0 | 0 | 7 | 9 | | 10 | 0 | 0 | 33 | 42 |
| **II. Applications** | | | | | | | | | | |
| | | | | | | | | | | |
| **A. Testing of:** | | | | | | | | | | |
| | | | | | | | | | | |
| 1. Objective: Road capacity improvements | | | | | 6.45994832 | | | | | |
| | | | | | | | | | | |
| *Criteria:* | | | | | | | | | | |
| | | | | | | | | | | |

| Evaluation Criteria | Raw Scores (Relative to BPR method) | | | | Weights | | Weighted Scores | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | LUCE | Mid-block & node | DUE | SBA | Objective Weights | Criterion Weights | LUCE | Mid-block & node | DUE | SBA |
| a) Reasonableness of response to capacity improvements | 0 | 2 | 5 | 6 | | 4 | 0 | 5 | 13 | 16 |
| b) Ability to reflect effects of small-scale capacity improvements (e.g., addition of intersection turn lanes) | 0 | 0 | 5 | 6 | | 3 | 0 | 0 | 10 | 12 |
| c) Ability to represent effects of capacity improvements on both travel time and traffic operations | 0 | 1 | 5 | 7 | | 3 | 0 | 2 | 10 | 14 |
| 2. Objective: Road pricing schemes | | | | | 1.80878553 | | | | | |
| *Criteria:* | | | | | | | | | | |
| a) Reasonableness of response to pricing schemes | 0 | 0 | 0 | 0 | | 4 | 0 | 0 | 0 | 0 |
| b) Range of pricing schemes that can be represented | 0 | 0 | -2 | -2 | | 2 | 0 | 0 | -1 | -1 |
| c) Ability to support representation of pricing effects in travel demand model | 0 | 0 | 5 | 3 | | 4 | 0 | 0 | 4 | 2 |
| 3. Objective: TSMO strategies | | | | | 4.78036176 | | | | | |
| *Criteria:* | | | | | | | | | | |
| a) Ability to reflect effects of small-scale TSMO strategies | 0 | 0 | 5 | 6 | | 5 | 0 | 0 | 12 | 14 |
| b) Ability to represent effects of TSMO strategies on both travel time and traffic operations | 0 | 1 | 5 | 7 | | 5 | 0 | 2 | 12 | 17 |
| **B. Support for:** | | | | | | | | | | |
| 1. Objective: GHG reduction and air quality analysis | | | | | 1.80878553 | | | | | |
| *Criteria:* | | | | | | | | | | |
| a) Accuracy of outputs used in GHG reduction/AQ analysis | 0 | 2 | 2 | 3 | | 6 | 0 | 2 | 2 | 3 |
| b) Number of assignment outputs that can be used for GHG reduction/AQ analysis | 0 | 0 | 0 | 0 | | 4 | 0 | 0 | 0 | 0 |
| 2. Objective: Regional scenario planning | | | | | 3.61757106 | | | | | |
| *Criteria:* | | | | | | | | | | |
| a) B/C of implementing/applying method for regional scenario planning | 0 | 1 | 2 | -2 | | 10 | 0 | 4 | 7 | -7 |
| 3. Objective: Performance measure calculation | | | | | 4.26356589 | | | | | |
| *Criteria:* | | | | | | | | | | |

| Evaluation Criteria | Raw Scores (Relative to BPR method) | | | | Weights | | Weighted Scores | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | LUCE | Mid-block & node | DUE | SBA | Objective Weights | Criterion Weights | LUCE | Mid-block & node | DUE | SBA |
| a) Ability to produce performance measure outputs for large, medium, and small-scale improvements | 0 | 0 | 1 | 3 | | 10 | 0 | 0 | 4 | 13 |
| 4. Objective: Project selection | | | | | 2.84237726 | | | | | |
| | | | | | | | | | | |
| *Criteria:* | | | | | | | | | | |
| | | | | | | | | | | |
| a) Ability to support project selection | 0 | 1 | 3 | 4 | | 10 | 0 | 3 | 9 | 11 |
| 5. Objective: Subarea planning | | | | | 6.45994832 | | | | | |
| | | | | | | | | | | |
| *Criteria:* | | | | | | | | | | |
| | | | | | | | | | | |
| a) Level of effort to implement/apply method for subarea planning | 0 | 0 | 0 | -3 | | 5 | 0 | 0 | 0 | -10 |
| b) Ability to reflect both capacity and operational effects of improvements for subarea planning | 0 | 1 | 5 | 6 | | 2 | 0 | 1 | 6 | 8 |
| c) Ability to reflect effects of large, medium, and small-scale improvements for subarea planning | 0 | 1 | 5 | 7 | | 3 | 0 | 2 | 10 | 14 |
| 6. Objective: Policy analysis (e.g., related to TPR) | | | | | 4.13436693 | | | | | |
| | | | | | | | | | | |
| *Criteria:* | | | | | | | | | | |
| | | | | | | | | | | |
| a) B/C of implementing/applying method for policy analysis | 0 | 1 | 1 | 0 | | 7 | 0 | 3 | 3 | 0 |
| b) Range of policies that can be represented | 0 | 0 | 2 | 2 | | 3 | 0 | 0 | 2 | 2 |
| 7. Objective: B/C analysis of transportation improvements (large, medium, and small-scale) | | | | | 1.80878553 | | | | | |
| | | | | | | | | | | |
| *Criteria:* | | | | | | | | | | |
| | | | | | | | | | | |
| a) Number and accuracy of outputs that can be used for estimating benefits (travel time savings, traffic operations benefits) | 0 | 0 | 3 | 3 | | 5 | 0 | 0 | 3 | 3 |
| b) Number and accuracy of outputs that can be used for cost estimation (i.e., travel delay, facility sizing) | 0 | 1 | 3 | 3 | | 5 | 0 | 1 | 3 | 3 |
| | **0** | **21** | **53** | **76** | **100** | | **0** | **48** | **129** | **183** |

[1] ~20,000 links, 1,500 zones.

[2] Application includes data collection, network coding, assignment method application, and interpretation and reporting of results.

[3] Typical application would be an assignment to reflect minor network modifications.