Integration of Dynamic Traffic Assignment in a Four-Step Model Framework – A Deployment Case Study in Seattle Model

For

The Third Conference on Innovations in Travel Modeling (ITM2010)
May 9-12, 2010, Tempe, Arizona

By

Robert Tung, PhD
RST International, Inc.
17288 SE 57th Place
Bellevue, Washington 98006
Phone: 425-644-5181
E-Mail: rtung@rstintl.net

Zhong Wang, PhD, PE
Seattle Department of Transportation
SMT, 700 5th Ave, Suite 3800
Seattle, Washington 98124
Phone: 206-386-4645
E-Mail: zhongwang@seattle.gov

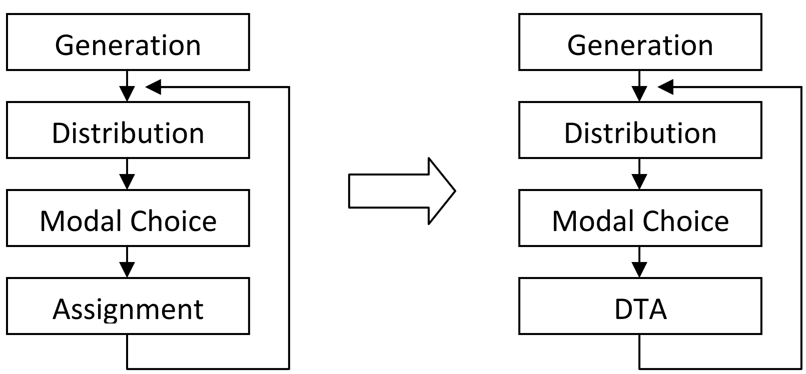
Yi-Chang Chiu, PhD
1200 E 2nd Street, Room 206
Dept. of Civil Engineering & Engineering Mechanics
University of Arizona
Tucson, AZ 85721
Phone: 520-626-8462
E-Mail: chiu@email.arizona.edu

Introduction

Recent advances in travel model development have shown an increasing interest in using dynamic traffic assignment (DTA) to bridge gaps between macro and micro models. On one end, macro models such as traditional four-step models have existed for nearly six decades as the main model framework for many planning agencies to perform successful demand forecasting at various scales. It is well understood that macro models are limited in solving modern planning and operational issues such as pricing, tolling, Travel Demand Management (TDM), Transportation Systems Management (TSM), emissions, and other congestion relief strategies. Basically, traditional macro models were built upon static trip behavior assumptions without temporal dynamics. Because of lacking the dynamic factors, the macro models cannot produce realistic traffic flows and speeds which are key information required for various policy and operational analyses. On the other end, micro models such as microscopic traffic simulations can model individual persons and vehicles and their movements by time and space. This high resolution modeling capability has been widely adopted as a mandate for many major traffic operation analyses. For the time being, micro models must rely on macro models to provide initial OD matrices so it can perform microscopic simulations. Because macro and micro models are based on different sets of travel behavior assumptions, the demand patterns produced from the macros models are often inconsistent with the network or supply side of assumptions in the micro models. Unfortunately, this inconsistency often rendered the initial demand to micro simulations unrealistic or useless. The modeler is always required to further adjust the OD. This results in an extremely time-consuming and unreliable process as there is no known systematic approach to expedite the calibration of a microscopic model. To remedy this problem, DTA is being seen as a viable solution to connect this missing link as DAT can perform regional simulation and assignment so that the sub-area carved out of this regional DTA model would retain realistic temporal and spatial OD demand pattern.

The concept of DTA has been around since 1970s' but only recently it becomes appealing to practitioners because of the advances in both software and hardware. In essence, comparing to static assignments used in the traditional macro models, DTA assigns traffic in much smaller time intervals and capacity constraints are properly enforced. Because of this dynamical interaction between time and space, the resulting traffic flows and speeds are more realistic. The usefulness of DTA has been demonstrated in many successful planning and operational studies such as: corridor management, work zone management, disaster evacuation, and other congestion relief studies. Most importantly, DTA has been categorized as the "meso-scale" tool in a "multi-resolution" modeling framework. This macro-meso-micro approach is being seen as the most cost-effective alternative in the short term to improve existing models, as to the ultimate long-term solution, that is, full scale activity-based model.

Most of the existing DTA applications are "operational planning" type of studies in which the OD matrices are prepared as input to DTA from macro models without feedbacks. In other words, there is no reported effort that equilibrates the travel time skims used in trip distribution and modal choice and outputs from DTA. Therefore, the "stand-alone" DTA modeling applications also suffer similar inconsistency problems as to the micro models wherein OD pattern are often incompatible with the network assumptions. Evidently, the only solution for this problem is to perform a full feedback loop implemented between DTA and other model components. Simply speaking, to replace the static assignment as in the final step of a four-step model with DTA, as illustrated in the diagram below:



Objective

The main objective of this research is to implement a full DTA feedback mechanism in a traditional four-step model framework and to document the findings and issues learned from the process. Seattle model will be used as the test model platform and DynusT (Chiu, Nava et al. 2009) will be used as the DTA tool. This research will specifically focus on network development, calibration and validation, and computing resources. Particular emphasis is also placed in deriving insights from comparing the proposed DTAembedded approach with the existing process and to understand the cost and benefit of integrating DTA in the 4-step process. The outcomes of this study would provide valuable insights to the travel demand modeling community that has not been fully informed in this regard from literature.

The Seattle Model

The Seattle travel demand forecasting model is built upon Puget Sound Regional Council (PSRC) regional model with extended zonal and network details within the Seattle city limit (Figure 1). It includes all data and model components from the PSRC new regional model (Version 1.0b) and more detailed street and transit networks and zone structure within the City of Seattle. Zones located outside the City of Seattle are consistent with the PSRC network and zonal resolution assuring an accurate means to estimate trips in and out of the City in a manner consistent with the regional model.

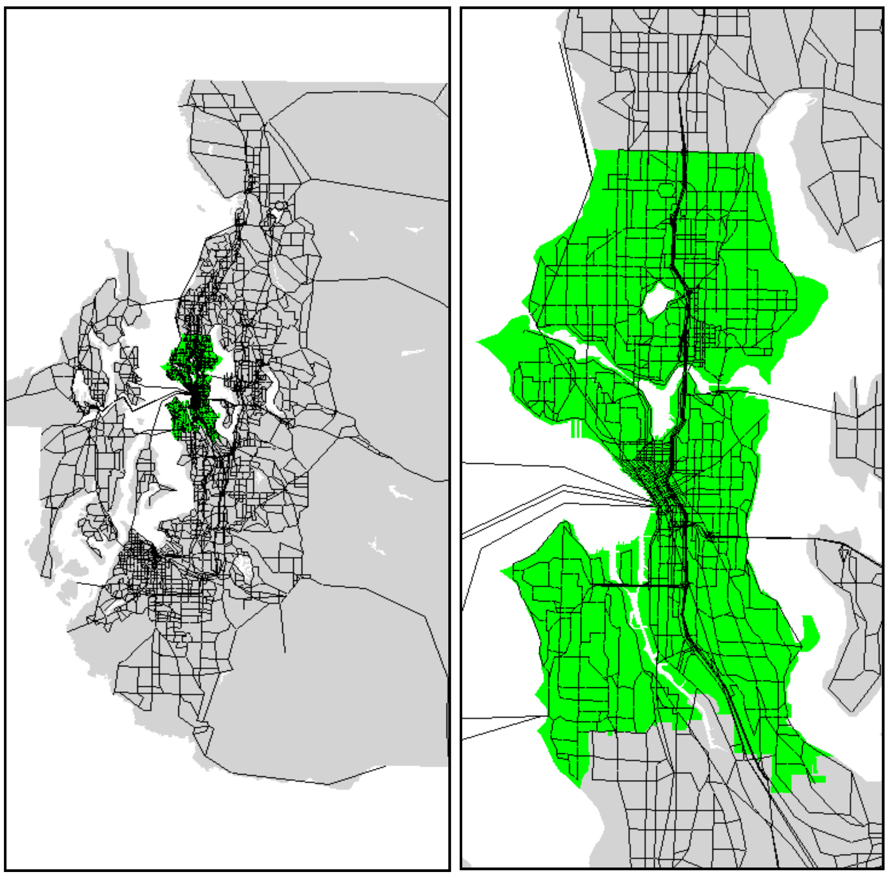


Figure 1: Seattle Model Network

The model has nearly 1300 TAZs and is implemented in an EMME platform. The key network statistics are shown in Table 1. On the demand side, the model has about 7.3 millions of total vehicle trips in 2005 and is projected to grow to 10 millions in 2030 as shown in Table 2, 3, and 4. The year 2005 was chosen primarily due to the fact that the most recent land use inventory done by the City was for 2005.

Table 1: Key Model Statistics

Internal Zones	1,238
P&R Lots	200
External Stations	18
Nodes	27,908
Links	23,972
Transit Lines	849
Transit Segments	32,179
Trip Classes	11
Time of Day	5

Table 2: 2005 Auto Vehicle Trips by Time of Day and Mode

Period	SOV	HOV	Truck	Total
AM	983,292	176,292	104,580	1,264,164
Mid-day	1,721,472	536,416	201,042	2,458,930
PM	1,124,537	382,502	116,784	1,623,823
Evening	888,251	410,576	57,164	1,355,991
Night	490,499	105,715	44,203	640,417
Daily	**5,208,051**	**1,611,501**	**523,773**	**7,343,325**

Table 3: 2030 Auto Vehicle Trips by Time of Day and Mode

Period	SOV	HOV	Truck	Total
AM	1,344,937	241,952	142,300	1,729,189
Mid-day	2,420,420	738,031	273,591	3,432,042
PM	1,555,328	531,076	158,873	2,245,277
Evening	1,228,583	561,996	77,753	1,868,332
Night	675,854	144,628	60,130	880,612
Daily	**7,225,122**	**2,217,683**	**712,647**	**10,155,452**

Table 4: Daily Transit Person Trips

2005	300,204
2030	569,776

The Seattle Model has 11 classifications of travel modes: single occupant vehicle (SOV), high occupancy vehicle vehicles with two people, high occupancy vehicle with three or more people, vanpool, drive to park & ride, walk to access transit, pedestrian, bicycle, light commercial vehicle, medium commercial vehicle, and heavy commercial vehicle.

To address the issue of peak spreading, a time-of-day model as a part of the Seattle Model was adopted from the PSRC regional model. It is used to predict the shift of some trips from the 3-hour peak periods to the off-peak periods, if it is projected to increase traffic congestion during the peak periods more than the capacity is allowed to accommodate. The Seattle Model forecasts five periods during a day: the AM peak (6 to 9 am), midday (9 am to 3 pm), PM peak (3 to 6 pm), evening (6 to 10 pm), and night (10 pm to 6 am). The time-of-day model allocates the trips within those time periods based on the capacity of the network.

There are eight modeling steps in the current Seattle land use and travel demand forecasting model: economic forecasting, land use forecasting, vehicle availability, trip generation, trip distribution, mode choice, time of day, and trip assignment. Each of these modeling steps is developed and applied to serve an individual purpose in the modeling process, and to provide outputs that are used by subsequent steps in the process, as well as to serve other planning applications (PSRC, 2007).

The trip assignment is the last step of the Seattle Model. The model performs the distribution, mode choice, and assignment steps in an iterative way. The assignment steps are all similar to one another except for the development of the skim matrices, which is described for each iteration as follows: (a) first iteration uses no input skim matrix for assignment and outputs the initial skim matrix for further iteration, (b) intermediate iterations use link averaging from the current iteration and the previous iteration to produce the output skim matrix for assignment, (c) last iteration is simple assignment with no output skim matrix.

The entire model structure is shown in Figure 2. The intent of this study is to replace static assignment with DTA while keeping other components constant including the feedback mechanism. The interaction between EMME and DynusT will be managed by a Python shell in an automated fashion.

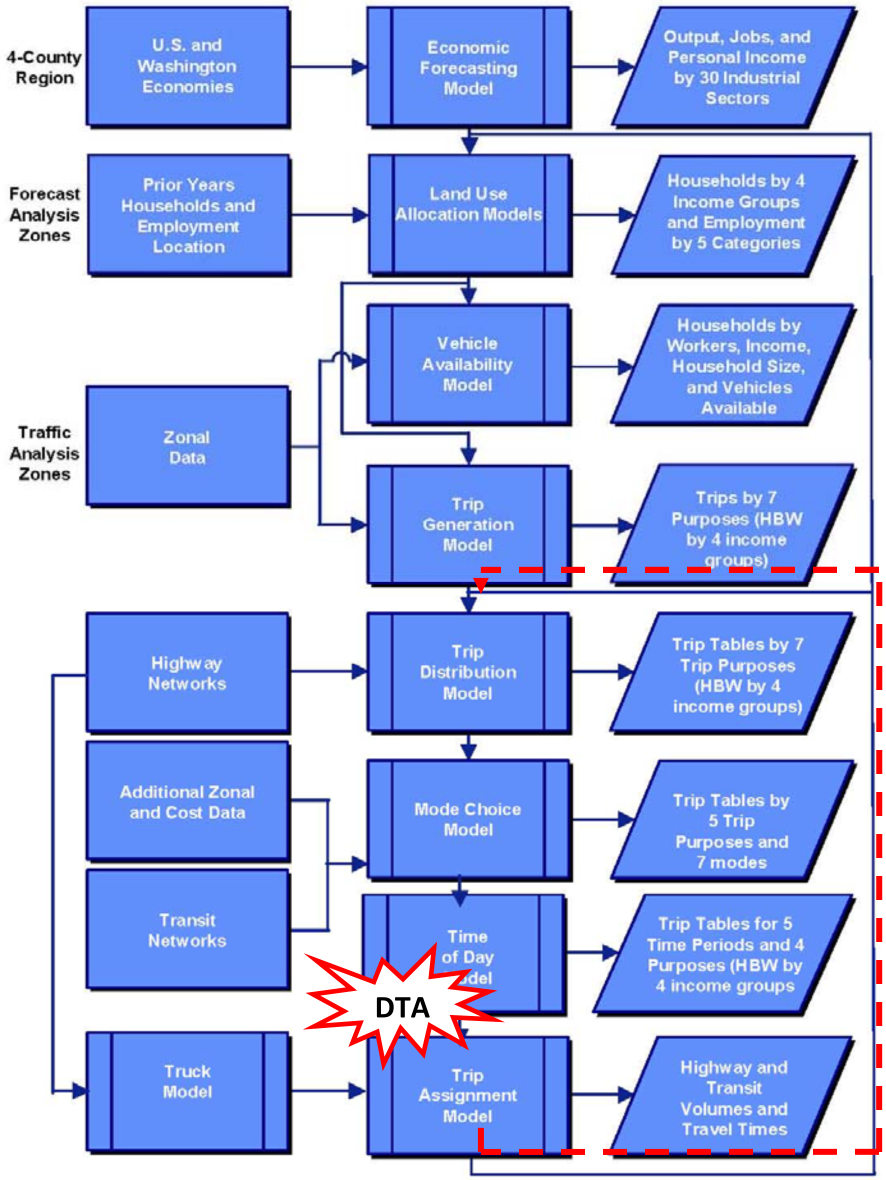


Figure 2: Seattle Model Structure and DTA Connections

DynusT (**Dyn**amic **U**rban **S**ystems in **T**ransportation)

DynusT is one of the latest simulation-based Dynamic Traffic Assignment (DTA) model that seeks for consistent dynamic user equilibrium (DUE) as defined by the DTA Primer (Chiu, Bottom et al. 2009). With unique algorithmic design and implementation, DynusT is capable of conducting large-scale simulation and assignment for long time periods (Chiu and Bustillos 2008; Chiu and Nava 2009).

As shown in Figure 3, DynusT consists of iterative interactions between its two main modules – traffic simulation and traffic assignment. Vehicles are created and loaded into the network based on their respective origins and follow a specific route based on their intended destinations. The large-scale simulation of network-wide traffic is accomplished through the mesoscopic simulation approach that omits inter-vehicle car-following details while maintaining realistic macroscopic traffic properties (i.e. speed, density and flow). More specifically, the traffic simulation is based on the Anisotropic Mesoscopic Simulation (AMS) model that simulates the movement of individual vehicles according to the concept that a vehicle's speed adjustment is influenced by the traffic conditions in front of the vehicle. In other words, at each simulation interval, a vehicle's speed is determined by the speed-density curve, and the density is defined as the number of vehicles per mile per lane with a limited distance - defined as the speed-influencing region (SIR) – downstream of the vehicle (Chiu and Zhou 2006; Chiu, Zhou et al. 2009).

After simulation, necessary measures of effectiveness (MoEs) are fed into the traffic assignment module. The traffic assignment module consists of two algorithmic components: a time-dependent shortest-path (TDSP) algorithm and time-dependent traffic assignment. The TDSP algorithm determines the time-dependent shortest path for each departure time, while the traffic assignment component assigns a portion of the vehicles departing at the same time between the same OD pair to the time-dependent least-travel time path following the "route swapping" type of traffic assignment procedure.

In DynusT, the assignment algorithm maintains the balance of computational efficiency and solution algorithm quality. Innovations in computational efficiency allow DynusT to perform 24-hour assignment, which is critical for estimating daily traffic patterns for the purpose of this study. The computational features include: (1) Reuse vehicle ID to commit computer memory only for those vehicles that exist in the network during simulation, thus, memory usage is not cumulative to the total number of generated vehicles; (2) Assign vehicles with time-dependent shortest paths (TDSP) that are solved based on an *epoch*, which is the time period over which network statistics are collected for solving for the TDSP. An *epoch* was defined to be about 1-2 hours in length. This is to ensure that the memory usage for the TDSP is limited by the length of the *epoch* regardless of the length of the total evacuation simulation period.

Once the assignment of the current iteration is finished, all vehicles are loaded and moved along their paths in the simulation module again to evaluate if the TDUE condition is satisfied. If so, the algorithmic procedure is terminated; otherwise, the next iteration continues.

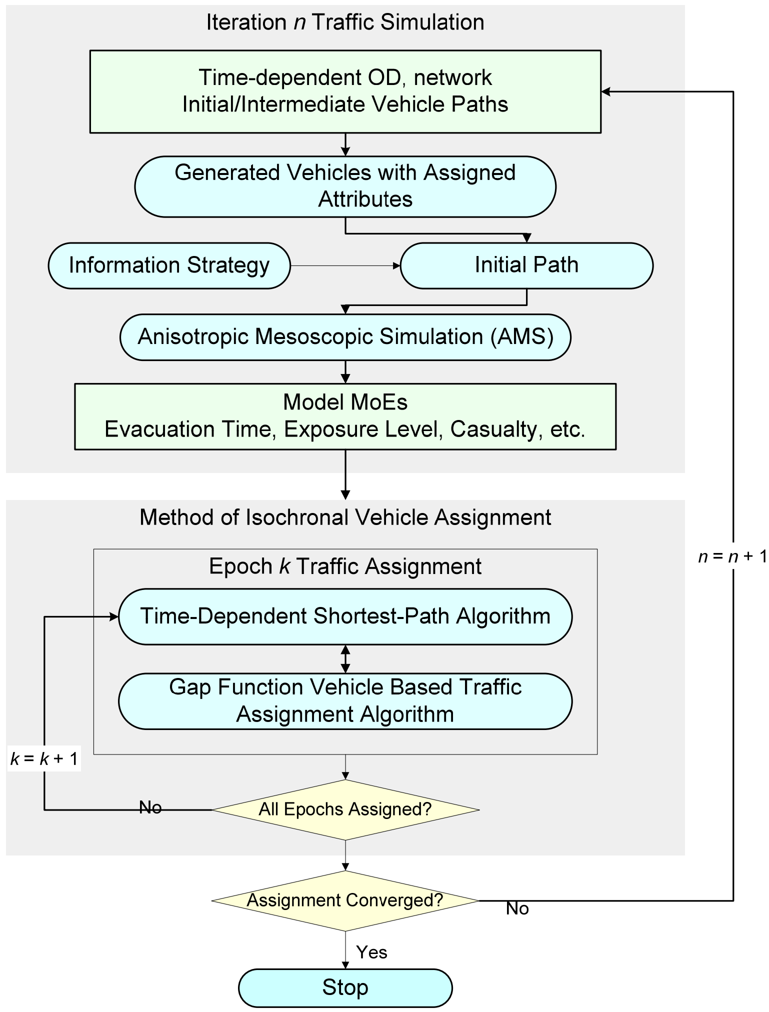


Figure 3: Traffic Simulation, Assignment and Link Volume Estimation Framework in DynusT

Reference

Chiu, Y.-C., J. Bottom, M. Mahut, A. Paz, R. Balakrishna, T. Waller and J. Hicks (2009). A Primer for Dynamic Traffic Assignment, Transportation Research Board.

Chiu, Y.-C. and B. Bustillos (2008). A Gap Function Vehicle-Based Solution Procedure for Consistent and Robust Simulation-Based Dynamic Traffic Assignment. Proceedings of the 87th Annual Meeting of the Transportation Research Board.

Chiu, Y.-C. and E. Nava (2009). "Method of Isochronal Vehicle Assignment for Simulation-Based Dynamic Traffic Assignment." Transportation Research Part B: Methodological **To be submitted**.

Chiu, Y.-C., E. Nava, H. Zheng and B. Bustillos (2009). DynusT User's Manual (http://dynust.net/wikibin/doku.php).

Chiu, Y.-C. and L. Zhou (2006). An Anisotropic Mesoscopic Traffic Simulation Model: Basic Properties and Numerical Analysis. Annual Meeting of Transportation Research Board, Washington, D. C.

Chiu, Y.-C., L. Zhou and H. Song (2009). "Development and Calibration of Anisotropic Mesoscopic Simulation Model for Uninterrupted Flow Facilities." Transportation Research Part B **Online, In press**.

Puget Sound Regional Council (2007). "Land Use and Travel Demand Forecasting Models: PSRC Model User's Guide (for Version 1.0)".