

# Traffic Analysis Toolbox Volume XIV: Guidebook on the Utilization of Dynamic Traffic Assignment in Modeling

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# Executive Summary

The use of Dynamic Traffic Assignment (DTA) in transportation modeling is an emerging analysis approach around the world. The benefits of applying DTA in transportation analysis increase with network size and level of congestion. This guidebook presents principles and direction that can be consistently applied when using DTA regardless of application platforms or software packages.

The major benefit of using DTA is the capability of the modeling method to take into account the spatial and temporal effects of congestion in determining route choice, time of departure choice, and mode choice. DTA is suitable for analyses involving incidents, construction zones, Active Transportation and Demand Management (ATDM) strategies, Integrated Corridor Management (ICM) strategies, Intelligent Transportation Systems (ITS), and other operational strategies, as well as capacity increasing strategies.

**The purpose of this guide is to provide practitioners with guidance on how to apply DTA within transportation models. This guide provides a set of proven approaches to model building, calibration, and alternatives analysis.**

The intended audience for this guidebook includes practitioners, program managers, and software developers. The first four chapters will be of primary interest to program managers while the entire guidebook will be useful to practitioners. Software developers should consider this guide when preparing documentation for their modeling software and providing instruction to their customers.

Macroscopic, mesoscopic, and microscopic simulation models can incorporate DTA methods. Multi-resolution modeling (MRM) is discussed in this guidebook as an effective method for linking analysis tools with different resolutions to enhance DTA. Within the MRM framework, results from one model are fed to another in an iterative process so that overall analysis results are improved and consistency between model assumptions is maintained.

This guidebook also discusses the data required to develop, calibrate, validate, and apply a DTA model. The guide provides a systematic process for DTA model error and validity checking, as well as model calibration that is considerate of project objectives and the variability of traffic conditions in the field.

This guidebook consists of two main parts. Part I: DTA Overview (Chapters 1 through 3) provides background on DTA modeling principles and software capabilities. Part II: DTA Applications (Chapters 4 through 9) provides guidance on how to apply DTA within transportation models.



# 1.0 Introduction

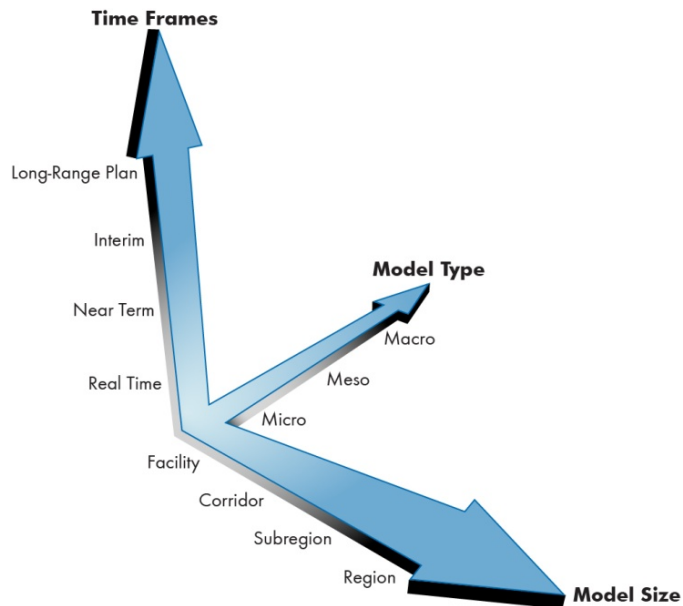
This guidebook on the utilization of Dynamic Traffic Assignment (DTA) complements and enhances other existing guidebooks on traffic modeling by providing guidance on DTA. Since DTA modeling is a new and emerging technique, basic DTA modeling methods and techniques are discussed in this guidebook. This guidebook explains how to approach the development and application of a transportation model with DTA for alternatives analysis.

Dynamic Traffic Assignment is an evolving technique in transportation modeling. As of late 2012 when this Guide was developed, both DTA modeling process and software capabilities are rapidly changing. Thus, this guidebook does not expand into great detail on DTA methods of application due to the evolving nature of DTA. Over time FHWA will expand upon and provide more detailed information on DTA methods and approach.

## 1.1 DTA MODELING CONSIDERATIONS

DTA is a modeling method that can be applied to models of different sizes and resolutions and to different contexts for analysis time frames. These three considerations are shown along different axes in Figure 1.1.

**Figure 1.1 DTA Modeling Considerations**



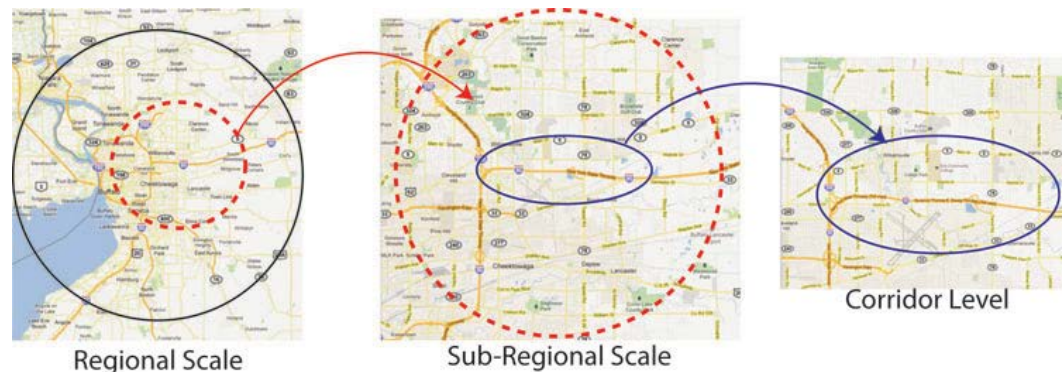
Source: Cambridge Systematics, Inc.

## Model Size

The size of model networks can vary greatly when DTA is applied. Since route choice is a major element of DTA, the size of the model network at a minimum should include alternative routes to allow route choice to occur.

Improving software and computing capabilities are making it possible to apply DTA at different scales. Figure 1.2 is an illustration of how different scales of DTA could be applied.

**Figure 1.2 Model Scales**



Source: Cambridge Systematics, Inc.

## Model Timeframes and Analysis Contexts

DTA can be applied for various time periods and time intervals. DTA also can be applied to near-term and future long-range plans, to fine tune travel demand estimates, and to conduct operational analysis on design improvements.

## Model Resolution

DTA may be incorporated into macroscopic, mesoscopic, and microscopic models.

- **Macroscopic models.** For the purpose of this document, macroscopic models refer to regional travel demand models for both traditional trip-based models and Activity-Based Models (ABM).
- **Mesoscopic models.** These models use aggregated flow relationships and include more precise representation of traffic operations than travel demand models. DTA applications are strongly associated with mesoscopic type modeling software.
- **Microscopic models.** These models simulate individual vehicle-to-vehicle interactions and traffic control strategies. DTA applications in microscopic models provide the most complex analysis of all the model types.

Traffic modeling often involves a combination of some or all of these model types. This concept is referred to as Multi-Resolution Modeling (MRM).

## 1.2 WHEN TO USE DTA?

DTA modeling methods provide the practitioner with extensive capabilities in transportation modeling. The capabilities of changing start times and using alternative route choices based on congestion and other information within the model allow for the testing of a multitude of transportation conditions. Applying DTA methods may require more effort than other static transportation modeling techniques, however; therefore, the need for DTA methods should be considered carefully, taking into account data needs, model building time, and calibration.

Project evaluations for which DTA would be an appropriate tool include the following:

- Bottleneck removal studies;
- Active Transportation and Demand Management (ATDM) strategies;
- Integrated Corridor Management (ICM) strategies;
- Intelligent Transportation Systems (ITS) strategies;
- Operational strategies;
- Demand management strategies;
- Additional capacity;
- Incident management response scenarios;
- Special events;
- Work zone impacts and construction diversion; and
- Managed lanes and tolling projects.

## 1.3 BASIC DTA REQUIREMENTS

The requirements for preparing and applying DTA consist of traffic modeling software capable of handling DTA, adequate and sufficient data for the development and calibration of a model, and the knowledge and skills to apply the tools. The following is a brief overview of the key requirements for applying DTA.

- **Regional Travel Demand Model.** The development of a DTA model requires Origin-Destination (O-D) inputs. Regional travel demand models are based on trips of different purposes with both an origin and destination. Building a DTA model without this type of information is very difficult. Ideally, the travel demand model for a region should be stratified into peak periods or individual hours. Daily regional models (24-hour assignments) are too coarse for a DTA modeling approach that examines congestion and traffic assignments at a time increment of less than 1 hour.

- **Robust Data Collection.** In order to build and calibrate a DTA model, sufficient amounts of data collected in the field should be available so that the variation of traffic and congestion is understood and quantified. The types of temporal-based data to be collected include traffic counts speeds, congestion, and geographic data such as base mapping and lane geometry. Chapter 5 in this guidebook provides a comprehensive discussion of data needs.
- **Transportation Modeling Software with DTA Capability.** The analysis software used must have DTA capabilities. Chapter 3 of this guidebook discusses the DTA capabilities required in traffic modeling software packages.
- **Transportation Modeling Skills.** The application of DTA is another layer on top of existing transportation modeling techniques. Having fundamental knowledge of travel demand modeling and micro/mesoscopic simulation modeling techniques and working knowledge of model calibration and statistical analysis is needed to apply DTA successfully.

## 1.4 PURPOSE OF THIS GUIDE

This guide demonstrates how to successfully apply DTA methods. These methods include recommended approaches to model building, calibration, and alternatives analysis. The intended audiences for this guidebook include the following:

- **Practitioners:** Applying DTA requires skills and knowledge in many types of transportation modeling. An understanding of travel demand models and meso- and microsimulation is required in addition to an understanding of DTA. This guidebook assumes that practitioners have some background in these areas.
- **Program Managers:** The intent of this guidebook is to provide direction on how to apply DTA. Research on the level of effort to apply DTA was not part of this effort; however, a program manager reading this document may gain a better appreciation for the effort that goes into DTA modeling, the types and amount of data that should be collected, and the types of modeling software tools that should be used.
- **Software Developers:** The capabilities of the traffic modeling software are essential. The intent of this guidebook is to help bridge knowledge and methodologies used by practitioners and software developers. Chapter 3 of this guide discusses features that practitioners should look for in a software application.

### Relationship to DTA Primer

A primer and FHWA DTA course that explain the fundamentals and concepts of DTA have previously been developed. The primer, which is a useful precursor to



this guidebook, is available at <http://onlinepubs.trb.org/onlinepubs/circulars/ec153.pdf>. A brief review of the fundamentals of DTA is presented in Chapter 2 of this guide.

## 1.5 ORGANIZATION OF THIS GUIDE

This guide is organized to provide a modeling framework for applying DTA. Chapters 2 and 3 provide background material on DTA modeling and traffic software. Chapters 4 through 9 provide how-to guidance on applying DTA.

- 2.0 **DTA Fundamentals.** The major concepts of DTA are discussed in Chapter 2, including the differences between using Dynamic User Equilibrium (DUE) and “one-shot” non-DUE assignment procedures.
- 3.0 **Modeling Capabilities.** Chapter 3 explains what software capabilities are available and what should be required in a software package if a DTA approach is used.
- 4.0 **DTA Modeling Framework.** Chapter 4 discusses the overall approach to applying DTA. It covers the scoping of a DTA modeling project and provides an overview of each of the steps in the modeling process.
- 5.0 **Data Requirements.** Chapter 5 discusses the data required to develop, calibrate, validate, and apply a DTA model.
- 6.0 **Base Model Development.** Building a base model is similar whether it uses a static or dynamic approach. The major focus of Chapter 6 is on methods for developing O-D inputs.
- 7.0 **Error and Model Validity Checking.** Before a base model can be calibrated or a future model can be used in an analysis, it is important to ensure that the model is free from errors and coding mistakes. In addition to basic error checking, it is important that the DTA model be “stress tested” to ensure the underlying behaviors and responsiveness of the model is adequate for the purposes intended. Chapter 7 provides a number of techniques for conducting these “validity” checks.
- 8.0 **Calibration and Validation.** Calibration is one of the most important model activities. Chapter 8 outlines a systematic process that considers the objectives of the project, statistical measures, and a strategy for adjusting the model to achieve calibration. Chapter 8 also suggests a validation step; whereby, the calibrated model is tested using a different data set.
- 9.0 **Alternatives Analysis.** The purpose of modeling is to test alternatives. With DTA there is a range of treatments and approaches that can be tested. Chapter 9 discusses where DUE and non-DUE testing could occur.

Appendix A provides summaries of several DTA implementations, including analysis objectives, study location, publication name and links to these publications.

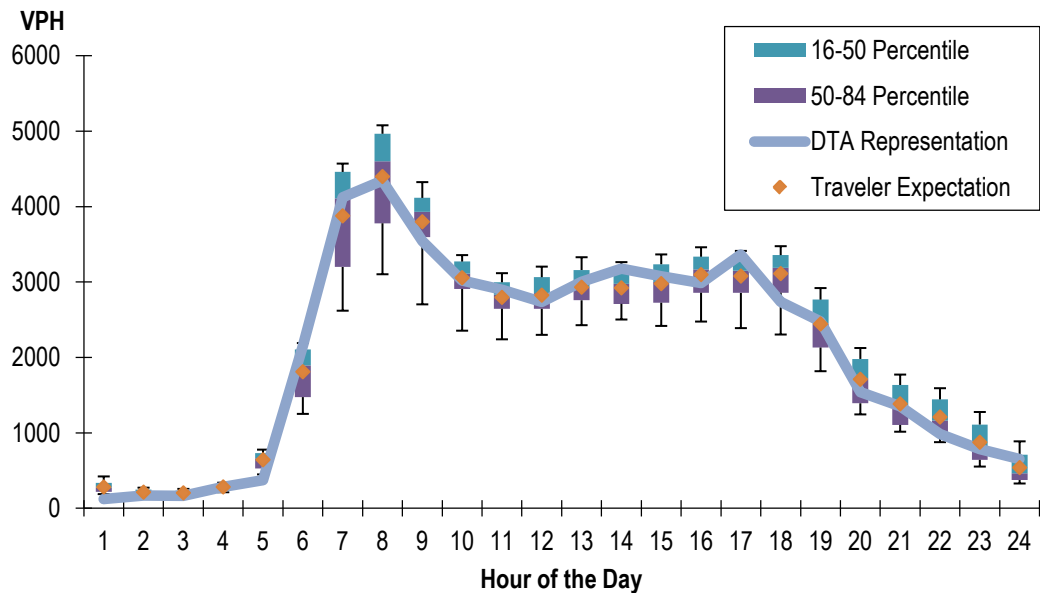
## 2.0 DTA Fundamentals

Dynamic Traffic Assignment (DTA) is a modeling approach that captures the relationship between dynamic route choice behaviors (path and start time) and transportation network characteristics. DTA research in the last four decades consisted of a wide range of traveler behavior assumptions, model formulations, and solution algorithms. This guidebook discusses DTA models from the perspective of equilibrium-based and non-equilibrium-based models, related to the most common and practical transportation modeling and planning applications.

From a traveler behavior standpoint, DTA is a technique that allows for modeling of both long-term traveler adaptation to experienced congestion and modeling of traveler behavior in response to unexpected congestion that occurs within a single day.

A collection of link volume data over multiple days for a freeway location on I-25 outside of Denver, CO is presented in Figure 2.1 to illustrate traffic variability over a 24-hour period. DTA aims to identify and depict the time-varying traffic patterns inherently consistent with actual congestion dynamics, which are characterized by time dependence and variability of traffic data across multiple observations.

**Figure 2.1 Traffic Variability**



Source: University of Arizona.

## 2.1 DTA PRIMER BACKGROUND

The *Primer for Dynamic Traffic Assignment* (Chiu, Bottom, Mahut, et al., 2011), published by Transportation Research Board (TRB), addresses the core concepts necessary for understanding DTA in relation to the static traffic assignment (STA) in terms of “equilibrium.” Equilibrium in DTA is typically based on the premise that the *experienced* travel time for all used routes is the same for travelers *departing at the same time*.

The DTA primer purposely left out other types of DTA models relevant to Wardrop’s principle (e.g., system optimal) or non-equilibrium-based DTA models (e.g., reactive models). Other definitions of DTA models found in the literature depict DTA from the following perspectives.

- Route choice from the traveler’s standpoint;
- Routing policy from the system’s standpoint;
- Different objectives, including user optimal, system optimal, or local optimal;
- Behavior assumptions, including repeated learning, reactive, or decisions based on limited information; and
- Information availability, including no information, pre-trip information, en route information, etc.

Because of the existence of such a diversified body of DTA models with different behavior assumptions and model formulations, the analysis team should avoid applying any models that claim to include DTA without a careful examination of the route choice behavior on which the model is based. It is important to select a DTA modeling approach based on route choice behavior that is most relevant to the problem of interest. The following are some cases that illustrate the types of DTA approaches consistent with the definition used in this guidebook.

### *Case 1. Long-Term Work Zone Impacts*

If the problem is to evaluate the impact to highway capacity caused by a long-term work-zone condition, it is intuitive to assume that over time daily travelers of the highway would be motivated to try different routes. Eventually these daily travelers (after repeated learning) will settle down to a set of optimal routes that best satisfy their travel objectives. This decision process requires an equilibrium-based DTA to properly depict the final individual route choice.

### *Case 2. Emergency Evacuation*

If the problem of interest is to understand what the best possible network performance could be for coordinating all travelers during an emergency evacuation situation, then the System-Optimal DTA model is more appropriate than the User-Optimal type of DTA modeling approach (Peeta 1994; Ziliaskopoulos 2000; Peeta and Ziliaskopoulos 2001; Zheng and Chiu 2010).

System-Optimal-DTA is a widely discussed DTA modeling approach in which the goal of the model is to solve for the assignment policies that lead to optimal system performance as opposed to the optimal performance of an individual. More discussion of evacuation modeling is presented in Chapter 3.

### *Case 3. Traveler Information Systems*

DTA can address the problem of understanding the impact of en route information that allows travelers to regularly receive updated traffic information and reroute as needed. This could include testing of both local and decentralized routing policies (Kuwahara and Akamatsu 1997; Chiu and Mahmassani 2001; Peeta and Ziliaskopoulos 2001; Gao and Chabini 2006).

### *Case 4. Short-Term Incident*

If the problem is to test an unexpected event such as a freeway incident, it is reasonable to assume that travelers will react to increasing congestion and changing traffic dynamics based on their instantaneous judgment as well as information from various channels. To model this some form of a non-equilibrium-based DTA modeling approach would be more appropriate than an equilibrium-based modeling approach. The DTA approach for short-term traveler responses should include en route diversion and information capabilities.

### *Case 5. Short-Term and Long-Term Analysis Capabilities*

Agencies may also be concerned with both the short-term and long-term impacts of a project. For instance, multiple modeling approaches may be needed to model a multi-year freeway construction project. The approach to identifying the correct application is to set clear parameters that highlight the need for both equilibrium and non-equilibrium DTA modeling methods. Ideally these two modeling methods are part of the same modeling software and the user does not have to create different models. The analysis team should also examine the objectives of the project and determine the modeling approach with the route choice behavior that is consistent with the application of interest.

### *Case 6. Capacity Improvement Studies*

DTA can be used to test the effects of capacity improvements such as new lanes. For instance, DTA can be useful in assessing the impacts of a new freeway lane (or lack thereof) to adjacent roadways.

## **2.2 EQUILIBRIUM-BASED DTA APPROACH**

Wardrop's User-Equilibrium principle (Wardrop 1952) as stated below defines the equilibrium condition that many transportation models and algorithms are developed to satisfy.

In a model network with many possible routes for *each O-D pair*, all used routes have equal and lowest *travel time (generalized cost)*. No user may lower their travel time (generalized cost) by unilaterally changing to a different route.

Many models and algorithms were developed in the realm of equilibrium-based DTA since the 1970s (Yager 1971; Merchant and Nemhauser 1978; Merchant and Nemhauser 1978; Ghali and Smith 1992; Mahmassani, Hu, Peeta, et al. 1993; Ben-Akiva 1996; Boyce, Lee and Ran 2001; Florian, Mahut, and Tremblay 2001). Peeta and Ziliaskopoulos (2001) provide a comprehensive review of DTA's history and future perspectives. The following is the commonly agreed-upon dynamic (time-dependent) user equilibrium (TDUE or DUE) condition that is directly related to and extended from the original user equilibrium (UE) condition.

In a network with many O-D zones and in a specific time period, for *each O-D pair and departure time increment*, all used routes have equal and lowest *experienced travel time (generalized cost)* and no user may lower their experienced travel time (generalized cost) through unilateral action.

In DTA the DUE condition applies to each O-D pair and departure time and is relevant to those travelers who travel at the same time period between the same O-D pair. In STA, path travel time is simply the summation of link travel times evaluated using some form of link travel time function. However in the DTA context, link/node travel times are time-varying due to the onset and dissipation of congestion. What travelers care about is the time they would actually experience traversing the chosen path. As such, the experienced travel time for a chosen path needs to consider the time instance at which travelers arrives at each link. Recognizing this time dependence would lead to a path choice that is consistent with the route choice behavior in a congested network (Chiu, Bottom et al. 2011).

## Equilibrium-Based DTA Algorithmic Procedures

The algorithmic procedures of STA and DTA share comparable structures. At their core they include an evaluation of the following:

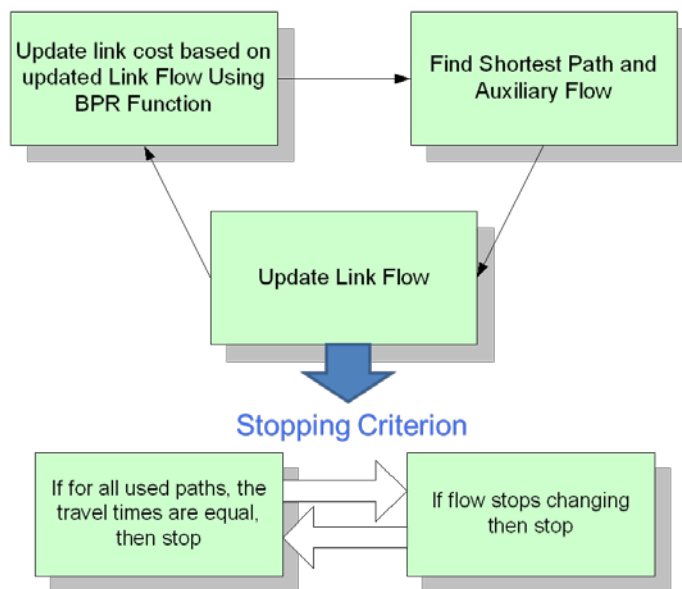
- **Shortest paths.** The purpose of a shortest path algorithm is to search for a new solution in the current iteration using the network traffic data produced by the network loading step. The shortest path in STA is the same across the entire time horizon, and therefore only one shortest path exists per O-D pair. In DTA, travel times vary in time increments and therefore a time-dependent shortest path (TDSP) is calculated for each origin-destination-departure time increment (O-D-T) combination. The distinct feature of TDSP from the traditional SP is that the shortest path search considers the experience travel time of the next searched link based on the arrival time at the previous link

(Gallo and Pallotino 1988; Ziliaskopoulos and Mahmassani 1993; Chabini 1998; Daganzo 2001).

- **Assignment of trips to paths.** In STA, the purpose of this step is to determine, for a given amount of trips travelling between an O-D pair, the assignment of trips to a set of routes such that the resulting travel times for the possible routes are equal. In equilibrium-based DTA this step applies to the O-D-T. Aside from the classic Frank-Wolfe algorithm, some of the modern methods include gradient projection<sup>1</sup> (Florian and Nguyen 1974; Wie, Friesz, and Tobin 1987) and origin-based or bush-based algorithms ((Bar-Gera and Boyce 2003; Dial 2006). The commonly used assignment algorithm for earlier DTA models is the method of successive average (MSA) (Sheffi 1984), but most of the modern methods apply gradient projection-based methods explicitly, aiming to reduce the relative gap.
- **Loading of trips on the assigned paths and evaluation of the resultant traffic conditions.** The purpose of loading trips to the network is to evaluate whether the latest assignment leads to satisfactory convergence or not.

Figures 2.2 and 2.3 show algorithm structures for Static and Dynamic Traffic Assignments, respectively.

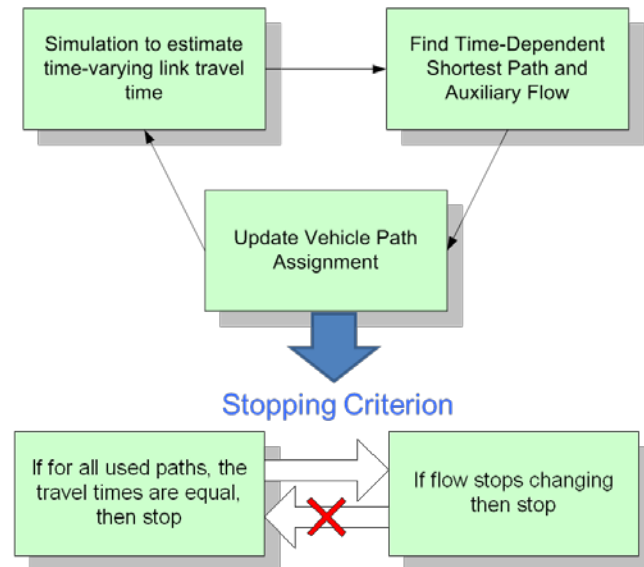
**Figure 2.2 Static Traffic Assignment Algorithmic Structure**



Source: DTA Primer, with permission from UA.

<sup>1</sup> A common step of non-linear optimization solution algorithm.

**Figure 2.3 Dynamic Traffic Assignment Solution Algorithm Framework**

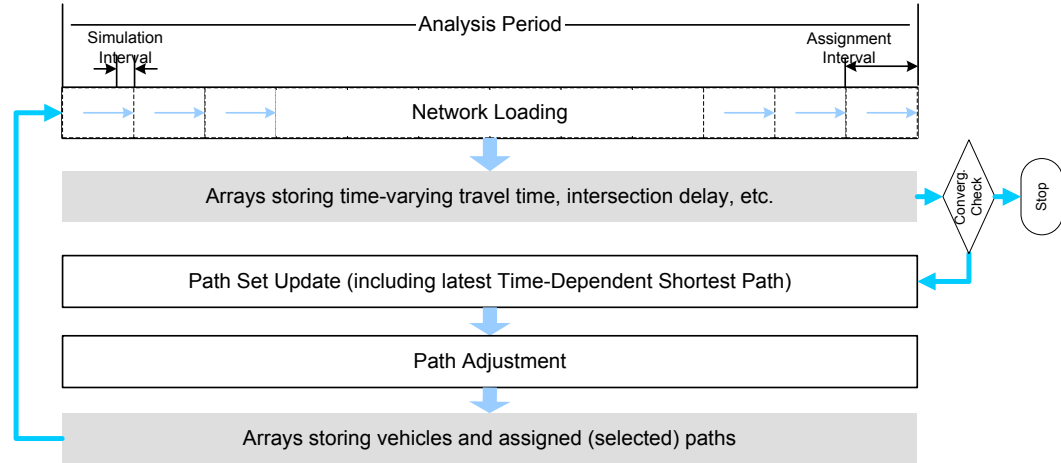


Source: DTA Primer, with permission from UA.

The STA problem is typically formulated as a mathematical programming/variation inequality problem. Due to its convexity in objective function and constraint sets, this problem has one unique optimal assignment solution. When a good assignment algorithm (one that is proven to reach the optimal assignment solution) approaches to UE, the link flow changes diminish; therefore, link flow change is the proxy measure of the UE condition and is often used as the stopping criterion because link flows are easy to measure. One should note, however, that diminishing link flow change is the necessary condition of UE but not the sufficient condition. In other words, an algorithm that is approaching the UE condition will also produce diminishing link flow change, but an algorithm that diminishes the link flow change does not necessarily guarantee to lead to the UE condition.

In DTA, using algorithms that use constantly changing travel times not only means calculating route travel times many times during the modeling period but also anticipating the future travel times of links along a driver's path. In turn, these new travel times are used to determine a vehicle's path. This process is depicted in Figure 2.4. Because travel times may change between the time the vehicle departs and the time the vehicle actually traverses a section of road, it is the "future" travel time that drivers use to assess their path choices. Most sophisticated DTA models operate in this fashion; whereby, route travel times are developed using not a snapshot of link travel times at the beginning of the trip, but instead a string of travel times equal to the sum of the travel times of each link in the route based on the time the vehicle will reach this link.



**Figure 2.4 General DTA Algorithmic Procedure<sup>a</sup>**


Source: DTA Primer, with permission from UA.

<sup>a</sup> Chiu, Bottom et al. 2011.

## Relative Gap

The goal of DUE models is to achieve a satisfactory level of convergence around the equilibrium condition. The measure of convergence used is often the Relative Gap, which compares the current assignment solution to the ideal shortest-route time for all O-D pairs and all departure intervals.

The relative gap is a rather common stopping criterion also used by static traffic assignment models. The typical definition of the total relative gap is as follows:

$$rel_{gap} = \frac{\sum_t \sum_{i \in I} (\sum_{k \in K_i} f_k^t \tau_k^t) - \sum_t \sum_{i \in I} d_i^t u_i^t}{\sum_t \sum_{i \in I} d_i^t u_i^t}$$

Where

$T$  = set of all departure time intervals

$t$  = departure time interval,  $t \in T$

$I$  = set of all origin-destination trip pairs

$i$  = origin-destination trip pair,  $i \in I$

$K_i$  = set of all used routes for origin-destination pair  $i$

$k$  = used route for origin-destination pair  $i$ ,  $k \in K_i$

$f_k^t$  = flow from used route  $k$  at departure time interval  $t$

$\tau_k^t$  = experienced travel time on used route  $k$  at departure time interval  $t$

$d_i^t$  = total flow from origin-destination pair  $i$  at departure time interval  $t$

$u_i^t$  = shortest route travel time from origin-destination pair  $i$  at departure time interval  $t$

The numerator is the *total gap*, which measures how far the current assignment solution is from the ideal shortest route time. Since the travel-time on all used routes will always be greater than or equal to the shortest route, the value of relative gap will never be negative. In most DTA applications, the solution is assumed to have converged to an equilibrium solution when the relative gap is less than a pre-specified tolerance level. Tolerance levels should be specified based on variability observed in field data. For more detailed information on the subject see Chapter 6 of the Guidance on the Level of Effort Required to Conduct Traffic Analysis Using Microsimulation.

Convergence occurs through an iterative process consisting of three sequential steps: Network Loading, Path Set Updating, and Path Assignment Adjusting. At each iteration, vehicles are dynamically loaded onto the network based on the path assignment, and new travel times are recorded. These new travel times are used to calculate the new shortest paths for each O-D pair and departure interval. Then, depending on the algorithm, a percentage of trips between each O-D pair and departure interval is assigned to different paths from those they used on the previous iteration, generally moving from higher cost paths to lower cost paths. The process repeats until the convergence criterion such as Relative Gap is met. Figure 2.4 depicts the general DTA algorithmic procedure.

## Other Stopping Criteria

In addition to Relative Gap as a measure of model convergence, other measures of a model's stability include waiting vehicles at entry locations, gridlock, and stable link flows and travel times. These different criteria are discussed below.

### *Waiting Vehicles*

In a DTA model, vehicles can wait at their loading points if they cannot begin their trip in their assigned departure time. Waiting problems often indicate heavy congestion in the vicinity of the entry links, a network coding error (poor connectivity), or a demand error (surge of demand). Typically, a model run with a high number of waiting vehicles is not a valid one. Such a situation should be avoided because it can significantly complicate the modeling of alternative scenarios.

### *Gridlock*

Gridlock in a DTA model can occur when one or more vehicles cannot move forward because another vehicle is blocking their movement. No useful simulation statistics can be obtained from a gridlocked network because the flow is zero and the travel time is infinity for one or more links. Gridlock can continue indefinitely unless it is possible for one or more drivers to change course and arrive to their destinations though another route. The analysis team should

review the simulation software manual for potential causes of gridlock and potential remedies.

### *Stable Link Flows and Travel Times*

A Relative Gap of zero is probably not achievable in a DTA model due to the stochastic nature of the traffic simulation. The analysis team should be aware of the range in link flow and travel time variations, and adjust the target Relative Gap accordingly. More model convergence iterations are required when link flows or travel times are not stable. Section 7.3 provides more discussion on model convergence.

## **2.3 NON-EQUILIBRIUM DTA APPROACH**

DTA-related terms have been used to describe rather different procedures and concepts that involve assigning a route to a vehicle. One concept is the one-shot simulation approach that regularly updates and assigns routes to newly-generated or en-route vehicles. The route choice mechanism in the non-equilibrium DTA approach reflects the situation in which drivers are reacting to information (including that gained by direct observation) about unexpected traffic conditions or environmental conditions and using this information in conjunction with the knowledge gained by adaptation (day-to-day learning) to experienced traffic conditions.

The non-equilibrium DTA approach is a desirable capability when evaluating unexpected events such as incidents, evacuations, or even the presence of pre-trip or en route real-time information. In the case of an incident, travelers need to assess and react to this particular event that was not considered when the traveler chose his/her initial route. A decision may need to be made as to where, when, and how to choose a different route to mitigate the impact of the event. For example, assigning a driver with an instantaneous shortest path at the time of departure would imply that the driver is accessing real-time information (e.g., TV, web, or smartphone) and chooses the route that is the best at time of departure. With the increasing use adoption of navigation devices and software, a higher percent of the traveling public may be developing this sort of route choice behavior as part of their commute in the future.

In the non-equilibrium DTA modeling approach, each vehicle is assigned an initial route when starting the trip. Different types of routes may be assigned to vehicles and each type corresponds to distinct behavior and information assumptions. These types of routes may include habitual routes, instantaneous shortest paths, and analyst-defined routes. The habitual routes can be supplied from a previously completed DUE model run. Doing so would assume that vehicles select a route based on prior knowledge and experience of the network condition. Instantaneous shortest paths are typically calculated regularly during simulation by using snapshots of the network's traffic state. Such sets of routes are made available for all newly generated vehicles until the next time instance at

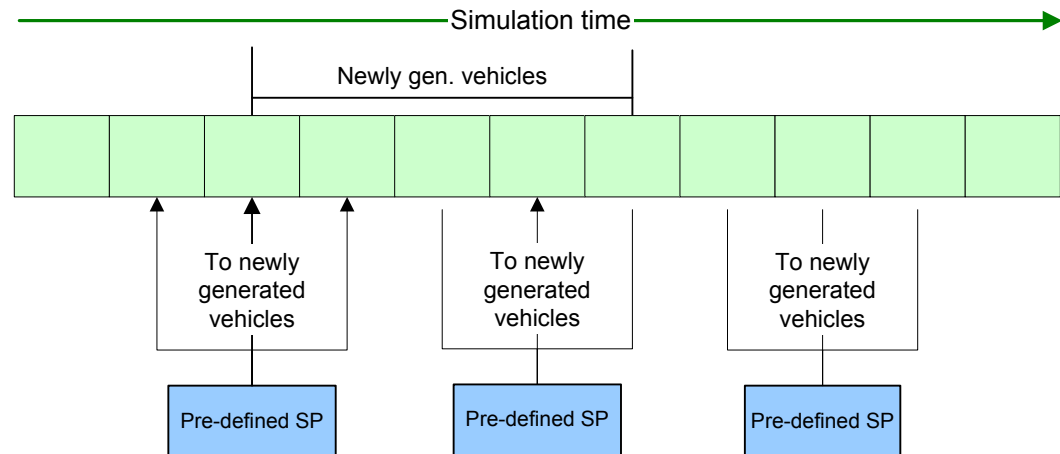
which a new set of shortest path times is calculated. This type of routing can be regarded as the outcome of pre-trip traveler information, where vehicles departing at different times access the best routes known at the departure time. The last type of routing is manually specified by the analyst based on certain objectives and needs.

In non-equilibrium DTA, it is also possible to divert vehicles en route in response to endogenous and/or exogenous stimuli. The endogenous stimuli could be the assessment of the level of deviation of the present route in contrast to the habitual routes. If the perceived delay exceeds a certain threshold, the vehicle may choose to divert to a different route. The exogenous stimuli could be triggered by travel information systems, such as DMS or in-vehicle device (e.g., radio or smartphone), equipped to receive real-time updates. Travelers utilize this information to access travel time for the remaining length of their journey.

### Algorithmic Structure for Non-Equilibrium DTA Approaches

Some documents refer to an approach in which the route set and flows are predefined and remain unchanged throughout the simulation (see Figure 2.5) as static assignment, but the use of “assignment” is different from the concept of the equilibrium-based DTA.

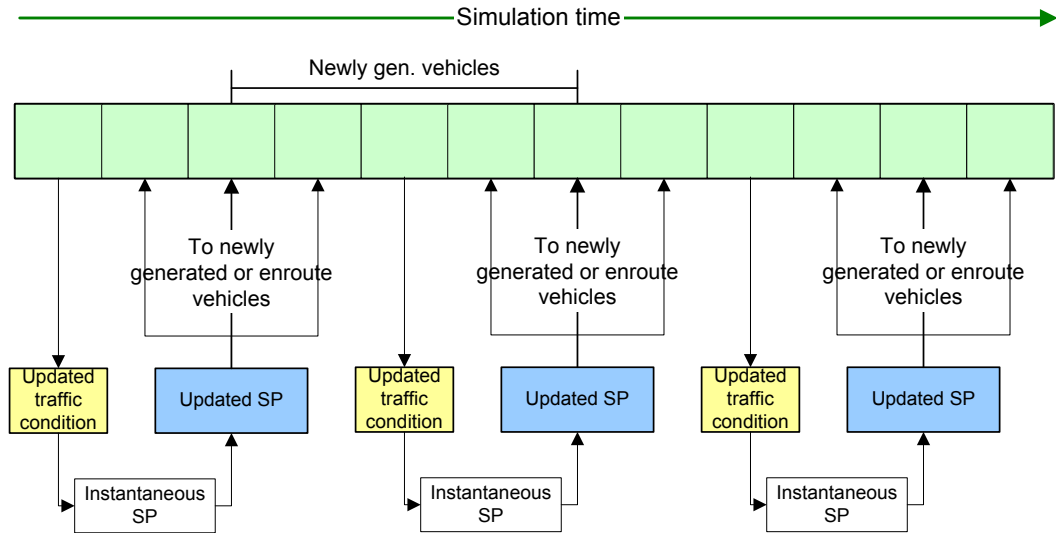
**Figure 2.5 Static Assignment in a One-shot Simulation**



Source: DTA Primer, with permission from UA.

A basic approach to one-shot assignment has shortest routes regularly updated based on prevailing traffic conditions (i.e., instantaneous link travel times) and has these routes “assigned” to newly generated vehicles at the start of the trip. This is sometimes referred to as dynamic assignment (see Figure 2.6), yet it should be recognized as a different notion of assignment from the equilibrium-based DTA methods.

**Figure 2.6 Dynamic Assignment (with Feedback) in a One-shot Simulation**



Source: DTA Primer, with permission from UA.

In a more flexible one-shot method, in addition to applying the above assignment approach for newly generated vehicles, each traveler (or a subset of travelers, called “informed travelers”) reevaluates the current route at each decision node, based on current (instantaneous) link travel times. A decision node is one at which there is at least one feasible route to the destination on two or more of the outgoing links of the node. This approach allows the traveler to divert away from the current route for a better one for the remaining trip, as a result of changes in link travel times since the last route choice was made (at an earlier decision node, or at the origin node). This method is sometimes referred to as one-shot dynamic assignment with feedback, but again, one must distinguish between this method and the notion of assignment defined for the equilibrium-based DTA.

## 2.4 MULTIPLE TRAVELER CLASSES (MTC)

The multiple traveler class DTA model implementation allows stratification of the traveler mix to follow different route choice behavior. In the MTC framework, a certain percent of travelers may choose to follow the DUE route choice principles, whereas others may choose to follow pre-trip or en route information, rendering their route choice “memoryless” and more responsive to unfolding traffic. With the increasing use of smartphones and in-vehicle telematics capabilities, a larger number of tripmakers may be following the routes recommended by navigation systems. In this case, the MTC modeling capability becomes relevant and advantageous as it improves modeling realism, granularity, and flexibility.



## 3.0 Modeling Capabilities

Two main topics are covered in this chapter. The first topic is the network-related capabilities that DTA models may have, and the second is the methodology of Multi-Resolution Modeling and how a DTA model becomes an essential element of the MRM framework.

### 3.1 NETWORK CAPABILITIES

An important aspect of DTA is its ability to capture dynamic interactions between travelers and the network. One significant interaction is vehicle movements at arterial intersections, especially turning movements or lack thereof (i.e., turn prohibitions). Another design-related network capability is restrictions to facilities based on traveler type, such as high-occupancy vehicle (HOV) and HOT lanes and truck restrictions.

The following information on network capabilities is presented in four categories: capacity, traffic control, pricing, and evacuation modeling.

#### Capacity

DTA is designed to model a wide range of scenarios, including temporary capacity changes. Capacity expansion and reduction adjustments can be implemented to represent certain Active Traffic Management (ATM) strategies, such as hard-shoulder running or reversible lane operations. Hard-shoulder running, reversible lane operations, rush-hour truck-lane restrictions, and truck-only lanes on freeways are good examples of freeway capacity changes. These strategies can be implemented using the pricing capability in DTA to restrict certain vehicle classes. Changing arterial capacity in practice is typically implemented through restricting roadside parking or reversible lanes during rush hours.

A DTA model considers the effects of capacity changes in assignment and simulation. To model a traveler's reaction towards an immediate change in capacity reduction one must consider both the reaction to prevailing congestion and the reaction to information describing congestion. The first aspect is based on the premise that a traveler may consider commencing diversion during the journey when, upon arrival at an intersection, his or her current travel time exceeds the historical travel time by a tolerance threshold.

The second aspect is premised on the provision of pre-trip and en-route information. When information indicates that a traveler's current route may be disrupted by an incident, the traveler may consider an alternative route. Depending on the spatial and temporal availability of the information, this rerouting decision can be commenced either at trip origin or mid journey. For

example, pre-trip information provided through the Internet or public access television (TV) may influence a certain percentage of travelers. Conversely, en route information provided by radio, DMS, or smartphone affects travelers' rerouting decision differently depending on temporal and spatial access. Radio or smartphone information only reaches a percentage of the network's travelers, while DMS information is spatially limited, reaching only those who traverse the DMS location.

Modeling route diversion generally follows this principle: the latest information accessed by the user will take the highest priority. For example, at the time of departure, a traveler can decide to reroute or not to reroute; however, at a later time, when traversing a DMS location he or she can engage in another rerouting decision.

In simulation and in real life, changes in capacity can happen in certain situations that are unknown to travelers beforehand, such as incidents. At the location of the incident, the simulation would reduce the number of lanes by a user-defined percentage. For those travelers caught on the link at the time of capacity reduction, the density will increase, thereby altering the speed-density relationship (i.e., density will increase and speed will decrease). Those travelers upstream of the link then experience a shock-wave that propagates backwards. The "choke-point" is located at the upstream location of the capacity reduction link, and the reduced speed occurs upstream of the "choke-point."

DTA provides functionality so that travelers in queue may find an alternative route based on their perceived delay, which is determined by past experience. Those travelers who are informed about the en route or pre-trip conditions of the network may choose an alternative route before entering the capacity reduction location.

Other time-dependent instances that are known to the travelers (e.g., work zones, hard-shoulder running, and reversible-lane operations) may experience something similar to that described above; however, the occurrence is repeated on a daily basis, so adaptation to the known occurrence is possible via DTA. Once the simulation iteration is complete, time-dependent travel-time information is fed to the shortest path algorithm which then recognizes the increase in travel time due to the occurrence. New shortest paths will be calculated that should avoid the problematic location, thus providing alternative routes bypassing the location. This has an effect on the surrounding area by increasing volume and travel times on alternative routes. Over many iterations, DTA works to find a new equilibrium based on the new network conditions.

For the case when capacity is increased (such as creation of a new facility, new lane capacity to existing roadways, temporary capacity increase during rush hour (hard-shoulder running or reversible-lane operations)), in the assignment procedure, the shortest path will recognize the improvement of travel time, and in turn, the traffic assignment will assign travelers to those facilities. If the



capacity is time-dependent, the DTA will determine the appropriate departure-time intervals that will most benefit from the increased capacity.

## **Traffic Control**

Typically, traffic control devices traffic signals, ramp meters, etc. assign right-of-way at intersections and junctions, and as a result these controls introduce delays. Traffic control devices on the roadway act as time-dependent capacity reductions and expansions. Typically, traffic control devices and strategies modeled in DTA are pretimed and actuated signals, yield signs, stop signs, and ramp metering. Coordination of pre-timed and actuated signals and ramp metering also can be modeled in DTA.

### *Signal Control*

Like the signal controllers in the field, a DTA model can have cycle lengths, phasing, splits, and offsets to represent the conditions of the real network. Having this information in place in a DTA model provides a realistic approach to emulating existing conditions. For instance, if a span of pre-timed signals along a roadway is coordinated, the directionality of progression would display the discharge of heavy traffic for a certain direction.

In DTA simulation, the prevailing saturation flow rate, phasing, movements, green-time allocation, and turn capacity play a significant role in experienced delay, which feeds travel-time information for traffic assignment to determine better routes. A DTA model could have different capacity for each major movement (left-turn, through, and right turn). Given the green time and turn capacity, the simulation will determine the discharge flow rate for each turning movement. The simulation also should consider the situation in which permissive left turns (and right turn on red) are allowed, which means the use of critical gap acceptance is considered. Depending on the theory and methodology of the simulation model – whether it be link-based or lane-based simulation – the model should consider the possibility of the congestion and spill-back of turning bays.

### *Ramp Meters*

Ramp metering is modeled by managing the flow rate of the on-ramp by way of a signal control on the ramp roadway. Different DTA models should have the capability of applying different ramp metering strategies from fixed time, to time of day, to adaptive strategies. The objective of adaptive ramp metering is to minimize travel time for a corridor or a freeway segment taking into account for freeway and ramp traffic. In the model, measured traffic flow and/or speed on the freeway mainline lanes, as well as delay and queues at on-ramps are fed into an algorithm to determine the appropriate metering rate.

Unmetered ramps are essentially a no-control situation in which vehicles are not subject to any delay caused by a meter when traversing the node. A fixed-time

ramp meter allows a ramp meter to be turned on during a modeler-specified time window. The metering rate is fixed at a specified level and vehicles traversing that link will be discharged at this given rate. Locally-adaptive ramp meters adjust the metering rate according to the traffic conditions of the mainline immediately downstream of the metered ramp. A user will specify a minimum and maximum rate, and the metering rate is adjusted within this range. Corridor-adaptive ramp meters group multiple consecutive ramp meters to operate as a coordinated ramp group. During the onset of congestion, if the meter alert is triggered for one of the ramps, the group to which this ramp belongs is set to be in the coordination state; otherwise, these meters are operated independently as locally-adaptive meters.

When the meter group is in the coordination state, the metered rates for each member ramp are computed based on the joint assessment of the congestion condition of the main-line encompassed by the meter group. All the ramps in the same group upstream of the bottleneck will start to have their metered rate decreased in order to accomplish the targeted reduced rate, without excessively penalizing the most downstream ramp.

## Pricing

DTA models can be designed to use several types of pricing schemes, namely, fixed, time-of-day, and congestion-responsive pricing. From a route-choice perspective, DTA assumes that HOV/HOT utilization is primarily a route-choice problem, and possibly a departure-time-choice problem in which a traveler could choose to leave earlier or later so as to avoid the higher toll. DTA employs the concept of a generalized cost; the costs are time-varying, including link travel times, intersection delays, lane-specific monetary cost, and facility-based bias factor. The three common types of pricing schemes modeled by DTA include the following:

- **Fixed Pricing.** This pricing scheme is of the simplest form in which a link's generalized cost is set at a constant price.
- **Time-of-Day Pricing.** The time-of-day pricing scheme significantly amplifies the fixed scheme by making the price dependent upon vehicle class and time of travel. Tolls are typically converted to time equivalence by dividing by value-of-time and then added to the travel time to form a generalized cost.
- **Dynamic/Variable Toll Pricing.** In dynamic pricing, the toll price is determined based on current or recent operations in a HOT lane and/or the general purpose lanes. Also, the pricing formula can vary depending on specific operating criteria such as maintaining a minimum speed of 35 mph at the HOT lane.

## Evacuation Modeling

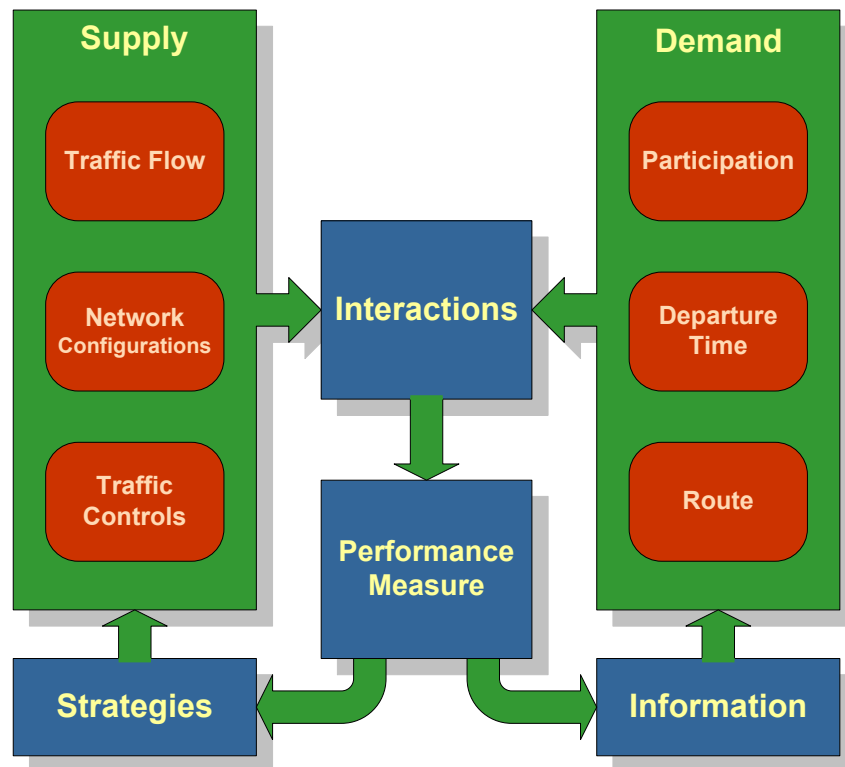
DTA has the ability to capture complex and dynamic interactions between demand and supply during an evacuation event. The total number of evacuees,

the intended evacuation destinations, the departure-time profile, and the chosen routes determine “desires” to request the transportation service. On the supply side the network topology, capacity, configurations, and traffic controls limit the amount of “available service” that can be used by the evacuees.

During an evacuation event, demand is usually much greater than supply, resulting in traffic congestion. Evacuees may change their evacuation decisions prior to or during evacuation in response to traffic management strategies such as evacuation information, contra-flow lanes, etc. Once the decisions are modified the traffic demand on evacuation routes would change, and so would the congestion resulting from the new demand-supply interaction. The system-level outcome of such an interaction, as depicted in Figure 3.1, can be properly captured through a DTA model equipped with pertinent simulation modeling components.

The “information” component is an important element in evacuation modeling. Evacuation-related information provided to evacuees by public or private entities through various information dissemination channels – such as commercial radio stations or highway advisory radios (HAR), TV, web site, or DMS – often affect evacuees’ evacuation decisions prior to or during evacuation. DTA can be applied to model different classes of users who have different levels of information as well as different levels of compliance with indicated routes.

**Figure 3.1 Demand-Supply Interactions for Evacuation Event**



Source: University of Arizona.

The overall evacuation modeling capability can be considered from either a “descriptive” or “prescriptive” perspective.

- **Descriptive capability.** Here the model is used to evaluate the outcome of the demand-supply conditions and evacuation management, as well as information strategies specified by the user. The descriptive capability is suitable for modeling “what-if” scenarios and for testing different strategies.
- **Prescriptive capability.** Here an optimal strategy would be sought to satisfy a specified objective. The search of the optimal strategy is automatically performed by the model through the simulation of the demand-supply interactions as well as a solution algorithm.

## 3.2 MULTI-RESOLUTION MODELING

Existing transportation analysis models share certain features but vary widely in their implementations and data requirements. Every tool type represents a tradeoff between geographic scope and level of resolution (scale versus complexity). Less detailed tool types are tractable for large networks, while more detailed tool types are restricted to smaller networks. Depending on network size and the types of analyses required, all tool types are potentially valuable for transportation analysis.

Microscopic simulation models are effective at analyzing system optimization strategies such as freeway ramp metering and arterial traffic signal coordination. Travel demand models are better at estimating mode shift, but microscopic and mesoscopic simulation models are better at estimating route shifts. Mesoscopic tools can estimate regional dynamic diversion of traffic and congestion pricing, while microscopic tools can estimate route shift at a smaller geographic scale.

Each tool type has different advantages and limitations and is better than other tool types at some analysis capabilities. An integrated approach can support transportation planning, design, and operations by combining the capabilities of these tools. Interfacing between different analysis tool types presents consistency challenges including maintaining the consistency across analytical approaches in the different tools and maintaining the consistency of performance measures used in the different tool types.

Multi-Resolution Modeling (MRM) encompasses tools with different traffic analysis resolutions. Three classes of modeling approaches – macroscopic, mesoscopic, and microscopic – are considered essential components of a general MRM methodology. Overall, the MRM methodology includes macroscopic trip table manipulation for the determination of overall trip patterns, mesoscopic analysis of the impact of driver behavior in reaction to mitigation strategies (both within and between modes), and microscopic analysis of the impact of traffic control strategies at roadway junctions (such as arterial intersections or freeway interchanges).

From a technical stand point MRM is a modeling technique that integrates models with different temporal and spatial resolutions, i.e., macroscopic, mesoscopic and microscopic modeling. The term “temporal resolution” refers to the time interval or frequency at which the dynamic state of the model is updated. “Spatial resolution” refers to the detail of network representations and flow characteristics.

A mesoscopic model’s resolution is typically fractions of a minute from one to ten seconds. The mesoscopic resolution requires more computational effort than the macroscopic model because the system state of the network is updated much more frequently. The resolution of a microscopic model is typically fractions of a second to a second. Again, the computational effort increases relative to the macroscopic and mesoscopic models because of the frequency of the update to the system state of the network.

In addition to the more frequent system state updates, the model flow behavior creates increasing computational time between the model resolutions. Macroscopic models are the least intensive and deal with groups of vehicles. Mesoscopic models are more intensive and deal with groups of vehicles at a more refined lane by lane level. Microscopic models are the most intensive and deal with the interaction between individual vehicles. The spatial resolution (geographic size and network detail) may vary between the model resolutions. Macroscopic models tend to have the larger areas and the coarsest network, including higher functional classification of roadways such as major freeways and arterials. Microscopic models tend to cover a smaller geographic area but with more detail, including minor streets and even driveways. Mesoscopic models’ spatial resolution ranges widely depending on the modeling needs.

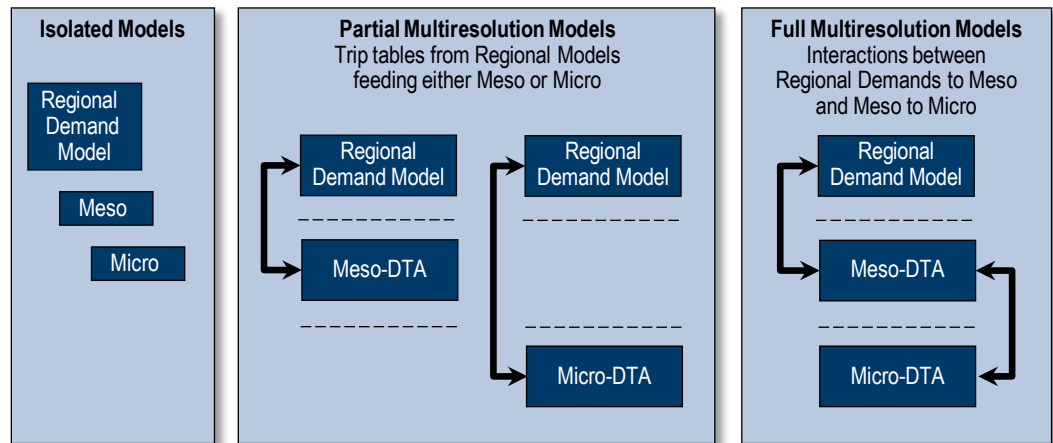
Each of these models serves different purposes, but these models are not mutually exclusive. Rather, these models can be complementary, and MRM aims to take advantage of that fact (<http://cedb.asce.org/cgi/WWWdisplay.cgi?164475>).

The notion of hybrid simulation also exists in literature (Florian, Mahut, and Tremblay 2001; Burghout 2004; Burghout, Koutsopoulos, and Andréasson 2005; Leclercq 2006; Mammam, Lebacque, and Salem-Haj 2006; Shi, Ziliaskopoulos, and Zhang 2006; Yang and Morgan 2006; Wilco Burghout 2007). Hybrid simulation generally refers to on-line or run-time integration of microscopic and mesoscopic simulation models. In a hybrid simulation model, a subarea is typically created that runs with the microscopic simulation logic and rules while the rest of the network runs with mesoscopic traffic simulation rules. In a hybrid simulation process, mesoscopic and microscopic domains are typically pre-defined and vehicles in both regions are simulated concurrently.

The concept of MRM discussed in this document is geared toward mostly the off-line model integration. Concepts and issues discussed below are also applicable to hybrid simulation.

The challenge in applying a MRM modeling framework lies in the consistency and effort requirements of the framework. Figure 3.2 demonstrates the relationship between different modeling resolutions in MRM.

**Figure 3.2 Multi-Resolution Modeling Frameworks**



Source: Cambridge Systematics, Inc.

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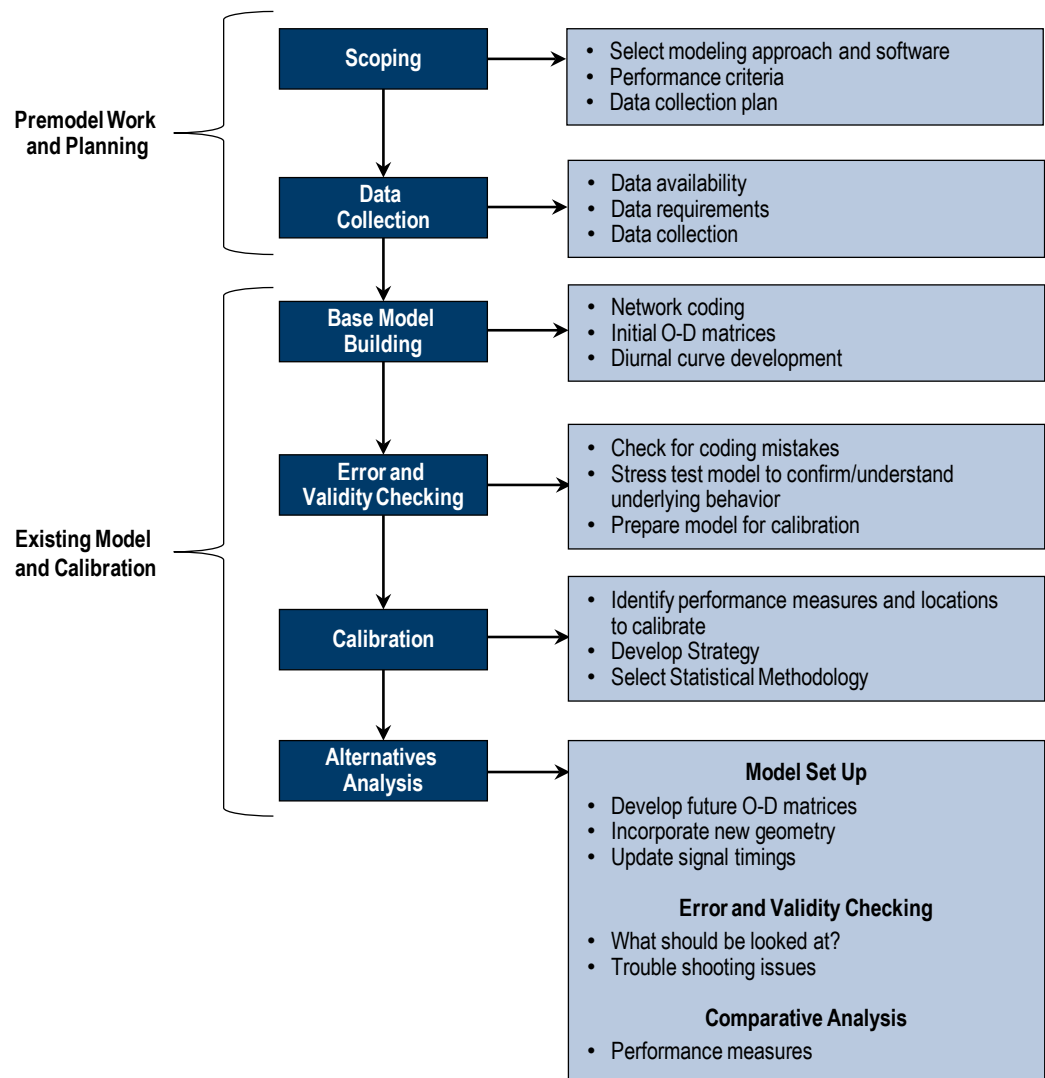


# 4.0 DTA Modeling Framework

## 4.1 DTA MODELING PROCESS

Transportation modeling using DTA should follow the seven-step modeling process that has been defined in Traffic Analysis Toolbox Volume III. This process is a sound modeling workflow and applies to DTA methods very well. Figure 4.1 presents a summary of the modeling work flow starting with scoping and ending with alternatives analysis.

**Figure 4.1 DTA Modeling Process**



Source: Traffic Analysis Toolbox Volume III. Modified by Cambridge Systematics, Inc.

## 4.2 SCOPING

Developing a scope for a DTA modeling project is the first step in the process. The initial stages of developing the scope include identification of the project objectives and identifying stakeholders and their key questions. Based on the project objectives and stakeholder issues the purpose of the model can be clarified by asking: “What questions do we want to answer with this model?”

The model scope includes the selection of the modeling tool, selection of study area, model calibration requirements, data collection plan, and the alternatives to be analyzed. Preparing a Methods and Assumptions Document including a statistical evaluation of existing available data could assist in developing an accurate level of effort for the modeling effort and is highly recommended. Finally, a level of effort and cost for the project is prepared.

### Project and Stakeholder Objectives

Project objectives should be discussed with the stakeholders at the outset of a project. The objectives of a project should be converted into tangible items such as the following:

“We will study the I-62 corridor for three different Transportation System Management (TSM) alternatives. The impact of TSM alternatives will be studied on I-62 from Crossroad “X” to Crossroad “Y.” The impacts studied will include but will not be limited to queuing and weaving conflicts. The effects of TSM on adjacent arterials will be examined within one mile of I-62.”

With this information discussed and documented the appropriate modeling tool and model limits can be determined.

### Model Limits

Setting model boundary limits is necessary for both the geographic area (spatial limits) and time periods (temporal limits) to be analyzed. The limits for a DTA model need to extend beyond the immediate project area and must include enough of the roadway network that travel patterns in and out of the area can be represented realistically. Some of these considerations include the following:

- **Geographic Limits:**
  - Must include the significant alternative routes in the area being studied;
  - Should consider natural barriers such as water crossings to minimize the number of external stations;
  - External stations should be located where field data can be easily used to compare; and
  - The extent of queued and congested vehicles should be contained within the limits of the model.

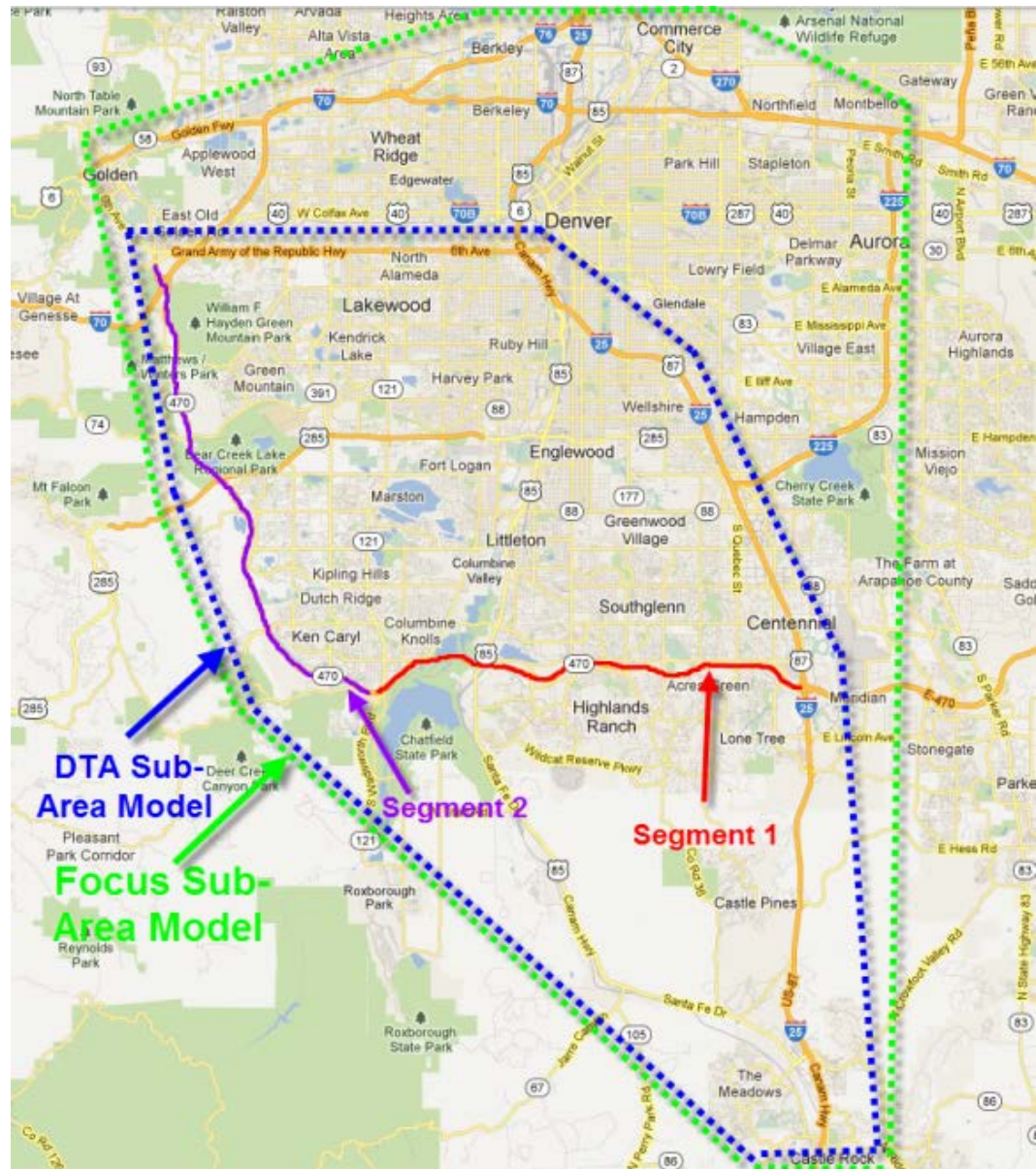
- **Temporal Limits:**
  - Duration of the model should allow for the build-up of congestion (warm up period) and the dissipation of congestion (cool down period); and
  - Time intervals should take into account data availability and the level of analysis detail required to answer the questions in the study.
- **Multi-resolution Modeling Considerations:**
  - If multiple models with different resolutions are used in the same study, each model resolution may have different boundaries;
  - Different model boundaries should be based on hierarchy of the coverage and resolution associated with each model. Generally,
    - Regional demand models cover the largest area;
    - Mesoscopic models would cover a smaller area than the regional demand models; and
    - Microscopic simulation models (most detail) would cover the smallest area.
- Depending on software capabilities and project purposes, some or all of the different model resolutions could have the same model boundaries.

Additional resources for model limit considerations can be found in:

- FHWA Traffic Analysis Toolbox:  
<http://ops.fhwa.dot.gov/trafficanalysisitools/>; and
- FHWA's The Interstate Access Informational Guide:  
<http://www.fhwa.dot.gov/design/interstate/pubs/access/access.pdf>.

Figure 4.2 presents an example of how the geographic model limits can be developed. The project in this example includes the facilities labeled as segments 1 and 2. Based on the need to analyze these facilities, the modeling boundaries are two-fold. First, the regional travel demand model will be “cut” into a focused area sub model, and the focus area will be used to provide origin-destination information that will be fed into a mesoscopic DTA model. The second part is the DTA model that covers a smaller area within the regional focus area model, but one that is still large enough to include the segments that are being studied.

Figure 4.2 Sample Model Limits



Source: Cambridge Systematics, Inc., ©2012 Google.

### Tool Selection

The selection of the appropriate traffic analysis tool can be facilitated by the process discussed in the Traffic Analysis Toolbox Volume II. Volume II presents a detailed approach for determining the type of traffic analysis tool based on a number of criteria. Figure 4.3 presents a summary of the criteria used in tool selection. There is also a spreadsheet tool that accompanies that guidebook ([http://ops.fhwa.dot.gov/trafficanalysistools/tat\\_vol2/index.htm](http://ops.fhwa.dot.gov/trafficanalysistools/tat_vol2/index.htm)).

The selection of DTA methods should be based on the needs of the project and the objectives of the stakeholders. DTA methods are preferred for a project where multiple routes are being modeled and the outcomes that are being tested include traffic diversion related to either congestion and/or ITS type strategies.

**Figure 4.3 Criteria for Selecting a Traffic Analysis Tool Figure**

Analysis Context: Planning, Design, or Operations/Construction						
1	2	3	4	5	6	7
Geographic Scope	Facility Type	Travel Mode	Management Strategy	Traveler Response	Performance Measures	
What is your study area?	Which facility types do you want to include?	Which travel modes do you want to include?	Which management strategies should be analyzed?	Which traveler responses should be analyzed?	What performance measures are needed?	What operational characteristics are necessary?
<ul style="list-style-type: none"> <li>● Isolated Location</li> <li>● Segment</li> <li>● Corridor/ Small Network</li> <li>● Region</li> </ul>	<ul style="list-style-type: none"> <li>● Isolated Intersection</li> <li>● Roundabout</li> <li>● Arterial</li> <li>● Highway</li> <li>● Freeway</li> <li>● HOV Lane</li> <li>● HOV Bypass Lane</li> <li>● Ramp</li> <li>● Auxiliary Lane</li> <li>● Reversible Lane</li> <li>● Truck Lane</li> <li>● Bus Lane</li> <li>● Toll Plaza</li> <li>● Light Rail Line</li> </ul>	<ul style="list-style-type: none"> <li>● SOV</li> <li>● HOV (2, 3, 3+)</li> <li>● Bus</li> <li>● Rail</li> <li>● Truck</li> <li>● Motorcycle</li> <li>● Bicycle</li> <li>● Pedestrian</li> </ul>	<ul style="list-style-type: none"> <li>● Freeway Mgmt</li> <li>● Arterial Intersections</li> <li>● Arterial Mgmt</li> <li>● Incident Mgmt</li> <li>● Emergency Mgmt</li> <li>● Work Zone</li> <li>● Spec Event</li> <li>● APTS</li> <li>● ATIS</li> <li>● Electronic Payment</li> <li>● RRX</li> <li>● CVO</li> <li>● AVCSS</li> <li>● Weather Mgmt</li> <li>● TDM</li> </ul>	<ul style="list-style-type: none"> <li>● Route Diversion                             <ul style="list-style-type: none"> <li>- Pre-Trip</li> <li>- En-Route</li> </ul> </li> <li>● Mode Shift</li> <li>● Departure Time Choice</li> <li>● Destination Change</li> <li>● Induced/Foregone Demand</li> </ul>	<ul style="list-style-type: none"> <li>● LOS</li> <li>● Speed</li> <li>● Travel Time</li> <li>● Volume</li> <li>● Travel Distance</li> <li>● Ridership</li> <li>● AVO</li> <li>● v/c Ratio</li> <li>● Density</li> <li>● VMT/PMT</li> <li>● VHI/PHT</li> <li>● Delay</li> <li>● Queue Length</li> <li>● # Stops</li> <li>● Crashes/Duration</li> <li>● TT Reliability</li> <li>● Emissions/Fuel Consump</li> <li>● Noise</li> <li>● Mode Split</li> <li>● Benefit/Cost</li> </ul>	<ul style="list-style-type: none"> <li>● Tool Capital Cost</li> <li>● Effort (Cost/ Training)</li> <li>● Ease of Use</li> <li>● Popular/Well-Trusted</li> <li>● Hardware Requirements</li> <li>● Data Requirements</li> <li>● Computer Run Time</li> <li>● Post-Processing</li> <li>● Documentation</li> <li>● User Support</li> <li>● Key Parameters User Definable</li> <li>● Default Values</li> <li>● Integration</li> <li>● Animation/Presentation</li> </ul>

Source: FHWA – Traffic Analysis Toolbox Volume II.

### Level of Effort

Based on the analysis tool, model limits, modeling requirements, and data collection needs, a work plan and corresponding level of effort (LOE) should be prepared. This LOE should anticipate the amount of time to be spent on model building and calibration.

Additional guidance on the question, “How much will it take to create a DTA model?” is difficult to provide at this time and within the context of this guidebook. The possibilities of different model boundaries, different model resolutions used in the same project, and the ranges of types of alternatives are too numerous to settle into a generic reference quantitative summary. There are resource documents for quantifying the level of effort for applying travel demand models and microsimulation models. These sources can be found at:

- Travel Demand Modeling Association of Metropolitan Planning Organizations – Advanced Travel Modeling Study, July 2011.
- Rossi et al., “Deciding on Moving to Activity-Based Models (or Not)”, TRB 2009.
- [http://www.tmiponline.org/Clearinghouse/Items/Introduction\\_to\\_Travel\\_Demand\\_Forecasting\\_Self\\_Instructional\\_CD-ROM.aspx](http://www.tmiponline.org/Clearinghouse/Items/Introduction_to_Travel_Demand_Forecasting_Self_Instructional_CD-ROM.aspx).
- Microsimulation Modeling, *Guidance on the Level of Effort Required to Conduct Traffic Analysis Report*, Number HRT-13-026.

There is no similar guidance document for mesoscopic modeling. Mesoscopic modeling is relatively new and a review of the practice and the level of effort required has not been conducted or identified as of yet.

The development of these models represents an investment by the sponsoring agency. The value of this investment should extend beyond the immediate project to include the potential re-use of the model for another phase of the project or a separate project. During the scoping phase flexibility and longevity of the model should be considered.

### 4.3 DATA COLLECTION

Data collection for models using DTA must include data from multiple days. The different days that data are collected should have some similarity between them primarily in terms of travel demand and spatial/temporal travel patterns. Also, if the analysis is to test impacts of an incident or inclement weather, it may be necessary to collect data from days when these occurrences happen.

Combining data from different days into one homogenous data set can cause difficulties in modeling, such as creating unrealistic congestion or not creating congestion where it typically occurs. Data should be collected over multiple days for capturing variability; however, each data day should be kept separate. Data requirements for DTA are covered in Chapter 5.

### 4.4 BASE MODEL BUILDING

Building a sound base model is necessary to create the foundation of the entire modeling process. One goal of base model development is to produce a model that is verifiable, reproducible, and accurate. Base model development tasks and data should be well documented and transparent. There are two components to base model building: supply and demand. The supply side for DTA modeling is similar to that for other types of modeling. Depending on the model type (macro, meso, or micro) the level of detail of representing geometry and traffic control may vary. The primary focus of base model building in this guidebook is the demand-side and the development of origin-destination matrices.

## 4.5 ERROR AND MODEL VALIDITY CHECKING

Checking for mistakes in coding is an essential component of the modeling framework. Errors of omission and transposition of information are common occurrences. Having an independent check of the model inputs is a step that can alleviate wasted effort further into the modeling process. There is no perfect error checking system so a analysis team must always be vigilant about the possibility that errors could still be in the model; however, attempting to render the model mistake free will save time.

Checking for model “validity” is a different activity than error checking, although the validity checking process may be useful in revealing errors as well. The validity checks discussed in this guidebook are a series of stress tests and diagnostic testing steps to help ensure that the models in fact can meet the objectives of the project. Often these stress tests are conducted as part of the model calibration effort. In this guidebook, stress testing is discussed in Chapter 7, and Error and Model Validity Checking in Chapter 8.

## 4.6 MODEL CALIBRATION

Calibration<sup>2</sup> is a process whereby the base model is adjusted to ensure that the model performance measures are realistic and statistically representative of observed field data. Calibration tends to be the area of a modeling that requires some effort to complete. With DTA applications there are more possibilities for route choice, temporal variability, and the complexities of the entire assignment process are introduced into the modeling steps. The calibration process is discussed in detail in Chapter 8, including the following steps:

- Establish calibration objectives and identify the performance measures and critical locations against which the models are to be calibrated.
- Determine the statistical methodology and criteria.
- Determine the strategy for calibration (i.e., which model parameters are going to be adjusted and in what sequence?).
- Conduct model calibration runs following the strategy and conduct statistical checks; when statistical analysis falls within acceptable ranges, the model is calibrated.
- Test or compare the calibrated model with data set not used for calibration. If the model replicates the different data set, the model is validated.

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<sup>2</sup> Often, travel demand modelers refer to this definition of “model calibration” as “model validation.”

## **4.7 ALTERNATIVES ANALYSIS**

The alternatives analysis in a DTA modeling process can vary greatly from analyzing short-term impacts such as an incident to testing long-term impacts such as an added lane. Transportation analysis software with a DTA component should have the ability to perform either type of analysis through a “one-shot” non equilibrium assignment or with an assignment using dynamic user equilibrium.



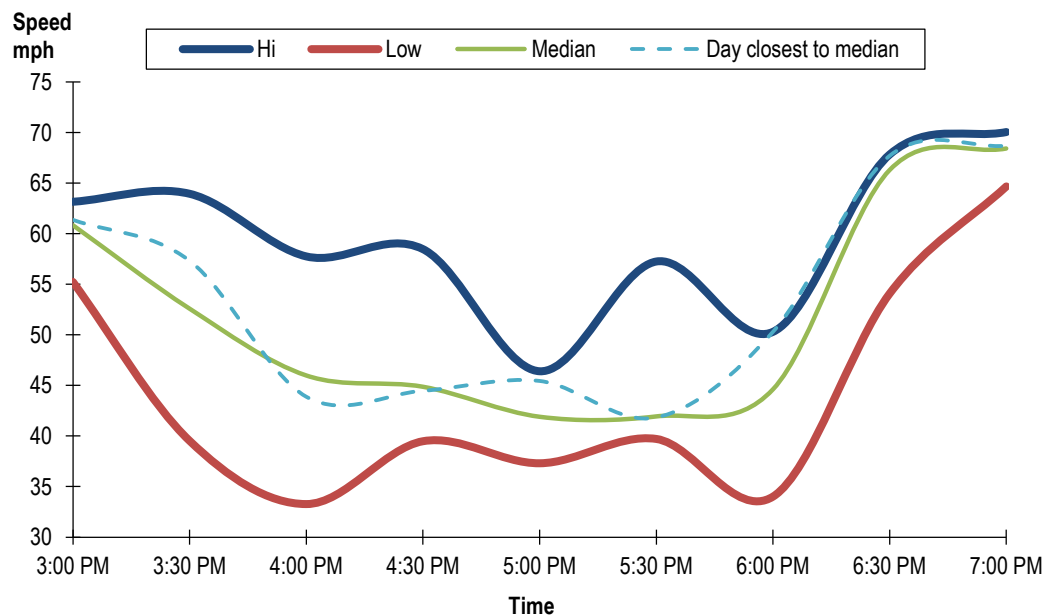
## 5.0 Data Requirements

Data requirements for DTA modeling are similar to data needs for microsimulation modeling. Traffic Analysis Toolbox Volume III<sup>3</sup> is a good resource for data requirements. As described in Volume III, three types of data are required for network development: Geometric Data, Control Data, and Demand Data. Additionally, data are needed for both calibration and validation, including travel times and queue length observations data. For more information on calibration and validation data refer to Chapters 7 and 8 of this document.

Other data considerations in DTA modeling include an increased emphasis on collecting data over multiple days and collecting travel time information over optional routes.

**Collecting data over multiple days.** Data collected over a number of days will help identify variability in the system. Without multiple days of data, there is no meaningful way to evaluate the results of a DTA model. Figure 5.1 illustrates the variability in speed data. (Note: the median values are shown for illustrative purposes and for assisting in identifying a typical day. It is not recommended that averaged data be modeled.)

**Figure 5.1 Variability in Spot Speeds at a Freeway Location**



Source: MNDOT TMC detector surveillance from data extract program.

<sup>3</sup> [http://ops.fhwa.dot.gov/trafficanalysistools/tat\\_vol3/Vol3\\_Guidelines.pdf](http://ops.fhwa.dot.gov/trafficanalysistools/tat_vol3/Vol3_Guidelines.pdf).

**Collecting Travel Time Information.** Collecting travel times via probe vehicle data provides important information for understanding route choice decisions within DTA models. Calibrating the model and ensuring the route choices make sense is at the core of DTA. Field data for possible and likely alternative routes should be collected. Figure 5.2 is an illustration of a corridor where the traveler has three viable routes to the same destination. Travel time data on these three routes can help establish whether model links are congested, which in turn affects the travel time of one or more paths, which in turn affects route choice.

**Figure 5.2 Route Choice Data**



Source: Cambridge Systematics, Inc., ©2012 Google.

## 5.1 DATA FOR NETWORK DEVELOPMENT

### Geometric Data

The transportation network is a major component of any transportation model, and it must be accurately portrayed as it exists in the field. While the exact nature of these data may vary depending on the modeling platform being used, the model must include basic information about the facilities themselves and how they operate. Such data can include roadway geometrics (basic alignment and curvatures), number of lanes, turning bay locations and lengths, lane alignments and turning lane configurations at intersections and interchanges, acceleration and deceleration lanes, lengths of on- and off-ramps, free-flow operating speeds, grades, vehicle specific lane usage (e.g., transit-only or HOV lanes), and other such information.

Other dynamic network elements also may need to be coded into the model, including time-of-day changes to available travel lanes (such as reversible lanes or peak hour parking bans), time-of-day turn bans, or time-of-day lane restrictions (e.g., bus lanes), depending on the time periods the model will be built to simulate.

Several sources are available for the collection of geometric information, as outlined in the remainder of this section. Often, field visits are needed to fill in the gaps in the data from existing sources.

- **GIS Databases.** Existing GIS databases may be leveraged to build the base structure of the network if none exists. While many public agencies have GIS databases of roadway networks maintained to a high level of geographic accuracy, their utility in developing a transportation model network may be an issue, as these databases were not constructed with transportation as a focus. In such non-transportation-oriented GIS databases, roadway segments are often not coded to the beginning and end of an intersection, and sometimes the connectivity is incorrect. In addition, many requisite attributes, such as operating speed or even number of lanes, are not included in such databases. Alternatively, commercial databases may be used to build the basis of the roadway network, and other attributes can be added as needed.
- **Existing Models.** Existing regional Travel Demand Models are a common source for developing the network for a DTA model. These demand models often lack the details required to create a successful DTA model (e.g., “stick” networks without interchange ramp details, missing intersection details, lower classification roadways omitted), however. Also, existing operations models or analyses (either microsimulation models or operational studies) may be used to get details for building the DTA model network.
- **Aerial and Ground-Level Photography.** Whether purchased, acquired from public agencies, or obtained free on-line, aerial photography is a good

resource in developing the network for a DTA model. While varying levels of detail are available in different geographic locations, often imagery is clear enough to see lane-level details that are needed in a DTA model network. Examining the pavement on detailed aerial photography will provide additional information regarding vehicle behavior and typical movements at that location (e.g., uneven wear on paint, oil stain patterns). Ground-level photography is another good resource for quickly taking a “virtual field visit” to verify lanes, turn configurations, signal operations, and roadway signage. When using either aerial or ground-level photography, especially that obtained from free on-line resources, care should be taken regarding the date on which the image was taken versus the date the other data was collected.

### **Control Data**

A required data component that is often difficult to acquire for DTA models is traffic control data. As traffic signals are often the bottleneck points on an arterial roadway, signal plans are essential in properly modeling the arterial. Locations of stop signs and yield signs are also needed. If present, the location of ramp meters also must be determined, along with the details of the metering (e.g., HOV/transit bypass lanes, number of metered lanes, metering rate or algorithm, etc.).

For signal-controlled intersections, the level of detail required varies by model platform, but the full phasing and timing plans are often needed, including any time-of-day changes and actuation details. Incorporating signal coordination is critical to DTA modeling to ensure proper simulation of capacity and travel time on arterial roadways. Finally, any impacts of advanced signal controller technologies (transit signal priority, adaptive signal controls or algorithms) on the operations of the signals should be assessed and incorporated in the DTA model as appropriate.

Data sources to gather control data are often limited to the agency or jurisdiction operating the control devices. Sometimes agencies will have an electronic database of signal control data that can be read and reformatted into the format required by the DTA modeling platform. Often, however, the data will not be in a usable electronic format, and it may need to be manually coded into the model.

Sometimes the data is outdated or missing from any database. Missing control data can be recreated through field observations or local knowledge or synthesized using software. Such software typically examines the functional class of the intersecting roadways and applies a phasing template; it may then use traffic counts or simulated flows to estimate timing splits between the phases. Whether control data are estimated by the analysis team or by using software, the resulting operations of the roadways (including turn capacity, simulated speeds, travel times, and/or queues on the roadways) should be compared to available data and field observations to ensure the realism of the assumed control plans.

## **Demand Data**

For DTA modeling, estimating the demand is of critical importance. This includes estimating not only the origin and destination patterns, but also the temporal distribution of the demand data. One common method for gathering O-D data is to collect point-based volume data and apply an estimate of the origin and destination data from models or surveys.

### *Volumes*

Robust traffic volume data is an essential input to the development of any transportation model. While the fidelity of different types of DTA can affect the fidelity of the volume data needed, the general assumption is that the volume data collected should be as disaggregated as the model outputs to which they will be compared. Usually this threshold is set at the 15-minute level. Using larger time periods of volume data (e.g., peak-period or AADT volumes) is not recommended, as the potential for error is introduced in the development of disaggregation factors. If possible, data also should be collected by vehicle class and by vehicle occupancy, especially if trucks or HOV vehicles have different route choice options, such as truck restrictions or HOV lanes. Ultimately, the project scope and analysis of historical data should be used to determine the temporal resolution for volume data.

Collecting traffic counts over a number of days is an important component as well. In addition to basic counts, it is important to identify a number of qualifiers to the data to allow the impact and influence of inclement weather or incidents to be included. Being aware of the actual conditions in the field for the period when the data were collected is necessary in order to assess the impacts on route choice as modeled by the DTA model.

In addition to the disaggregate nature of the volume data needed, the variability of the volume data must be addressed. Enough data should be collected to show the variability of volume under different circumstances (incident conditions, inclement weather, day-to-day or seasonal demand fluctuations, etc.). This is especially important if the model is expected to be used to help analyze atypical conditions, such as incident scenarios.

Sources for the collection of volume data ideally will include existing permanent count stations or instrumented roadways which allow for the comparison of multiple days of data across multiple points in the network. Such collection allows the comparison of weeks, months, or an entire year of data, and the data can be filtered against days known to have inclement weather, major incident impacts, or unusual demand days, seasonal impacts, or special events. This also allows for the compilation of a single “typical” day’s volume for the model calibration from all count locations.

It is good practice to develop a data collection plan prior to collecting the required data. The plan should include multiple days of data. Determining the number of days for data collection will require statistical analysis of historical

data. Considerations of the actual range in data values and the targeted confidence that is desired for the project should factor into the analysis.

Since it may not be possible to have all the desired data collected at one time for all locations, it may be necessary to synthesize counts into one data set. Consistency between data from different days must be considered.

After the data are collected and assembled, the consistency of the data should be reviewed. Major discrepancies that cannot be explained by queued vehicles on the roadway, or traffic sources and sinks such as connecting roadways, parking lots, or driveways between the count locations, should be identified, then investigated for error and addressed through volume balancing or suspect count exclusion. These discrepancies and the methods utilized to resolve them should be documented.

### *Origin-Destination Data*

O-D data are impossible to observe for an entire population or large study area, and instead must be sampled and estimated. Given the complexities of estimating the O-Ds, the DTA model will usually need to rely on the estimates of the O-D data or subarea analysis using a regional Travel Demand Model for a validated base year. In such cases, the temporal limits must be determined and the appropriate “time-slicing factors” developed to split the peak-period demands into the individual 5-minute or 15-minute periods required by the DTA model. While these factors may be developed from counts, **care should be taken to estimate the true demand by time slice and not the capacity constrained throughput measured by volumes in congested conditions.**

Other data sources for estimating or sampling O-D data may be useful for the calibration of the DTA model. These include random roadside probe vehicle methods (license plate recognition studies, Bluetooth readers, electronic toll collection transponder readers, etc.) Alternative methods include aerial surveillance (usually only practical for smaller areas) or the purchase of such data from wireless phone providers or other commercial vendors.

### *Transit Demand*

Transit demand information can be collected from transit providers. The typical types of information are published bus routes, stops, and time tables. This information can typically be obtained in printed or electronic form from the transit provider. Also required is boarding and alighting information from stops.

## **5.2 DATA FOR MODEL CALIBRATION**

Data required for model calibration include measures of effectiveness that can be quantified in the field and produced from model outputs. This type of data includes the following:

- Travel times;
- Travel speeds;
- Traffic counts (including temporal peaking);
- Lane utilization;
- Probe vehicle data;
- Number of queued vehicles;
- Number of stops;
- Observed congestion locations and extent of congestion; and
- Transit operations.

### 5.3 PREPARING A DATA COLLECTION PLAN

A good practice in conducting any modeling project is the preparation of a Data Collection Plan. The following discussion outlines an approach and work steps in collecting data. Specific steps in the development of the Data Collection Plan include the following:

- **Research and Identify Available Data for the Study Area.** Existing data sources and data requirements should be researched to identify the quantity and quality of available data for the analysis area. The Data Collection Plan also should identify those individuals/stakeholders responsible for compiling the data. The analysis manager should work closely with stakeholders in compiling the data. If possible, the analysis manager should obtain samples of the datasets prior to full collection to view the content and format of the data and adjust collection plans as necessary.
- **Establish Sample Size Requirements.** Information regarding the variability of historic data should be used to establish the maximum sampling error to be tolerated by the analysis.
- **Identify Gaps and Recommend an Approach to Filling Them.** Once available data sources have been investigated and dataset samples reviewed, the analysis manager should assess the appropriateness of the available data for use in the analysis and identify any critical gaps in data availability. Potential approaches to filling data gaps should be investigated and recommended approaches should be documented in the Data Collection Plan.
- **Identify Data Management Strategies.** In this step, procedures for conducting data quality control and project data archiving should be identified. Any required thresholds for minimum data quality should be identified, as should high-level descriptions of processes for addressing data shortcomings. Plans for archiving the data also should be identified. Responsibilities for data quality testing and data archiving should be clearly defined.

- **Develop Data Collection Plan.** The Data Collection Plan is a document that outlines the types of data needed, the sources of available data, and the methods for collecting any additional data. This plan, typically prepared for an agency and stakeholders to approve, should contain budget and schedule estimates.

Once the Data Collection Plan is developed, the required data should be collected in accordance with the plan. Generally, implementing the plan will involve the following activities:

- **Assemble/Collect Data on Physical Infrastructure and Geometrics.** Much of these data are likely to be available in existing models and regional geographic information systems (GIS).
- **Assemble/Collect Existing Traffic Performance Data within the Study Area.**
- **Gather Available Information from Existing Studies.** These studies include those currently underway as well as those that have been recently completed. Example studies include existing conditions analyses, environmental impact studies, and lists of projects and strategies that have been planned or programmed.
- **Conduct Field Reviews within the Study Area.**
- **Collect New Data as Specified in the Data Collection Plan.** All data collected in this effort should be analyzed and archived according to the data management procedures documented in the Data Collection Plan. Any identified problems with data quality or the successful archiving of data should be immediately communicated to the analysis managers.

The Integrated Corridor Management Analysis Modeling and Simulation Guide postulates that 10 to 20 percent of the overall study budget should be allocated to developing the data collection plan and to assembling/collecting data.



## 6.0 Base Model Development

This chapter outlines the process for developing a base year DTA model. It describes steps that go into building the base year model and discusses issues requiring consideration.

There are two main components to base model development:

1. **Supply.** As represented by the transportation network; and
2. **Demand.** As represented by the trips that travel on the network.

### 6.1 DEVELOPMENT OF TRANSPORTATION NETWORK

DTA models are more data-intensive and less error-tolerant than static models. Often the DTA analysis team works with network data that are as detailed as the data required for microsimulation modeling, but cover an entire region instead of a facility. DTA models, like microsimulation models, are sensitive to the physical characteristics of the network and the presence of signal controls. Erroneous data on a single link or signal with high-traffic volume can significantly influence travel patterns on the network. For this reason, the DTA analysis team should create a network that resembles the physical network as closely as possible.

Depending on the simulation component of the DTA traffic software package, the data required for the network may be similar to either a planning model or a microsimulation model. Often, the analysis team starts with the network from the regional planning model and then adds more detail as needed. Alternatively, one can start from scratch by using public or private datasets, which often contain more roadway links compared to a planning network. The advantages and disadvantages of each approach depend on the data available, coverage, quality, and restrictions.

#### Link Characteristics

The most important macroscopic link characteristics of a DTA model are the number of lanes, speed, and capacity. Those can be transferred to a DTA model from the regional demand model depending on the compatibility of the data inputs between the two models. Speeds may be set equal to free flow speeds or the posted speed limits depending on the software package definitions. Special attention should be focused on the link capacities, which in planning models are factored down from the Highway Capacity Manual (HCM) theoretical values to account for vehicle interactions such as weaving and the operation of signals and stop signs.

In contrast, DTA models that use either mesoscopic or microscopic flow models do not use capacity as a direct input. Capacities are an outcome of the vehicle interactions, which are affected by link settings such as free flow speed, saturation flow rates, traffic control, and other driver behavior settings. Capacities in these models, when properly applied, are close to the theoretical values of uninterrupted HCM capacity. (For arterials it is about 1,900 vehicles per hour per lane (vphpl) and for freeways it generally exceeds 2,000 vphpl).

DTA models in mesoscopic and microscopic flow models often have additional link characteristics such as vehicle density, driver response time, and look-ahead parameters for lane changing. These parameters are dictated by the simulation methodology and the capabilities of each software package. In order to calibrate this type of model, these parameters are adjusted to reflect observed operations.

### **Level of Detail**

The model network needs to faithfully resemble the physical roadway network. It is important that all the important intersections and roadway links of the study area are imported to the model. If links and intersections are omitted they should generally belong to a roadway functional class that is at least one level down from the roadway class of the links on which the MOEs are collected. For example, if the flow and speed of arterials are to be investigated, the analysis team should make sure to enter collector streets and all their intersections with the arterials. Local streets that provide access to adjacent properties and do not carry through traffic can be omitted and substituted with zone connectors.

As noted, the planning model is a good starting point, but it may not have the level of network detail that is required for a DTA model. For example, in a planning network the number and placement of intersections on a major arterial does not have an impact on the speed of the arterial. In contrast, if an intersection is omitted from a DTA model, vehicles will travel with the prevailing speed and will not stop or wait for a green light or stop sign. To ensure that modeled travel times are not faster than they should be, all critical intersections meeting the functional classification criteria mentioned above should be entered in the model.

Pocket turn lanes, which are generally omitted from planning models, are another example of network detail that cannot be neglected in a DTA model. If a pocket lane is omitted, turning vehicles will delay through-moving vehicles until they find a sufficient gap in the opposing traffic stream to turn. Intersection movement capacity and the resulting delay influences both the simulation times and the routing decisions and cannot be properly estimated unless turning bays and intersection configuration are entered accurately in the DTA model. Aside from pocket lanes, the analysis team should reconsider links smaller than a vehicle's length, code merge and diverge sections at a junction, and remove centroid connectors connected to intersections and connect them at midblock locations.

Like microsimulation models, some DTA models require the analysis team to explicitly define the lane connectivity at each intersection. Defining the lane connectivity involves determining the movements that use a particular lane (e.g., right turn and through movements for the rightmost lane). Unlike corridor microsimulation models, regional planning models are usually not concerned with intersection geometry and movement capacities.

All simulation-based DTA models, even those that do not allow the user to explicitly define lane connectivity, distinguish between different movement types to calculate delay. Left-turning vehicles facing a signal or opposing traffic may encounter significantly more delay than through or right-turning vehicles. DTA models keep a record of the delay encountered by each vehicle and movement and use this information for path building. This is another difference from the majority of static models, which frequently define delay only at the link level assuming that all movements experience the same delay. When using DTA models that internally define the permissible movements on each lane of an intersection, the analysis team should have an understanding of the internal rules that are applied in the model.

### **Traffic Control Information**

Traffic control information includes information about stop signs, yield signs, lane controls, and traffic signals. Traffic signal data include signal phasing, signal timings, coordination parameters, actuated control settings, and other parameters. Traffic control information can vary from project to project, but it does represent a substantial amount of information that must be accurately entered for the models to operate correctly. Depending on the capabilities of the software, the types of signals a DTA model may simulate include the following:

- Pretimed signals, in which both phase timing and phase sequencing are predefined and do not change during the signal's operation;
- Single-ring actuated signals, in which the phase sequencing and the movements that comprise each phase are predetermined, but the phase timing varies based on vehicle presence during operation;
- Dual-ring actuated signals, in which both the timing of each phase and the movements in operation vary based on conditions on the ground; and
- Dual-ring actuated coordinated signals, in which the timing and sequencing may change as above, but the cycle length remains constant allowing for signal coordination.

Traffic signal data can be found in various data formats, including relational databases, Excel, PDF, and proprietary data formats that signal optimization software use. Due to the differences in the operational and hardware characteristics of the traffic controllers in the field, a single standard format for storing signal data has not been widely adopted. Instead, many agencies have defined their own custom-built format that is often incompatible with the DTA

software and for which a preexisting importer does not exist. As a result, and for a large modeling region involving more than one agency or city, information may come from disparate data sources containing descriptive data that are not easy to associate with the node-link-movement structure of a DTA network.

When signal optimization software have been used to optimize signalized corridors or small areas, the analysis team may be able to use a software importer to transfer the data from the signal optimization file(s) into the DTA model. If the signal optimization software network and DTA network are incompatible with each other, the analysis team will have to develop equivalency protocols before importing signal timing data.

Importing signal data from agency traffic signal controller databases into a DTA model will be difficult if the database format and model input format are not compatible. Creating an equivalency profile or script application to automate the conversion of data is worthwhile if the model includes a large number of intersections.

### **Time-Dependent Network Properties**

DTA models allow for testing the effects of changes that may occur in the course of the modeled period. The types of network properties that can vary by time include the following:

- Traffic signal properties can vary by time of day.
- Network events that can alter the network connectivity or movement characteristics, such as:
  - Incidents;
  - Work zones;
  - Variable speed limits; and
  - Reversible or peak-period HOV lanes.

### **Fidelity**

The types of analyses for which the model will be used determine the level of detail required. A rule of thumb is to code in transportation facilities that are one functional class level below the level of interest for the study. One highway network may be used to represent the entire day, but it may be desirable to have networks for different periods of the day that include varying and or operational strategies, such as reversible lanes or peak-period HOV lanes. Multiple period networks representing the strategies being evaluated can be stored in a single master network file that can be activated and deactivated as needed.

## Availability of Network Data

Digital street files are available from the Census Bureau (TIGER/Line Files), local agencies (e.g., GIS departments), and commercial vendors. Selecting the links for the coded highway network requires the official functional classification of the roadways within the region, the average traffic volumes, street capacities, TAZ boundaries, and a general knowledge of the area. Other sources for network development include the following:

- FHWA National Highway Planning Network;
- Highway Performance Monitoring System (HPMS);
- Freight Analysis Framework Version 3 (FAF3) Highway Network;
- NAVTEQ Data;
- National Transportation Atlas Database; and
- Various state and metropolitan planning organization (MPO) transportation networks.

All of these third-party resources may be useful as starting points for development or update of a model network; however, each source has limitations in terms of cartographic quality, available network attributes, source year and, especially with commercial sources, copyrights, which should be considered when selecting a data source.

Any use and or transfer of data from third-party sources into models will require review and possibly editing to ensure that the data are in fact correct.

## Link Data

Once the initial transportation network has been developed, the analysis team must input the physical and operational characteristics of the links into the model. These include:

- Number of lanes;
- Lane width;
- Link length;
- Grade;
- Curvature;
- Pavement conditions (asphalt, gravel, etc.);
- Sight distance;
- Bus stop locations;
- Crosswalks and other pedestrian facilities;

- Bicycle lanes/paths; and
- Other data.

The specific data to be coded for the links will vary according to the DTA software. Many of these attributes are stored in local jurisdictional databases and can be transferred to the highway network links. In the absence of readily available data, the data can be manually collected in the field.

### **Traffic Operations and Management Data for Links**

Traffic operations and management data for links consist of the following:

- Warning data (incidents, lane drops, exits, etc.);
- Regulatory data (speed limits, variable speed limits, HOVs, high-occupancy tolls (HOT), detours, lane channelization, lane use, etc.);
- Guidance information (dynamic message signs and roadside beacons); and
- Surveillance detectors (type and location).

## **6.2 DEVELOPMENT OF ORIGIN-DESTINATION INFORMATION**

Origin and destination information describes the trip making activity that occurs in a transportation network. Ideally, O-D information for base and future-year analyses would be generated by travel demand models as they are well suited to capture travel desires given varying land use. The overall objective is to provide O-D matrices by vehicle type (e.g., single or high-occupancy vehicle, taxi, and truck) for each time slice during the entire study period that are consistent with ground counts yet sensitive to future-year changes in demand and/or supply.

### **Methods for Developing O-Ds**

The main method for developing information on the spatial pattern of trips within urban areas traditionally has been O-D surveys. When sufficient observations are gathered for statistical reliability, these surveys can be factored up to compute the flows among traffic zones. This information then becomes the basis for the O-D information that is input to the DTA software.

Unfortunately, O-D surveys of a statistically sufficient sample size are expensive and difficult to implement. Traffic data, and in particular, traffic counts are readily available and can be used to synthesize O-D information directly using O-D matrix estimation (ODME) techniques.

Regional travel demand models represent the most comprehensive source of O-D information in that they are calibrated models based on observed data and also have the capability to predict future conditions in a consistent manner.

Travel demand models are designed to capture this trip making information for existing conditions, but more importantly for alternative scenarios including future year conditions. There are two main types of travel demand models that produce O-D information:

1. Four-step models, in which O-D information from conventional trip-based travel demand models is used to produce trip tables; and
2. Activity-/tour-based models, in which O-D information from activity-based models is in the form of trip rosters or trip synthesizers.

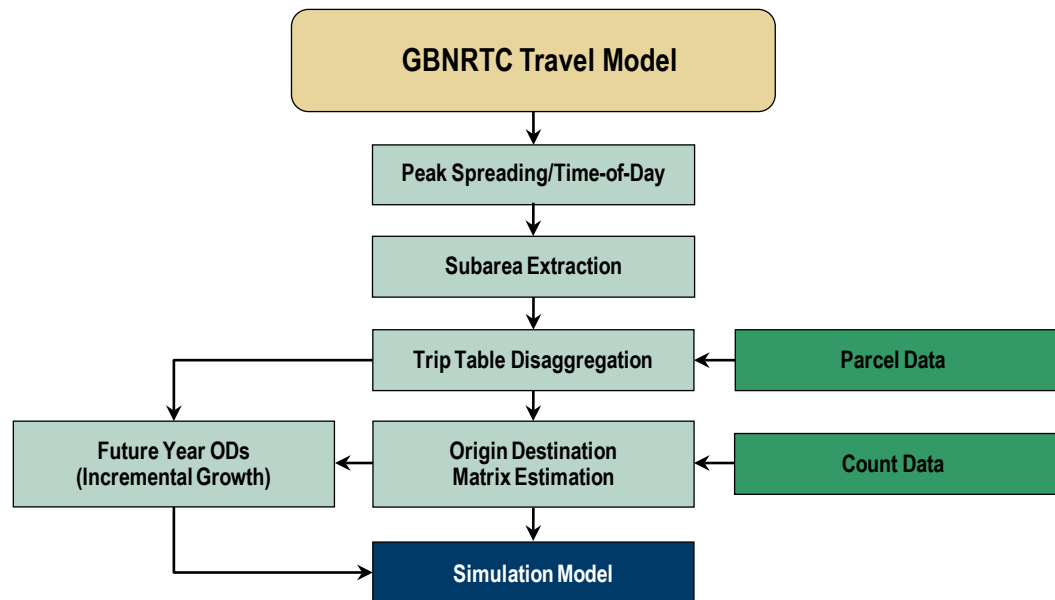
The link between travel demand and simulation models is the O-D information, which can be extracted from the regional model to provide demand inputs to the simulation model. By providing a direct link to the regional model, the O-D information is consistent with the regional travel patterns used by the regional model.

Maintaining a connection to changes in regional supply and demand from the travel demand model. Maintaining this connection with the simulation model ensures that regional travel patterns are reflected in the base and future O-Ds, including the following:

- Distribution of travel demands as reflected by the regional model's destination choice models;
- Mode shares reflective of supply and demand dynamics embedded in the mode choice models within the regional model;
- Incorporation of traffic count data that provide a more realistic representation of the operational characteristics of the existing transportation network;
- Refined models to estimate smaller time increments and to incorporate peak spreading sensitivity; and
- Procedures to pass on the adjusted O-D patterns from the validated base-year matrices to the future O-D matrices.

Figure 6.1 shows an example of the process that was developed for a study in Buffalo, New York. It illustrates the flow of data and highlights the steps and procedures that enable a direct connection between the travel demand model and a simulation model using DTA. The text that follows explains each of these steps.

**Figure 6.1 Example Modeling Process Flow Chart**



Source: Greater Buffalo Niagara Regional Transportation Council.

## Linking Travel Demand Models and DTA

Travel demand models are usually regional in scope as they are primarily used to estimate future conditions over a wide area. Regional models usually have less detailed networks than corridor-level models because the goal of the regional model is to estimate regional travel patterns. The TAZ system that accompanies the regional network also is less detailed and thus not suitable to support detailed traffic analyses. As a result, the O-D matrices that are extracted from the regional model usually cannot be used directly for the DTA model; they need to be disaggregated to a finer level. The granularity is determined by the objective of the transportation analysis.

The starting point is identification of the links within the regional model that represent the extents of the network that will be used for the DTA model. These links form the basis of the subarea model. The base-year subarea model components are then updated to reflect as realistic a representation as possible of the facilities within the subarea corridor. This includes the following:

- Updating the roadway network to ensure accurate representation of the simulated areas, including all ramps and intersections that will be simulated; and,
- Disaggregating the TAZs and the accompanying O-Ds within the simulation model extents to a more refined zonal structure in order to accurately load the traffic.

Figure 6.2 shows an example of a subarea network of the Scajaquada Expressway Corridor in Buffalo, New York (the facilities to be simulated), in the context of

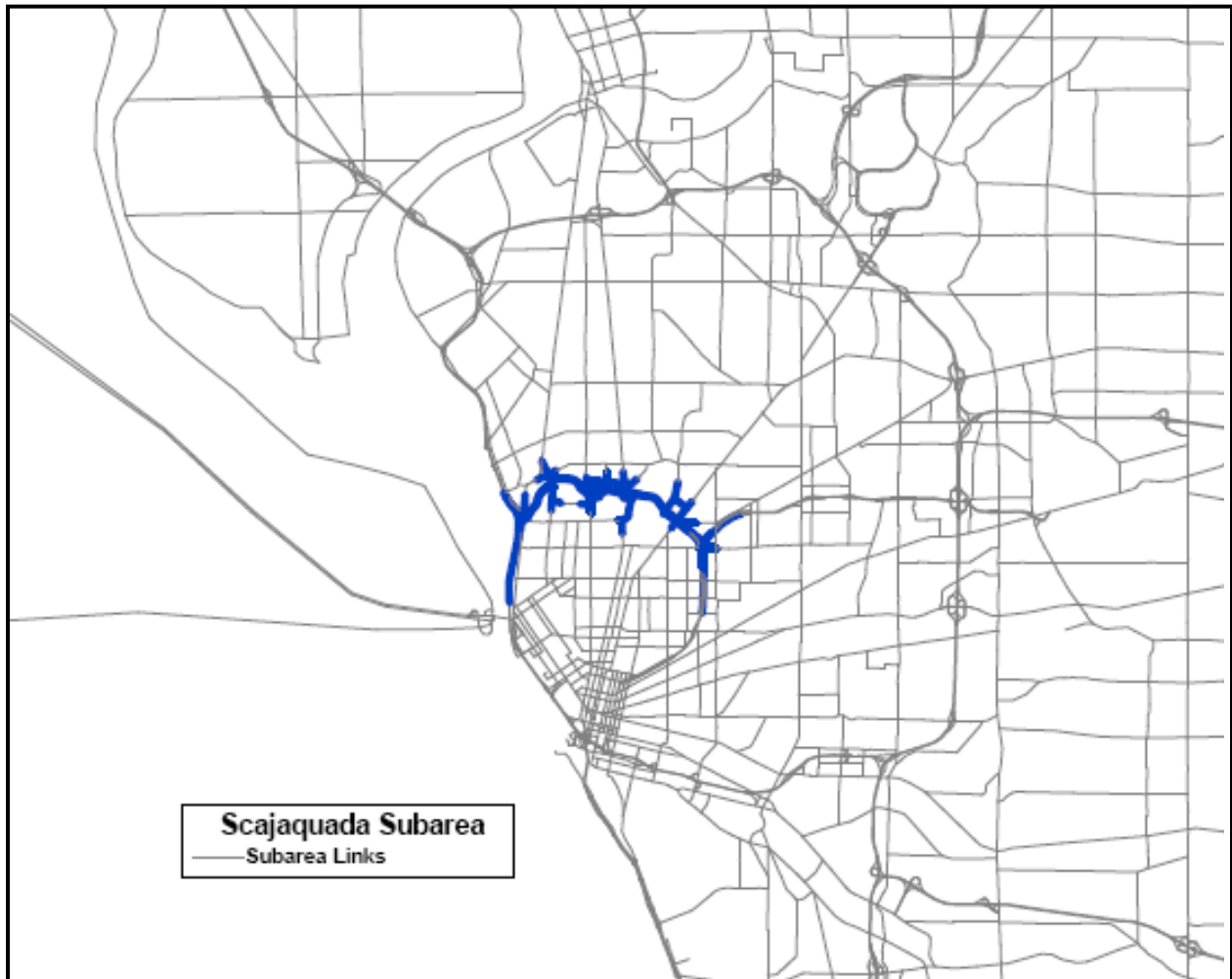


the larger regional model network. Figure 6.3 shows an example of smaller subarea TAZs overlaying the larger regional TAZs in the study area in order to more accurately represent trip generators in the subarea network.

### *Subarea Extraction*

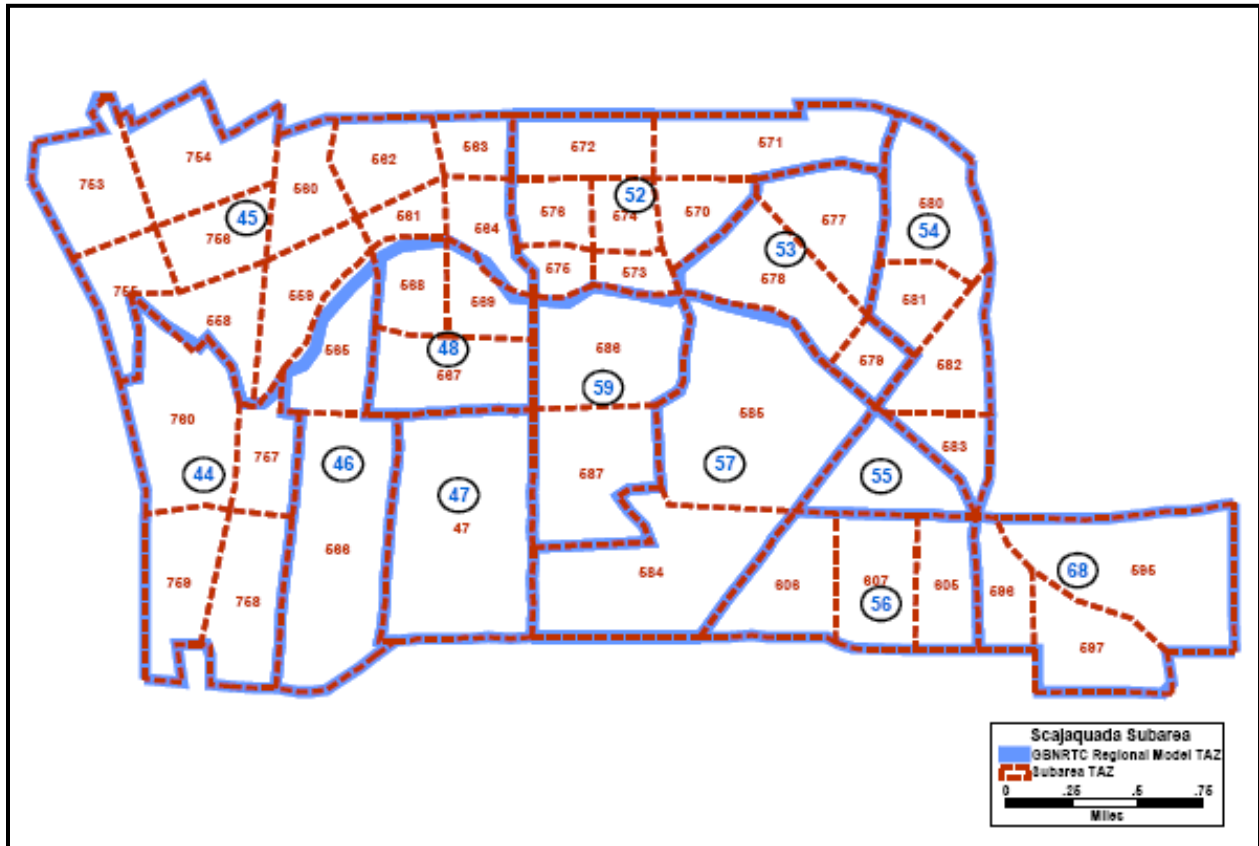
Subarea extraction is a common procedure that is embedded in most planning model software packages that enables the user to extract the network and related trip table as defined by the extents of the subarea into new files. These procedures are performed during the assignment phase and produce O-D trip tables for the subarea for each individual time period. These subarea O -Ds form the basis of the seed matrices for the corridor-level demand calibration.

**Figure 6.2 Example Subarea Network**



Source: Greater Buffalo Niagara Regional Transportation Council.

Figure 6.3 Example Corridor TAZ Disaggregation



Source: Greater Buffalo Niagara Regional Transportation Council.

### *Approaches to Disaggregation*

There are several approaches that can be used to disaggregate trips from larger regional TAZs to the smaller zones. One simple approach is to distribute the trips (origins and destinations) to the smaller subarea zones based on the ratio of the area of the subarea zone to the larger regional zone. This approach does not take into account where the development is located in the regional zone, nor does it consider what kind of development resides in what part of the zone. It should be taken into account that different land uses have sometimes very different trip generation characteristics.

A better approach is to distribute the trips based on the actual land uses within each of the smaller subarea zones. Using parcel data or other land use data that are defined at the local level, estimates of trip making activity at each of the subarea zones can be made by applying trip rates to the land use from sources such as the Institute of Transportation Engineers (ITE) Trip Generation Manual or by applying the trip rates developed for the regional model. These estimates of trip activity can then be used to redistribute the regional zone-based trips.

The updated disaggregated subarea zonal layer then becomes the TAZ layer for the regional model. New centroids and centroid connectors are added to the network to provide access to/from the new subarea zones and the regional model is rerun with the updated inputs.

### *Time of Day and Peak Spreading Models*

Most traditional regional travel demand models are calibrated and validated to large time periods and are estimated by applying regional factors to every O-D pair based on observations from a travel survey or from observed traffic data. These same regional factors are usually applied to future-year forecasts as well. This approach assumes that the temporal distribution of trips is constant by geography and by time, regardless of the location and temporal extents of congestion. DTA not only requires much smaller time increments in order to simulate traffic operations accurately, but also the level of trip making in any particular time slice is sensitive to the level of congestion at that particular time. Travel demand models employ static methods of assignment and allow traffic volumes to exceed capacity; therefore, it is highly desirable that the method selected for slicing up the O-D information into smaller time intervals is one that considers the level of congestion in the system.

Many of the more sophisticated activity/tour-based models are sensitive to differing levels of congestion and do provide trip (or tour) departure information at smaller time increments. As more agencies develop these types of models, the linkages between the demand-side and the operational models will become more commonplace.

In the absence of sophisticated time-of-day models, there are other methods based on empirical data that can be applied. One such method relies on the fact that there may be a different temporal distribution for every O-D pair that is related to the level of congestion between that O-D pair. For O-D pairs that experience little or no congestion, no peak spreading will occur. For O-D pairs that experience high congestion levels, significant peak spreading will occur and will continue to occur as congestion increases over time. In other words, the level of temporal redistribution is sensitive to changes in demand over time or in response to changes in network supply.

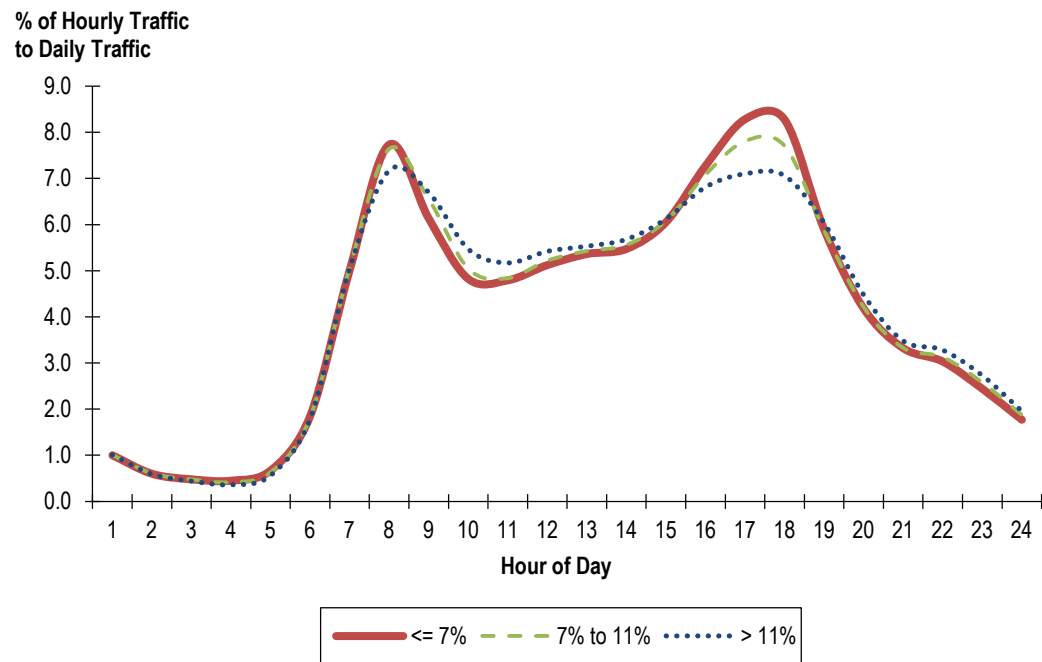
This approach uses estimates of hourly demand and is sensitive to changes in supply and/or demand assuming that the amount of temporal spreading that is likely to occur between any O-D pair is based on the level of congestion that is present along the shortest path between that particular O-D pair. A set of temporal distributions was developed by Margiotta,<sup>4</sup> *et al.* that vary based on the

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<sup>4</sup> Margiotta, R., H. Cohen, and P. DeCorla-Souza, *Speed and Delay Prediction Models for Planning Applications*, Sixth National Conference on Transportation Planning for Small and Medium-Sized Communities, Spokane, Washington, 1999.

level of congestion as measured by the daily volume to hourly capacity ratio (AADT/C). These distributions were developed as a mechanistic way of moving demand from one time period to another as the level of congestion changes. Figure 6.4 shows an example of how the distribution of trips over the entire day might change in response to different levels of congestion.

**Figure 6.4 Daily Profile of Trip Departures**



Source: Cambridge Systematics, Inc.

### Matrix Estimation and O-D Adjustment Techniques

Before the O-D information can be used reliably to represent base-year conditions, it must be calibrated to observed traffic data. One calibration approach is to further refine the travel demand model itself so that it produces outputs that more closely match observed traffic conditions. Adjustments to the model can be made to achieve this depending on the availability of observed data as well as time and resource constraints. This method can be a valid approach for estimating future year traffic simply by applying the refined travel model and maintaining a direct link between the regional travel model and the DTA model.

Another approach is to adjust the O-D matrices themselves. This can be a manual process whereby the analyst assigns the O-D information to the transportation network and then compares the assignment results to the observed data such as traffic counts. These comparisons form the basis for adjustments to the O-D information in order to get a better fit. The adjusted trip table is then reassigned and the process is repeated until a good fit has been achieved and the O-D information is calibrated. Fortunately, automated processes have been developed

to perform this calibration step, which is commonly known as Origin Destination Matrix Estimation (ODME).

Most ODME methods in use today are based on an iterative, bi-level process that switches back and forth between traffic assignment and matrix estimation. The overall objective is to provide O-D matrices by vehicle type (e.g., auto and truck) for each time slice that are consistent with ground counts yet sensitive to future-year changes in demand and/or supply. Implicit within that objective are the following considerations:

- Maintaining consistency with route choice behavior so that predicted traffic flows can be estimated as the result of an assignment process in which a predicted O-D matrix is assigned on the network. Link utilization is flow-dependent, and should be calculated with equilibrium flows.
- Achieving a balance between the need to closely match the target counts and the desire to find a new matrix that is close to the prior matrix, as estimated by the regional travel demand model.

Currently, most of the automated matrix estimation processes are built for use with static assignment models. Static and dynamic assignment methods can produce very different travel paths in the model. As a result, the adjusted O-Ds within the DTA models must be tested to see if path choices are similar enough to produce consistent traffic flows. This can be an iterative process where capacity and delay information from the dynamic models is passed back to the static models and the matrix adjustment process is rerun until a good fit has been achieved. Research efforts are underway to develop matrix estimation techniques that utilize a dynamic approach.

Estimating future year travel using this approach involves an additional step in order to bring together the changes in travel demand as estimated by the travel model with the adjustments to the base year trip matrices that may have been made during calibration. A common approach to achieve this is to calculate the growth component for each traffic analysis zone or each O-D pair and apply that to the calibrated base year demand. This incremental approach does maintain a link between the regional travel model and the DTA model. Care must be exercised using this approach as it is possible for these adjustments to produce negative or counter-intuitive forecasts.

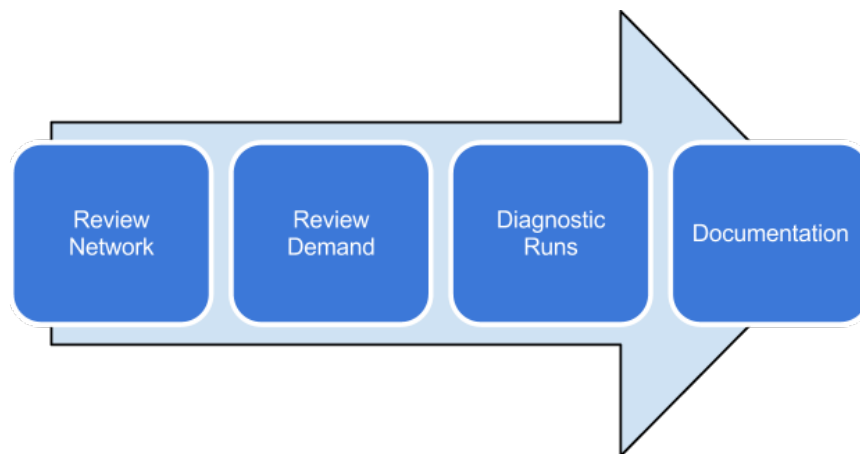


## 7.0 Error and Model Validity Checking

The purpose of error checking (identifying mistakes) and validity checking (model diagnostic runs) is to improve the quality of the models prior to calibration and alternatives analysis. Some of the biggest sources of rework and difficulty in calibration occur when network coding errors have not been identified and addressed. In these cases, instead of comparing the simulation results to field data during calibration, the analysis team is either uncovering mistakes in network coding, or worse, attempting to match field data with an error-prone network. A thorough quality control process should be in place to examine and remedy such coding issues. A good quality control process involves a systematic checking of a model by a knowledgeable person who is independent of the network developer.

In addition to error checking the model files, it is important to conduct a series of diagnostic model runs to verify that the model reasonably represents travel conditions and behaviors observed in the field. This chapter discusses different types of diagnostic runs that are designed to identify issues in the model, prior to conducting the model calibration process. Often these diagnostics tests are considered to be part of calibration. This guidebook recommends tackling this step prior to the start of calibration to allow the focus of the calibration to be on adjusting the model parameters to match field results. Figure 7.1 presents the steps involved in the error and model validity checking process. Descriptions of each of these steps are provided in the following sections.

**Figure 7.1 Error and Model Validity Checking Process**



Source: Cambridge Systematics and University of Arizona.

## 7.1 NETWORK REVIEW

Once the network has been converted to the appropriate format for the DTA model, it is best to further examine the properties and attributes of the network, including links, link-to-link connectivity (i.e., nodes or link connectors), traffic control properties, zone and demand data, and any other fields of information regarding the created network.

### Network Connectivity

Common examples of network connectivity issues to be considered are as follows:

- Missing connections (e.g., a ramp interchange is missing);
- Link directionality (e.g., links coded opposite of the intended direction);
- Lane connectivity:
  - Moving from a link with more lanes to a link with fewer lanes,
  - Moving from a link with fewer lanes to a link with more lanes, and
- When GIS files are assembled from different sources to create one cohesive file for model development, the blending of the files may contain errors.

### Link Speed Limits

A network converted from a planning model will most likely not contain existing speed limit information; however, estimated free-flow speeds from the model would most likely be available. The analysis team may choose to use this information, but examining the variance of assumed speed limits is wise.

### Intersection Geometry

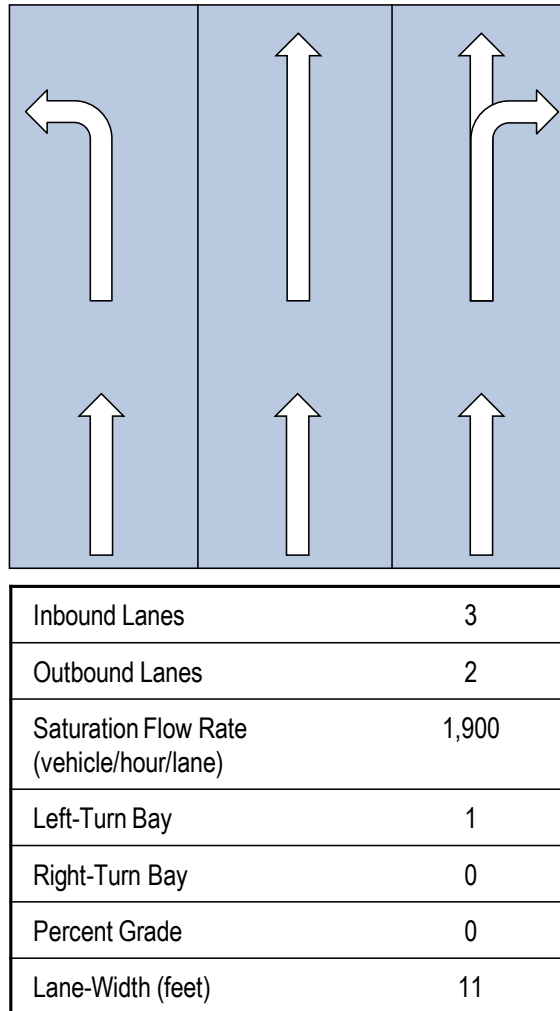
The goals of checking the intersection geometry are to ensure that the connectivity of intersection geometry is correct for each intersection approach and to determine that the geometry is correctly represented. The attributes that should be rectified if not correct include the following:

- Link connectivity;
- Lane connectivity;
- Traffic control;
- U-turn restrictions;
- Turn/lane prohibitions; and
- Turn bay lengths.

The list of link attributes illustrated in Figure 7.2 serves as an example of factors required to correctly capture intersection geometry.



**Figure 7.2 Intersection Approach Geometry Attributes**



Source: University of Arizona.

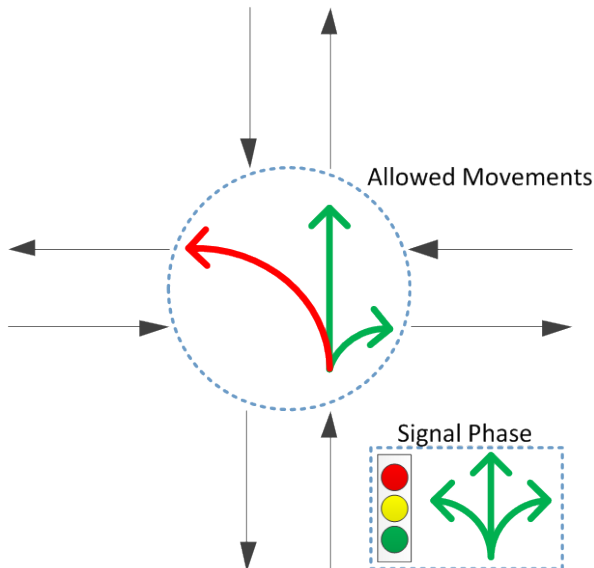
Note: Saturation flow rates if required as a model entry are a field measured input.

### Traffic Control

Traffic control must be consistent with network connectivity. Mistakes, such as the one demonstrated in Figure 7.3 below, would typically include:

- Skipped signal phasing;
- Signal timings inconsistent with geometry;
- Incorrect cycle lengths, split times, and offsets;
- Missing approaches; and
- Incorrect timing, phasing, offset and coordination.

**Figure 7.3 Inconsistency between Connectivity and Traffic Control**



Source: University of Arizona.

### Network Paths

Different DTA models may have different ways of generating vehicles entering and exiting the network. Regardless of the model mechanism, each zone in the network should have at least one generating function and one destination function. When checking for network connectivity, the analysis team should be checking that for every zone to zone connection that there are logical and accessible paths for vehicles to take.

### Network Coding Checklist

To help improve the quality of work being performed, it is best to have a checklist of all necessary activities. This list should be maintained by both the analysis team and the personnel assigned to quality control. The following is a short example of issues to review in network coding.

- **Connectivity:**
  - Arterial connectivity at intersection:
    - Correct cross-street connectivity;
    - Turn bays of all approaches;
    - Outbound turn movements; and
    - Number of lanes for each outbound and inbound.

- Arterial connectivity at non-intersection:
  - Outbound movement directions;
  - Speeds of connecting links;
  - Number of lanes of connecting links; and
  - Freeway ramp connectivity.
- Ramp turn bays:
  - Allowable turn movements;
  - Link speed;
  - Number of lanes;
  - Outbound connectivity; and
  - Traffic control.
- Freeway at nonramp connection:
  - Outbound movement directions;
  - Speeds of connecting links; and
  - Number of lanes of connecting links.
- **Traffic Control:**
  - Correct traffic control at node:
    - Movements are coded for each phase;
    - Phases correspond to correct turn movements;
    - Actuated settings and detectors;
    - Cycle length, green time, amber time, all red time; and
    - If two-way stop sign or yield sign, the major/minor approaches.
  - Network Paths and Connectivity:
    - Each TAZ has at least one generator and one exiting mechanism;
    - Correct downstream connectivity to complete vehicle trip; and
    - Appropriate network functional type.

## 7.2 REVIEW DEMAND

The travel demand inputs must also be validated before model calibration. One of the most common difficulties arises in disaggregating the demand from existing peak-period O-D matrices to time-dependent demand matrices at a finer temporal granularity (e.g., 15-minutes). Generally, it is not advisable to take a single 24-hour O-D matrix and apply the diurnal distribution factor to produce

the time-dependent O-D matrices. In the single 24-hour O-D matrix, the trip directionality information for the AM and PM periods are aggregated. If time-of-day O-D matrices (e.g., AM peak, mid-day, PM peak) are available, then the trip directionality is inherently preserved in each matrix, and each time-of-day matrix can be directly disaggregated into finer resolution matrices.

Care also needs to be taken in estimating the diurnal distribution of O-D matrices. If vehicle departure associated with an origin is derived from survey data, such as a daily travel survey, then the diurnal factor can be directly applied. On the other hand, if such a distribution is derived from traffic data, then one must consider the time lag needed for traveling from the origin to the data collection point, and the diurnal distribution must be temporally adjusted to account for the time lag.

## 7.3 MODEL VALIDITY CHECKING

Diagnostic model runs help locate and remedy potential coding errors in the network before the start of calibration. Often modelers will find coding errors in the network in the calibration phase, which adds delays to the schedule. An adequate amount of time should be allocated to this stage of diagnostics prior to calibration. The diagnostics stage will require several runs of the model – not for the purpose of producing useful simulation results, but simply for identifying trouble spots in the network.

There are two types of diagnostics: single-run testing and iterative-run stress testing.

### Single-Run Testing

Simulation, when used as a diagnostics tool, is unforgiving when finding errors in the network coding. Such instances may include the following:

- Incorrect/incomplete turn movements at an intersection;
- Incorrect signal phase movements at an intersection;
- Lack of connectivity to/from a node or link;
- “Floating” nodes/links;
- Reverse-direction links; and
- Hidden/stacked nodes and links found to be duplicates.

Some errors may come from the conversion process, and some other errors may come from the source of the network. It is best practice to maintain a list of errors to report back to the maintainers of the source network. (Documentation is discussed later in this chapter).

### *Network Loading*

The single-run test can help determine whether vehicles exit the network based on the initial travel routes assigned by the simulation. The demand used for single-run testing can be a short period of demand, such as a fraction of a peak period of demand. Running a portion of demand reduces the computational time for testing and helps find potential coding errors in the network much more quickly. Multiple model runs may be required to identify and fix different coding errors in the network. While executing multiple runs of the model, the analysis team should incrementally increase the demand to 100 percent. At this point, most (if not all) links, approaches, and paths will have been traveled and most obvious coding errors will have been identified.

Testers should also examine network loading locations where vehicles enter the network. Entry queue volumes should be examined for excess queuing and unreasonable delay. Depending on the method of vehicle generation, attention should be paid to whether enough capacity is available for vehicles to enter the network. Possible remedies include, but are not limited to:

- Creating multiple entries for a single origin;
- Increasing the entry capacity; and
- Review if temporal demand /entry volumes are correct

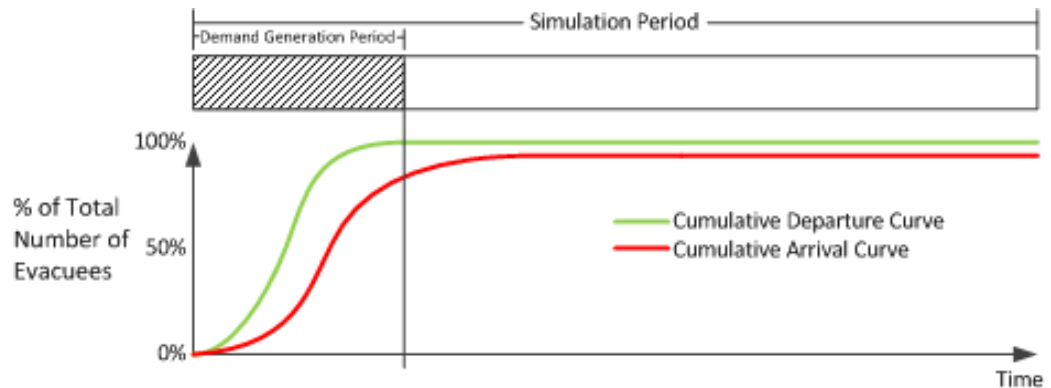
### *Emptying the Network of All Vehicles*

In this test, the important aspect on which to focus is whether the vehicle has completed its trip. This will accomplish the task of determining whether there is a problem with connectivity and false prohibition of movements in the network. If connectivity is incorrect (e.g., the downstream node of a traveler's starting link is not connected to the network), then the vehicle has no possible way of reaching its destination.

In simulation, there are two time periods: the simulation period and the demand generation period. Demand generation for this testing purpose can be a short period (e.g., a peak-hour of demand). The simulation period for this testing should be a much longer time period. This allows all generated travelers to exit the network, even those vehicles generated late in the demand generation period. Figure 7.4 illustrates these concepts.

After this simulation has completed, the analyst should review the simulation results via numerical output that indicates the number of vehicles in/out of the network after simulation or by reviewing graphical output via animation of simulation results to determine if vehicles are “stuck” somewhere in the network.

**Figure 7.4 Cumulative Curves Demonstrating Network Emptying**



Source: University of Arizona.

### *Locations of Unreasonable Traffic Flow*

When all vehicles have been emptied from the network, the next step is to look into locations in the network that are unreasonable. Simulation results demonstrating long, consistent periods of congestion that do not recover until the end of simulation are indicators of unreasonable results, which include the following:

- Low speed;
- High density;
- Low flow rates;
- Prolonged queuing; and
- Unintuitive used/unused routes.

Errors in link and node/connector attributes are typically identified in these tests.

### **Stress Testing - Iterative Assignment**

Once the single-run testing is completed, the next step is to begin performing stress tests on the network, which essentially means bringing the network to run at full demand. Similar to what was performed with the initial testing, it is best to start off with a lower amount of demand. This means reducing the demand being used by some overall factor that will allow for quicker model runs. The demand should be incrementally increased as any issues are addressed. As stress to the network increases, the confidence in the network conditions grows before undertaking calibration.

Examining the results of a simulation run should include identifying locations that are severely congested and/or that never seem to fully recover. A good test is to trace downstream of these routes and look for the following:

- Limitations to connectivity;
- Incorrect lane count;
- Inappropriate destination locations for exiting trips;
- The appearance of known bottlenecks (may not be correct in intensity but the locations should begin to appear); and
- Incorrect correspondence between demand and the network.

### *Results from Iterative Assignment*

It is important to keep an eye on the numerical results generated by iterative assignment runs: looking at the numerical output summarizing the results of network convergence and stability tell how well the network is running as a whole. The DTA feature within the modeling software must be enabled while conducting these runs. With each iteration, it is important to track the progress (rate of improvement to a “converged” run). A convergence chart should be prepared and used frequently throughout the modeling process. Figure 7.5 illustrates a convergence chart where the model was not approaching convergence. In this example the stress test would be indicating that there are significant issues in the model and the analysis team should go back through the network checklist to confirm if there are any items that were overlooked.

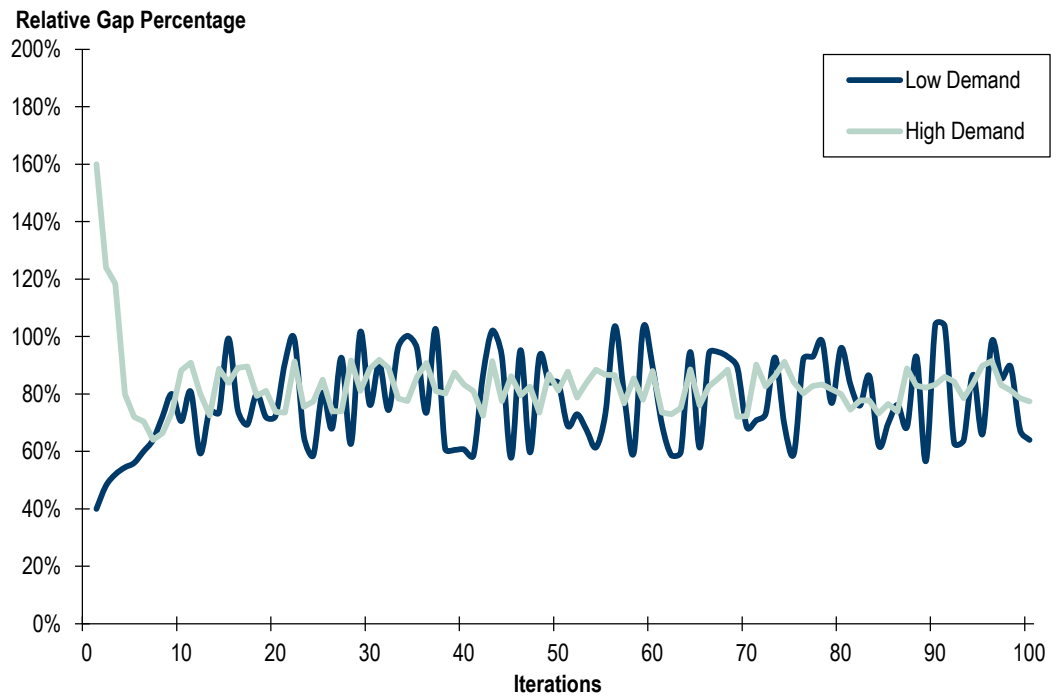
Figure 7.6 is an illustration of the same model shown in Figure 7.5, but with convergence moving in the right direction.

Another aspect to consider in regard to convergence is the stability of the convergence rate. Stability means that convergence has improved steadily over iterations, and at the end of the simulation the change in convergence from iteration to iteration “plateaus.” Other useful metrics to monitor are average travel time, average speeds, average stop time, and average trip distance.

### *Path Assignment*

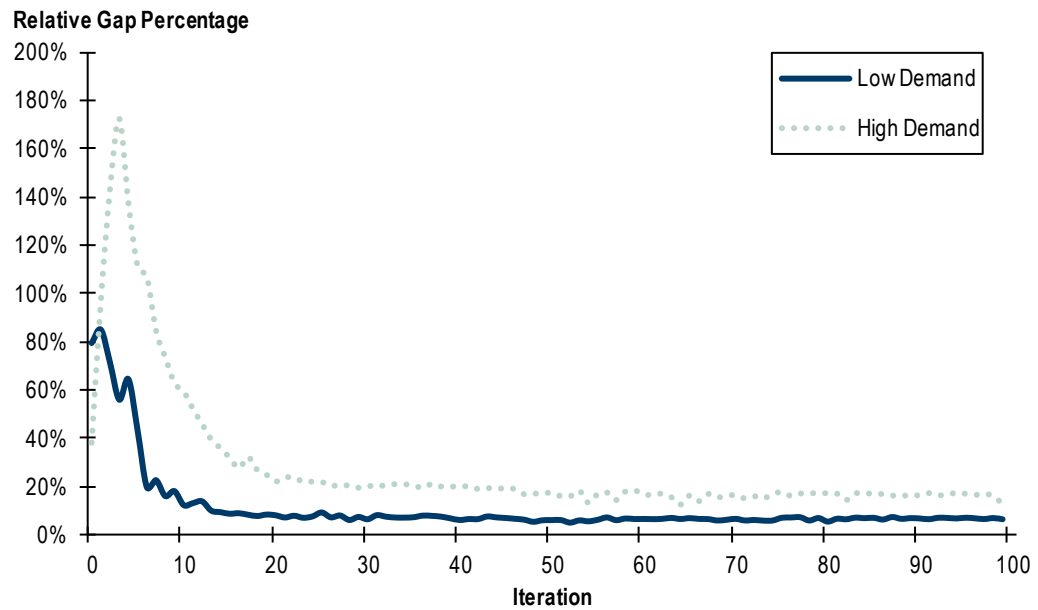
Another important aspect of running the models to equilibrium is the feasibility of the paths assigned. It is important to understand the core methodology of the DTA tool, especially how paths are determined and assigned. It should be intuitive to recognize paths that are not feasible – for example, paths that are circuitous or far reaching and out of the way. In many cases, these result from local connectivity issues that force path assignment to use what would seem to be the most intuitive paths. In other cases, it may be due to the attributes of the assignment model or other incorrect inputs that require adjustment.

**Figure 7.5 Convergence Example: Model not Approaching Convergence**



Source: University of Arizona.

**Figure 7.6 Convergence Example: Model Approaching Convergence**



Source: University of Arizona.



The analysis team also should look for paths that seem to be oversaturated when they should not be according to the existing conditions observed. For example if there is an existing HOV or managed lane that operates at free flow in the field but the model testing has the lanes oversaturated, the DTA model's method of restricting vehicle classes (HOV, toll, managed lanes) may be incorrectly used or coding could be missing that was supposed to restrict the vehicle classes.

## 7.4 DOCUMENTATION

A checklist should be maintained throughout error and validity checking; this can serve as documentation for the technical report. Rather than attempting to remember everything that was performed in the diagnostics phase of the project, analysis teams should continuously report documentation throughout the diagnostics. Also, any errors found in the source model network(s) should be reported back to the originator(s) of the model(s).

Documentation can be as simple as maintaining an Excel sheet logging changes and dating progress or a printed log of changes and dates. Elements to be recorded in the documentation phase include the following:

- Personnel working on network:
  - Date and time of personnel working; and
  - A summary of work being performed (e.g., links, node, freeway, arterial, or other area of focus).
- Individual changes to the network such as:
  - Connectivity correction;
  - Attribute update to link or node;
  - Addition/deletion of link or node; and
  - Identifier of element changed/edited such as link ID or node ID.



## 8.0 Model Calibration

The objective of transportation model calibration is to properly represent observed field traffic conditions in the model. In the calibration process it is important to understand both the approach and methods for calibration and the end goal of calibration.

DTA models employ a wide range of simulation techniques from different time resolutions to different simulation algorithms. Analysis teams conducting model calibration must have a clear understanding of DTA principles and the DTA methodology within the software. Ideally, the software documentation provides guidance on the model parameters and their impact on the performance of the model. This chapter outlines an approach to calibration of a DTA model independent of the specific software package being used.

This section of the guidebook discusses the following:

- Terminology used in model calibration;
- Software and DTA considerations in calibration;
- An overarching calibration process applicable to any software package;
- Recommended sequence of calibration adjustments; and
- A model calibration checklist.

### 8.1 CALIBRATION TERMINOLOGY

For the purposes of this guidebook **calibration** is defined as a process whereby the analyst selects the model parameters that cause the model to best reproduce field-measured local traffic operations conditions. This process also includes the statistical verification of the model outputs vis à vis the field-measured conditions.

**Validation** in transportation modeling is often used as the term for verification of the model outputs. Validation in this guidebook is defined as a process in which a calibrated model is tested using a different set of existing traffic data to determine if the calibration parameters are applicable to other conditions.

### 8.2 DTA CONSIDERATIONS

The analysis team must understand the underlying simulation and modeling techniques in a DTA model in order to understand how the model would react to network and demand changes and the measures of effectiveness that should be the focus of calibration. With this understanding, the analysis team can then make the adjustments so that the simulation results reflect observed conditions.

In calibration of any transportation model, some of the more typical measures used are volumes, speeds, travel time, and congestion (length and duration of queuing). These measures are used in a DTA model as well; however, with DTA there are other measures that require additional attention in calibration, including route choice and trip making by time of day.

The fidelity of a model with DTA depends on more than link volumes. It is important that the trip characteristics (path and time of trip taken) reflect observed conditions and expectations. Increasingly, vehicle path data are becoming available through Bluetooth and GPS technologies, enhancing the ability to accurately assess DTA models.

### **Model Scale Considerations**

Models using DTA tend to cover large areas, and the ability to obtain good calibration data for the entire model may be limited. There are methods of addressing these circumstances. The analysis team may use screen lines and cut lines as a method for capturing trip making in the project area.

Another consideration is dividing the model into a primary and secondary area. The primary area is where the subject of the analysis is located and where the data with the highest fidelity are located. The secondary area is important to the model for network completeness but is outside of direct influence by the mitigation strategies under consideration, and may not have data of the highest fidelity.

## **8.3 CALIBRATION PROCESS**

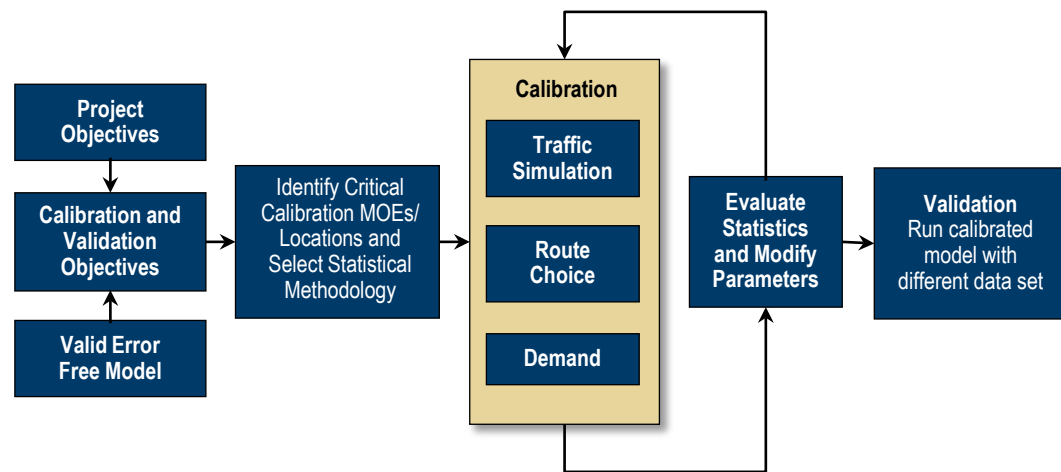
The general DTA model calibration process is comparable to what has been used for microscopic traffic simulation models and presented in the Traffic Analysis Toolbox Volume III. There are DTA-specific considerations that need to be addressed in the adjustments applied to model components as well as overall model behavior. The overall process for calibration is presented in the following summary list.

1. Establish calibration objectives and review project objective to ensure that the calibration task directly supports the project objective.
2. Identify the performance measures and critical locations against which the models will be calibrated.
3. Determine the statistical methodology to be used to compare modeled results to the field data.
4. Determine the strategy for model calibration and identify parameters within the DTA models that are the focus of adjustments.
5. Assemble field data previously collected for comparison to model outputs

6. Conduct model calibration runs following the strategy and conduct statistical checks. When statistical analysis falls within acceptable ranges, then the model is considered to be calibrated.
7. Validation: Test or compare the calibrated model with a data set not used for calibration. If the model replicates the different data set the calibration parameters and model are considered to be validated.

A detailed discussion of each step in the calibration process is presented in the following subsections. Figure 8.1 below depicts a general procedure applicable to calibrating a DTA model.

**Figure 8.1 DTA Model Calibration Framework**



Source: Cambridge Systematics, Inc.

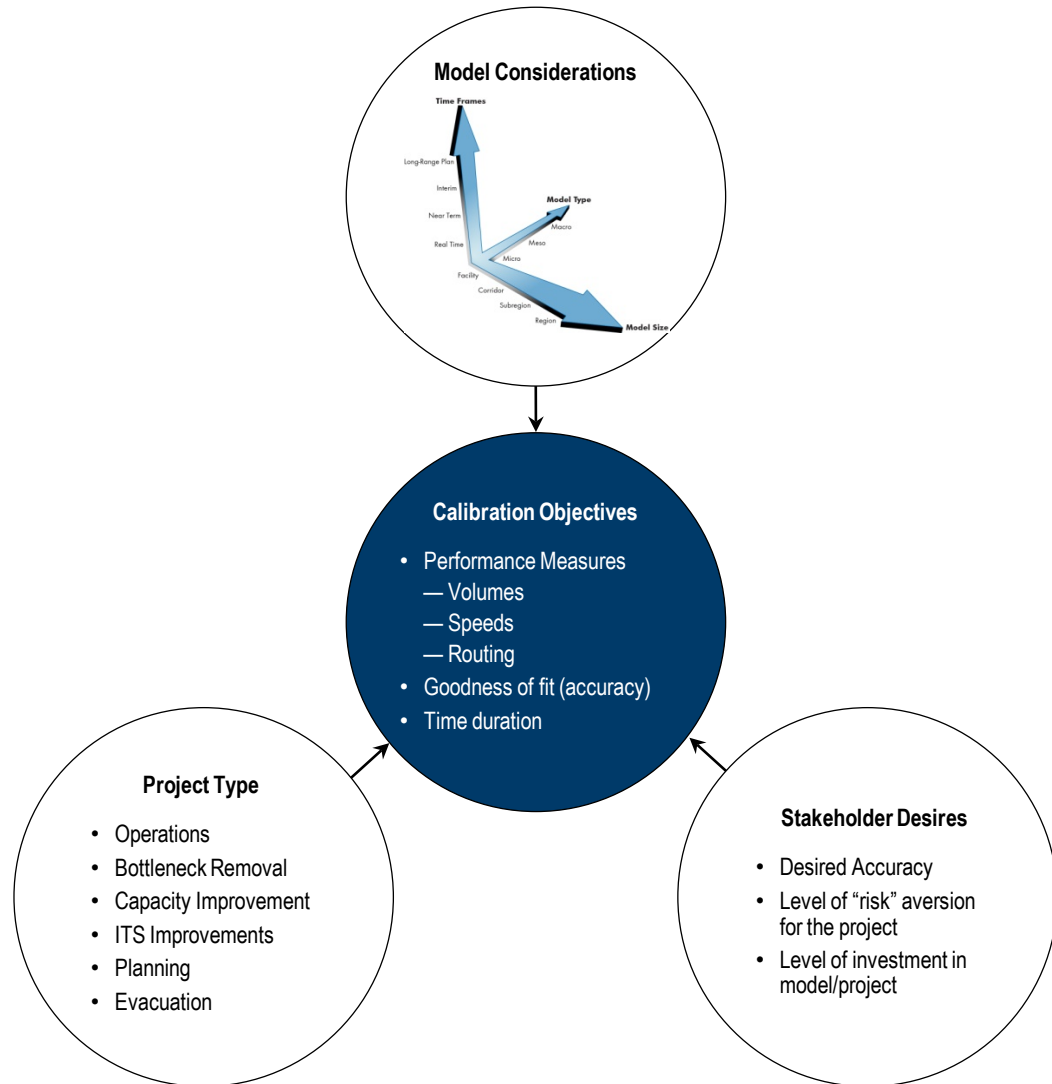
## 8.4 ESTABLISH CALIBRATION OBJECTIVES

Model calibration objectives must be consistent with project objectives. Type of project, stakeholder objectives, and model considerations feed into the calibration objectives, as depicted in Figure 8.2. The following example demonstrates how these objectives influence the decision on model calibration objectives:

### *Example: Near-Term Bottleneck Removal and Prioritization*

Agency “A” is preparing to expend a significant portion of its capital funds on a series of bottleneck improvement projects. It has more projects than it has funds. The level of accuracy desired is high because the funds need to be allocated as prudently as possible. The agency has recognized the complexity of the problem and has programmed sufficient funds for data collection, including an O-D survey. The regional demand model has recently been updated and both mesoscopic and microscopic base models are available. The desired operational analysis on the freeway bottlenecks is a microsimulation analysis.

**Figure 8.2 Calibration Objective Considerations**



Source: Cambridge Systematics, Inc.

Calibration objectives: The desired level of accuracy (low margin of error) would be high for this project because sufficient data would be available for model development and calibration. The number of measures tested should be expanded to include path making, in addition to traffic volumes and travel speeds.

Overall, model calibration needs to be a well-planned task because it may consume substantial resources if the calibration acceptance targets are not properly and realistically defined upfront.

## 8.5 IDENTIFY PERFORMANCE MEASURES

The performance measures used in model calibration are the measures that can be collected in the field and produced by the model software. In the calibration process the field data are compared to the model outputs, and if the calibration acceptance criteria are satisfied, calibration is considered to be complete.

The performance measures for calibration should also be consistent with the performance measures to be used to evaluate scenarios. The analysis team should begin by identifying a set of “must-have” performance measures, then estimate the resource requirements, then gradually include additional “good-to-have” performance measures if budget and schedule allow. Defining all-inclusive and over-ambitious calibration targets often leads to overwhelming resource requirements and execution risk. Calibration and targets should be agreed upon by key stakeholders during the scoping phase.

The collection of performance measurements in the field can be used in developing model calibration acceptance targets. It is important to understand that there are variations and discrepancies in empirical data either because of instrument errors or because of differences in data collection dates. The calibration acceptance targets may need to be adjusted based on the variability observed in the data. There are several documented statistical measures that describe the “goodness-of-fit” of a model in calibration. These include traffic volumes, speeds, travel times, and congestion.

### Identify Critical Locations

Bottleneck locations are typically the most important areas to focus on during the calibration process. In arterial street modeling, bottlenecks are typically found at intersections or where road characteristics change resulting in decreased capacity (such as lane reduction, etc.). In freeway modeling, bottlenecks occur in similar locations – where road characteristics change resulting in decreased capacity, and upstream or downstream of interchanges related to weaving and merging traffic. There also are external causes of bottlenecks, such as sight distance variation, vistas, and other driver distractions, that are more difficult to assess but equally important to understand. Understanding the cause of a bottleneck is the first step in calibrating a model to replicate its effects, which is why it is important to develop an existing conditions report.

A summary of the data collection activities should include a description of all the critical locations and important performance measures. The observed values of each measure should be included (e.g., “the maximum queue at each study area intersection is reported in Table X”; “volumes along the freeway and on all freeway ramps can be found in Figure Y”).

## Calibration Statistics

Various statistical methods can be used to measure how well a DTA model is calibrated. A model will never be perfect, so the analysis team should identify a level of error tolerance after studying the variability of field data in the real world transportation system to be modeled and the stochasticity of the DTA model. The model should be able to emulate the actual performance in the field and the variability of that performance. Specific examples of statistical approaches to this end are provided in Chapter 6 of the Level of Effort Guide. Furthermore, quality and consistency issues may exist in the calibration data set; perfectly matching a set of inconsistent data may be impossible and undesired from a modeling perspective. A calibrated DTA model should consistently reproduce the spatial and temporal characteristics of the local traffic patterns within the specified level of tolerance.

## 8.6 CALIBRATION STRATEGY

Model calibration involves adjusting model parameters and inputs to improve the model's ability to replicate local conditions. This chapter focuses on the calibration strategy for dynamic user equilibrium (DUE) in DTA models irrespective of their simulation resolution: mesoscopic, microscopic, or hybrid. DTA models may differ in their approaches, but their challenge is similar: providing a solution to the DUE problem and using this solution as the basis for equilibrium.

Observed data sets that are statistically significant and provide good coverage of the analysis area are a prerequisite for the calibration process. As presented elsewhere in this guidebook, the objective of building a DTA model is to model the spatial and temporal characteristics of congestion. To calibrate the base-year model, observed data should exist on volumes, travel times, and queues. Counts alone are insufficient, because in DTA models (consistent with traffic flow theory and field observations), the same flow can be observed under congested and uncongested conditions. As a result, a model calibrated against counts only may have limited predictive ability due to the fact that it may not adequately replicate congestion and the associated time-varying travel times that drivers use in making route decisions.

To make calibration practical, a sequential process must be followed in which the traffic flow model is calibrated before the route choice model. This ensures that capacities and the relationship between traffic speed and flows are being modeled accurately. Route choice depends on the time-varying speeds provided by the traffic simulation model. As a last resort and at the concurrence of the analysis team, O-D matrix adjustments may be necessary if during the calibration the accuracy of the input demand is determined to not be adequate. By calibrating both the traffic simulation and the route choice model before adjusting the demand, the analysis team will reduce the need to adjust demands. The recommended sequence and steps in the calibration process is as follows:



1. Calibrate traffic flow parameters (capacity and speed-flow relationships);
2. Calibrate route choice (software parameters, costs by link, travel time, driver preference, global driver behavior);
3. Calibrate temporal O-D matrices including time departure adjustments; and
4. Fine-tune (quantitative analysis – adjust local variables to match queues and operations).

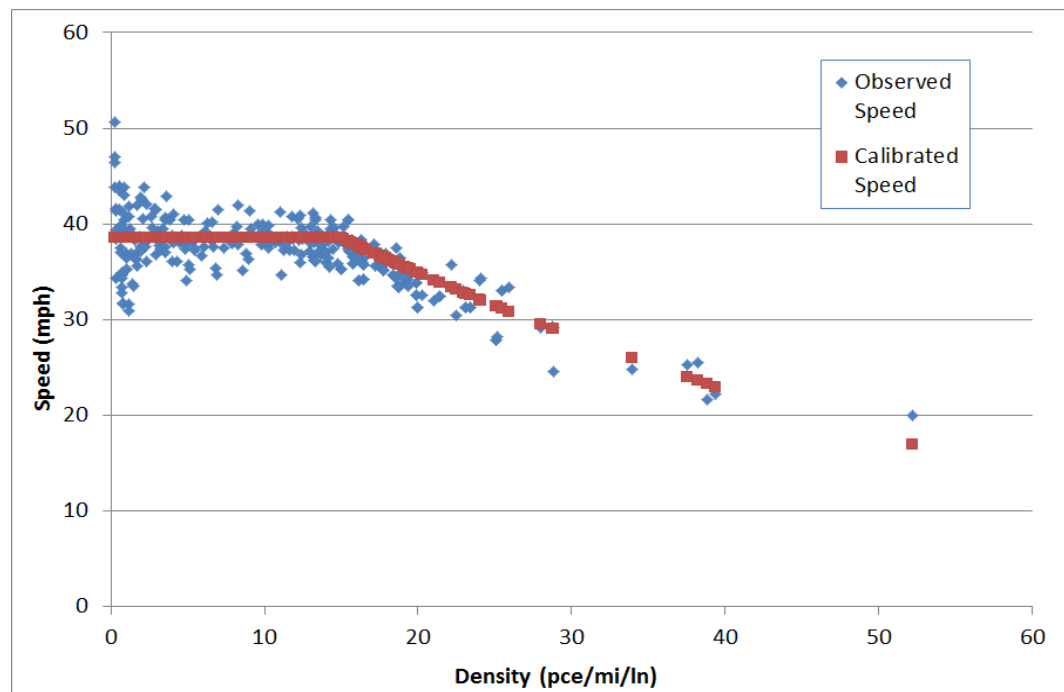
### Calibrate Traffic Flow Parameters

The following steps are included in this stage:

- Review the model software manuals and guidance about the suggested approach to calibrating relevant attributes in the simulation model;
- Observed data should reflect both the free-flow and congested conditions; and
- Under various simulated density conditions, estimated speeds should correspond to the observed speeds under similar traffic conditions.

Typical statistical metrics determining the goodness-of-fit of the simulated measures can be used such as the linear regression model. Figure 8.3 illustrates how observed and calibrated speeds can be compared.

**Figure 8.3 Comparison of Observed versus Model Estimated Speeds**



Source: University of Arizona.

Existing simulation-based DTA models adopt a wide range of simulation methodologies, ranging from microscopic to mesoscopic simulation logic rules. Experienced capacity in a simulation model can be estimated based on the simulation logic and how vehicles maneuver based on the underlying car-following and lane-changing models. For instance, the interaction between vehicles and the roadway is influenced by driver aggressiveness, which is ruled by the simulation logic. Attributes such as gap acceptance and reaction time to congestion or controlled-intersections affect the experienced capacity and performance of the simulated roadways.

### **Calibrate Route Choice**

Route choice is a critical component of a DTA model. The route choice model could be implemented in various ways, each based on specific choice behavior assumptions (e.g., dynamic user equilibrium or random utility maximization) and model constructs (e.g., utility functions or generalized cost function). Calibrating the route choice model involves determining the best coefficients of the variables in the utility function or cost function. In calibrating route choice the settings on how drivers respond to roadway attributes and congestion and to changes in the transportation system are established, which affects the modeled link volumes and speeds.

For example, if there is a bias in the study area towards continuous flow facilities such as freeways, then the route choice model should be calibrated to reflect differing weights of travel times associated with different types of facilities. The goal of the adjustments is to more realistically reflect the true route choice behavior.

Once the traffic simulation model is able to reproduce traffic flow streams with the proper characteristics such as capacity and speed, the analysis team should turn their attention to the calibration of the route choice model. The most important parameters affecting route choice are travel time, link-based cost, distance, functional class, number of turns, and percentage of time not moving. Assigning the proper weights to these parameters improves the goodness-of-fit of the base-year model and increases the model's predictive ability in scenario analysis.

Evaluating the outcomes of adjusting the route choice can be accomplished by inspection and can provide useful insights for the calibration process. Another technique is to plot the used routes between O-D pairs to ensure that the paths that the model generates are realistic based on field data and local knowledge.

The analysis team should first calibrate the global parameters of the route choice model before adjusting any local parameters that determine local driving behavior. Determining the most effective approach will depend on the software package and the analysis team's experience in using the software.

## Calibrate Dynamic O-D Matrices

Dynamic demand adjustment is a field of active research. No clear guidelines or algorithms have emerged as optimal for all network sizes and types of congestion patterns. Several prevalent approaches are inspired by classic methods developed for static O-D calibration/estimation problems to match link counts, but research is now focusing on methods to better match the congestion pattern.

Before resorting to any demand adjustment, it is crucial that the analysis team eliminate all network coding errors and calibrate both the traffic flow model and the route choice model adequately. Typically, the demand adjustment process modifies the trip table in an iterative manner. Trips are added or subtracted between specific O-D pairs and time periods at each iteration, and subsequently the DTA model is run to convergence to reevaluate the changes in the demand. Depending on the algorithm used for demand adjustment, traffic flows can improve but travel times or the trip length frequency distribution may deviate from the targets. It is important that the analysis team guide the demand adjustment process in each step to make sure that the changes in the demand matrices are defensible.

### *Data Preparation*

The data requirements for demand adjustment are addressed in Chapter 5. In summary, the count and travel-time data used for adjustment should cover most of the travelers and a wide region of the simulated area. It also is important that the set of data used for demand modifications is checked for consistency and does not contradict other datasets used in model calibration. Time-dependent count and travel-time data will guide the demand adjustment process to develop a demand profile that is consistent with the time-varying profile of the observed data.

### *Departure Time Adjustment*

If the demand is in the form of trips and not tours, time-of-day factors (or diurnal curves) derived from travel studies can be applied to the static trip table from the regional model by purpose and vehicle class. Frequently, trip tables are partitioned into 10- or 15-minute intervals within which demand is considered constant. The time-of-day factors help determine the total demand in each interval so that when they are assigned they result in traffic flows that have the time-of-day profile of the observed data. The granularity of the input counts and travel-time data to be used in the adjustment process should be consistent with the fluctuations of the travel demand and the observed properties of the transportation system. For large networks it is not unusual to work with hourly data if the demand profile is relatively constant and the model spans an entire day.

## **Fine-Tuning**

The fine tuning stage is the final opportunity to improve the model fit at isolated locations. This stage of the calibration process occurs towards the end and after the major calibration elements are completed. The model should be in reasonably good shape already so that the model analysis team need only focus on improving the performance of some critical areas. The process of adjusting the inputs to improve the model fit is rooted in an understanding of the causes of congestion and other traffic phenomena, as well as common sense and modeling judgment.

The isolated locations where the model fit is unacceptable are referred to as outliers. Outliers are defined by volume, speed and/or congestion. The quantitative analysis consists of investigating one outlier at a time. An outlier can be described as a location in space and time where the model results are not reflecting reality. Often outliers are correlated and by correcting one outlier others can be improved simultaneously. Understanding how a specific model parameter impacts traffic simulation and route choice is critical to identifying outlier correlations.

It is generally recommended that the analysis team begin by adjusting the link attributes at the outliers locations or just downstream of the location. After the model is adjusted, it should show queues developing at the major bottleneck locations presented in the existing conditions report. If these locations have higher than expected volumes the parameters should be adjusted to affect the throughput at the bottleneck. The parameter adjustments should be consistent with the explanation of the bottleneck cause detailed in the existing conditions report.

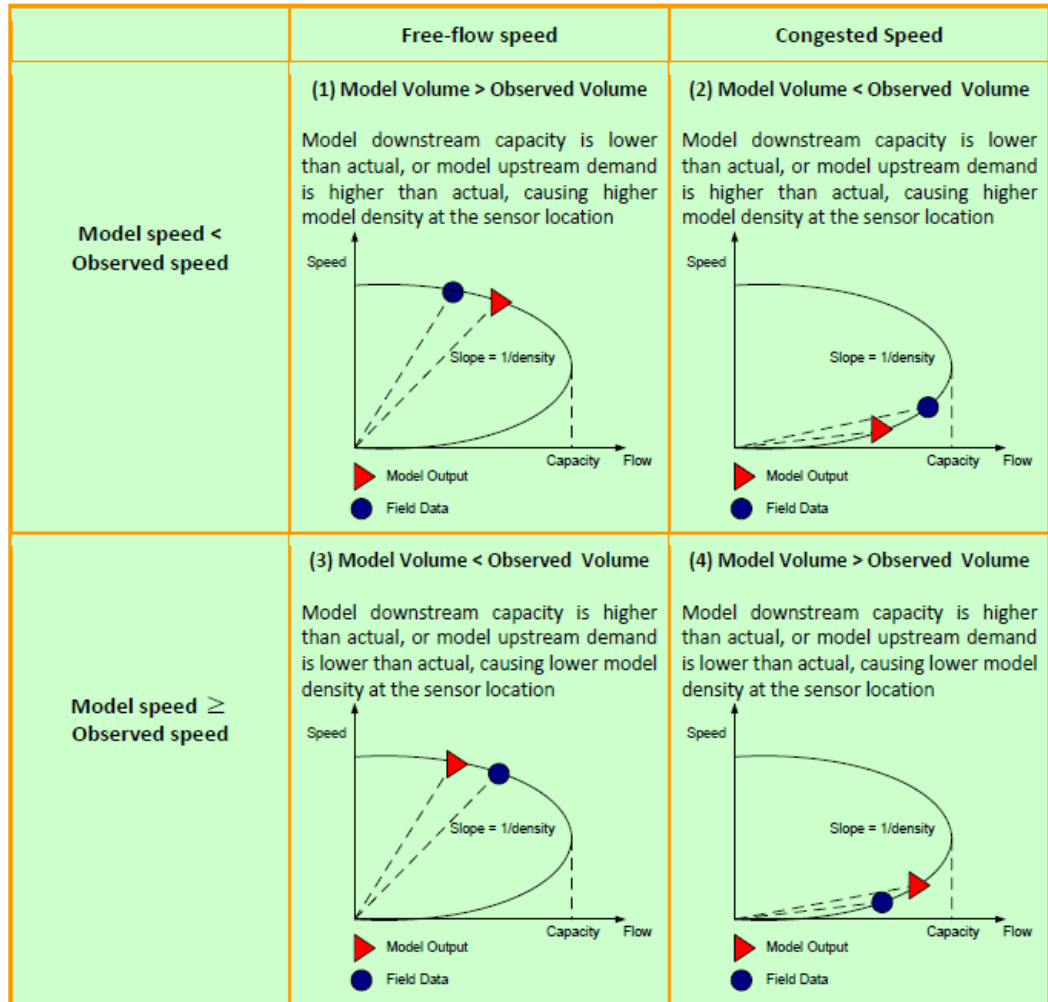
The calibration statistics (verification) should be produced and reviewed after each model run. The ability to automate the quantitative analysis and identification of outliers will greatly reduce the time required for calibration.

After the major bottleneck throughputs are calibrated, the remaining outliers can be assessed at locations where congestion data are available. The outliers can be grouped into four categories as outlined in Figure 8.4. Depending on which group the outlier is classified as, the analysis team may have to adjust the capacity or demand. The interdependency between volume, travel time, and route choice means that if parameters are adjusted to improve travel time, the next time the model is run the improved travel time may attract more vehicles and result in the same amount of congestion.

## **Mesoscopic Model Calibration Considerations**

Microscopic modeling methods, including a calibration process and suggested criteria, are documented in Traffic Analysis Toolbox Volume III. Currently, no similar guidelines exist for the preparation and calibration of mesoscopic simulation models. The practices and methods for calibrating models with DTA discussed in this guidebook are applicable to all types of DTA models.

Figure 8.4 Calibration Outliers



Source: DTA Primer.

## 8.7 MODEL VALIDATION

It is important that validation data be cleaned and free of inconsistent abnormalities. Frequently, the validation data set consists of data that have not been used for calibration. It is valuable to test the model's response to a change in the transportation system and not only its ability to reproduce the base-year conditions. If field data exist from a period in time before or after the base-year model, the analysis team can validate the direction and magnitude of the change the model predicts against observed data. Such a comparison can provide confidence to the stakeholders of the model's predictive capabilities. If the model's response is not satisfactory, the base-year model can be recalibrated with a new set of parameters that more accurately predict the non-base-year conditions while maintaining the fit of the original base year model. This subsequent validated model is then utilized for analysis.

In some transportation modeling applications it can be challenging to obtain one good data set for model calibration let alone obtain a second dataset for model validation. As the availability of data improves through technology, the ability to conduct a robust model validation will become less costly. Conducting validation of models will help increase the confidence in model results.

## 8.8 MODEL CALIBRATION CHECKLIST

A checklist has been developed describing the model calibration process discussed in this chapter. This checklist may be altered as needed by agencies as specific calibration requirements are developed.

- Prepare base model (see Chapter 6).**
- Error check base model (see Chapter 7).**
- Review and update calibration objectives:** It is likely that time has passed since the project was scoped and the objectives of calibration were developed. Take time to review the objectives prior to any calibration activities. The objectives should be guiding principles and provide direction as to the priority of calibration. Ensure that over the course of the project there has not been a change in focus or direction, and update the calibration objectives as needed.
  - Where is the primary area of concern within the model for calibration?
  - What model performance measures are most important for calibration?
  - What are the statistical criteria for calibration acceptance?
- Assemble performance measures used for calibration:** The performance measures used for calibration have been identified during the identification of calibration objectives. In the data collection part of the study, the data for calibration have been collected and documented.
  - Assemble calibration data into a format that can make it efficiently comparable to model outputs.
  - Prepare model output formats that are readily reproduced and will facilitate the iterative process of calibration.
- Establish model calibration criteria.**
- Stress Test Model:** (See Chapter 7 for guidance) A pre-calibration activity that occurs after the base model has been constructed and errors and mistakes have been eliminated in the testing of model sensitivities.

- **Develop Calibration Strategy:**
  - Review software vendors' recommended approach.
  - Prepare stopping criteria for DUE.
  - Develop an approach and sequence for adjusting model parameters.
- **Conduct Calibration Runs:**
  - Run model and compare results.
  - Implement calibration strategy.
  - Develop calibration statistics.
- **Report Calibration Results.**
- **Validation:**
  - Prepare second model data set.
  - Prepare second set of calibration data.
  - Run calibrated model with new data set.
  - Compare model results and field performance data.





## 9.0 Alternatives Analysis

### 9.1 SHORT-TERM VERSUS LONG-TERM IMPACTS

DTA can be used to analyze both short-term and long-term impacts of an alternative of interest. A short-term impact can temporarily motivate tripmakers to adjust their travel choices, such as departure time, route, etc. If this travel choice change is a temporary reaction to the stimulus and the tripmakers soon revert back to their original habitual travel choice, then this temporary effect is considered a short-term impact. On the other hand, if the stimulus is persistent over time or is of high magnitude that generates fundamental and long-term behavior change, the effect is considered a long-term impact.

#### Short-Term Impact Analysis – Non-Equilibrium-Based DTA

It is difficult to define the temporal span of what is “short-term” or “long-term” because this definition varies by person or situation. This guidebook suggests that the short-term analysis aims to depict the congestion immediately after the start of the stimulus up to a certain period thereafter. During this period, tripmakers traveling on their habitual routes in the impact area may or may not anticipate severe congestion. A portion of the tripmakers may try various means to assess the situation (e.g., congestion experience or information from media sources or other en-route information) and decide on the best course of action, which could include changing departure time, route, or mode choice.

From a modeling standpoint, the short-term impact could be captured by having tripmakers initially follow their habitual (DUE) routes if their departure time is prior to the start of the incident, until they begin to receive external stimuli that motivate their possible diversion from their habitual routes. If they depart during the incident period, then their choice may be influenced by stimuli such as traffic information. The non-equilibrium-based DTA modeling approach may be suitable in this modeling context.

Modeling short-term impacts using a non-equilibrium DTA approach mostly involves a one-pass run of simulation. When tripmakers start their trip with the habitual paths typically obtained from the DUE baseline case, they exercise various diversion decisions when faced with unexpected congestion or new traffic information. The pre-trip/en route diversion rules will determine where, when, and why a trip-maker diverts. Generally, the reaction behavior could be modeled in pre-trip or en-route simulations as described below.

- **Pre-trip.** Tripmakers may choose to change their routes should they be informed that their habitual routes are impacted by an unexpected incident; otherwise, tripmakers may continue with their habitual routes.

- **En route.** Tripmakers may choose to divert (when possible) taking into account availability of diversion points should they experience unexpected delay or are informed about extraordinary driving conditions by roadside devices such as dynamic message signs (DMS) or in-vehicle telematics such as radio, GPS, smartphone, or other mobile computing devices.

The number and logic of diversion rules could vary by decision context. How frequently a trip-maker is exposed to such decision contexts, and how frequently a trip-maker is making such a decision, continues to be an active research area. The actual implementation of these rules could vary across different software model systems.

### **Long-Term Impact Analysis – Equilibrium-Based DTA**

In the event that the stimuli are temporally persistent, some impacted tripmakers may seek and settle on other good routes for future use. The outcome of such a learning and adaption process is new habitual route choice behavior. The long-term impact analysis is aimed at understanding the extent of the trip-maker deviating from his/her prior habitual route/departure time to another possible route/departure time and how such a decision may impact other roadways. The equilibrium-based DTA approach appears to be the most suitable for modeling such long-term impacts.

### **Multiple Trip-Maker Classes**

Accurately depicting heterogeneous travel choice behavior continues to be one of the greatest challenges in the development and research of traffic analysis models. A simulation-based DTA approach can resolve this challenge by being flexible to simultaneously simulate tripmakers stratified with different route choice objectives and/or information access. This is called the “multiple trip-maker class” (MTC) concept in literature. The MTC concept allows the model analysis team to capture the impacts/benefits of various ITS strategies by specifying the market share of tripmakers with different route choice objectives. The actual utilization of such a feature could vary between software implementations.

## **9.2 RANDOM VARIATION**

Microsimulation guidelines recommend that multiple model runs with different random number seeds are necessary to produce statistically significant distributions of model outputs. Running multiple runs takes into consideration that microscopic models involve a wide range of random processes throughout the simulation. There is ongoing research regarding whether the same process should be applied to simulation-based DTA models, but doing so is technically feasible and sound.

Two issues need to be considered when addressing random variation. First, if a mesoscopic traffic simulation approach is used, it is theoretically known that random variation is smaller than that in a microscopic model if the O-D attributes of the simulated population remain unchanged across scenarios. On the other hand, if the O-D attributes also vary across compared scenarios, then the random variations will be greatly increased. Under the varying O-D attribute condition, multiple model runs may be needed to provide statistically significant results. The number of model runs and the time it takes to run the model set should be considered in the scope. For a smaller model this may not be significant effort, but in larger models this could take longer and impact the schedule and resources.

Another approach is to generate a vehicle roster from the baseline case and keep the same identical population/trips across different scenarios. The purpose is to keep trip-maker attributes (e.g., departure time and O-D pair) unchanged across scenarios, thereby eliminating the randomness introduced by O-D variations. The possible drawback of this strategy is that the analysis is based on one set of demands and not on a range of demand variations. The general procedure to ensuring demand/trip consistency, as shown in Figure 9.1, entails the following steps:

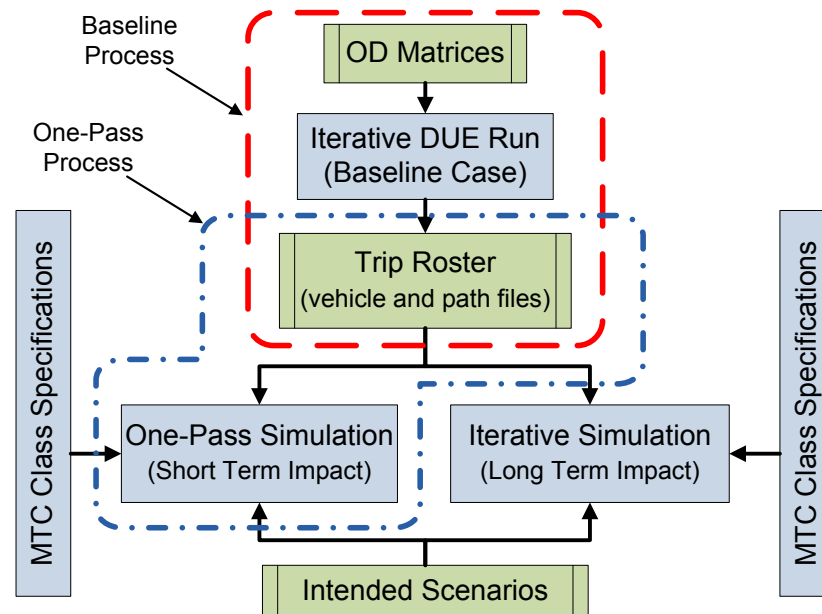
1. Start with the baseline case by using time-dependent O-D trip matrices or a trip-maker trip roster produced by an external source as the trip-maker generation mode and run the DTA model to DUE.
2. At the end of the DUE run of the baseline case, regardless of the demand generation mode (O-D or trip-maker trip roster), the DTA model will produce output containing attributes of each simulated trip-maker and the last-updated trip-maker path from the baseline case.

### 9.3 WARM START VERSUS COLD START

Having each vehicle start with a habitual path from the base case is called a “warm start,” which typically converges faster and produces more consistent results than a “cold-start” model run. A cold start means starting the DTA model without using previously converged DUE paths.

A warm start would be appropriate if the same trip roster is used from the baseline case to ensure that identical trips are being modeled and compared. In this case the output of each trip-maker’s last-updated path from the baseline case is used as the initial path in the compared scenario case. If the scenario involves a significant demand change from the base case then the warm start is not an option.

**Figure 9.1 Baseline and Scenario Modeling Framework**



Source: University of Arizona.

## 9.4 STAND-ALONE DTA ANALYSIS VERSUS INTEGRATING WITH A DEMAND MODEL

A DTA model can be used as a stand-alone model system or be integrated with a demand forecasting model. If a DTA model assumes that the demand is an exogenously given model input, then the model is to address the route choice decision only. One common concern is how other travel choices may be affected by the scenario of interest (e.g., departure-time choice or mode choice), and addressing this issue may require integration with a demand forecasting model.

### Stand-Alone

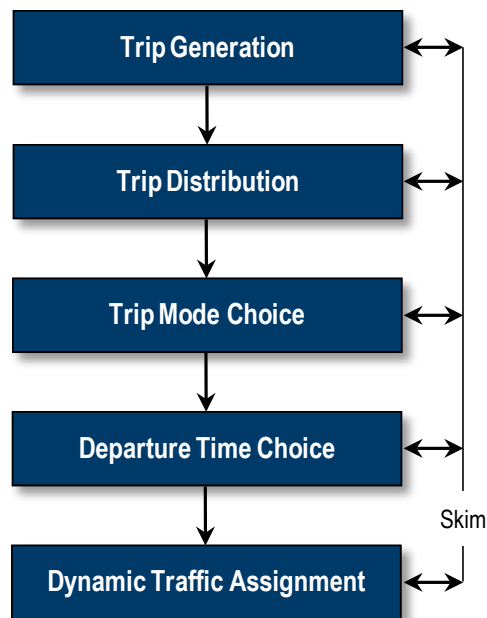
When using a DTA model as a stand-alone model, the choice dimension being addressed is mostly route choice, unless the DTA model is either integrated with other demand forecasting capabilities or designed to simultaneously model multiple choice dimensions. When performing scenario comparisons, it is critical to keep the population/trips identical across different scenarios in order to ensure that departure times, O-Ds, and attributes remain unchanged. If the alternatives of interest are modeled using vehicles with different trip O-D pairs or attributes, then randomness may be introduced, hindering the ability of the analysis to depict the true impact of the scenario of interest. Although different DTA models may have different ways of implementing such characteristics, it is critical for an analysis team to ensure consistency across compared scenarios.

## Feedback Framework

The need for a feedback between DTA and travel demand model varies by project purpose and analysis context and applications. In general, if the scenario of interest is deemed to trigger multidimensional travel choice adjustments, such as departure time and/or mode choice, then the analysis should consider an appropriate feedback framework and procedure to depict such choices.

The feedback process could be generally supported by either a trip-based or activity-based model framework. The trip-based model framework, as shown in Figure 9.2, takes the so-called “skim” data (zone-to-zone travel times) and feeds these back to various prior steps to re-estimate trip generation, distribution, mode share, and/or departure time choice.

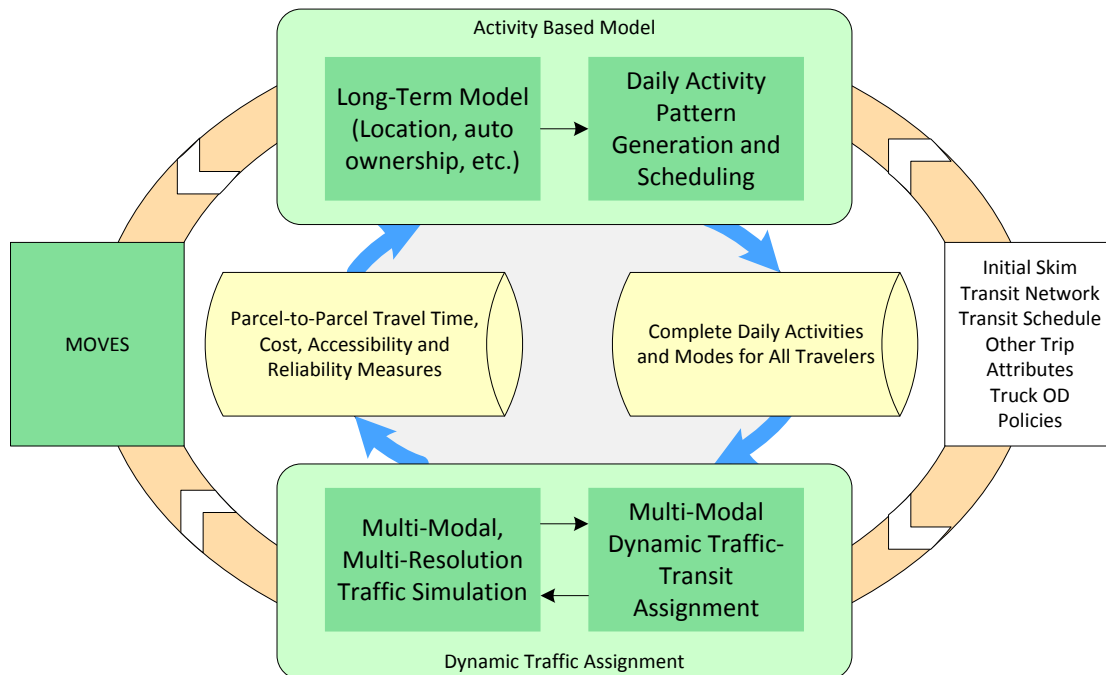
**Figure 9.2 DTA Feedback in a Trip-Based Travel Forecasting Framework**



Source: University of Arizona.

The main feedback mechanism from DTA to an activity-based model (ABM) is the so-called skim matrices, which are the zone-to-zone (or parcel-to-parcel or location-to-location) travel times informed by the traffic simulation model. The change of travel time due to the scenario of interest could trigger the adjustment of different travel decisions. The concept of the SHRP 2 C10 feedback framework is illustrated in Figure 9.3.

**Figure 9.3 Feedback Project Modeling Framework**



Source: Cambridge Systematics and University of Arizona.

## 9.5 INTERPRETING MODEL OUTPUTS

Resources for interpreting results include:

- <http://ops.fhwa.dot.gov/publications/fhwahop06005/index.htm>; and
- <http://ops.fhwa.dot.gov/publications/fhwahop08054/index.htm>

Simulation-based DTA models generally provide MOEs at vehicle/person, link, path, corridor, and network levels.

### *Vehicle/Person Level*

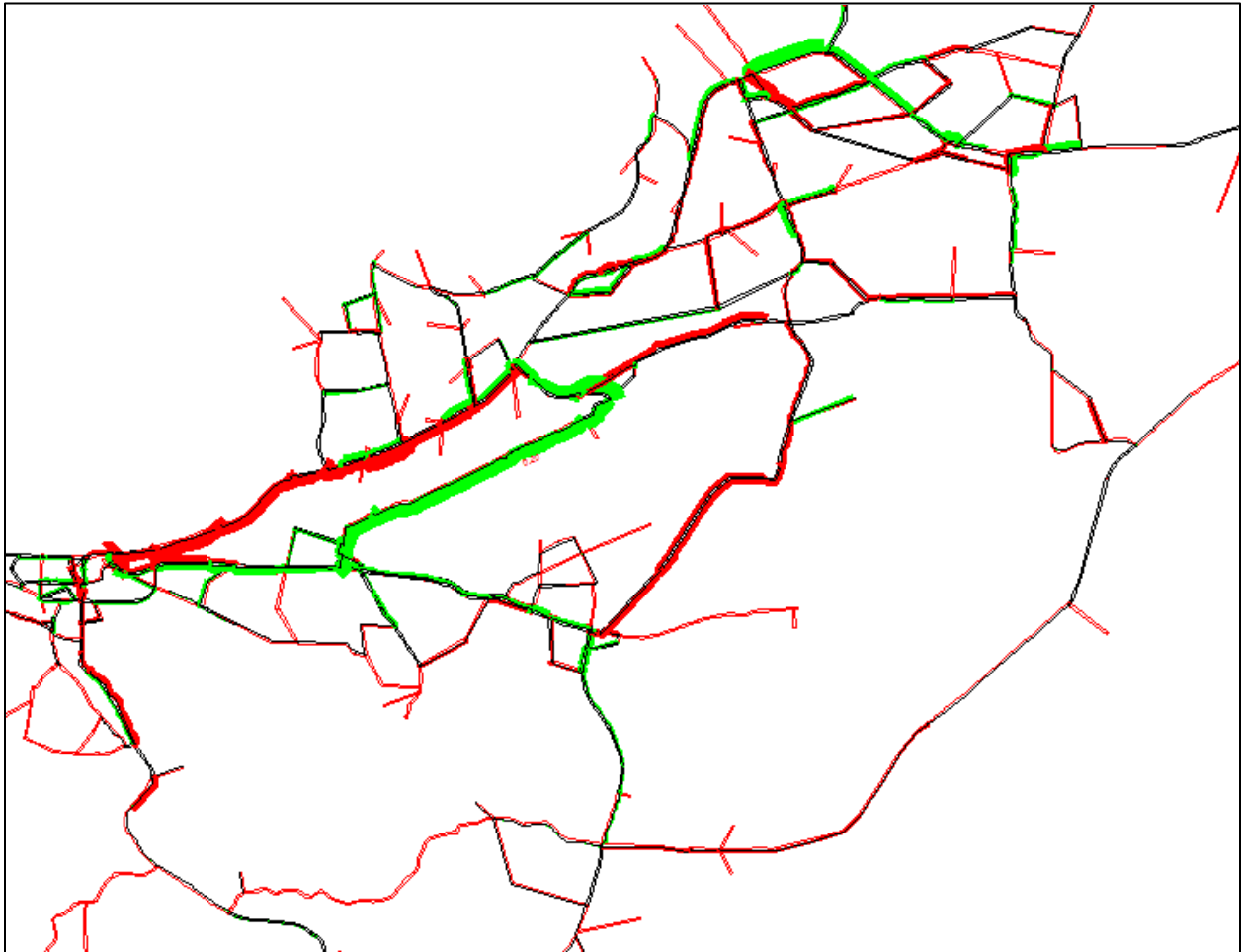
When the same vehicle roster is utilized in all compared scenarios, vehicles with the same ID in different scenarios can meaningfully be compared. For example, in the baseline case, all the vehicles passing through a work zone link can be tagged, and then the chosen routes of these vehicles can be compared before and after the work zone.

### *Link Level*

In the link-level comparison, individual route choices and travel interact to form aggregated time-varying MOEs at each link of the network. The diversion in the work zone example also could be depicted and understood by comparing the volume/speed difference before and after the work zone to infer the total

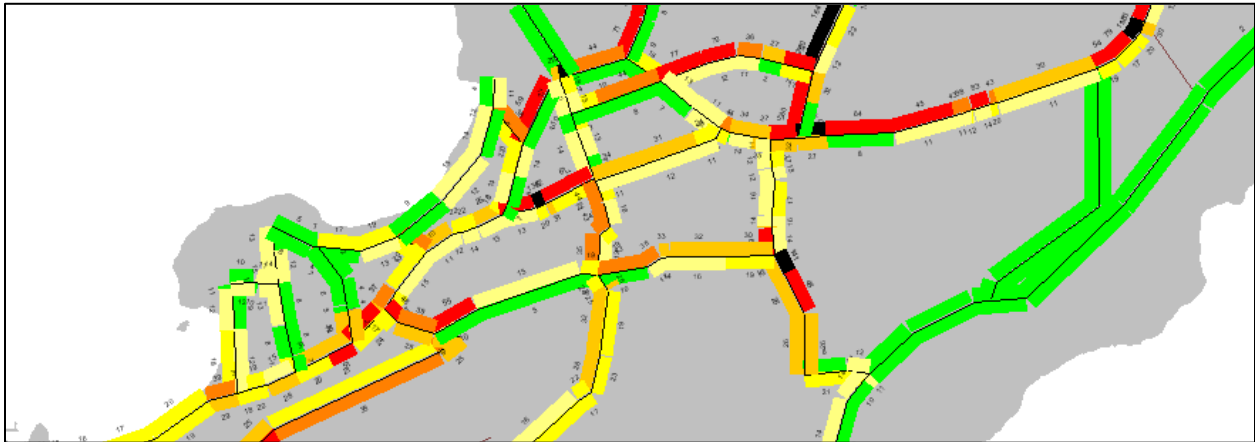
diversion around the work zone impact area. Figures 9.4 and 9.5 are examples of model outputs utilizing link-level analysis. In Figure 9.4 the red bands indicate where traffic volumes have decreased while the green bands indicate where traffic has increased. The thickness of the bands is an indication of the magnitude of the change in traffic. Figure 9.5 illustrates different levels of congestion by roadway link.

**Figure 9.4 Link Volume Difference between Two Different Sets of Model Results**



Source: University of Arizona.

**Figure 9.5 Speed/Density Plot for Links**



Source: University of Arizona.

### *Path Level*

Another way of reviewing the results is as follows: for a given O-D pair and departure time, show the set of used paths and their respective travel flow. The path sets and assigned flows for the given O-D pair will change by time. Visualizing the path set and flow change is a powerful way of depicting the model outputs.

### *Corridor Level (Heat Diagram)*

A common approach to showing the spatial and temporal extent of congestion is the space-time diagram (i.e., speed contour diagram or heat diagram). Figure 9.6 provides a sample speed contour diagram. The diagram shows the speeds occurring in the freeway, where green indicates speeds greater than 65 mph, while red indicates speeds less than 25 mph. Time is represented from left to right while the distance is from top to bottom.

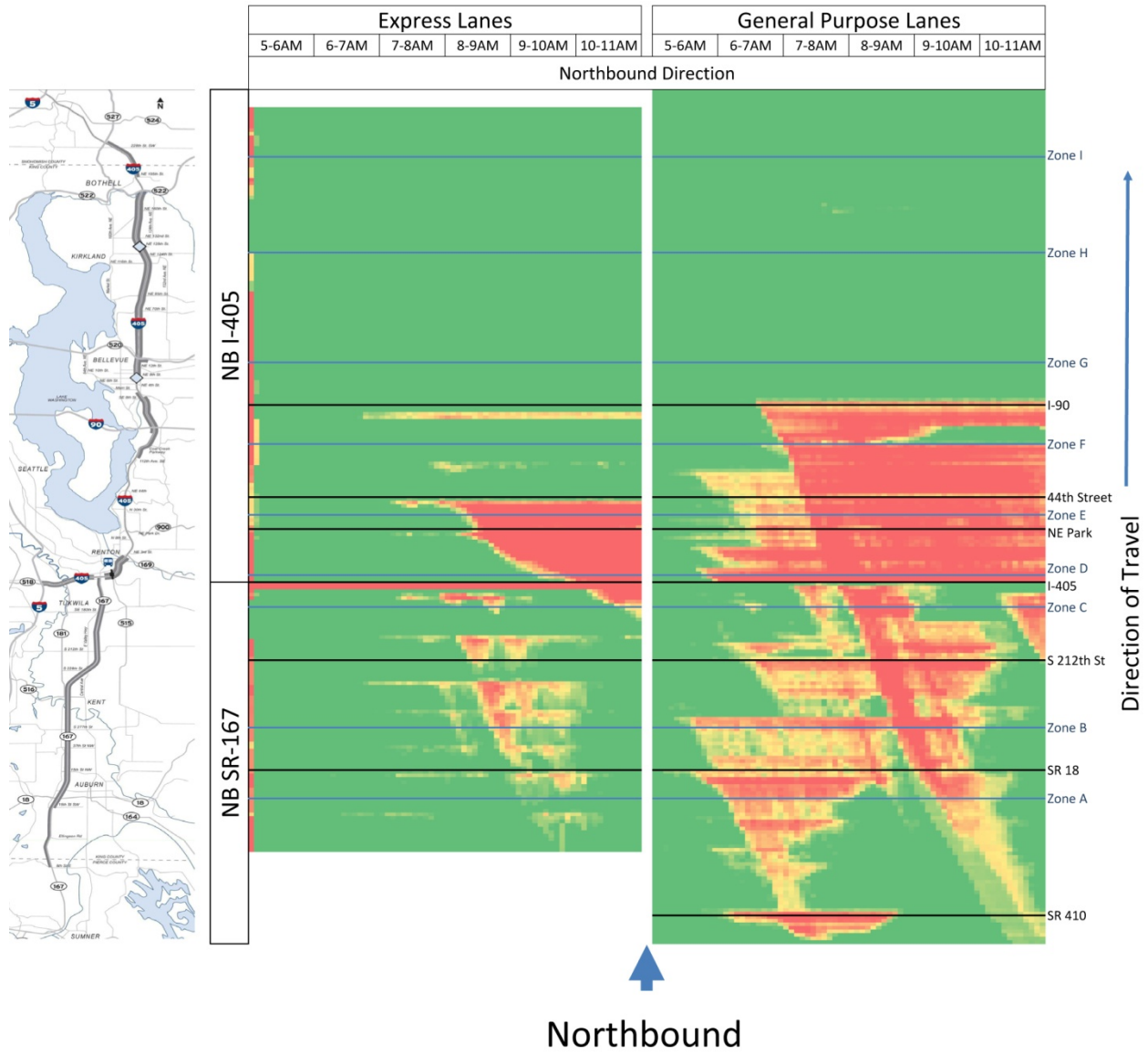
### *Network Level*

The network-level results can be displayed and analyzed textually or graphically. Most DTA software models generate overall statistics reports for the analyzed scenarios, but such network-wide statistics may be misleading if not interpreted carefully. For example, the impact of a work zone represented as a percent travel-time increase could vary depending on the extent of the area chosen as the basis of comparison. As a result, it is important to properly define the impact area for scenario comparison.

Graphical or animation representation of the simulation results for the entire region also will reveal local areas of congestion or critical spots. This information is useful for visual inspection and for understanding the characteristics, congestion, and/or impact of the scenario of interest. Figure 9.7 shows an example of network-wide animation of traffic dynamics.

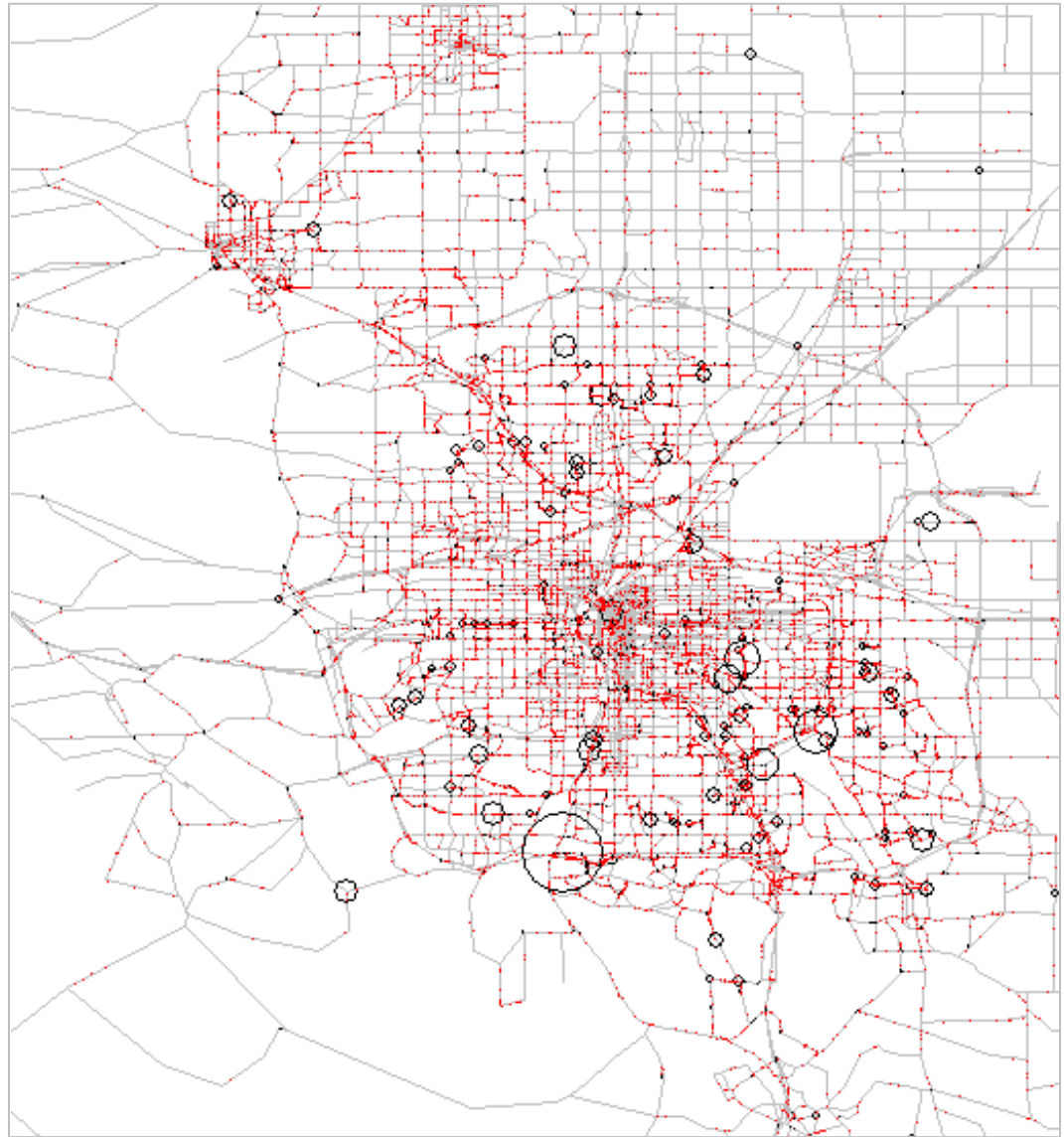


Figure 9.6 Speed Contour Diagram for Corridor-Level Analysis



Source: Cambridge Systematics, Inc.

**Figure 9.7 Network-Wide Animation of Traffic Dynamics**



Source: University of Arizona.

# A. DTA Applications

## Phoenix Area DTA Model

A microsimulation-based DTA model was built for the City of Phoenix, Arizona, involving 2,000 traffic signals.

Morgan, D., Large-Scale Microscopic Simulation-Based Dynamic Traffic Assignment, presented at the 2012 DTA International Symposium, Martha's Vineyard, Massachusetts, June 2012, <http://www2.ie.psu.edu/dta2012/> (accessed November 2012).

## Eureka, California, DTA Model

A microsimulation-based DTA model was build for the City of Eureka, California. The model was used to study the traffic impacts of development and growth and to evaluate operational improvements.

Morgan, D., and D. Mayberry, A Methodology for Estimation and Calibration of a City-Wide Microsimulation Model, presented at the Third Transportation Research Board Conference on Innovations on Travel Modeling, Tempe, Arizona, May 2010, <http://itm2010.fulton.asu.edu/ocs/index.php/itm/itm2010/index> (accessed November 2012).

## California State Route 1 DTA Model

A hybrid mesoscopic and microscopic DTA model was developed for a 45-mile stretch of the California State Route (SR) 1. The model was used to study the traffic diversions over a large area caused by various construction alternatives.

Fehon, K., K Sterner, and W. Michael, Macro-Meso-Micro Simulation Integration: The State Route 1 Corridor Approach, TRB Integrated Corridor Systems Management Conference, Irvine, CA, September 2009, <http://pressamp.trb.org/conferences/programs/program.asp?event=522> (accessed November 2012).

## U.S. 101 Corridor DTA Model

A hybrid meso-microsimulation model was built for a 50-mile section of U.S. 101 in Ventura and Santa Barbara Counties in California for analyzing corridor management plans.

Pravinvongvuth, S., and W. R. Loudon, Development of a Corridor System Management Plan Using a Hybrid Meso-Microsimulation Model, presented at the TRB Integrated Corridor Systems Management Conference, Irvine, California, September 2009, <http://pressamp.trb.org/conferences/programs/program.asp?event=522> (accessed November 2012).

### **El Paso Loop 375 DTA Model**

A multi-resolution model was built for State Highway Loop 375 in El Paso, Texas, and was used to evaluate time-dependent variable pricing for HOT lanes.

Shelton, J. A., and Y-C Chiu, A Multi-Resolution and Simulation Assignment Capability for Analyzing Time-Dependent Variable Pricing on High-Occupancy Toll Lanes, presented at the TRB Integrated Corridor Systems Management Conference, Irvine, California, September 2009, <http://pressamp.trb.org/conferences/programs/program.asp?event=522> (accessed November 2012).

### **Minneapolis DTA Model**

A DTA model was built for a Minneapolis corridor to test Integrated Corridor Management strategies, including dynamic pricing, signal retiming, and information provision about parking availability.

Chiu, Y. C., M. Hickman, L. Head, V. Papayannoulis, B. Kary, D Deeter, and A. Creek, Minneapolis Integrated Corridor Management Pioneer Site Concept and Strategy Modeling – Part 2: Analysis, Modeling and Simulation Innovations, presented at the TRB Integrated Corridor Systems Management Conference, Irvine, California, September 2009, <http://onlinepubs.trb.org/onlinepubs/conferences/2009/Corridor/Chiu2.pdf> (accessed November 2012).

### **Downtown Seattle DTA Model**

A mesoscopic DTA model was built for downtown Seattle containing a few hundred signals and used for toll revenue estimation.

Wellander, C., M. Mahut, Y. Dehghani, A. Natzel, and M. Xyntarakis, Refining Toll Analyses through Use of DTA Modeling: the Alaskan Way Viaduct Project in Seattle, presented at the 2012 DTA International Symposium, Martha's Vineyard, Massachusetts, June 2012, <http://www2.ie.psu.edu/dta2012/> (accessed November 2012).

### **Doyle Drive and Geary DTA Models, San Francisco, California**

Two mesoscopic DTA models were built for the northwest portion of the San Francisco County. The models contained a few hundred signals and were used to evaluate construction staging and Bus Rapid Transit scenarios.

Sall, E., I. Juran, I., M. Xyntarakis, and M. Mahut, “Rapid Implementation and Validation of Dynamic Traffic Assignment,” presented at the Third Transportation Research Board Conference on Innovations on Travel Modeling, Tempe, Arizona, May 2010, [http://itm2010.fulton.asu.edu/ocs/custom/allpapers/ppts/85\\_ppt.pdf](http://itm2010.fulton.asu.edu/ocs/custom/allpapers/ppts/85_ppt.pdf), (accessed November 2012).

Sall, E., M. Xyntarakis, and B. Charlton, “Easy Breezy Beautiful DTA Modeling of the Geary Boulevard Bus Rapid Transit Project – Was it Really That Simple?,” presented at the 13<sup>th</sup> TRB National Transportation Planning Applications Conference, Reno, Nevada, May 2011, [http://www.trbappcon.org/2011conf/TRB2011presentations/Session9B/05\\_SALL\\_EASY\\_DTA.ppt](http://www.trbappcon.org/2011conf/TRB2011presentations/Session9B/05_SALL_EASY_DTA.ppt) (accessed November 2012).

### **San Francisco County DTA Model**

A mesoscopic DTA model was built for the entire San Francisco County Area containing more than one thousand traffic signals. The model was used for analysis of congestion pricing and Bus Rapid Transit scenarios. Project reports and a code repository with useful scripts can be found at <http://code.google.com/p/dta/> (accessed November 2012).

### **City of Bellevue, Washington, DTA Model**

A mesoscopic DTA model was built for the city of Bellevue in the State of Washington. The following paper contains the calibration report and results from the sensitivity analysis.

Dong H., and J. Clark, Sensitivity Analysis on Dynameq: A View from Practice, presented at the 90<sup>th</sup> TRB Annual meeting, Washington, D.C., January 2011, [http://www.inrosoftware.com/en/pres\\_pap/TRB2011/Dong\\_Clark\\_Bellevue.pdf](http://www.inrosoftware.com/en/pres_pap/TRB2011/Dong_Clark_Bellevue.pdf) (accessed November 2012).

### **Olympia, Washington, DTA Model**

A mesoscopic DTA model was built for the City of Olympia, the capital of Washington State to model ITS and Transit Signal Priority strategies.

Janarthanan, N., and M-N. Shyu, Project Experience of a Dynameq Simulation Model: TRPC – Smart Corridors Project, presented at the 2010 EMMU Users Conference, Montreal, Quebec, Canada, [http://www.inrosoftware.com/en/pres\\_pap/montreal/2010/Oct4\\_UsersConf\\_V6.pdf](http://www.inrosoftware.com/en/pres_pap/montreal/2010/Oct4_UsersConf_V6.pdf) (accessed November 2012).

### **Ljubljana, Slovenia, DTA Model**

A regional mesoscopic DTA model was built for the City of Ljubljana, the capital of Slovenia, to study public transport related scenarios. More information can be found at [http://www.pnz.si/dta/DTA\\_model\\_of\\_Ljubljana.pdf](http://www.pnz.si/dta/DTA_model_of_Ljubljana.pdf) (accessed November 2012).

### **City of Malmö, Sweden, DTA Model**

A regional mesoscopic DTA model was built for the city of Malmö in Sweden to study highway and transit infrastructure projects. More information can be found at:

[http://www.inrosoftware.com/en/pres\\_pap/stockholm2012/Presentation\\_Model\\_City\\_Malmo1.4.pdf](http://www.inrosoftware.com/en/pres_pap/stockholm2012/Presentation_Model_City_Malmo1.4.pdf) (accessed November 2012).

### **City of Portland, Oregon, DTA Model**

A regional mesoscopic DTA model was built for the City of Portland, Oregon to be used for the MPO's long-range planning needs. The following link contains a presentation with more information:

[http://www.inrosoftware.com/en/pres\\_pap/international/portland2011/DTA\\_in\\_Planning-Walker.pdf](http://www.inrosoftware.com/en/pres_pap/international/portland2011/DTA_in_Planning-Walker.pdf) (accessed November 2012).

### **Tel-Aviv, Israel, DTA Model**

A regional mesoscopic DTA model was built for the city of Tel-Aviv in Israel consisting of 200 zones and 300 traffic signals. The following presentation contains information about the network and the calibration statistics: [http://www.inrosoftware.com/en/pres\\_pap/TRB2009/DTA\\_Mahut.pdf](http://www.inrosoftware.com/en/pres_pap/TRB2009/DTA_Mahut.pdf) (accessed November 2012).

### **City of Montreal, Canada, DTA Model**

A regional mesoscopic DTA model was built for the city of Montreal in Canada consisting of 400 zones and 600 signals. The following presentation contains information about the network, calibration statistics, and methodology [http://www.inrosoftware.com/en/pres\\_pap/international/ieug06/7-1\\_Pascal\\_Volet.pdf](http://www.inrosoftware.com/en/pres_pap/international/ieug06/7-1_Pascal_Volet.pdf) (accessed November 2012).

### **Houston, Texas DTA Model**

A regional mesoscopic DTA model was built for the city of Houston, Texas. The following paper describes the methodology used for simulating vehicles and the technical challenges in building a mesoscopic model for millions of trips.

Lam C. P., C. Van Slyke, H. Wang, and C. Brown, Applying Mesoscopic Simulation to Evacuation Planning for the Houston Region, presented at the 12<sup>th</sup> Transportation Research Board National Transportation Planning Applications Conference, Houston, Texas, May 2009, [http://www.trbappcon.org/2009conf/TRB2009papers/ws202\\_Applying\\_Meso\\_in\\_Houston\\_Evacuation\\_Model\\_papers.pdf](http://www.trbappcon.org/2009conf/TRB2009papers/ws202_Applying_Meso_in_Houston_Evacuation_Model_papers.pdf) (accessed November 2012).

### **Houston, Texas Mesoscopic Evacuation Model**

A mesoscopic DTA model with thousands of zones was built for the City Houston in Texas and used to evaluate evacuation planning scenarios, such as contra-flow lanes and ramp closures. The following presentation discusses the technical challenges in building the model and provides network and demand statistics.

Lam C. P., C. Van Slyke, H. Wang, and C. Brown, Applying Meso-scopic Simulation to Evacuation Planning for the Houston Region, presented at the 12<sup>th</sup> Transportation Research Board National Transportation Planning Applications Conference, Houston, Texas, May 2009, [http://www.trbappcon.org/2009conf/TRB2009presentations/ss2/01\\_applying\\_meso\\_scopic\\_simulation\\_to\\_evacuation\\_planning\\_h\\_gac2.ppt](http://www.trbappcon.org/2009conf/TRB2009presentations/ss2/01_applying_meso_scopic_simulation_to_evacuation_planning_h_gac2.ppt) (accessed at 2012).



## B. Foundations of Dynamic Traffic Assignment (DTA) Workshop: Selected Recent DTA Analyses

The Federal Highway Administration assembled this list of recent examples (2009 and later) of DTA analyses as a supplement to its Foundations of Dynamic Traffic Assignment Workshop. The list of examples was collected from public sector agencies, academia, and consultants to provide examples from a broad cross-section of application areas that will assist students in applying DTA techniques to conduct traffic analyses in their regions.

### Work Zone/Construction

<b>1. Project Title:</b> Atlanta's Memorial Drive DTA Case Study, part of ARC's Strategic Regional Thoroughfare Plan/Regional Thoroughfare Network	
<b>Location Modeled:</b> Atlanta, GA, area bounded on the north by Ponce de Leon Avenue, on the south by Glenwood Avenue, on the east by Moreland Avenue and on the west by I-75/85 Downtown Atlanta CBD	<b>Project Dates:</b> 2010-2011
<b>Sponsor:</b> Atlanta Regional Commission (ARC)	<b>Contact:</b> Guy Rousseau, <a href="mailto:grousseau@atlantaregional.com">grousseau@atlantaregional.com</a>
<b>Application Used:</b> Cube Voyager/TP+, Cube Avenue DTA, VISSIM microsimulation	
<p><b>Project Description:</b></p> <p>This mesoscopic analysis was carried out by using dynamic traffic assignment (DTA) to address the issue of motorist selection of differing routes during periods of congestion along with the changing of these routes within the congested time period itself. This DTA process allowed for an examination of queues and delays associated with congestion. DTA procedures have recently been tested successfully in the Atlanta metropolitan 20-county region to determine its viability in large scale applications. This step down process provides the necessary integration of macroscopic and mesoscopic analysis procedures to ensure analysis consistency and compatibility. This level of analysis allowed for an examination of travel and transportation network characteristics during peak periods. The trips for each of the AM and PM peak periods within the study area are developed by extracting the trips from the regional travel demand model using hourly assignments. The third level of analysis is microscopic analysis which dealt with the detailed operational characteristics of the transportation network at specific locations, along the corridor, or within isolated areas of the overall corridor. This microscopic analysis was carried out by extracting the area to be studied in detail from the mesoscopic model and using more rigorous analysis procedures of a micro traffic simulation model. The traffic volumes and travel patterns established in the mesoscopic analysis are incorporated into the microscopic analysis, thus maintaining the integration with the macroscopic and mesoscopic levels of analysis. The end result of the DTA analysis is a recommended design concept developed through a cooperative process that, in turn, mitigates potential conflicts during the environmental assessment (as prescribed by the National Environmental Protection Act (NEPA)), final design and construction phases of the project. As such, the ARC will be developing corridor plans that lead to a project further along in the implementation stages. In addition, regional travel trends will be considered in developing the concept by carrying through the travel analysis methodology tested in the case study process. Another potential result of the DTA analysis is the identification of short-term safety and/or operational improvements for the corridor.</p>	
<b>Related Links:</b> <a href="http://atlantaregional.com/transportation/studies/strategic-regional-thoroughfare-plan">http://atlantaregional.com/transportation/studies/strategic-regional-thoroughfare-plan</a>	

2. Project Title: Presidio Parkway Construction Traffic Management Plan	
<b>Location Modeled:</b> Northwest quadrant of the City of San Francisco, California	<b>Project Dates:</b> August – December 2009
<b>Sponsor:</b> San Francisco County Transportation Authority	<b>Contact:</b> Elizabeth Sall, <a href="mailto:Elizabeth.sall@sfcta.org">Elizabeth.sall@sfcta.org</a>
<b>Application Used:</b> Dynameq	
<p><b>Project Description:</b> Doyle Drive is the 2-mile long southern approach to the Golden Gate Bridge. Carrying roughly 17,000 weekday transit riders and 127,000 weekday persons in cars, it is both the primary highway and transit link from San Francisco and the South Bay, to the North Bay Counties as well as an essential east-west connection for trips within San Francisco. Built over 60 years ago, Doyle Drive is also one of the most seismically unfit facilities in California and plans for its replacement facility, the Presidio Parkway, have been underway since the 1970s. The final funding gap was closed by the American Recovery and Reinvestment Act of 2009 (ARRA) to facilitate the signing and certification of the final joint EIS/EIR. Accordingly, the construction time line has been significantly accelerated in order to meet ARRA requirements. This left the San Francisco County Transportation Authority (SFCTA), Caltrans and other local agency partners with little time to evaluate the traffic impacts from the construction of the Presidio Parkway. Recognizing the need to identify potential bottlenecks and queues as a result of the construction (and test possible solutions to these issues), SFCTA decided to implement Dynamic Traffic Assignment (DTA) for this quadrant of the city.</p>	
<b>Related Links:</b> <a href="http://www.presidioparkway.org">www.presidioparkway.org</a>	
3. Project Title: Interstate 10 Corridor Improvement Analysis	
<b>Location Modeled:</b> Interstate 10, El Paso, TX	<b>Project Dates:</b> 9/2010 – 8/2011
<b>Sponsor:</b> Texas Department of Transportation	<b>Contact:</b> Jesus Heredia, P.E., <a href="mailto:Jesus.Heredia@txdot.gov">Jesus.Heredia@txdot.gov</a>
<b>Application Used:</b> DynusT-VISSIM, Synchro (Multi-resolution)	
<p><b>Project Description:</b> The Texas Transportation Institute conducted a corridor analysis on Interstate 10 in El Paso to determine the impact of direct connectors at the Loop 375 interchange. The goal was to determine if the proposed connectors would alleviate severe congestion at an adjacent diamond interchange or if additional roadway construction (e.g., additional diamond interchanges, ramp reversals,) would be needed. A DTA simulation-based modeling approach utilizing DynusT was used in the analysis. DynusT networks were coded for future conditions to analyze traffic patterns and rerouting based upon proposed diamond interchange construction and ramp reconfigurations. Future network conditions included a proposed tolling scenario on Border Highway.</p>	
<b>Related Links:</b> PowerPoint slides available by request.	

## Transit Operations

4. Project Title: Geary Boulevard Bus Rapid Transit Environmental Impact Report	
<b>Location Modeled:</b> Northwest quadrant of the City of San Francisco, California	<b>Project Dates:</b> Spring 2010 – ongoing
<b>Sponsor:</b> San Francisco County Transportation Authority	<b>Contact:</b> Elizabeth Sall, <a href="mailto:Elizabeth.sall@sfcta.org">Elizabeth.sall@sfcta.org</a>
<b>Application Used:</b> Dynameq	
<p><b>Project Description:</b> In order to model the impacts and benefits of a potential Geary Boulevard Bus Rapid Transit, the Authority was able to successfully link the SF-CHAMP regional activity-based travel demand model with the subarea DTA model by directly using raw SF-CHAMP trip tables for the base and future years. The DTA model in turn provided</p>	



reasonable intersection-level data for use in a traffic microsimulation model. The DTA model was validated to several hundred mainline and intersection counts as well as travel speeds. The project team developed open-source python-based tools to make quick work of most calibration, validation, and model input, output, and summary tasks. The DTA model provided two main benefits: (1) a needed link between a regional travel demand model and a traffic microsimulation model able to more reliably model traffic diversions in the corridor; (2) more reliable travel time and Level of Service (LOS) outputs of different scenarios for areas that were not scoped to be modeled by traffic microsimulation.

**Related Links:** [http://www.trbappcon.org/2011conf/TRB2011presentations/Session9B/05\\_SALL\\_EASY\\_DTA.ppt](http://www.trbappcon.org/2011conf/TRB2011presentations/Session9B/05_SALL_EASY_DTA.ppt)  
[www.gearybrt.org](http://www.gearybrt.org)

#### 5. Project Title: West Palm Beach Transit Oriented Development Traffic Impact Analysis

<b>Location Modeled:</b> Southeast Florida (regional model), West Palm Beach (detailed subarea)	<b>Project Dates:</b> 2009 - ongoing
<b>Sponsor:</b> Florida Department of Transportation, District 6	<b>Contact:</b> Ana Elias, <a href="mailto:ana.elias@jacobs.com">ana.elias@jacobs.com</a>

**Application Used:** Cube Base, Cube Voyager, Cube Analyst (ME), Cube Avenue

#### Project Description:

District 4 of the Florida Department of Transportation developed a traffic impact analysis toolkit initially used to study a transit-oriented development in West Palm Beach. Dynamic traffic analysis was included in this toolkit to improve temporal specificity. The resulting analysis toolkit is capable of extracting time-varying trip tables from the Southeast Regional Planning Model (SERPM), calibrating these to observed traffic counts by time of day (using dynamic origin-destination matrix estimation techniques), and performing a hybrid static/dynamic traffic assignment on the full regional network in order to extract a fully dynamic traffic simulation model for any arbitrary user-defined subarea of this region.

**Related Links:** [http://www.fsutmonline.net/images/uploads/southeastfloridafsutms/Citilabs-SERPM\\_DTA.pdf](http://www.fsutmonline.net/images/uploads/southeastfloridafsutms/Citilabs-SERPM_DTA.pdf)

## Truck Operations/Border Crossings

#### 6. Project Title: Dynamic Modeling Methods for Analyzing New Truck Routes for the BOTA Port-of-Entry

<b>Location Modeled:</b> Bridge of Americas – El Paso/Cuidad Juarez, Mexico	<b>Project Dates:</b> 10/2010 – 1/2011
<b>Sponsor:</b> Texas Department of Transportation	<b>Contact:</b> Omar Madrid, P.E., <a href="mailto:Omar.Madrid@txdot.gov">Omar.Madrid@txdot.gov</a>

**Application Used:** DynusT-VISSIM, (Multi-resolution)

#### Project Description:

The Texas Transportation Institute examined the effects of new truck routes destined for the Bridge of the Americas (BOTA) Port-of-Entry in El Paso, Texas. The analysis determined how the proposed truck rerouting would influence the surrounding transportation system and whether the changes would improve southbound traffic flow into Mexico or have an adverse effect. The analysis used a regional dynamic traffic assignment model (DynusT) to simulate present day network conditions at the system-wide level. This is necessary to determine both car and truck paths in and around the study area. Once the network model was simulated to equilibrium conditions, a sub-area cut will be extracted and converted to a microscopic model (VISSIM) which was capable of analyzing various vehicle classes at a high level of detail.

**Related Links:** PowerPoint slides available by request.

#### 7. Project Title: Integrated Dynamic Bi-National Travel Demand Model

<b>Location Modeled:</b> El Paso/Cuidad Juarez, Mexico border region	<b>Project Dates:</b> 9/2010 – 8/2011
<b>Sponsor:</b> Texas Transportation Institute – Center for International Intelligent Transportation Research	<b>Contact:</b> Rafael Aldrete, Ph.D., <a href="mailto:r-aldrete@tamu.edu">r-aldrete@tamu.edu</a>

**Application Used:** TRANUS - VISUM - DynusT- (Multi-resolution)

**Project Description:**

The objective of this project was to develop a mesoscopic bi-national (i.e. El Paso - Juarez) simulation model capable of running DTA to conduct transportation studies in the border region. In order to develop the DTA model, a combination of macroscopic and mesoscopic transportation planning software (e.g. VISUM, TRANUS, and DynusT) was required. In addition, researchers used a VISUM-DynusT Converter (VDC) tool previously developed by the Texas Transportation Institute and PTV America to integrate the transportation network between the macroscopic and mesoscopic level. The dynamic bi-national travel demand model allowed researchers to analyze the impact of proposed new port-of-entry infrastructure and the impacts of existing border crossing during recurring and non-recurring events (e.g., bridge closure due to bomb threat, protesters, etc.). In addition, variable tolling options allowed for a more robust approach to analyzing proposed managed lanes in the region.

## Integrated Corridor/Systems Management

<b>8. Project Title: A DTA model platform and analysis approach for the City of Bellevue</b>	
<b>Location Modeled:</b> Cities of Bellevue, Kirkland and Redmond and their fringe area, with detailed network and traffic controls in the City of Bellevue limits and its vicinity.	<b>Project Dates:</b> Ongoing
<b>Sponsor:</b> City of Bellevue	<b>Contact:</b> Hu Dong, <a href="mailto:hdong@bellevuewa.gov">hdong@bellevuewa.gov</a> Judy Clark, <a href="mailto:jclark@bellevuewa.gov">jclark@bellevuewa.gov</a>
<b>Application Used:</b> Dynameq and EMME	
<b>Project Description:</b> Unlike other DTA models nationwide developed specifically for a transportation project, The City of Bellevue is trying to build a generic DTA platform for the whole city area and develop a streamlined procedure for fast and efficient application for the City's transportation projects. This platform includes a base year DTA model and a future year (2030 at this time) baseline. The City is developing a procedure that starts from its BKR travel demand model which covers a much larger area than the DTA model, and includes how to test a transportation project under the new platform, how to report the DTA outputs, and how to disseminate the output information to the transportation professional and public. The base year DTA model has been calibrated and the future baseline is under fine-tuning when this project information is provided.	
<b>Related Links:</b> "Sensitivity Test on Dynameq, View from Practice", <a href="http://amonline.trb.org/12kaba/12kaba/1">http://amonline.trb.org/12kaba/12kaba/1</a> TRB Annual Conference, Jan 2011	
<b>9. Project Title: Thurston Regional Planning Council (TRPC) Smart Corridors Project</b>	
<b>Location Modeled:</b> Thurston County, WA	<b>Project Dates:</b> 2009 - ongoing
<b>Sponsor:</b> Thurston Regional Planning Council	<b>Contact:</b> Natarajan Janarthanan, <a href="mailto:janartn@wsdot.wa.gov">janartn@wsdot.wa.gov</a> Ming-Bang Shyu, <a href="mailto:shyum@wsdot.wa.gov">shyum@wsdot.wa.gov</a>
<b>Application Used:</b> DYNAMIQ	
<b>Project Description:</b> TRPC is an intergovernmental board made up of local government jurisdictions within Thurston County in Washington State. The county has an area of 727 square miles and a population of little less than 250,000. The county is the home of the State's capitol, city of Olympia. TRPC received Congestion Mitigation and Air Quality (CMAQ) grant to reduce PM10 emissions in the County. TRPC decided to focus their efforts on two key corridors in the county and focused on smart corridor techniques. TRPC had an EMME model for the base and future year. But they wanted to build a mesoscopic model to evaluate signal coordination and transit signal priority, to integrate arterial/freeway management and to measure PM10 emissions. INRO's software product DYNAMIQ was chosen by the TRPC. The efforts to build a mesoscopic model for the whole county but focusing on two main corridors and areas surrounding them were undertaken in 2009. The existing year model was completed before the end of the year 2009. This project is on-going and managed by Jailyn Brown of Thurston Regional Planning Council.	

<b>Related Links:</b> PowerPoint Slides available by request.	
<b>10. Project Title: Manhattan Traffic Model</b>	
<b>Location Modeled:</b> The whole of the island of Manhattan in addition to parts of New Jersey, the Bronx and Brooklyn	<b>Project Dates:</b> 9/2009 – 9/2011
<b>Sponsor:</b> New York City DOT	<b>Contact:</b> Mike Marsico, mmarsico@dot.nyc.gov
<b>Application Used:</b> Aimsun	
<b>Project Description:</b> The Manhattan Traffic Model (MTM) is a multi-tier model developed for NYCDOT by Cambridge Systematics, STV and TSS- Transport Simulation Systems in order to assess traffic operations for Manhattan, New York. NYCDOT is working with other regional agencies to coordinate modeling activities where the MTM network will be made available to address cumulative network impacts of construction projects, roadway closures and traffic operations plans, as well as to provide a point of departure for future work and the creation of a sustainable regional model.	
<b>Related Links:</b> <a href="http://www.nyc.gov/html/brt/downloads/pdf/201005_34th_traffic_analysis_summary.pdf">http://www.nyc.gov/html/brt/downloads/pdf/201005_34th_traffic_analysis_summary.pdf</a> <a href="http://www.aimsun.com/press/Published%20of%20of%20MTM%20article%20in%20TTL.pdf">http://www.aimsun.com/press/Published%20of%20of%20MTM%20article%20in%20TTL.pdf</a>	
<b>11. Project Title: Maricopa Association of Governments Inner Loop Traffic Operations Model Development</b>	
<b>Location Modeled:</b> Greater Phoenix, AZ	<b>Project Dates:</b> ongoing
<b>Sponsor:</b> Maricopa Association of Governments (MAG)	<b>Contact:</b> Bob Hazlett, P.E., <a href="mailto:bhazlett@azmag.gov">bhazlett@azmag.gov</a>
<b>Application Used:</b> TransModeler (DTA based on microscopic traffic simulation)	
<b>Project Description:</b> Maricopa Association of Governments (MAG) sponsored a project to develop a 500 square-mile simulation model for the inner loop region of the Phoenix metropolitan area. This project includes the development of the simulation network, input of the traffic control, and demand estimation (including congested travel time estimation via dynamic traffic assignment (DTA)). The geographic area comprises a high-capacity network of arterials and major freeways in the most populous region of the metropolitan area.	
<b>Related Links:</b> PowerPoint slides available by request.	
<b>12. Project Title: Toronto 400 Series</b>	
<b>Location Modeled:</b> Area between (and including) Highway 400, 401, 404 and 407 in the Greater Toronto Area	<b>Project Dates:</b> 08/2008 - ongoing
<b>Sponsor:</b> Ministry of Transportation of Ontario (MTO)	<b>Contact:</b> Goran Nikolic, <a href="mailto:goran.nikolic@ontario.ca">goran.nikolic@ontario.ca</a>
<b>Application Used:</b> Aimsun	
<b>Project Description:</b> The proof-of-concept is for the simulation framework covering the 400-series highway network and major arterial roads in the Greater Toronto Area.	
<b>Related Links:</b> <a href="http://www.aimsun.com/press/A_model_approach.pdf">http://www.aimsun.com/press/A_model_approach.pdf</a> , <a href="http://www.traffictechnologytoday.com/features.php?BlogID=316">http://www.traffictechnologytoday.com/features.php?BlogID=316</a>	
<b>13. Project Title: Modym (Montreal, Canada)</b>	
<b>Location Modeled:</b> The island of Montreal	<b>Project Dates:</b> 5/2011 - ongoing
<b>Sponsor:</b> Ville de Montréal	<b>Contact:</b> Francine Leduc, <a href="mailto:fleduc_2@ville.montreal.qc.ca">fleduc_2@ville.montreal.qc.ca</a>
<b>Application Used:</b> Aimsun	
<b>Project Description:</b> The City of Montreal wishes to build a reusable, super large-scale simulation base model of Montreal. EMViM modeling group is using Aimsun to provide an extensible modeling environment that can cover the entire island of	

Montreal and allow it to vastly expand the Montreal model. EMViM is using Aimsun's micro-meso hybrid capability to overcome mesoscopic restraints, particularly on freeway merge and diverge sections and connections to arterial networks, where modelers can now zoom in for greater granularity.	
Related Links: <a href="http://www.aimsun.com/press/TP-TSS%20%283%29.pdf">http://www.aimsun.com/press/TP-TSS%20%283%29.pdf</a>	
<b>14. Project Title: Integrated Corridor Management</b>	
<b>Location Modeled:</b> Minneapolis, MN	<b>Project Dates:</b> 9/2006 – 8/2009
<b>Sponsor:</b> FHWA	<b>Contact:</b> Yi-Chang Chiu, <a href="mailto:chiu@email.arizona.edu">chiu@email.arizona.edu</a>
<b>Application Used:</b> DynusT	
<b>Project Description:</b> This project is aimed at establishing the ICM modeling methodologies and applying that to the Minneapolis Pioneer Site. In this project the UA team applied DynusT as the primary modeling tool. The DynusT modeling capabilities utilized in this project include the simulation-based DTA analysis encompassing information strategies, ramp metering, congestion pricing, and transit simulation and assignment, for various incident scenarios. The origin-destination (O-D) table and speed profile calibration procedure appeared to be effective and efficient in establishing a satisfactory baseline case.	
Related Links: PowerPoint slides available by request.	

## Safety Analysis

<b>15. Project Title: Loop 375/SH20 Alameda Interchange Safety Analysis</b>	
<b>Location Modeled:</b> Loop 375/SH 20 Alameda Diamond Interchange – El Paso, TX	<b>Project Dates:</b> 4/2010 – 8/2010
<b>Sponsor:</b> Texas Department of Transportation	<b>Contact:</b> Gus Sanchez, <a href="mailto:gsanche@dot.state.tx.us">gsanche@dot.state.tx.us</a>
<b>Application Used:</b> DynusT-VISSIM Synchro (Multi-resolution)	
<b>Project Description:</b> The Texas Transportation Institute conducted a safety review of a diamond interchange and surrounding areas to determine long-term mitigation strategies aimed at reducing traffic accidents in the study area. DynusT was used to analyze long-term strategies that consisted of future network improvements. Long-term strategies included additional on and off ramps on Loop 375 up and downstream of the diamond interchange, additional roadway capacity, and proposed direct connectors to Cesar Chavez Border Highway. Additional roadway capacity scenarios were also modeled, including additional lanes on Loop 375, connectivity between Alameda Ave and Interstate 10 via Old Hueco Tanks Rd. The conceptual Border Highway East Extension was also modeled with DynusT to analyze traffic patterns near the Zaragoza and Tornillo ports-of-entry in El Paso County. All scenarios included a tolled corridor on Cesar Chavez Border Highway.	
Related Links: PowerPoint slides available by request.	

## Demand/Access Management

<b>16. Project Title: Dynamic Traffic Assignment for Lake County, CA</b>	
<b>Location Modeled:</b> Lake County, CA	<b>Project Dates:</b> 6/2011 - ongoing
<b>Sponsor:</b> Lake County/City Area Planning Council and Caltrans, District 1	<b>Contact:</b> Jaime Hostler, <a href="mailto:jaime_hostler@dot.ca.gov">jaime_hostler@dot.ca.gov</a>
<b>Application Used:</b> TransModeler (DTA based on microscopic traffic simulation)	
<b>Project Description:</b> Caliper is working with Caltrans and area transportation staff to calibrate a model spanning most of Lake	

County, CA. The focus of the model is the management of traffic demand between routes north and south of Clear Lake. The corridor is more than 50 miles in length, is made up of State Routes 20, 29, and 53, and includes considerable local network detail in the towns through which the routes pass. When the model is calibrated and validated, alternative strategies for traffic calming and access management in the towns will be considered with a view to attracting traffic to the route south of the Lake, which impacts local communities to a much lesser degree. At the center of the routing analysis is a microscopic simulation-based dynamic traffic assignment (DTA), which will be used to determine the route choice implications of the various strategies to be studied.

**Related Links:** PowerPoint slides available by request.

## Special Events/Closures/Evacuations

### 17. Project Title: White House Area Transportation Study

**Location Modeled:** Core areas of Washington D.C. and Arlington, VA

**Project Dates:** 2005-2010

**Sponsor:** Federal Highway Administration

**Contact:** [david.roden@aecom.com](mailto:david.roden@aecom.com) or [douglas.laird@dot.gov](mailto:douglas.laird@dot.gov)

**Application Used:** TRANSIMS

**Project Description:**

The White House Area Transportation Study (WHATS) evaluated strategies designed to mitigate the impacts of street closures around the White House on vehicle, pedestrian, and transit travel in downtown Washington D.C. Data from the MWCOC regional model was integrated with TRANSIMS travel simulations to quantify the effectiveness of each strategy. A detailed model was developed, calibrated and validated against observed conditions, and applied for alternatives analysis and evaluation. The first phase of the study evaluated several tunnel configurations under E Street and Pennsylvania Avenue.

The environmental and engineering impacts of these alternatives were identified and construction and impact mitigation costs were estimated. The second phase of the study focused on K Street transitway alternatives and traffic operations strategies. TRANSIMS simulations quantified the highway and transit impacts of these alternatives on individual travelers and the network as a whole. The traffic operations strategies included designating key facilities for travel through and around the White House core and reconfiguring other facilities to support better pedestrian and transit operations.

**Related Links:** [http://www.npc.gov/npc/Main\(T2\)/Planning\(Tr2\)/PlanningStudies \(Tr3\)/Transportation.html](http://www.npc.gov/npc/Main(T2)/Planning(Tr2)/PlanningStudies (Tr3)/Transportation.html)

### 18. Project Title: Santa Clara County Earthquake Evacuation Simulation Model

**Location Modeled:** San Francisco Bay Area/Santa Clara County metropolitan area(hybrid/static DTA); Santa Clara County (full DTA and simulation model)

**Project Dates:** 2009 (pilot study completed)

**Sponsor:** County of Santa Clara County, CA

**Contact:** Mike Wallace, Fehr and Peers:  
[m.wallace@fehrandpeers.com](mailto:m.wallace@fehrandpeers.com)

**Application Used:** Cube Base, Cube Voyager, Cube Avenue

**Project Description:**

The Santa Clara County (CA) Information Services Department, which houses the Emergency Operations Center for Silicon Valley, has performed a number of analyses to evaluate evacuation plans for potential catastrophic seismic events on the San Andreas fault line (i.e., “the Big One”). These included GIS modeling of earthquake damage impacts using FEMA HAZUS-MH software and detailed shelter mapping. The information generated by these GIS-based analyses was combined with data from the Santa Clara Valley Transportation Authority (VTA) and City of San Jose traffic forecasting models to develop strategic models of evacuation travel demand and the effects of potential road network destruction on vehicle traffic generated by uncoordinated self-evacuation attempts. In the course of developing these models, the countywide dynamic traffic assignment and simulation model used in this study was validated against average weekday peak periods conditions and shown to meet and exceed the criteria used to measure the accuracy of the VTA static highway traffic assignment model.

**Related Links:** <http://www.scribd.com/fullscreen/72733941>

<b>19. Project Title: Charles River Bridge Closure Analysis</b>	
<b>Location Modeled:</b> Boston and Cambridge, MA	<b>Project Dates:</b> 2009-2011
<b>Sponsor:</b> Executive Office of Transportation (EOT)	<b>Contact:</b> Mikel Murga, MIT mmurga@mit.edu
<b>Application Used:</b> Cube Base, Cube Voyager, Cube Avenue	
<p><b>Project Description:</b></p> <p>Mikel Murga, a transportation engineering and planning professor at the Massachusetts Institute of Technology, used Cube Avenue to develop a city-wide dynamic traffic assignment model of Cambridge and Boston. The motivation for this model was to research the network traffic effects of policies regarding the closure of bridges across the Charles River. In particular, the DTA and simulation model was able to represent the process of queue formation at intersections and bottlenecks due under alternative network configurations.</p>	
<b>Related Links:</b> <a href="http://www.scribd.com/fullscreen/72733838/">http://www.scribd.com/fullscreen/72733838/</a>	

## Congestion/Value Pricing

<b>20. Project Title: An Open-Source Dynamic Traffic Assignment Tool for Assessing the Effects of Roadway Pricing and Crash Reduction Strategies on Recurring and Non-Recurring Congestion</b>	
<b>Location Modeled:</b> Salt Lake City, UT, Portland, OR, Raleigh, NC	<b>Project Dates:</b> March 1, 2011 to January 1, 2013
<b>Sponsor:</b> FHWA Planning Office	<b>Contact:</b> Brian Gardner, <a href="mailto:Brian.Gardner@dot.gov">Brian.Gardner@dot.gov</a>
<b>Application Used:</b> DTALite	
<p><b>Project Description:</b></p> <p>The purpose of this research is to provide transportation planners and engineers with a rigorous and computationally efficient tool to assess corridor and network-wide effects of pricing and crash-reduction strategies on recurring and non-recurring congestion, using performance measures that can be directly applied in investment-level planning and decision-making processes. The research team proposes to build this capability into an open-source dynamic traffic assignment model designed for practical everyday use within the context of an entire large-scale metropolitan area network. The research product will assist state DOTs and regional MPOs to rapidly and systematically examine the effectiveness of traffic mobility, reliability and safety improvement strategies, individually and in combination, for a large-scale regional network, a subarea or a corridor.</p>	
<b>Related Links:</b> <a href="http://code.google.com/p/nexta/">http://code.google.com/p/nexta/</a>	
<b>21. Project Title: Traffic, Tolling and Financial Analysis Support for Alaskan Way Viaduct and Seawall Replacement Program</b>	
<b>Location Modeled:</b> City of Seattle (downtown plus surrounding neighborhoods)	<b>Project Dates:</b> 01/2011 to 12/31/2012
<b>Sponsor:</b> WSDOT	<b>Contact:</b> Chris Wellander, <a href="mailto:wellander@pbworld.com">wellander@pbworld.com</a> ; Youssef Dehghani, <a href="mailto:dehghani@pbworld.com">dehghani@pbworld.com</a>
<b>Application Used:</b> Dynameq (DTA); EMME (Static Model)	
<p><b>Project Description:</b></p> <p>The objective of this project is to develop a DTA tolling model that more accurately predicts traffic flows and travel times through the SR 99 Alaskan Way Viaduct study area in comparison to the static macroscopic model used in previous analyses. This model will be used to evaluate potential diversion and their impacts; as well as potential toll traffic and associated revenues. Key drivers for development of the DTA tolling model include the heightened concern over diversion impacts from the tolled tunnel; the associated formation of the committee to assess impacts and identify possible mitigation; and the need to develop more realistic estimates of toll traffic revenues. Factors making the DTA more suitable for these purposes include:</p>	



In uncongested conditions, static models produce constant traffic flows that represent the average conditions. In contrast, DTA models produce time-dependent flows that closely follow the observed link or movement volumes.

In congested conditions, static models produce traffic flows that represent the desired link volume and not the one that can actually go through a link. Static models are structurally incapable in constraining flows to not exceed capacities. As a result, in congested conditions unrealistic flows and travel patterns are produced. In contrast, DTA models produce volumes that more closely match the observed values and never exceed capacity.

Dynamic models are significantly more capable than static models in replicating or estimating congestion patterns, bottlenecks, queues, and spillback phenomena.

Dynamic models yield simulated speeds that are much closer to the observed values. This is due to the fact that vehicle simulation is used instead of link-specific analytical functions. DTA models, unlike static ones, capture accelerating, decelerating, merging, and queuing.

**Related Links:** <http://www.wsdot.wa.gov/Projects/Viaduct/>

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