Metropolitan Washington Council of Governments
National Capital Region Transportation Planning Board

Results of FY2006 Travel Forecasting Research

September 22, 2006

Vanasse Hangen Brustlin, Inc.
8300 Boone Blvd, Suite 700
Vienna, VA 22203
(703) 847-3071

This page intentionally left blank

Table of Contents

This page intentionally left blank

Introduction

This report combines into a single document the technical memoranda prepared by VHB for TPB during its FY2006 work program for research in travel demand forecasting. The work tasks for this time period covered herein are:

1. Attend Meetings and Assess TPB Work Program in Models Development and Data Collection
2. Review Managed Lanes Modeling
3. External Trip Forecasts
4. Review Experience with Equilibrium Assignment
5. Review of Current Use of Activity-Based Modeling

Rich Roisman (items 1, 2, 3, and 5) and Dan Goldfarb (item 4) served as the primary authors, with assistance from Dalia Leven and project management from Phil Shapiro and Frank Spielberg.

This page intentionally left blank

Task 1: Attend Meetings and Assess TPB Work Program in Models Development and Data Collection

This page intentionally left blank

At TPB's direction, VHB staff have been attending and participating in meetings of the Travel Forecasting Subcommittee and other TPB bodies over the past fiscal year. TPB also requested that VHB provide an assessment of the TPB work program in models development and data collection to provide guidance for future work program activities in upcoming fiscal years.

Overall, VHB believes that TPB's work program in this area is sound, and recognizes that TPB must continue to meet ever-increasing demands within an increasingly constrained budget; however, there is always a need for new initiatives to improve TPB's ability to best serve the travel forecasting and travel monitoring needs of the National Capital Region. The following represent areas where VHB suggests that TPB consider additional work in models development and data collection in the upcoming work program:

1. **Evaluate Simulation Models.** TPB staff has expressed their intention to purchase a copy of Citilabs' Cube Dynasim simulation modeling software to test it for use in work program activites. While Cube Dynasim's compatibility and scaleability with TPB's existing travel demand forecasting platform (Citilabs' TP+/Cube) makes it an appealing choice, there are many criteria that must be weighed when selecting a simulation platform. There are a number of other simulation models available, including VISUM, Paramics, and others. It might be in TPB's best interest to test some other simulation models as well as evaluate what kind of a model and what kind of applications of a simulation model will best meet its needs.

2. **Model Validation.** As part of its model validation process TPB may want to consider several best-practices including in the findings of the recent Transportation Research Board (TRB) Metropolitan Planning Organization (MPO) State of the Practice study. One such practice is dynamic validation, which can also be considered sensitivity testing. Dynamic validation is an iterative process that involves:

    - Changing a parameter such as employment or housing in selected zones and reviewing the results to determine how the forecast changed due to those changes

    - Removing one major link at a time from several locations to determine how the model results have changed.

    Dynamic validation has been used by travel forecasters in both Las Vegas and Boise, Idaho. TPB may also wish to consider further research and documentation of this process to determine how it could best be implemented in its forecasting model.

3. **Changes in Travel Behavior due to an Aging Population.** TPB needs to consider now what will happen to trip making characteristics as the baby boomer generation moves into retirement. The baby boomers make up a considerable segment of the regional population and while many of them will leave the area, a majority will probably remain here due to the attractiveness of the region. Travel behavior for the baby boomers will be considerably different over time – there will be more part-time workers and more non-work trips. By looking at the behavior of the retired sub-group now, TPB can get some idea of what will happen when the group gets larger, but continued research is probably needed: as with other

aspects of their lives, in travel behavior the boomers will not follow in their parents' footsteps.

4. **Airport Trip Generation.** The major airports in and around the TPB region have undergone improvement and expansion projects in recent years, some of which (like Dulles International Airport) are not yet complete. As the nature of the airports change, so do their trip generation characteristics, and TPB should consider how these changes impact its process. There has been work by others on this issue that TPB may be able to build upon. Some trip generation rates are documented in the Federal Highway Administration (FHWA) publication *Intermodal Ground Access to Airports- A Planning Guide*; however, much of that information is now at least a decade old.

5. **Further Research on External Trips.** In addition to looking at the absolute number of forecast external trips, the purpose and direction of trips should also be considered. As exurban development grows, the proportion of external productions is likely to grow while the proportion of external attractions is likely to decrease. The relationship between external-external (E-E) and external-internal (E-I) trips may also change. TPB should investigate the regional impact of these potential changes.

Task 2: Review Managed Lanes Modeling

This page intentionally left blank

TPB staff requested that VHB review work performed to date by other MPOs around the United States to analyze High-Occupancy Toll lane (HOT lane) and managed lane proposals to assess travel demand modeling techniques employed in these analyses. This chapter summarizes the results of our review.

Background: Current TPB Approach to Modeling HOT Lanes

Beginning with Version 2.1C, the TPB model included highway tolls as an out-of-pocket cost variable in mode choice, but did not consider tolls in any other section of the model chain. Path building was based solely on minimum travel time and did not include the effects of tolls. As part of the model refinements developed for the demand forecasts for the Intercounty Connector (ICC) in Montgomery and Prince George's Counties and later incorporated into model version 2.1D, tolls were considered in trip distribution and highway assignment and updated in mode choice.

The ICC model refinements converted link-based highway tolls into minutes that were added to the composite travel time impedance used in path building at the end of trip distribution. TPB's distribution model is income-stratified, so different values of time (VOTs) apply to different income groups for work and non-work trips. An average VOT is applied for single-occupancy vehicle (SOV, drive alone) trips and high-occupancy vehicle (HOV) trips in mode choice but can be varied by time-of-day (TOD). In highway assignment different VOTs are used for each separately assigned vehicle class and for peak and off-peak travel. In addition to SOVs, multi-occupant autos, and trucks, TPB's model includes a separately-assigned vehicle class for airport autos. As in mode choice, an average VOT is applied but can be varied by TOD.

Following the initial TPB model refinements to improve toll sensitivity, the Maryland State Highway Administration (SHA) began exploring the concept of Express Toll Lanes (ETLs, the preferred SHA term for managed lanes) for both the ICC and the Interstate 270 corridor in Montgomery and Frederick Counties. Since the ETL concept relied heavily on the use of variable tolls to maintain travel time reliability on the managed facilities, TPB further refined its model to address variable tolls during highway assignment. The current TPB model employs a post-processor during highway assignment where per-mile tolls on managed lanes are varied to maintain flow in the level of service (LOS) C/D range. Since all of the managed lanes are part of freeways, this is equivalent to a range of 1400 to 1800 vehicles per lane per hour.

TPB previously had reviewed the loaded highway network after each assignment iteration and then manually adjusted the toll on each link before performing the next iteration. This process proved to be time-consuming and labor intensive, and TPB now employs an automated procedure to adjust tolls after each iteration of assignment.

Literature Review

VHB staff conducted a literature review to identify any published documents (besides those received directly from the survey of MPOs) that describe managed lane modeling procedures that have been employed. The review did not turn up any significant newly-published documents. The Transportation Research Board (TRB) synthesis of toll modeling techniques under preparation by iTRANS consultants of Canada was discussed and ultimately deemed not relevant to TPB's work program. Two 2003 articles from *Transportation Research Record* which summarize the efforts to model managed lanes and other toll facilities in the Houston, Orlando, and Miami / Fort Lauderdale regions provide valuable information about the development and validation process for the inclusion of toll choices in multinomial logit (MNL) and nested logit (NL) structures.

A similar review of national toll modeling practices was performed for the North Central Texas Council of Governments (NCTCOG, the Dallas MPO) and the resulting report by Urban Analytics was published in March 2004. This report reviewed the toll modeling programs in place or under development at the time in Portland, Oregon; Phoenix, Arizona; Atlanta, Georgia; Pittsburgh, Pennsylvania; Washington, D.C.; San Diego and Sacramento, California; Minneapolis-St. Paul, Minnesota, and several sketch planning approaches developed by FHWA. The report recommended a short-term, medium-term, and long-term approach for NCTCOG to improve their model to address managed lane facilities:

- Highway assignment post-processing (short-term)
- Add tolls as discrete elements in mode choice (medium-term)
- Activity-based / tour-based model (long-term)

It is worth noting that the report's review of Washington, D.C. mischaracterized TPB's model approach to toll and managed lane facilities. References to each document are included following this chapter.

Information Received From MPOs

VHB staff contacted MPOs that indicated they were modeling HOT lanes or managed lanes in the TRB MPO State of the Practice survey, as well as other MPOs identified based on the literature review and other print and web publications. Ultimately, the following MPOs were contacted first via e-mail, and then with a follow-up telephone call (if necessary):

- Orlando (METROPLAN Orlando)
- Salt Lake City (Wasatch Front Regional Council)
- Minneapolis / St. Paul (Metropolitan Council of the Twin Cities)
- Phoenix (Maricopa Association of Governments)
- Dallas (NCTCOG)
- Atlanta (Atlanta Regional Commission)
- Los Angeles (Southern California Assocation of Governments)
- Portland, Oregon (METRO)
- Denver (Denver Regional Council of Governments)
- San Diego (San Diego Association of Governments)
- Seattle (Puget Sound Regional Council)
- San Francisco (Metropolitan Transportation Commission
- Houston (Houston-Galveston Area Council)

Most of the MPOs responded either with information via email, a web link to existing model documentation that addressed the issue of HOT lanes, or via telephone. Some MPOs referred VHB to consultants working on the issue for the MPO, and several areas had nothing to share at this time, since their toll models are at an early stage of development or are not undergoing improvements to address tolls. The results from each city that responded are summarized below:

Seattle

The Washington State Department of Transportation (WSDOT) is using the Seattle (PSRC) model for their Congestion Relief Analysis (CRA) study in the Seattle-Tacoma area. The PSRC model addresses tolls in trip distribution, mode choice, and network assignment. Network coding convention provides access to HOV/HOT lanes only at specific crossover points (slip ramps) or via direct access ramps from interchanges, so it assumes a physically-separated facility.

For the CRA study, six model runs with tolls ranging from zero to $1.00 (year 2000 dollars) for the AM peak, PM peak, midday, and night periods are used. A spreadsheet-based toll matrix was developed to optimize tolls based on time of day, link volume, and type of vehicle; for example, $0.60 per mile peak, $0.20 per mile midday, and zero at night. The three-hour peak periods are then split into six periods of 30 minutes each to determine the range of possible peak period tolls if dynamic tolling were implemented.

Atlanta

The current Atlanta TP+ model addresses managed lanes by using a post-processor during highway assignment. Managed lane facilities are modeled as HOV facilities that can be used by SOV and commercial vehicle trips by paying a toll. The post-processor, which is implemented in a TP+ script, varies tolls between assignment iterations based on the congestion levels: there is a direct relationship between the congestion levels and the assigned toll. The process is similar to an equilibrium assignment, in this case the equilibrium point falls at or near the break point between LOS C and D. Per-mile tolls are explicitly coded for SOVs and trucks at V/C ratios of zero (minimum toll), 0.8, and 1.0 (maximum toll: $0.40 per mile for SOVs, $0.80 per mile for trucks); the system interpolates tolls for V/C ratios between these points. To perform a managed lane assignment, first the regular model structure is run, then the relevant links in the peak and off-peak highway networks are identified as managed lane facilities by changing the PROHIBITION link attribute. Then the managed lane assignment is run using the modified network and the TOD trip tables from the initial model run. The assignment results in loaded TOD highway networks with managed lanes.

ARC is currently developing additional managed lane procedures that will ensure that managed lane facilities maintain LOS C or better during highway assignment, allow for different HOV restrictions (HOV-2, HOV-3) and corresponding tolls on different facilities (e.g., SOV pays one toll, HOV-2 pays a lower toll, HOV-3 pays no toll), and that better model true dynamic tolling operations. The toll optimization procedure is also being refined as part of this work. The current TP+ script used for managed lanes assignment is included following this chapter.

Salt Lake City

The Salt Lake City (WFRC) model addresses managed lanes by adding toll travel as a discrete choice in the mode choice model structure. The model can test HOT lanes and managed lanes and can analyze flat tolls or variable tolls based on distance or time period; however, each type of facility (HOT lanes or managed lanes) must have the same toll rate. The WFRC mode choice model is a NL structure which divides auto trips into drive alone, shared-ride (2 occupants), and shared-ride (3+ occupants). The revised model structure contains the following alternatives:

- Drive Alone Non-Toll
- Drive Alone Toll
- Shared Ride 2, Non-Toll, Non-HOV (General Purpose Lanes)
- Shared Ride 2, Non-Toll, HOV
- Shared Ride 2, Toll
- Shared Ride 3+, Non-Toll, Non-HOV (General Purpose Lanes)
- Shared Ride 3+, Non-Toll, HOV
- Shared Ride 3+, Toll

The mode choice model is income-stratified, so toll sensitivities are considered much in the way fare sensitivities would be considered for transit riders – i.e. low-income travelers are more sensitive to cost. The peak period auto utility equations are based on AM travel time differences because it is assumed that this will produce conservative toll forecasts when applied to both peak periods. Diurnal distribution of peak home-based work (HBW) managed lane trips is assumed to be 40% AM peak and 60% PM peak.

The mode choice model also includes a disutility function applied to all trips that utilize managed lane facilities for less than two miles; this function is reflective of the fact that paying a toll is generally not convenient for a short trip. Finally, a peak period toll bias constant increases the managed lane share due to increased reliability; the bias increases as time savings increases, up to a benefit of 5 minutes of in-vehicle time (IVT) for HBW, non-home based (NHB), and home-based college (HBC) trips and 2.5 minutes for home-based other (HBO) trips.

The mode choice path builder assumes (free-flow) speeds of 68 mph for managed lane facilities, although the operating agency may not be able to deliver that level of performance. If this speed cannot be maintained during highway assignment either the toll rates must be increased or the assumed speeds must be decreased in mode choice. A VOT of $30 per hour is used to convert toll costs to time equivalents. The VOT is based on sensitivity tests and path reasonableness checks and is intentionally high to exclude illogical toll paths.

WRFC's managed lane model enhancements have not been calibrated to existing regional data. The enhancements have also been applied to the model used by the Mountainland Association of Governments (MAG), the MPO for the Provo / Orem area south of Salt Lake City. There are limited observed data from the HOV facilities currently operated along Interstate 15 in the region, but as that dataset grows it will be used to perform reasonableness checks on traditional HOV forecasts to calibrate the new elements of the mode choice model. Replicating HOV volumes must be done before calibration of the toll elements of mode choice can be undertaken.

Dallas

The NCTCOG TransCAD model addresses managed lanes by applying tolls during highway assignment. During a user equilibrium (UE) assignment, per-mile tolls (adjusted to constant 1999 dollars) are applied to the managed lane links and the corresponding toll for the drive alone vehicle class is higher than for the shared-ride (HOV) vehicle class. The VOT for conversion to generalized cost is $10 per hour (in constant 1999 dollars) and is applied to all toll facilities and each of the TOD assignments. Toll costs are not included in trip distribution or mode choice.

NCTCOG's current procedures for modeling managed lanes follow the short-term recommendations from the Urban Analytics report. NCTCOG has expressed interest in moving toward the recommended medium-term improvement -- including toll nests in their mode choice model.

Phoenix

The Phoenix MPO responded to VHB's request for information by forwarding the Urban Analytics report, which included a review of the MAG model. MAG originally addressed managed lanes during highway assignment by adjusting per-mile tolls on managed lane links between assignment iterations in order to maintain LOS D/E on the managed facilities. It is not clear whether this procedure is semi-automated like Atlanta's, or more manual like the current TPB technique. More recently, MAG added a toll/non-toll nest to the drive alone branch of its NL mode choice model. In addition to including tolls in the SOV/toll utility function, there is a travel time savings term calculated as the difference between tolled and non-tolled travel times, which the report calls a "reliability" factor.

Denver

DRCOG has an extensive report as part of its Integrated Regional Model (IRM) project, which is a multi-year effort to improve its modeling capability. The report includes reviews of the Portland and Houston models as of 2003-2004, which serve as an interim reference point since those areas did not respond to VHB's request for information on their current modeling programs. The IRM report ultimately recommended that DRCOG implement a tour-based model similar to one under development in Columbus, Ohio, and look for HOV and toll model elements in areas with existing managed lane facilities like San Diego and Orange County, California. If DRCOG elected to pursue upgrades to its existing trip-based model, the IRM report recommended including toll options in its mode choice model.

In the shorter term, DRCOG converted its older MinUTP-based model into an updated, TransCAD-based model known as Compass. Based on a review of the draft Compass documentation, the current model includes tolls in trip distribution. HOT links are coded in the highway network as links with different tolls for SOV and HOV vehicle classes. DRCOG's previous distribution model was based solely on travel time rather than generalized cost. There was a concern that ignoring toll costs would overestimate demand for a managed lane project. Toll costs in distribution are converted and included in highway travel time impedance using a

VOT of $4.00 per hour for low-income work trips, $8.00 per hour for middle-income work trips, $16.00 per hour for high-income work trips, and $6.00 per hour for non-work trips. The same VOT in (1996 dollars) is carried into mode choice, which is an MNL model that does not have a toll choice. In mode choice the VOT is also adjusted based on occupancy.

The Compass model uses a UE highway assignment. Tolls are included in the path algorithms. VOT for assignment is $8.00 per hour for peak travel and $6.00 per hour for off-peak travel. Toll costs are $0.16 per mile in 1996 dollars, which is the average toll rate for the E-470 tollway on the eastern perimeter of metropolitan Denver. E-470 uses fixed, distance-based tolls for all vehicles. Interstate 25, the main north-south freeway through Denver, has a reversible HOV facility in the center of the roadway; seven miles of this facility plus an additional mile on US 36 will convert to HOT operation in June of this year. This change will be represented in the DRCOG model by coding different link tolls, but there are no other special assignment procedures for HOT lanes.

San Diego

The SANDAG model includes toll and non-toll choices as part of the auto nest in its mode choice model, so following binary mode choice the following choices are possible for auto trips:

- SOV Non –Toll
- SOV Toll
- HOV Non-toll and non-HOV lane
- HOV Non-toll
- HOV Toll

Separate network links are coded for managed lanes, planned access points, and direct access ramps. Managed lane speeds are coded 5 mph faster than adjacent mixed flow lanes. Separate skims of congested time, distance, and managed lane distance are taken for each discrete auto choice for three TOD periods: AM peak period, PM peak period, and off-peak. The input link times and costs are used for path building. A weighted disutility that includes managed lane trips is used in the distribution model. Managed lane toll costs are $0.10 / mile for off-peak travel, and $0.26 / mile for peak travel. The HOV and toll choice constants were computed using observed data from the Interstate 15 managed lanes.

Each trip table is separately assigned to the highway network, by mode and by TOD. Following assignment, the speed on the HOT lane is set to LOS D if the modeled LOS is worse than D. This is done to reflect the real world operation of the Interstate 15 managed lanes, where tolls can be raised as high as $8.00 to maintain flow during times of extremely high congestion.

Houston

H-GAC did not respond to VHB's request for information; however, the review of the H-GAC model included in the Denver IRM report indicates that toll nests are explicitly included in their NL mode choice model. Houston is currently developing a tour-based model.

Portland

METRO did not respond to VHB's request for information. Based on the documentation included with the Denver IRM report, Portland currently maintains both a traditional four-step (trip-based) model and a tour-based model, both of which are generally optimized for transit forecasting. The trip-based model does not include explicit consideration of tolls.

Conclusion

Most of the available research recommends moving toward tour-based models as the best way to model managed lanes; however, that is not a viable option for TPB at this time, and the issue of how many MPOs are actually taking steps to develop tour-based models is discussed in Chapter 5 of this report. For trip-based models, representation of toll trips as discrete choices in a NL mode choice model structure appears to be the best option, but the research is not conclusive. The primary obstacle to including managed lane tolls in mode choice is the lack of observed data to use for calibration and validation. Since there are currently no managed lanes operating in the TPB region, calibrating toll elements in mode choice would require borrowing from the few other regions that operate managed lanes and rescaling the coefficients for metropolitan Washington. This process carries inherent risks and may not improve model results enough to pursue: more research would be needed to determine the best approach to implementing changes to TPB's mode choice model if staff desires to move in that direction.

TPB is currently employing an approach similar to Atlanta in modeling managed lanes, and VHB feels this is the best strategy for TPB at this time. Finally, VHB also recommends that TPB consider following Salt Lake City's method of using the AM peak period for developing toll forecasts, and consider Seattle's approach of further subdividing the peak period to increase the variability of dynamic tolling in the model.

References

Conversation with Bob Sicko, Mirai Associates (consultant to WSDOT), March 1, 2006.

Y. Dehghani, T. Adler, M. Doherty, and R. Fox, "Development of a New Toll Mode Choice Modeling System for Florida's Turnpike Enterprise." *Transportation Research Record* #1858, 2003, pp. 9-17.

Denver Regional Council of Governments, "The Integrated Regional Model Project, Vision Phase, Final Report," prepared by PBConsult and Gallop Corporation, March 2005. Main report and technical appendices for specific area models.

Denver Regional Council of Governments, Draft Compass Model Documentation, Integrated Regional Model Refresh Phase, prepared by Parsons and Cambridge Systematics, 2004 and 2005. http://www.drcog.org/index.cfm?page=TransportationCompass (requires signed release from DRCOG)

Email from Sreekanth Ande, Denver Regional Council of Governments, March 27, 2006

Email from Ken Cervenka, North Central Texas Council of Governments, February 28, 2006. Documentation on NCTCOG assignment procedures on the web at: http://www.nctcog.org/trans/modeling/documentation/index.asp

Email from Andy Li, Wasatch Front Regional Council, March 6, 2006.

Email from Bill McFarlane, San Diego Association of Governments, February 27 and March 24, 2006 (includes attached memo from PBConsult on mode choice model)

Email from Guy Rousseau, Atlanta Regional Commission, February 27, 2006.

Email from Mark Schlappi, Maricopa Association of Governments, February 24, 2006.

G. Erhardt, F. Koppelman, J. Freedman, W. Davidson, and A. Mullins, "Modeling the Choice to Use Toll and High-Occupancy Vehicle Facilities." *Transportation Research Record* #1854, 2003, pp. 135-143.

J. Lieb, "HOT-lane users on I-25 may pay up to $3.25," *Denver Post*, March 10, 2006.

Memo from Ron Milone, COG, to ICC Files, December 16, 2003.

North Central Texas Council of Governments, "Estimating Demand for Value Pricing Projects: State of the Practice," prepared by Urban Analytics and URS Corporation, March 2004.

Task 3: External Trip Forecasts

This page intentionally left blank

TPB staff requested that VHB review how high-growth MPOs forecast productions and attractions at external stations in order for TPB to consider alternative approaches to for forecasting external trips. This chapter summarizes our review.

Background: Current TPB External Trip Forecasting Process

The current 6,800 square-mile TPB 2,191 traffic analysis zone (TAZ) system contains 47 external stations. TPB's last auto external survey was conducted in 1994 and consisted of a license plate survey of inbound vehicles crossing the expanded cordon, and a follow-up mail-out / mail-back postcard survey that yielded 16,000 responses. TPB's last truck external survey was conducted in 1996 and consisted of 5,000 surveyed trucks at 12 sites near the cordon. All surveyed trucks were inbound except at the Chesapeake Bay Bridge (William Preston Lane, Jr. Memorial Bridge) in Anne Arundel County, where information was collected from outbound trucks (east to the Eastern Shore of Maryland). Together these two surveys form the current external trip base data for the TPB model.

TPB also coordinates with the Baltimore Metropolitan Council (BMC) to ensure consistency in trip forecasts in the overlap area between the two agencies' modeled regions and to receive output from the BMC model for Baltimore County, which is *internal* to the BMC model but immediately *external* to the TPB modeled area. Finally, TPB coordinates with staff from the Virginia Department of Transportation (VDOT) and the Fredericksburg Area MPO (FAMPO) to ensure consistency in trip forecasts in the Fredericksburg area, the majority of which is within the TPB modeled area[1]. In general, future year external trips are determined using annual growth based on the growth in the area served by each external station, or by using the growth in trips from neighboring MPOs where available. The current TPB work program includes data collection for an auto external survey during FY2006, and processing, cleaning, and submission of the final survey report during FY2007.

Literature Review

VHB staff reviewed the available literature about procedures for forecasting external trips in high-growth metropolitan areas. This review did not discover any recent documents of direct significance, although the travel modeling procedures for a range of MPOs were studied for possible relevance. Most MPOs use physical cordon counts as the basis for estimating external trips, like TPB. Some variation was found in how the MPOs applied these counts to their models, but the methods for data collection were strikingly similar.

The Model Validation and Reasonableness Checking Manual published in 1997 by FHWA indicates the need for a cordon count in order to determine the number of externally-based trips that will not be included in the regional trip generation model. A report produced in 2001 for the Puget Sound Regional Council also indicated this as the only method for updating external trip tables. The number of external stations used to collect this data varies greatly according to the geography and infrastructure of the region, although all major routes should be counted and should include a range of different facility types. This type of count can be performed as an

[1] FAMPO has a separate model administered by VDOT. The MWCOG modeled area does not include the area of Spotsylvania County south of VA 606.

intercept survey that gathers detailed origin and destination data as was completed for the Maricopa Association of Governments which allows the counts to be used as a supplement to the trip distribution table and preloaded onto the network. In areas that elect to only take volume counts at the external stations (as is done in Rhode Island) a gravity model is required to assign the externally-based trips onto the internal network.

In metropolitan regions that are completely enclosed within a single state, there may be a statewide model that utilizes this procedure that allows the MPO to use the state's forecasted internal trips as external trips instead of performing physical counts. Adjacent MPOs can also check their external trip forecasts with each other as is done between the Northeast Ohio Areawide Coordinating Agency (NOACA) in Cleveland and the Akron Metropolitan Area Transportation Study (ATAMS).

While cordon counts are used almost universally as the values for the base year model, several methods were found for estimating the growth of external trips. Some MPOs grow these trips based on socioeconomic forecasts from nearby cities. Linear regression using historical trip rate data is the most common method of growth estimation. NOACA uses the Fratar method to estimate the growth in external through (external-external) trips while assuming that the percentage of external trips at each station remains constant.

One final issue that was mentioned frequently in the literature was the estimation of externally based truck trips. Trucks are frequently making trips through the metropolitan areas and cannot be surveyed in the same way as passenger vehicles. Other methods, including the electronic tracking of trucks and license plate tracking can be used to determine the routes taken by these heavy vehicles. Alternatively, truck traffic can be assumed to be equal to a certain percentage of the counted passenger traffic.

Survey of MPOs

VHB staff contacted 14 MPOs to obtain information about their procedures for forecasting external trips, and received responses from nine.[2] VHB staff also had informal, face-to-face conversations with representatives of four other MPOs to inquire about their procedures for forecasting external trips.

The results of the survey closely mirror the results of the literature review: MPOs either essentially follow the same process as TPB, or obtain external trips from a statewide model's internal trips.

MPOs That Essentially Follow the Same Process as TPB

As noted in the literature review, most MPOs throughout the United States use procedures similar to those currently employed at TPB to collect base data for and forecast future external

[2] The MPOs were chosen either because they modeled a region similar to the TPB region, or because they had been identified as high-growth in the Transportation Research Board (TRB) MPO State of the Practice Survey. In the TRB survey, high-growth MPOs are those where the percent difference between previous growth (generally through 2005) and forecast future growth (to 2025 or 2030) in population and employment was in the top 25% of those MPOs surveyed.

trips: collecting base data at external stations through a combination of traditional link traffic counts and license plate or mailout / mailback surveys, and forecasting future trips by using a straight-line extrapolation or a simple growth-factor. According to the survey responses, these methods are used in the following metropolitan areas: Atlanta, Georgia; Charlotte, North Carolina; Tampa, Florida; San Antonio, Texas; and Las Vegas, Nevada.

Atlanta

The Atlanta Regional Council (ARC) reports using a growth-factor method to forecast future external trips in its model set. For reasons of air quality / conformity analysis, ARC has recently expanded its modeled area to 20 counties, so the regional cordon and external stations have been relocated as many of the old external stations are now internal to the model. ARC gave no indication that their external trip forecasting procedures would change as a result of the expanded modeled area.

Charlotte

The City of Charlotte Department of Transportation (CDOT) is the lead agency for development and application of the Metrolina (Metropolitan Carolina) Regional Model, which models travel in the Charlotte area, an 11-county, bi-state area encompassing four separate MPOs that previously each had their own separate model.[3] The Metrolina Regional Model uses historical trends to prepare growth factors for forecasting future external trips, with the resulting growth averaging 2.5% per year through 2030.

Tampa

The Florida Department of Transportation (FDOT) District 7 is the lead agency for development and application of the Tampa Bay Regional Planning Model (TBRPM) for a five-county area.[4] Forecasts of external trips in the TBRPM use growth factors developed from historical trends and coordination with other outside agencies to account for special sources of travel growth.

San Antonio

The San Antonio-Bexar County MPO forecasts external trips by reviewing the regional population and employment forecasts and converting the resulting growth into total regional trips for use in their travel demand model. A fixed percentage of these trips are then designated as external trips. Although external surveys are typically planned for every 3-5 years, prior to their 2005 external survey the previous survey was conducted in 1990.

Las Vegas

While the Las Vegas area has and is continuing to experience very high growth, most of the growth appears to be occurring within the area already modeled by the Regional Transportation

---

[3] Charlotte, NC; Concord; NC; Gastonia, NC; and Rock Hill, SC

[4] Hillsborough, Pinellas, Pasco, Hernando, and Citrus counties. In Florida, counties frequently serve as MPOs, so the TBRPM covers four MPOs (Citrus County does not currently have a designated MPO)

Commission of Southern Nevada (RTC), the Las Vegas MPO. Furthermore, the geography of the Las Vegas Valley and its immediate surroundings dictate a limited number of routes in and out of the area and extremely low population density along those routes; consequently there are a limited number of major cordon crossings in the RTC model and only ten external stations. RTC forecasts growth in external trips using the internal regional population projections and assumes a fixed percentage of external trips.

RTC has added a new external TAZ for the location of the Ivanpah Valley International Airport, a major new airport to be located approximately 25 miles south of Las Vegas.[5] The new airport is just beginning its Environmental Impact Statement (EIS) and currently is expected to be open in the year 2017, but is likely to have an impact on both the travel and development patterns in region before that time. RTC has indicated they are likely to consider a new approach for forecasting external trips in 2007, but did not indicate what alternatives are being considered. It is probable that during that review consideration will be given to expanding the modeled region to fully include the area around the new airport; such an expansion would bring the southern portion of the modeled region to the Nevada / California border, meaning RTC could use the California statewide model as a source of external trip forecasts.

MPOs That Obtain External Trips from a Statewide Model

Increasingly, individual states are developing statewide travel demand models. States with fully implemented statewide models include (but are not limited to) Rhode Island, New Hampshire, Wisconsin, Kentucky, New Jersey, Oregon, Michigan, Massachusetts and Pennsylvania. Not all of the existing statewide models are sophisticated enough to provide good information on trips in areas bordering MPO modeled regions and serve as external trip inputs to the MPO models; however, this method *is* being employed by the following MPOs: Boston, Massachusetts; San Francisco, California; Los Angeles, California; and Sacramento, California.[6]

California Statewide Model

The California Statewide Model was developed by the California Department of Transportation (Caltrans) with consultant support from Dowling Associates. The model is implemented in TP+ and was specifically intended to provide external trips for the various MPOs statewide, in addition to modeling intra-state travel. Representatives from the California MPOs expressed satisfaction with the statewide model as a source for external trip forecasts for their area, stating that it made that aspect of regional forecasting easier.

---

[5] This is approximately the same distance from downtown Washington to Dulles International Airport.
[6] Boston, San Francisco, and Los Angeles are included because their size and level of complexity is similar to Metropolitan Washington; Sacramento is considered a high-growth region. VHB also contacted the MPO in Modesto (Stanislaus County COG), a rapidly growing area that is ninety minutes' drive time from Sacramento and two hours from both San Francisco and San Jose. StanCOG indicated that they did not know their procedure for forecasting external trips and that a consultant performed the work, but VHB could not obtain a response from the consultant; however, it is reasonable to assume that StanCOG forecasts its external trips from a combination of coordination with adjacent MPOs (particularly for I-E trips to the north, west, and south) and the use of the statewide model.

Massachusetts Statewide Model

The Massachusetts Statewide Model was developed by the Massachusetts Executive Office of Transportation (EOT) and is the source of external trips for the Central Transportation Planning Study (CTPS, the Boston MPO) model. Because EOT also works directly with the MPOs and their member jurisdictions to prepare statewide population and employment forecasts[7] that are used as inputs to the statewide model, coordination and consistency across the state is assured.

Recommendations

The literature review and survey of MPOs resulted in the conclusion that the methodology for forecasting future external trips is not a "hot" issue at this time and thus, is not receiving very much attention neither from MPOs nor the transportation research community. MPOs are quite focused (like TPB) on making improvements to the model chain that improve the ability to forecast travel within the modeled region. MPOs that do not use a statewide model to forecast external trips are not doing anything significantly different than TPB's current process.

However, in both high-growth regions and complex moderate-growth areas like the National Capital Region, the issue of forecasting external trips is growing in importance as jobs and household continue to locate farther away from traditional urban core areas and contribute to an increased share of external trips in overall regional travel. TPB is planning in the Version 2.2 model release to make some model improvements to address the issue of external trips.[8] There are pieces of the various approaches seen in the above review that can be applied to the TPB process.

Clearly, the use of internal trips from a statewide travel demand model as external trips for the TPB model is not a feasible approach at this time. Maryland lacks a statewide model[9], and although Virginia does have a statewide model,[10] the Virginia Department of Transportation (VDOT) has encountered problems with its application. VDOT modeling resources are currently focused on developing and applying the regional models in smaller MPOs statewide, and they expect it will be 2-3 years before the statewide model is available for regular use.

A possible approach is to combine elements of both of the above procedures. First, TPB could create a model "super-region" at the super-district or county level extending as far as 150 miles

[7] Like the rest of New England, Massachusetts has extremely weak counties and strong towns and cities and no unincorporated areas; thus a state-level agency like EOT can work with an MPO and towns and cities to create detailed, micro-level statewide forecasts.

[8] See COG/TPB (2006), Section 2.1.2 – Refinement of Growth Assumptions at External Stations.

[9] Although Maryland does not have a statewide model, URS Corporation created a model for use in the Maryland Transportation Authority (MdTA) Bay Crossing Task Force study that is examining options for increasing capacity across the Chesapeake Bay. The URS model includes all of Maryland except for Washington, Allegany, and Garrett counties. Information from URS may be helpful in developing the super-regional approach described in the chapter.

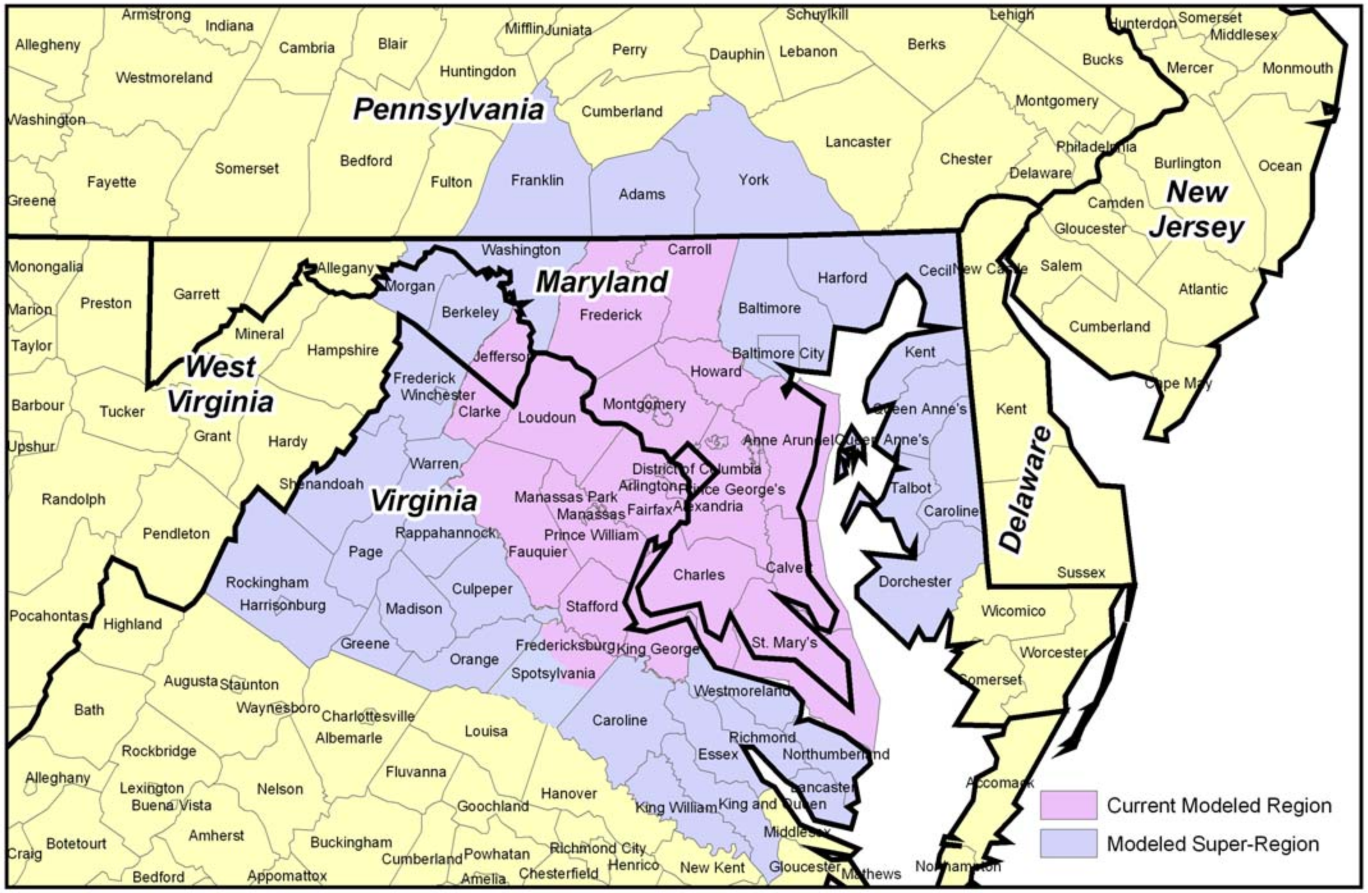
[10] Developed by Wilbur Smith Associates and completed in 2004, the Virginia statewide model implemented in TP+ breaks the Commonwealth into 200 TAZs, and contains both a macro-level model to forecast E-E trips through Virginia and a micro-level to forecast intra-state (I-I) and external (E-I and I-E) trip flows.

from Washington, D.C. based on data available from the 2000 Census Transportation Planning Package (CTPP) and anticipated changes to the areas that regularly interact with the TPB area (see Figure 3-1). The number of external stations in the model network could be increased to match each station with a super-regional county or super-district. In Virginia and Pennsylvania, it may be worth considering adopting the statewide model network for those areas outside the current TPB modeled area for compatibility. Following the collection of external station base counts through traditional counts and surveys, the data could be supplemented by the super-regional jurisdictions and MPOs, similar to the coordination TPB already does with BMC and FAMPO, just over a larger area. For future year external trip forecasts, rather than extrapolating or using a growth-factor, TPB could use the updated population / household and employment forecasts for the super-regional jurisdictions and convert the growth to productions and attractions and ultimately external (E-E, E-I, and I-E) trips.

Special attention will need to be paid to coordination with existing small MPOs in or near the super-region who may have existing modeling programs, such as the Hagerstown, Cumberland, and Winchester MPOs. These agencies will benefit from the use of the TPB model to produce external trip matrices for their areas.[11] Those areas that may have a designated MPO following the 2010 census, such as the Gettysburg, PA area, should also be considered. Finally, the super-region could encompass most or all of the State of Maryland, thus creating a *de facto* Maryland statewide model. In addition to improving TPB's forecasting process, this model could be useful to the Baltimore Metropolitan Council (BMC), Hagerstown Eastern Panhandle MPO and other areas throughout the state. In view of the benefits accrued to areas in Maryland outside the Capital Region, this effort may be undertaken jointly with BMC and the Maryland DOT. It could also be expanded to create statewide modeling capabilities in Maryland. In view of the benefits to Maryland, TPB may wish to seek additional funding from BMC and the Maryland Department of Transportation (MDOT) to support development of this process for forecasting external trips.

[11] The potential benefits have led to this type of coordination being planned in Arizona;, the Pima Association of Governments, the Tucson MPO, plans to perform its upcoming (next year) external survey in conjunction with MAG in Phoenix. The two cities are approximately 110 miles apart.

Figure 3-1: Potential COG/TPB Super-Region for Modeling External Trips



VHB *Vanasse Hangen Brustlin, Inc.*

1 inch equals 33 miles

N

References

Boston MPO, 2005. Travel Modeling and Other Techniques Used for SIP Project Analysis, http://www.bostonmpo.org/bostonmpo/SIP/Travel%20Modeling%20Techniques.pdf.

Cambridge Systematics & Urban Analytics, September 24, 2003. Travel Demand Model Improvement Program, presented to Southern California Association of Governments Modeling Task Force.
http://www.scag.ca.gov/modeling/mtf/presentations/092403/Model_Improv_38_idge_System.ppt#326,2,Technical Approach

Charlotte Department of Transportation. Metrolina Regional Travel Demand Model, DRAFT Technical Documentation.

Denver Regional Council of Governments, 2000. Travel in the Denver Region.
http://www.drcog.org/documents/DRCOG%20TDR%20Report.pdf

Email from Aichong Sun, Pima Area of Governments

Email from Anna Gallop, City of Charlotte Department of Transportation

Email from Elaine Martino, Florida Department of Transportation, District Seven

Email from Hongxiang (Sarah) Sun, Regional Transportation Commission of Southern Nevada

Email from Lark Downs, Stanislaus Council of Governments

Federal Highway Administration, 1997. Model Validation and Reasonableness Checking Manual.
http://tmip.fhwa.dot.gov/clearinghouse/docs/mvrcm/ch3.stm

Horowitz, A. J., 2005. Tests of a Family of Trip Table Refinements for Long-Range, Quick-Response Travel Forecasting, Transportation Research Record.
http://www.trb-forecasting.org/papers/2005/ADB40/05-0100_Horowitz.pdf

Metropolitan Washington Council of Governments, National Capital Regional Transportation Planning Board, 2006. Fiscal Year 2006 Development Program for TPB Travel Forecasting Models.

Murthy, S. & Salem, R. The Rhode Island Statewide Travel Demand Forecasting Model.
http://onlinepubs.trb.org/onlinepubs/circulars/ec011/murthy.pdf

Parsons Transportation Group, Inc., March 5, 2001. PHOENIX EXTERNAL TRAVEL SURVEY: EXECUTIVE SUMMARY.
http://www.mag.maricopa.gov/pdf/cms.resource/househould-travel-survey18728.pdf

Personal conversation with Bruce Griesenbeck, Sacramento Area Council of Governments

Personal conversation with Chuck Purvis, Metropolitan Transportation Commission

Personal conversation with Guy Rousseau, Atlanta Regional Commission

Personal conversation with Keith Killough, Southern California Assocation of Governments

Personal and telephone conversation with Paul Agnello, Virginia Department of Transportation

Regional Transportation Commission of Southern Nevada, Regional Transportation Plan FY 2006-2030. Appendix IIB, Travel Demand Model Documentation.

Santa Barbara County Association of Governments, September 16, 2004. The 2030 Travel Forecast For Santa Barbara County: Final Report. http://www.sbcag.org/PDFs/publications/2030TravelModel.pdf

Sharag-Eldin, A. & Chow, L., June 2003. External Stations Forecast Analysis for NOACA 2025 Model Update. http://www.noaca.org/techmemo.html.

Sharma, S., Lyford, R. & Rossi, T. The New Hampshire Statewide Travel Model System. New Hampshire Department of Transportation & Cambridge Systematics, http://onlinepubs.trb.org/onlinepubs/circulars/ec011/sharma.pdf.

Telephone Conversation with Deardra Sprott, San Antonio / Bexar County MPO.

Telephone conversation with Scott Peterson, Central Transportation Planning Staff. *Contact at Massachusetts Executive Office of Transportation for Statewide Model is Bob Frey, (617) 973-7449.*

University of Washington, Cambridge Systematics & Bhat, C., June 30, 2001. Recommendations for Integrated Land Use and Travel Models. http://www.psrc.org/datapubs/pubs/model_designrecommendations.pdf

This page intentionally left blank

Task 4: Review Experience with Equilibrium Assignment

This page intentionally left blank

New techniques are sometimes introduced into the travel demand forecasting process with little long-term follow-up evaluation. Equilibrium assignment, while being more soundly based in theory, has been criticized for being overly sensitive to small network changes resulting in significant changes in volumes on links far removed from the alternatives being studied. If these apparently anomalous behaviors are to be accepted, equilibrium assignment should yield results that are demonstrably better than those produced by other methods.

This chapter evaluates equilibrium assignment as well as other techniques. The purpose of this chapter is to review issues with the applications of equilibrium assignment, mitigation strategies for some of these issues, and to provide an update on the state-of-the-practice in highway assignment application at the MPO level.

State of the Practice

TRB recently conducted a survey to determine the state-of-the-practice in travel demand modeling for MPOs. The survey was sent to 381 MPOs across the United States and 228 responded. The MPOs were classified into three categories based on metropolitan area population: small, medium, and large. Metropolitan areas with populations less than 200,000 were categorized as small; those with populations between 200,000 and 1 million were categorized as medium; and those with populations greater than 1 million were categorized as large. MPOs that responded consisted of 116 small MPOs, 74 medium MPOs, and 36 large MPOs. Table 4-1 provides a summary of the number of surveys and responses.

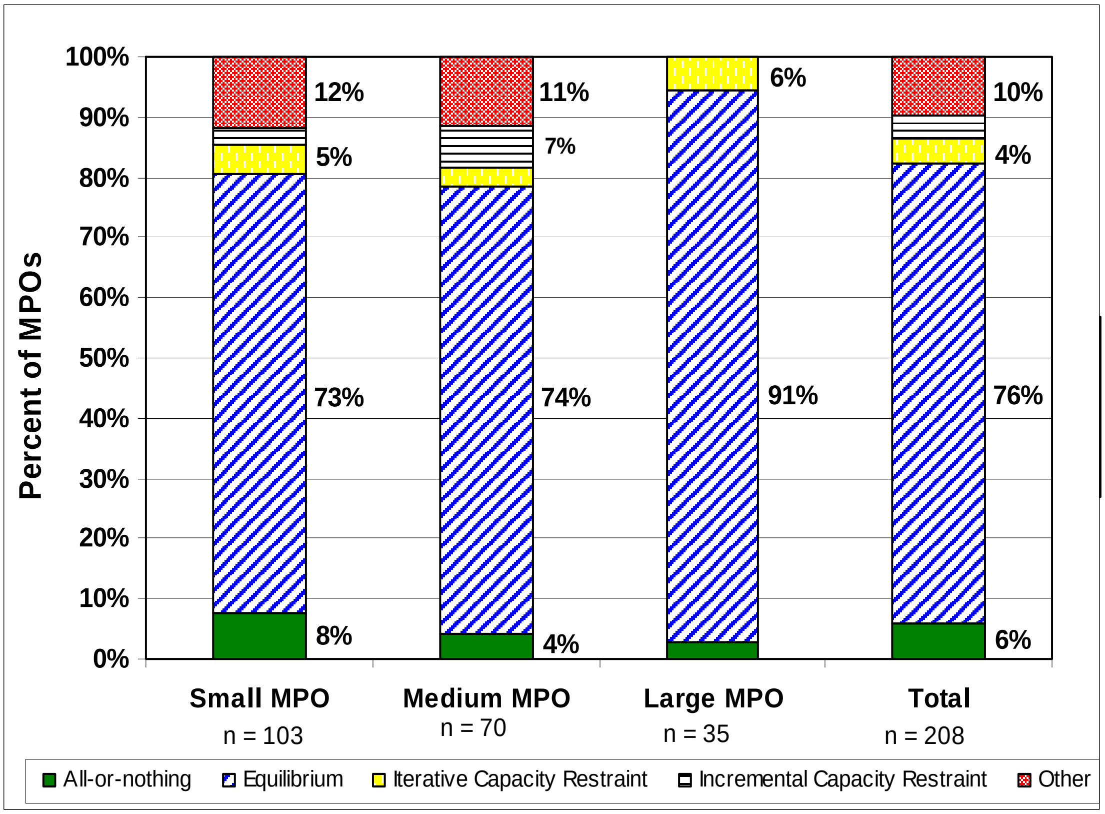
Table 4-1: Survey Responses

MPO Classification	Surveys Sent	Responses Received	Percent Responding
Small (Population less than 200,000)	205	116	57%
Medium (Population between 200,000 and 1 Million)	133	74	57%
Large (Population greater than 1 Million)	43	36	84%
Total	381	228	60%

For almost all agencies, highway traffic is assigned using an equilibrium method. Figure 1 shows the assignment method used by MPO size. Few agencies were able to report the number of iterations required to achieve closure in equilibrium assignment or the closure tolerance used. Many reported that they used the default values of their software packages. Few agencies had examined equilibrium assignments to see if the results were stable and none of those sampled reported problems such as those noted in studies conducted for FTA.[12] These problems have included issues with stability and consistency with the assignment results.

[12] AECOM, 2005.

Figure 4-1: Highway Traffic Assignment Method



A recently observed issue with equilibrium assignment is the problem with reaching convergence. For a traffic assignment, equilibrium is reached in a network when for a specific trip interchange the travel time can not be improved by unilaterally changing paths. The basic assumptions are that each trip chooses the minimum impedance (e.g., travel-time, distance, cost, etc.) and all trips have full information on all impedances for all possible paths. Travelers consistently make the correct decisions regarding route choice, and all travelers have identical behavior. It has been shown that in a highly congested network hundreds of iterations are required until a true state of equilibrium is reached. This problem has been documented in work done by AECOM,[13] Bill Allen,[14] and work that VHB has done. Our work includes reviewing FTA's Summit reports as well as a paper published at the TRB Planning and Applications Conference in 2005 documenting the issue of equilibrium convergence.[15]

There have been several papers published or in the process of being reviewed for publication that deal with the convergence issue with respect to equilibrium assignment. Researchers such as David Boyce and Hillel Bar-Gera have published work on new algorithms that are reported to converge to equilibrium faster and provide a stable solution.[16] Researchers at Caliper Corporation have also funded and refined equilibrium methods that are supposed to reach

[13] Woodford, 2006.
[14] Allen and Schmitt, 2005.
[15] Goldfarb and Spielberg, 2005.
[16] Boyce, Ralevic-Dekic; and Bar-Gera, 2004.

equilibrium faster without hundreds of iterations.[17] Robert Dial recently completed additional research on this topic and was partially funded by Caliper.[18] All of this new research claims and provides examples of applications where by employing a refined equilibrium algorithm the solution was achieved quickly and was stable. Dial and Caliper apply acyclic sub-networks. Boyce and Bar-Gera apply an origin-based assignment algorithm. Caliper researchers have found some issues with the Bar-Gera solution.[19] All of these researchers documented that the Frank-Wolfe method in congested networks will not reach a true equilibrium state and that a new method must be used in congested networks.

Assignment Algorithms

Prior to the application of equilibrium assignment algorithms, many MPOs applied incremental capacity restraint (ICR) assignment algorithms. These algorithms assign part of the trip table, usually proportioned into four equal quarters, and after each increment recalculate travel times and then assign the next proportion until the complete trip table is assigned. This technique was replaced by equilibrium assignment. A key question is what benefit is there to equilibrium assignment given that it replaced the ICR algorithm.

In order to evaluate the performance of different highway assignment algorithms including equilibrium, a travel demand forecast model (TDFM) was used for the Washington, D.C. Metropolitan Area from the year 1990. It was applied to develop forecasts for the year 2000. The most recent land-use data for the year 2000 was obtained and used as the land-use inputs. The objective of this exercise was not to test the validity of the land-use forecast, but to focus on the different assignment techniques. Forecast highway volumes were developed for an approximately 40 mile long portion of the Capital Beltway Corridor (I-495/I-95) in the State of Maryland. Figure 4-2 shows the geographic location of the study corridor and the major surrounding highway facilities.[20]

The average daily traffic (ADT) and the PM peak hour were simulated and compared to count data for the year 2000. This exercise represented a ten year forecast using the model set from 1990. The observed-to-simulated traffic volumes were compared using a series of statistical measures.

The TDFM set used for this project applied an ICR algorithm as the base assignment algorithm. This was a typical algorithm that was used prior to the wide spread application of the equilibrium algorithm. The ICR algorithm served as the baseline for comparison to the other algorithms.

---

[17] Slavin, Brandon, and Rabinowicz, 2006.
[18] Dial, 2006.
[19] Slavin, et al, 2006
[20] Maryland State Highway Administration, 2003.

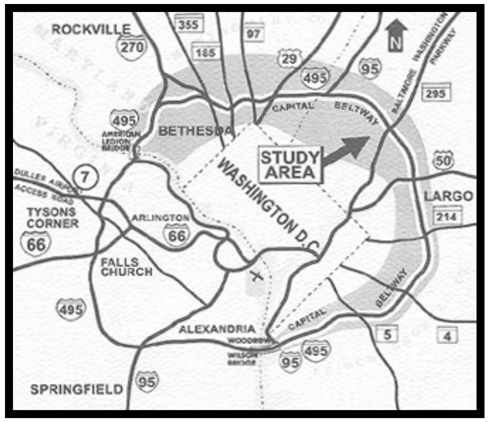


Figure 4-2

After application of the ICR algorithm, an all-or-nothing (AON) assignment was performed. The purpose in applying the AON assignment for this project was to quantitatively evaluate the assignment as compared to other algorithms and to test the model structure for expected results. By definition, the AON assignment would be expected to over-simulate the freeway links on the Capital Beltway. These links have the highest free-flow speed in the transportation network; therefore, without updating link travel times due to congestion, trips in the vicinity of the freeway would take advantage of the facility's very high performance level. It was expected that the AON assignment results would show higher than observed volumes for the year 2000 and produce the highest traffic volumes when compared to the other assignment algorithms.

The equilibrium assignment algorithm has become the standard algorithm applied for highway assignment by TPB.[21] The primary purpose of this exercise is to quantitatively evaluate the differences in the equilibrium assignment versus the incremental capacity restraint assignment for an actual regional TDFM set. Unlike other tests of the equilibrium assignment, it was not related to an academic exercise or a calibration and validation effort.

The objective of an equilibrium assignment is to disperse traffic across a network so that all paths between origin and destination pairs have equal impedances, usually travel time. The equilibrium assignment process applied here defined equilibrium as when the impedance difference in travel times was less than 3.5 percent across all origin and destination zone pairs. The 3.5 percent was determined to be the acceptable level based on the software vendor's recommendations.[22]

The measures of effectiveness used for the evaluation of the assignments were the percent root mean square error (RMSE), the standard error of regression, and a trend line analysis. The RMSE and the standard error of regression measured the difference in the forecast to the observed count volume. These were the key measures that best quantified which algorithm produced the closest results to the observed count data.

Daily Traffic Assignment Results

[21] Milone, 2002, pp. 1-4 – 1-8.
[22] Comsis Corporation, 1996, pp. Assign-32.

Table 4-2 summarizes the results of the assignment algorithms for freeway links along the Capital Beltway in Maryland:

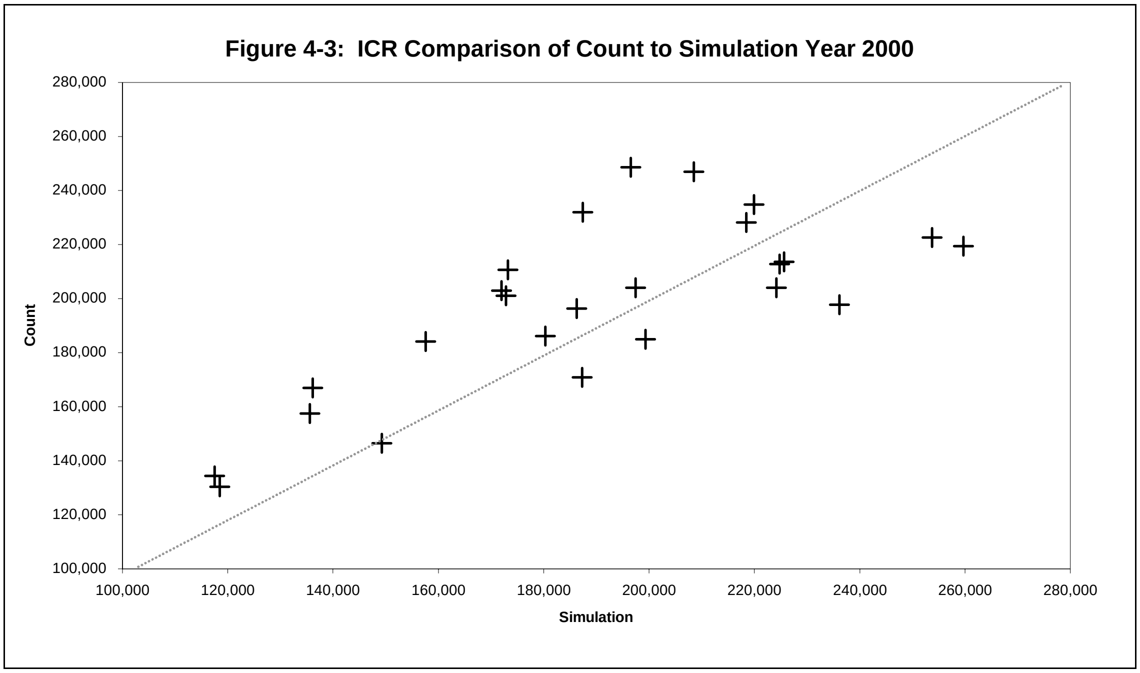
Table 4-2: Summary of Assignment Algorithm Evaluation			
Algorithm	**RMSE**	**Standard Error of Regression (1 x 10^3)**	**Trend Line y-intercept (0,0) Slope**
Incremental Capacity Restraint	13.9%	28.15	1.029
All or Nothing	31.6%	64.06	0.078
Equilibrium	11.8%	24.03	1.003

Some general observations are that both the incremental and the equilibrium algorithms matched the count data reasonably well. As expected, the AON assignment did not match the observed data very well. It was expected that the AON assignment would result in an over-simulation. The AON performance was as expected, and this served to confirm that the model assignment process was working. If the AON did not result in an over-simulation, that might have been indicative of a network coding problem. The AON served a dual purpose: the first was as a comparison mark for the other assignment algorithms and the second as a quality control measure.

The remaining two assignment algorithms produced results that were about the same. There was one point where all of the forecast results increased while the count decreased around the interchange at Georgia Ave (MD 97) in Montgomery County. This could be a result of construction on the Beltway in this location during the year 2000. It was not expected that the model network would reflect the effects of construction, even if it were a multi-year project.

The base assignment, which was the ICR algorithm with four iterations, produced reasonable results. The RMSE for this assignment was 13.9 percent. It might have been expected to see some over-simulation on the freeway links since the incremental capacity restraint algorithm is not as responsive to travel time changes as an equilibrium algorithm. The results for this assignment did not show any particular patterns concerning over-simulation on the Capital Beltway. The assignment over-simulated at the Potomac River crossings, but for most of the corridor it under-simulated. The over-simulation in the vicinity of the river crossing could be a result of network supply. There are limited river crossings, including two on the Beltway, and they represent choke points in the system. Based on the Capital Beltway results, it appears that the model was not as successful in simulating the traffic flow from Maryland to Virginia as compared to other links along the Capital Beltway. This is most likely not an assignment issue but more related to trip distribution.

Figure 4-3 shows the scatter plot for the ICR assignment. The under-simulation is apparent on the plot. Most of the data points fall above the diagonal axis line $y = x$. The trend line analysis resulted in a slope of 1.029. This is reasonably close to 1.0. Overall, the ICR assignment produced relatively good results.



The AON assignment results showed a pattern of over-simulation. The RMSE was 31.6 percent, which was the highest RMSE compared to the other assignment algorithms. Figure 4-4 shows the scatter plot results from the AON assignment. Except for two data points, all of the links were over-simulated, as could be expected from this type of algorithm. The trend line analysis showed a 0.078 slope showing further evidence of the over-simulation. The Capital Beltway is surrounded by other major and minor arterials, as well as collector facilities, in a dense suburban setting. Given the high speed on the freeway versus the surrounding street network, more trips used the freeway even when this meant backtracking and traveling excessive distances past the destination zone. In reality, when there is a high level of congestion on the Capital Beltway short trips are expected to utilize the arterial network. As expected, the AON algorithm did not represent travel in a mixed urban setting where multiple alternative routes exist. Compared to the ICR assignment, the AON is a poor substitute.

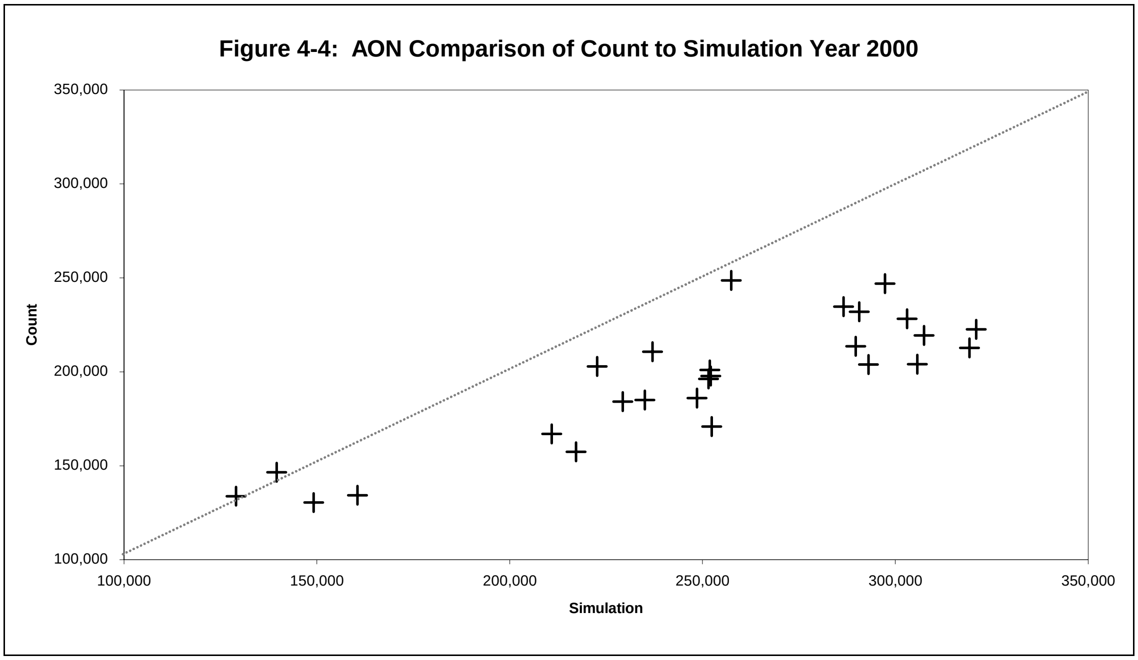
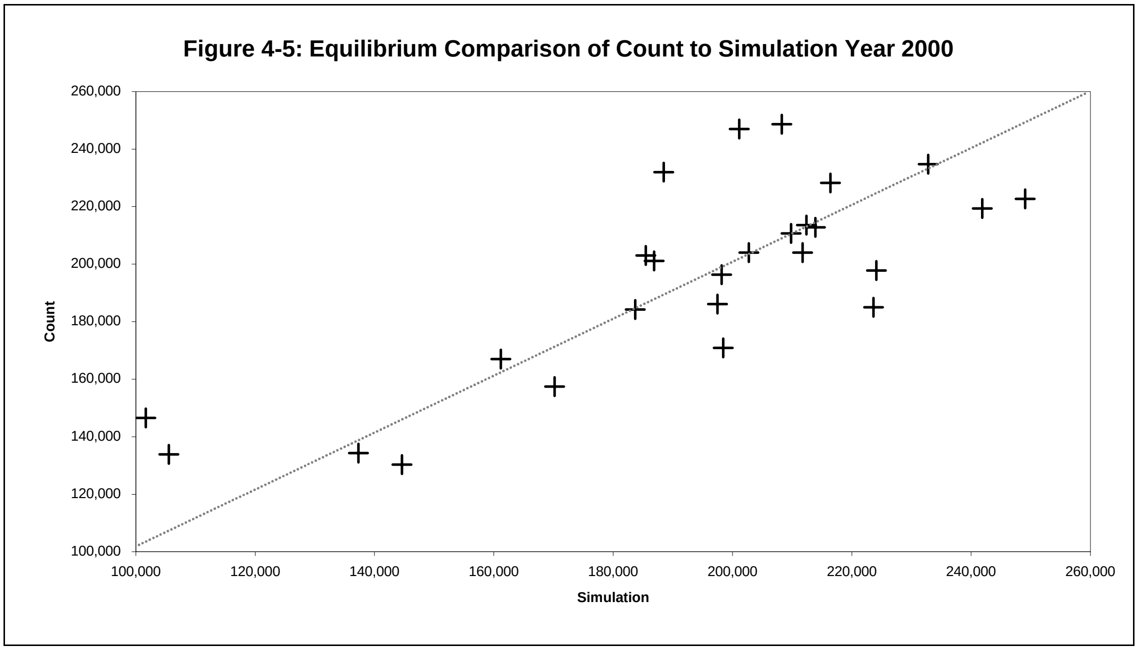


Figure 4-5 shows the scatter plot results for the equilibrium assignment algorithm. The equilibrium algorithm is designed to spread traffic across all competing routes. It stops once the sum of all impedances (in this case travel times) on the links are equal within a given tolerance level.

The equilibrium assignment algorithm showed the lowest RMSE for all of the tested algorithms. The RMSE was 11.8 percent, and the trend line analysis resulted in a slope of 1.003. Although marginally better than the base incremental assignment algorithm, the equilibrium assignment did take a longer time to execute. The amount of time was about ten minutes longer, or roughly a 30 percent increase. Given the improved results, the time difference was not substantial. As with all of the assignments, the Potomac River crossings were over-simulated by the equilibrium assignment. For the river crossings, it did not perform any worse or better than the incremental algorithm.

Time of Day Assignment Evaluation

As part of this project, a PM peak period assignment was performed using both an incremental capacity restraint assignment and an equilibrium assignment. The time-of-day (TOD) method applied for this project factored the trip tables by purpose prior to the final highway assignment. The factors were taken from the latest version of the regional travel demand model. The PM peak period was defined as from 4:00 pm to 7:00 pm.



The results of the assignments were then used to derive PM peak hour volumes. A simple peak hour to peak period factor was applied to each link volume. The factor was taken from the permanent count stations along the Capital Beltway. The data showed that for the year 2000, the peak hour was 34 percent of the peak period. This was consistent for all of the stations.

Table 4-3 presents a summary of the TOD results. For this evaluation, the RMSE was the key measure used to evaluate the results. The RMSE for the incremental capacity restraint assignment were 51.2 percent for the Inner Loop of the Capital Beltway and 48.5 percent for the Outer Loop. The RMSE using the equilibrium assignment was somewhat better. The Inner Loop RMSE with the equilibrium assignment was 20.9 percent and for the Outer Loop was 24.5 percent. The equilibrium algorithm performed much better when doing a peak period assignment as compared to the daily assignment. This could be due to a variety of factors. One major factor could be the level of network saturation in the peak period versus the daily.

Table 4-3: RMSE Summary of TOD Assignment (by direction)

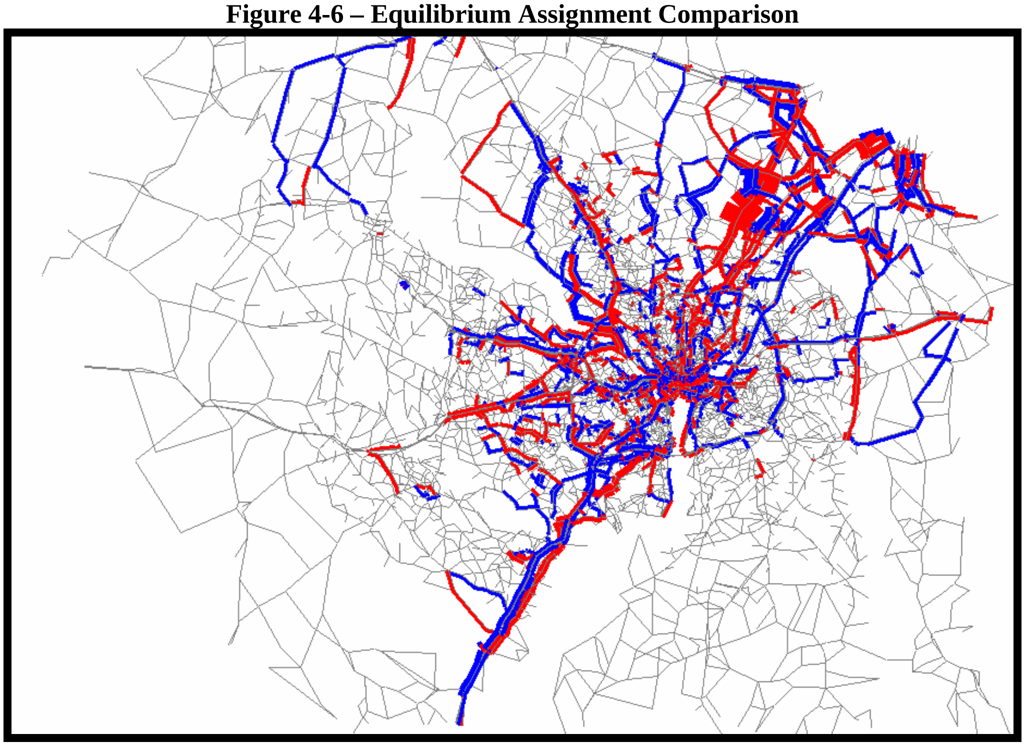
Algorithm	Inner Loop	Outer Loop
Incremental Capacity Restraint	51.2%	48.5%
Equilibrium	20.9%	24.5%

Equilibrium Assignment Issues

The purpose of this exercise was to quantitatively evaluate the performance of different assignment techniques commonly used in travel demand forecast models. The equilibrium algorithm did produce the best results, but there are several outstanding issues related to the closure of the equilibrium assignment. Even when the time between all travel paths is less than 0.1 percent, small changes in the network result in large discrepancies across the network. Localized network changes, even as small as adding lanes to a specific facility, can result in different assignment results far from the network change.

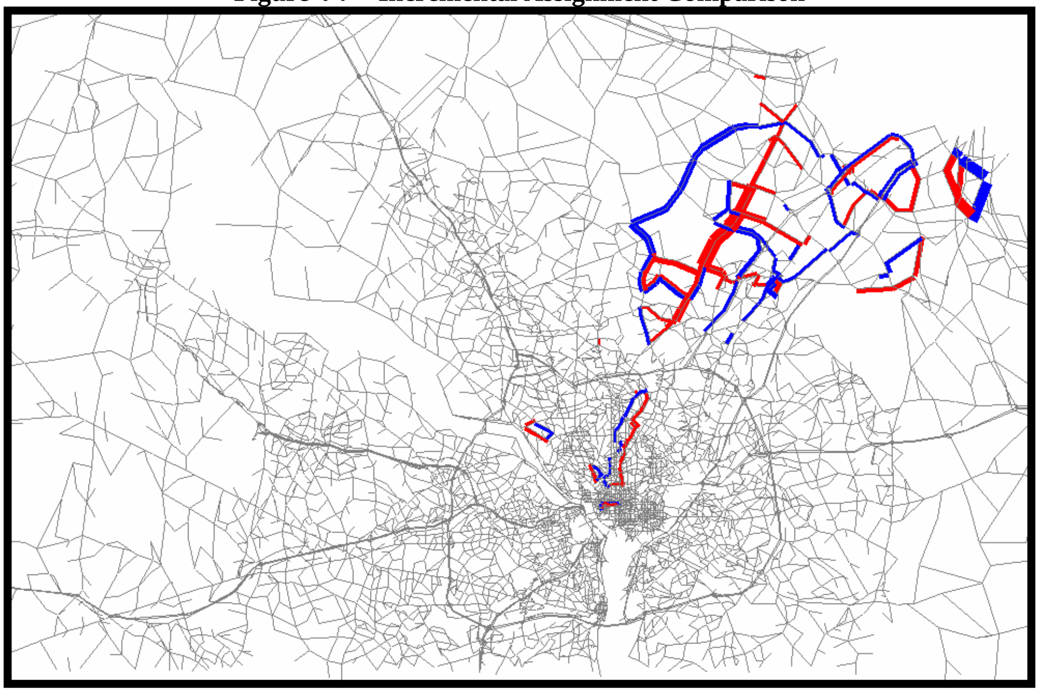
Figures 4-6 and 4-7 show an example of this issue. Using a more recent model set, a lane was added in each direction to six miles of US 29 in Howard and Montgomery Counties. Figure 4-6 shows the difference between the network assignments using an equilibrium assignment. The gap was 0.1 percent and the assignment took over 30 iterations to be completed. Figure 4-7 used the same two networks, but applied an ICR algorithm. Each increment assigned 12.5 percent of the daily trip table. Figure 4-6 shows changes in link volumes throughout the greater metropolitan area, even in areas far from the network change. Figure 4-7 shows the change in assignment for predominately the area surrounding where the network change was made. Figure 4-7 shows a change pattern that is much more logical and easier to comprehend. The network differences far from the impacted area in Figure 4-6 are challenging to accept and do not make logical sense. The ICR algorithm does provide some stability in the assignment between the two test alternatives.

Figure 4-6 – Equilibrium Assignment Comparison



The question is whether the benefits of applying an equilibrium assignment outweigh the instability of the results. It is problematic that small changes in the network produce differences in the results for areas far from where the network changes were made. Increasing the number of iterations can be useful for both algorithms in order to improve their performance. For equilibrium assignment to show stability the gap must be less than 0.1 percent. With this small of a gap, the number of iterations for a large network will be well over 30. For an ICR algorithm, a greater number of iterations can result in closer replication of the equilibrium assignment with less network instability.

Figure 4-7 – Incremental Assignment Comparison



A limited comparison of simulated and observed data was made between an ICR algorithm with eight iterations and an equilibrium assignment with a gap of 0.1 percent. This comparison was done using the more recent model set for the Washington, D.C. metropolitan area while looking at two different cutlines composed of a total of 12 facilities. The first cutline served more local traffic while the second cutline served predominately commuter traffic. The resulting difference in the RMSE between an equilibrium assignment with a gap equal to 0.1 percent and an incremental capacity restraint algorithm with eight iterations was found to be very small. The RMSE for both cutlines combined was 21.4 percent for the incremental capacity restraint assignment and 20.6 percent for the equilibrium assignment. After applying a post-process link refinement routine the difference in individual facilities at the ADT level was less than or equal to one percent. Table 4-4 summarizes the results.

As part of on-going transit project planning work, AECOM has come to the same conclusion. Using the TPB model set as well as the Hampton Roads Planning District Commission (HRPDC) model set for the Hampton Roads area, AECOM has shown that for equilibrium to be reached in congested networks greater than 500 iterations are required, and only with this many iterations can stability be achieved when applying an equilibrium assignment. These issues with equilibrium assignment have only been brought to light as a result of transit analysis for New Starts programs. Using FTA's Summit software abnormalities in the highway assignment have been discovered while testing different transit alternatives and calculating user benefits. Prior to these exercises issues with convergence and the instability of the assignment went unnoticed.

Table 4-4: Summary of Cutline Results for Count Year			
Facility	**2000 Count (ADT)**	**Incremental Capacity Restraint 8 iterations (ADT)**	**Equilibrium gap=0.1% (ADT)**
US 29	45,000	63,112	59,433
I-95	165,000	166,528	169,102
MD 216	16,100	11,667	12,821
US 1	34,000	38,609	35,065
MD 108	15,000	27,107	22,708
Washington Grove Ln	19,300	17,175	18,119
Shady Grove Road	49,500	41,581	41,581
Redland Road	22,000	31,504	34,248
Southlawn Lane	2,000	1,553	5,926
MD 28	52,000	51,452	42,881
Baltimore Avenue	5,300	11,863	13,110
MD 586	35,200	30,203	30,753

One technique used to address this issue with stability and equilibrium assignment is a type of hybrid approach. The Baltimore Metropolitan Council (BMC) uses this hybrid equilibrium assignment method. The technique applies an equilibrium assignment for a designated base year, and then uses the resulting weights from each of the assignment iterations for future year assignments. This is essentially an iterative assignment and the averaging proportions are derived from an equilibrium assignment and the linear optimization of the λ (lambda) function. This process was tested using the model set detailed earlier in this memorandum. It was found to be more stable than the equilibrium assignment but not as stable as the incremental assignment. The results of this evaluation are summarized in Table 4-5.

The resulting RMSE for the hybrid approach was 23.4 percent compared to 20.6 percent for the equilibrium assignment and 24 percent for the eight iteration incremental assignment. This technique does address the concerns for having all paths in the network approaching a state of equilibrium, but for the additional level of work, it does not seem to add much benefit.

Table 4-5: Summary of Cutline Results for Count Year with Hybrid Equilibrium Assignment				
Facility	**2000 Count (ADT)**	**Incremental Capacity Restraint 8 iterations (ADT)**	**Equilibrium gap=0.1% (ADT)**	**Hybrid Equilibrium with Fixed Weights From Base Equilibrium Assignment (ADT)**
US 29	45,000	63,112	59,433	63,565
I-95	165,000	166,528	169,102	155,988
MD 216	16,100	11,667	12,821	13,179
US 1	34,000	38,609	35,065	37,894
MD 108	15,000	27,107	22,708	23,502
Washington Grove Ln	19,300	17,175	18,119	19,567
Shady Grove Road	49,500	41,581	41,581	42,767
Redland Road	22,000	31,504	34,248	34,043
Southlawn Lane	2,000	1,553	5,926	9,800
MD 28	52,000	51,452	42,881	45,929
Baltimore Avenue	5,300	11,863	13,110	13,537
MD 586	35,200	30,203	30,753	32,520

Conclusion

An objective of this chapter was to quantitatively evaluate the performance of different assignment algorithms and critically evaluate the performance of an equilibrium assignment. Recent in-depth analysis of the application of equilibrium assignment has shown instability in the results. When there are small network changes in a localized area, the equilibrium assignment results show large changes in the network for areas that are far from where the network modifications were made. This can be problematic when comparing alternatives and measuring regional benefits.

The incremental capacity restraint assignment used in the primary analysis was composed of four iterations. Each of the four iterations assigned an additional 25 percent of the trip table to the network and then recalculated the shortest path. Using a more recent model set, it was shown that by increasing the number of iterations the discrepancy between the equilibrium results and the incremental assignment results could be decreased. Applying a link refinement post-process as outlined in the National Cooperative Highway Research Project Report Number 255 (NCHRP 255) resulted in a marginal difference in the future forecast between the equilibrium assignment and the eight-iteration ICR assignment.

Even though the equilibrium assignment is theoretically superior to the ICR algorithm, it is troubling that there is instability in the equilibrium assignment and that there are large changes in volumes in areas far from where the network modifications were made. The benefit of an ICR assignment is that results are stable. Increasing the number of iterations can improve the ability of the incremental algorithm to simulate the observed data. Given the large number of iterations required for stability with the equilibrium assignment there is some benefit to applying the incremental algorithm and increasing the number of iterations. The basic issue with respect to equilibrium assignment is related to the stability of the model results. It is much easier to track trips through the network with an incremental approach. This ability to track and understand the travel patterns as well as the added stability are real benefits in planning applications. The drawback is that the ICR assignment did not simulate as well as the equilibrium assignment. Although there was not a lot of difference, a choice has to be made between the need for stability and the accuracy of the model results. With current and future research into finding better ways for equilibrium convergence new techniques may evolve that provide a faster convergence and stability over the current application of the Frank-Wolfe methods.

While new methods of reaching convergence with equilibrium algorithms are being developed for macro-level assignments, the move to more meso-level and micro-level traffic assignments is the future. This is true even within the framework of the region travel demand forecast model. TPB should allocate time and resources to examining these evolving methods and how they can be applied.

References

AECOM Consult, Inc., "Research on Highway Congestion Relief", Working Paper, prepared for Federal Transit Admininstration, June 2005.

Allen, William and Schmitt, David, "Using Your Model Effectively", 10th TRB Transportation Planning Applications Conference, Portland, OR, April 24-28, 2005.

Boyce, David; Ralevic-Dekic, Biljana; and Bar-Gera, Hillel, "Convergence of Traffic Assignments: How Much is Enough?" *Journal of Transportation Engineering*, ASCE, January/February 2004.

Comsis Corporation, *MinUTP Technical Manual*, Silver Spring, MD, Comsis Corporation, 1996.

Dial, Robert B., "A Path-Based User-Equilibrium Traffic Assignment Algorithm that Obviates Path Storage and Enumeration," *Transportation Research Part B*, March 13, 2006.

Goldfarb, Daniel and Spielberg, Frank, "Does the Emperor have Clothes? A Comparative Evaluation of Assignment Techniques," 10th TRB Transportation Planning Applications Conference, Portland, OR, April 24-28, 2005.

Maryland State Highway Administration, *Capital Beltway Corridor* Study, Maryland State Highway Administration Web Site, Baltimore, Maryland, 2003.

Milone, Ronald, *COG/TPB Travel Forecasting Model Version 2.1/TP+, Release C User's Guide*, Washington, D.C., Metropolitan Washington Council of Governments, December 2002.

Slavin, Howard; Brandon, Jonathan and Rabinowicz, Andres, "An Empical Test of Alternative Traffic Assignment Methods," TRB 2006 Annual Meeting, Washington, D.C. January 2006.

Woodford, William / AECOM Consult, "*Evaluation of Highway Congestion Relief Benefits*," White Paper and Presentation for FTA Workshop on Travel Forecasting for New Starts, Minneapolis, MN, June 2006.

Task 5: Review of Current Use of Activity-Based Modeling

This page intentionally left blank

TPB staff requested that VHB review the current use of activity-based models in the United States and abroad. Activity-based models have been hailed as the next major advance in travel demand forecasting, with many claiming that the resulting models provide a framework and paradigm that will permit more accurate forecasts than the so-called traditional four-step, trip-based models, and will provide the ability to analyze a wider range of transportation and land-use policies. This chapter summarizes our review of the state of the art and practice in activity-based models.

While a few agencies have implemented and are using activity-based models to conduct work program activities, there is limited information on the results of these initial applications of the model. We were unable to find detailed documentation of the use of the activity-based models for project planning studies. A number of large MPOs have added elements of advanced modeling practice (e.g., strategic work trips, tour-based modeling) into their existing trip-based models, have structured data collection so that information suitable for building activity-based models is available, and have in their long-term model development plans expressed an intent to explore and to likely transition to a fully-implemented activity-based model. Agency staff with who we have discussed travel modeling and discussions on both the Travel Model Improvement Program (TMIP) listserv and a Yahoo! listserv for a coalition of MPOs interested in activity-based models indicate that MPOs are moving forward slowly, as they still have many concerns about the need for a complete activity-based model and its application to typical MPO work program elements, such as air quality / conformity analysis, corridor and project planning studies, and transit studies.

Advanced Travel Demand Models: Is It Truly An Activity-Based Model?

The terms "activity-based model" and "tour-based model" are sometimes incorrectly used interchangeably. Activity-based models (ABMs) by definition use the tour (rather than the trip) as the basic unit of travel and are therefore also tour-based models; however, not all tour-based models are activity-based. Adding to the confusion is the use of "journey-based" as a substitute for tour-based. The primary difference between the two constructs is that *true* activity-based models begin with the inclusion of a full daily activity pattern (DAP) for each member of a synthetic household prior to tour generation and carry the DAP through the entire model chain to trip assignment.[23] The use of the daily activity pattern and corresponding activity scheduler prior to tour generation allows the model to simulate intra-household interactions in travel, provides more explicit and detailed time-of-day modeling, and avoids illogical destination or mode choices. Figures 5-1 through 5-3 illustrate the workflow of the Columbus, Ohio activity-based model.[24]

---

[23] In tour-based and activity-based models tours are converted back to trips for network assignment.
[24] Anderson, et al., (2003)

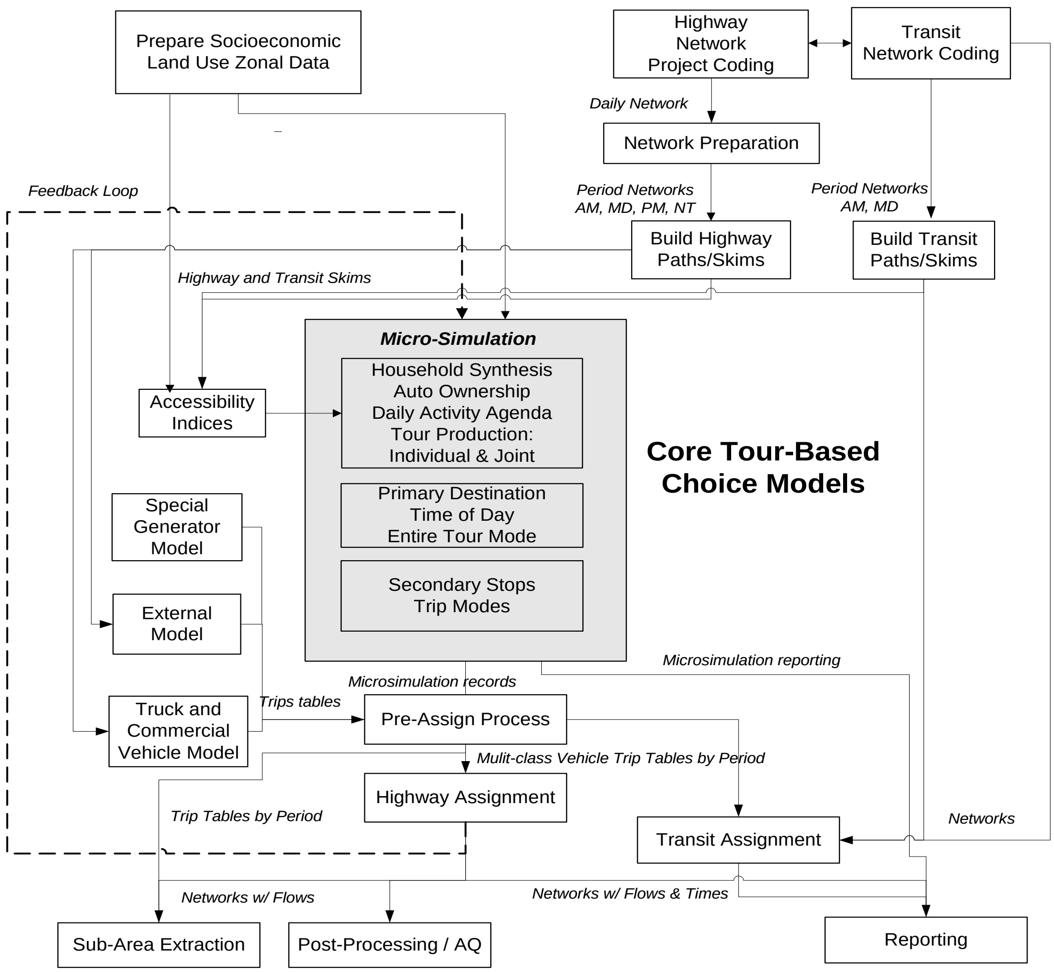


Figure 5-1: MORPC Tour-Based/Microsimulation Models – General Applications Flow

MPOs and Other U.S. Agencies Currently Using or Developing Advanced Models

As of the publication of this memo, there are three (3) models that may be characterized as ABMs in use by public agencies in the United States:

- New York, New York (New York Metropolitan Transportation Council – NYMTC)
- Columbus, Ohio (Mid-Ohio Regional Planning Commission – MORPC)
- San Francisco, California (San Francisco County Transportation Authority – SFCTA)

In New York and Columbus, the models were developed as part of the MPO work program and are now being run by the MPO to support activities such as conformity analysis and corridor studies for both highway and transit projects. SFCTA's model covers internal San Francisco

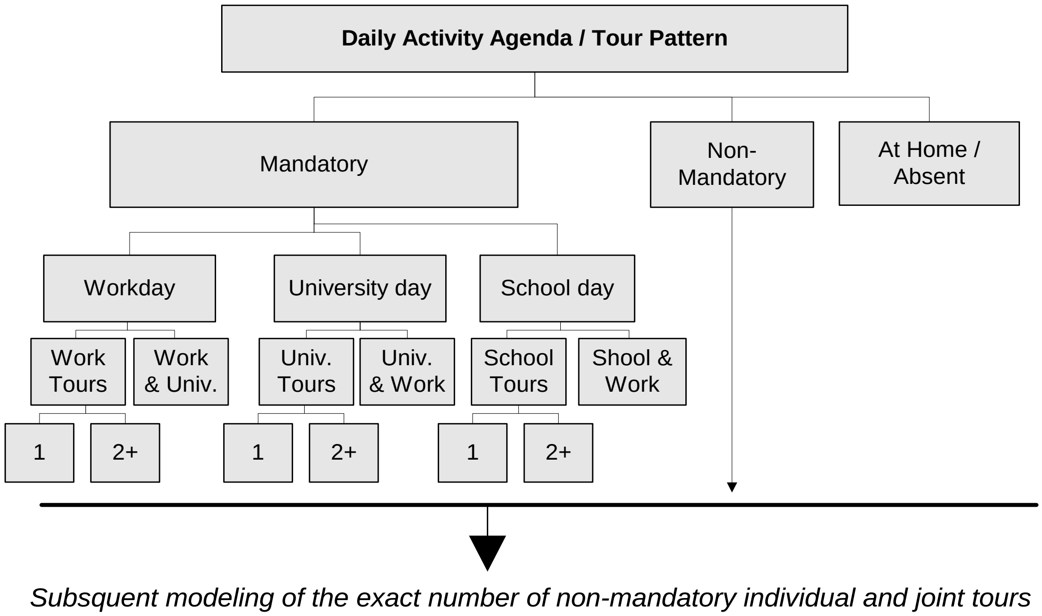


Figure 5-2: MORPC Classification of Daily Activity Patterns

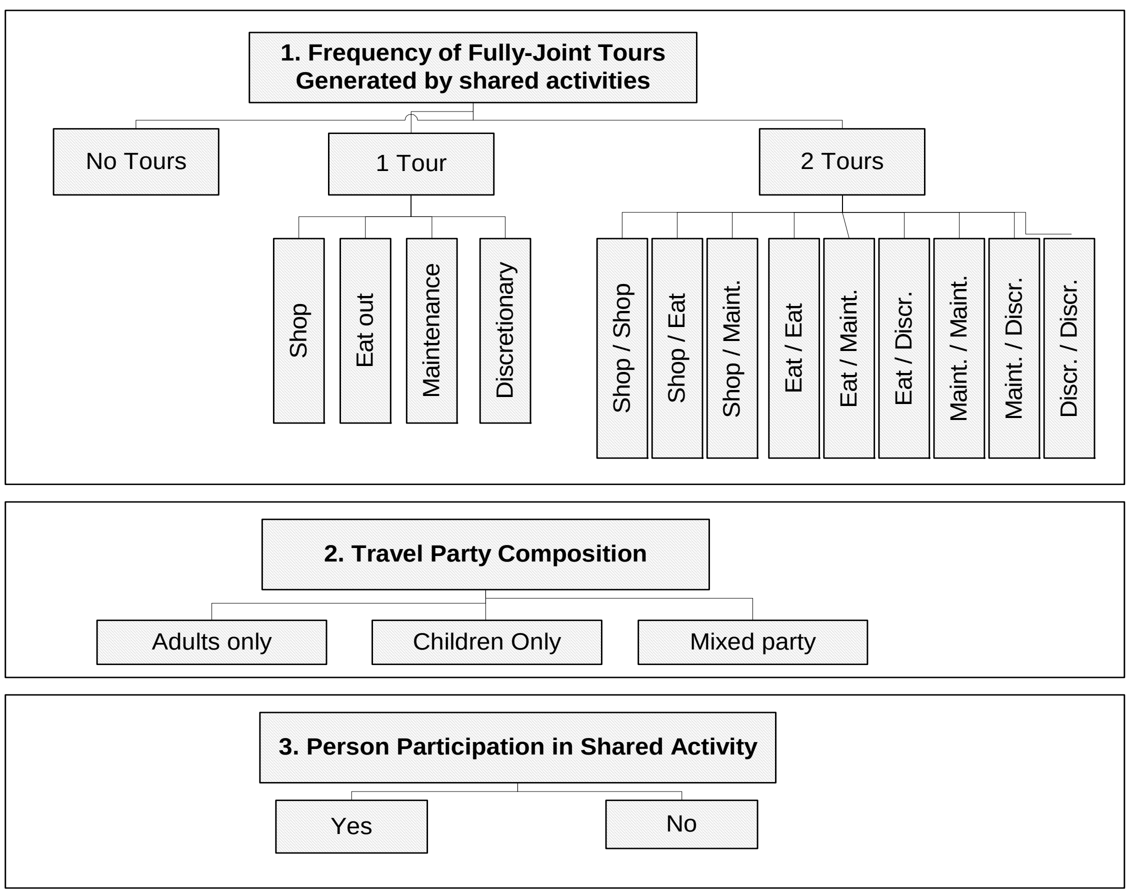


Figure 5-3: MORPC Joint Travel in the Modeling Hierarchy

County[25] travel only; regional modeling and external-internal trips to San Francisco are handled by the Metropolitan Transportation Commission (MTC) traditional four-step model. All three models received *significant* consultant support for model development, testing, calibration and validation, and are receiving additional consultant support for the next round of model improvements.[26]

In Portland, Oregon, METRO has not actively used its activity-based model since the late 1990s, having found the results not entirely satisfactory; however, at that time, results from the activity-based model were used to support re-estimation of the trip-based model, and that four-step model set (which is among the most robust trip-based models in the county) is the current MPO production model. Near-term model development efforts will primarily be focused on improving the trip-based model – such as upgrading the mode choice model structure from multinomial logit (MNL) to nested logit (NL). Use of an NL structure will assist in a transition back to an improved activity-based model should METRO choose that option further in the future. In addition, METRO's next household travel survey, currently expected around 2008, could include information regarding daily activity patterns to support an improved activity-based model. Separate research and testing of the TRANSIMS activity-based model continues in the Portland area.[27]

Several other MPOs are either in various stages of development of an advanced model by adding advanced model chain elements to their existing trip-based models, or have plans (some formal, some less formal) to move toward a tour-based or activity-based model. These MPOs include:

- Atlanta, Georgia (Atlanta Regional Commission – ARC)

ARC is in its third year of work program activity toward developing an advanced model set for the Atlanta region, allocating approximately $100,000 per year to support these activities. ARC has recently implemented a population synthesizer but currently the synthetic population is applied back into their trip-based model.[28] ARC has not definitively committed to fully implementing an activity-based model but is adding advanced model elements to its system, such as the population synthesizer, while maintaining a parallel track of improvements to its existing trip-based model. That trip-based model will be calibrated and validated for an expanded 20-county modeling region very soon.

- Sacramento, California (Sacramento Area Council of Governments – SACOG)

SACOG's most recent travel survey conducted in the year 2000 also included an activity survey. Model design for an activity-based model occurred during 2001. Model development is near

---

[25] The City and County of San Francisco are coincident. San Francisco's land area is approximately 47 square miles, making it smaller than Washington D.C.; however, its 2005 estimated population is nearly 800,000, making it denser than Washington.
[26] Consultant support for each model is as follows: NYMTC – PBConsult; SFCTA – Cambridge Systematics and Parsons Brinckerhoff; MORPC – PBConsult and AECOM Consult. Caliper Corporation is currently providing support for the NYMTC code optimization in TransCAD.
[27] See Gliebe (2006).
[28] Consultant support for ARC was provided by John Bowman

completion, and SACOG expects to adopt their activity-based model as the MPO production model and use it to support development of their updated regional Long Range Plan starting next month.[29] SACOG has been separately developing a series of sophisticated land-use models and a GIS-based scenario tester integrated with their trip-based models, and the long-term plans are to integrate these with the activity-based model set.

- Dallas, Texas (North Central Texas Council of Governments – NCTCOG)

NCTCOG is not developing its own advanced model at this time but is coordinating closely with the development of an activity-based model at the University of Texas in Austin (see section below).

- Denver, Colorado (Denver Regional Council of Governments – DRCOG)

DRCOG plans to have an activity-based model developed within two years, and has recently completed work on model design. The DRCOG activity-based model will be an enhanced version of the approach used for the SFCTA activity-based model.[30] Model development is now under way. DRCOG also plans to integrate their activity-based model with the UrbanSIM land use model.[31] The DRCOG integrated activity-based model will exist in an object-oriented environment and on a relational database platform to improve the ability to quickly make updates and improvements to the system.

- Seattle, Washington (Puget Sound Regional Council – PSRC)

PSRC does not have any formalized plans to develop an advanced model, but an activity-based model is the logical outcome of the agency's models development and improvement plan from 2001. PSRC's upcoming (this year) household survey will be designed to capture information about daily activity patterns to provide base data for use in the construction of an activity-based model. PSRC uses UrbanSIM for its land use model and plans to integrate that functionality into its advanced travel demand model.

- San Francisco, California (Metropolitan Transportation Commission – MTC)

MTC is in the early stages of a $250,000 consultant contract to conduct the first phase of a model specification and training study that will lead to development of an advanced model set. An additional $250,000 was planned for the current fiscal year for model development and improvement activities. MTC plans to work with SFCTA staff to conduct an analysis and comparison of results from the SFCTA activity-based model with MTC's existing trip-based model.

- Phoenix, Arizona (Maricopa Association of Governments – MAG)

[29] Consultant support for SACOG was provided by DKS Associates with Mark Bradley and John Bowman.
[30] Consultant support to DRCOG provided by Cambridge Systematics, Mark Bradley, and John Bowman. See Sabina and Rossi (2006).
[31] UrbanSIM is an open-source land use model developed by researchers at the University of Washington.

MAG expects to begin development of an activity-based model in 1-2 years.

- El Paso, Texas (El Paso Metropolitan Planning Organization)

The El Paso MPO has begun converting its trip-based model into a tour-based framework as a first step toward building a full advanced model set. The El Paso MPO plans to conduct travel surveys in 2007, so they are beginning consideration of updating their instrument to capture information on daily activity patterns.

- Santa Barbara, California (Santa Barbara County Association of Governments – SBCAG)

SBCAG and the University of California, Santa Barbara (UCSB) have begun the initial stages of cooperative and coordinated research into activity-based modeling in the MPO region. Kostas Goulias at UCSB is an active researcher in activity-based modeling.

- St Louis, Missouri (East-West Gateway Council of Governments)

East-West Gateway has a next-generation model specifications document from 2003 that outlines future development of a tour-based model. Recent activities have been directed toward improvements to the regional trip-based model, so no formal work on developing an advanced model has occurred to date.

Other U.S. Activity-Based Models

There are also activity-based models used as university research tools, such as the Comprehensive Econometric Microsimulator for Daily Activity-Travel Patterns (CEMDAP) from the University of Texas and the Florida Activity Mobility Simulator (FAMOS) from the University of South Florida in Tampa. CEMDAP is noteworthy because it has been applied to the NCTCOG modeling region, and is currently being used for a direct comparison with NCTCOG's trip-based model.[32] The results of that comparison are not yet available. Several MPOs who have expressed an interest in moving toward an advanced model system have also advocated the use of UrbanSIM, which includes a household and employment synthesizer, to create an integrated land use / transportation model for their region.

The majority of MPOs are like TPB in that they have an interest in advanced model constructs. However, they are proceeding cautiously and observing the state of the art, the evolving state of the practice, and watching in particular the experience of the MPO first-adopters of the advanced models. This will allow them to learn from others whether the results make sense, are implemented in a cost-effective manner, and are able to support the MPO work program and adequately respond to the transportation questions being posed by MPO board members and member jurisdictions / agencies.

---

[32] NCTCOG is not funding the CEMDAP research; it is 100% funded by the Texas Department of Transportation (TxDOT)

Experience with Activity-Based Models outside the United States

Based on a literature review, modeling efforts outside of the United States have not led to the implementation of *purely* activity-based models in any large metropolitan area. While several of the more recent metropolitan and national models in Europe do not strictly adhere to the traditional four-step trip-based forecasting method, none of them are *truly* activity-based. The Stockholm Model System uses separate models to forecast tours with different purposes. The Netherlands National Model is a tour-based model that incorporates activity choices by splitting tours into more activity categories than in a traditional model. The ALBATROSS system, also developed in the Netherlands, is an activity-based model that simulates in which activities residents will participate and forecasts their travel needs based on these schedules.[33] As this system has not yet been fully implemented by the Dutch government, its success is still unmeasured.

The metropolitan transportation agency in Jerusalem, Israel, is preparing to issue an RFP for a multi-year program to convert its trip-based model into an activity-based model. Australia has two advanced models. The Transport and Environmental Strategic Impact Simulator (TRESIS), is an activity-based model developed by the University of Sydney and applied for research purposes in the five largest metropolitan areas: Sydney, Melbourne, Brisbane, Perth, and Adelaide. The Land Use, Travel Demand, Microsimulation Model (LUTDMM), a joint project of the New South Wales state government and the University of South Australia in Adelaide, also an activity-based model, has been tested in a small area in northern Adelaide. Not enough is known about the planning requirements and functions in Australia to know how applicable these models would be to the U.S. experience, but the projects and initial results seem promising.[34] No other information about advanced models either being applied or under development in areas outside the United States was found in the literature review.

Application of Activity-Based Models in the United States

The three active U.S. activity-based models (San Francisco, Columbus, and New York City) have been used to support the full spectrum of MPO planning activities – air quality conformity analysis, transit and highway studies, including FTA New Starts analysis, and others. But while the models have been applied to a wide variety of projects, the total number of applications is still quite limited -- approximately 10-20 projects – not a significant base from which to draw conclusions about the usability of the models. Obtaining objective information about the effectiveness of the models proved difficult. However, it was possible to discuss the activity-

[33] ALBATROSS is one element of the current activity-based model systems developed by the Dutch and Belgian governments and research universities -- built to show improvements over the previously-developed PATRICIA, the nested logit models used as benchmark data, and RAMBLAS, an early simulation system. To ALBATROSS the developers have now added AURORA, a new model that incorporates an activity *rescheduler*. An extended version of AURORA called FEATHERS (Forecasting Evolutionary Activity-Travel of Households and their Environmental Repercussions, and a GPS/PDA-based application for collecting activity diary data, PARROTS (PDA System for Activity Registration and Recording Of Travel Scheduling) will be developed for and applied in the Flanders region of Belgium. See Arentze, et al. (2006).

[34] See Xu (2005) and Stopher (2005).

based models with MPO staff and other public agency staff with project planning experience using the models.

- NYMTC Model

NYMTC reports that the New York Best Practices Model (NYBPM)[35] has been used since 2002 to support air quality conformity analysis and a series of single-mode and multimodal transportation studies, including:

  - Southern Brooklyn Transportation Improvement Study
  - Gowanus Expressway (I-278) Study
  - Tappan Zee Bridge / I-287 Corridor Study
  - Bruckner Expressway (I-278) / Sheridan Expressway (I-895) Study
  - Bronx Arterial Needs Major Investment Study (MIS)
  - Kosciuszko Bridge Study
  - Goethals Bridge Modernization Environmental Impact Study (EIS)

It appears from a review of several of the documents from the above studies that the full NYBPM model chain was not always applied – sometimes it was just the detailed assignment module. This may be due to the relative instability of the model at the time the studies were conducted –some parties may have been pushing to apply the NYBPM before it was truly ready to serve as a production model.

Regardless, a representative from the New York Metropolitan Transportation Authority (MTA) who worked on the Tappan Zee Bridge / I-287 Alternatives Analysis[36] did not report any major problems with the application of the NYBPM in the study. The NYSDOT project manager for the Kosciuszko Bridge[37] study initially reported that the study team's experience with the NYBPM was "frustrating," but further questioning revealed that the problems the team encountered were primarily with coding errors in the model network, a problem hardly unique to activity-based models. Once the network was fully quality-checked, the project manager stated that they were very satisfied with the model results, that they seemed intuitive, and that the level of detail provided was improved over previous models, down to the level of lane changes.

- SFCTA Model

The SFCTA model has been used to provide forecasts for two major transit projects – the New Central Subway light rail transit (LRT) project, and the Geary Corridor Study, which is considering multiple transit options.[38] The Geary study is currently in Alternatives Analysis, and different scenarios are being tested. The Central Subway study has progressed to the point where the SFCTA model was used with FTA's Summit program to calculate user benefits for

---

[35] This is NYMTC's preferred name for their current model.
[36] This is a multimodal study jointly conducted by MTA / Metro-North Railroad, the New York State Department of Transportation (NYSDOT), and the New York State Thruway Authority.
[37] A study of a 1.1 mile section of the Brooklyn-Queens Expressway (I-278) in New York City. The Kosciuszko Bridge connects Brooklyn and Queens.
[38] The choice of transit technology in the Geary corridor, either LRT or bus rapid transit (BRT) is a hot button issue in San Francisco

consideration in a New Starts application. While some adjustments to the model were required to prepare the outputs for use as inputs to Summit,[39] both SFCTA staff and a transit planner from the San Francisco Municipal Transportation Authority[40] who worked on the New Starts application for the Central Subway project also reported satisfaction with the results of the SFCTA model, including the interaction with Summit.

The SFCTA model has also been used for equity analysis and environmental justice analysis of transportation projects[41], as well as mobility and accessibility measures and transit service measures, such as vehicle utilization (crowding). While the SFCTA model employs a disaggregate approach to tour generation, tour destination choice, and tour mode choice, it still employs an aggregate network assignment.[42] This greatly lowers the accuracy of model assignments below the corridor level, and since many of the above measures are most useful at the street level or lower, SFCTA commonly re-assigns the model results using Synchro or VISUM to produce the fine-grained measures required for their studies.

- MORPC Model

MORPC reports that they use their activity-based model for air quality / conformity analysis, transit alternative analysis, and for highway major investment studies. Information was available on the use of the model for a New Starts analysis, the North Corridor Transit Project (NCTP) AA/DEIS, a study of a 13-mile corridor. As with the SFCTA model, the MORPC model required some “tweaking” for use with FTA’s Summit program to calculate user benefits (UBs),[43] but once those issues were resolved the resulting UBs were generally reasonable. A consultant using the MORPC model for the UB calculation did report some frustration with long model run-times and the size of model data files when having to make minor corrections, but still deemed the UB results to be good.[44]

Benefits of Activity-Based Models: Fully Realized?

In concept, there are benefits to be realized through the use of tour-based and activity-based models. The concepts of the tour as the primary unit of travel and of the constraints on traveler behavior imposed by a daily activity pattern are arguably closer to the “reality” of travelers’ behavior than the paradigm of the four-step models. The initial applications of the activity-based models in the United States show that activity-based models can be implemented in the

---

[39] See Freedman, et al (2006) for a detailed discussion of these issues.
[40] MUNI, the primary transit operator in San Francisco and the project sponsor (applicant) for FTA New Starts funding.
[41] See Castiglione, et al (2006) for a detailed discussion of this application.
[42] This was done due to resource limitations during the initial development of the model; SFCTA has expressed an interest in moving toward microsimulation / disaggregate assignment in the future.
[43] Most of the issues revolve around FTA’s requirement to use a fixed trip table across all alternatives to calculate UBs and the incompatibility of this method with activity-based models. See Vovsha (2006) for a detailed discussion of how this was resolved for the MORPC model in the NCTP study. Proponents of activity-based models have argued that FTA needs to change its requirements to allow variable trip tables when calculating UBs. FTA has (unofficially) considered such changes and conducted research as to how they might be implemented, but currently has no plans to change its methodology.
[44] See Schmitt (2006).

framework of the metropolitan transportation planning process. These applications, coupled with the accrued benefits and satisfaction to date of the three activity-based models in use and the promise of the ability to respond to policy questions not easily treated in four-step models, has been enough for a few other MPOs to actively pursue adoption of activity-based models of their own. However, review of literature and of recent work in activity-based modeling shows that the touted benefits have not yet been fully realized, and probably will not be fully realized for some time. Furthermore, there has not been an evaluation of how well existing activity-based models support the needs of MPOs.

Concerns

The use of activity-based models by three out of hundreds of MPOs does not indicate state of the practice; it indicates "bleeding-edge" state of the art and a highly advanced proof of concept that is just starting to gain acceptance in those three metropolitan areas. There are still many concerns about the new models in general and their applicability that have yet to be meaningfully addressed:

- Model Response

No comprehensive comparison tests between a "traditional" model and an activity-based model for the same metropolitan area or project have been performed to date. Modelers understand the sensitivity and responses to different travel scenarios resulting from trip-based models. It is not yet known how those responses compare with those provided by activity-based models.

- Data

Typically, for model estimation / calibration / validation, activity-based models require a larger amount of data and at a finer level of detail than traditional trip-based models, due in part to the disaggregate nature of activity-based models that employ microsimulation. Agencies validating activity-based models, in addition to relying on their own collected dataset such as home interview surveys and activity diaries, are also relying on the Census data, including the Public Use Microdata Sample (PUMS). There is a concern that the Census Bureau will eliminate PUMS for the 2010 census due to confidentiality issues. Other data sources such as the long form responses and the CTPP are to be sharply reduced as they are being replaced by the American Community Survey (ACS), which combines more frequent sampling with a smaller sample size and fewer questions. The decreased availability of Census data products is a cause for concern for all modeling efforts, but it is a greater concern for agencies adopting activity-based models due to the increased data requirements and dependence on census data, especially for the population synthesis elements. A very extensive validation effort is planned for the DRCOG activity-based model, and this along with the recent validation for the SACOG activity-based model should be reviewed by TPB to see both what data are used and what actions are considered for adjusting to data availability problems.

- Hardware and Run-Time

The current TPB model (Version 2.1D #50) takes 15-17 hours to run on a single 3.0GHz computer running 32-bit Windows 2000. By contrast, the MORPC activity-based model runs on a 3-5 machine cluster (one master, 3-4 slaves). This includes at least one multiple-CPU machine running 64-bit Windows and utilizing parallel processing and distributed computing. Run times range from 20-48 hours for a metropolitan area much smaller than that served by TPB.[45] NYMTC initially reported model run-times as long as one week using the NYBPM, although now reported run-times have been reduced to about 80 hours. Both agencies are working to improve run times, but even getting to these levels has required major investments in computing power. In adopting an activity-based model, TPB would need to work with member agencies to address expectations of quick turnaround of model results for a given project, and commit funding for hardware upgrades.[46]

- Software and Code

While some model chain elements of the existing activity-based models are built using existing model platforms (TP+/Cube, TransCAD), large sections of these models are being executed using large blocks of C++ or Java code outside the modeling software, and some of the programming code is already being revisited to provide code optimization in an effort to improve model run-time performance. Some models are also being run under open-source environments such as the Linux operating system. TPB has recently invested considerable time and money converting much of the remaining FORTRAN code in the Version 2.1D model into TP+ scripts to provide model integration and consistency. The need to "outsource" model chain elements to procedures outside the main modeling platform is in some ways an evolutionary step backwards and likely something TPB may not wish to revisit.

- Model Ownership

The vast majority of TPB's model applications and models development work is currently performed by TPB staff, with occasional consultant support for certain tasks. As noted previously, the development and application of an activity-based model is a multi-year, often multi-million dollar project with massive consultant participation. While it is unreasonable to expect such an undertaking to be feasible without consultant support, it may not be in TPB's best interest to be too dependent on one or more consultants to maintain, improve, or run their models. There is a danger that TPB could lose control of their modeling process if they are dependent on a consultant. The ongoing use of consultants at MORPC and NYMTC to tweak the models and perform programming code fixes likely makes this a real possibility.[47]

---

[45] The MORPC region is approximately 2,300 square miles, roughly one-third of the TPB region. MORPC model run-times are dependent on the horizon year of the model run and which of the three clusters (two at MORPC, one at COTA, the Central Ohio Transit Authority) is used for the model run. See Anderson, et al. (2006)..

[46] SFCTA reports current model run-times of 12 hours and SACOG reports run-times of around 9 hours. Both models have benefited from code optimization, but it is important to note that they are also applied to smaller areas (geographically and demographically) than the TPB modeling region.

[47] SFCTA noted that since the initial release of their activity-based model, most model development has been performed internally by SFCTA staff. In some ways SFCTA, with its model focused on a single jurisdiction and internal model development, is in the same position that the Montgomery County Department of Park and Planning (M-NCPPC) was in ten years ago; TPB should watch with interest how modeling in the Bay Area evolves as MTC develops their activity-based model – will SFCTA continue its own models development program like the Prince

- Institutional Issues

TPB must consider the following question: will "the model" be more trusted by non-modelers if/when the switch is made to an activity-based model, or will the time spent educating and gaining the trust of decision-makers in the current modeling process revert to distrust and a renewed perception of the model as a "black box" when the decision-makers are presented with a new process that is not fully understood and doesn't produce the results they are accustomed to receiving?

TPB's forecasting activities are more closely scrutinized than most MPOs, as evidenced by the recent TRB model review and responsive actions. While the level of scrutiny has served to advance the state of model development in the Washington region, it has also consumed significant staff and fiscal resources. Moving to an activity-based model would likely require a significant increase in available funding to support additional staff and training to introduce new skill-sets (programming and model techniques) into the TPB knowledge base, provide consultant support, and would introduce another level of scrutiny to TPB's activities, since the model would be radically changed.

While more review of TPB's models development program would likely lead to a more widely-accepted process by member jurisdictions and regional decision-makers, TPB must weigh the question of resources, both time and staff. TPB technical staff must be able to do their work without constantly being under the regional microscope, and must be able to focus their efforts on actual model development rather than responding to critiques. Meanwhile, while an activity-based model is under development, TPB staff should still be able to apply and improve its existing trip-based model to support work program activities, which would result in staff supporting two models simultaneously for several years.

Conclusions

The 2002 report of the Florida Statewide Model Task Force considered the merits of trip-based vs. activity-based models and concluded that "…the panel felt that these approaches [activity-based models] may not yet be ready for full-scale adoption in Florida….However, the panel felt that the state should…be mindful of data collection opportunities that may help pave the way for developing and implementing such models in a more long-term model enhancement program."[48] Likewise, the 2004 draft documentation of the Charlotte-area regional model states the following:

> This model estimates *trips*, i.e., individual trip segments between each stop. This is the conventional definition of travel that has been in common use in the past 40 years. At the start of this project, consideration was given to using a newly emerging definition of travel: *tours* (or *journeys*). A tour is generally defined as the round trip of a person's travel throughout the day, such that almost all tours

George's Planning Department (M-NCPPC), or focus on applications and let the MPO (MTC) take the lead on models development like Montgomery Park and Planning did with TPB?

[48] Page 18.

start and end at the person's home. Although this definition more closely mirrors the way in which travel is commonly made, the state of the art in tour-based modeling in 2004 was judged to be insufficiently well developed to permit its use in the Metrolina model at this time. Within about 5-7 years, however, tour-based modeling is expected to become more common and at that time (shortly after the 2010 Census), it should be feasible to update this model using that definition of travel.[49]

While the Florida report refers to activity-based models and the Charlotte report refers to only tour-based (and not activity-based) models, a conclusion similar to the general theme of both reports as it pertains to advanced, non-trip-based model structures can be reached in 2006 for TPB: now is not the right time for TPB to begin full-scale adoption of an activity-based model – the technique is not yet widely accepted, and there are still numerous issues to be resolved before activity-based modeling is "ready for prime time" in the Washington region. However, there are steps that TPB can and should take now to ensure that proper consideration can be given to activity-based models several years in the future.

The best activity that can be undertaken to keep pace with advanced model development is to ensure that current data collection efforts include data that will allow transition to a tour or activity-based framework. TPB's current plans for the upcoming home interview survey include an activity diary. It is crucial that this part of the home interview survey remain in place if activity-based models are to be an option for TPB over the next decade or longer. Even if it is five years or more before activity-based models are in wide enough use and well enough accepted that TPB should consider developing an activity-based model, the data collected in this survey will be used for that effort. The upcoming home interview survey will likely be the source of data for model estimation, calibration, and validation of any future activity-based model. If activity-based models do prove successful, waiting for the next survey after 2006 to be conducted to capture daily activity pattern data may place TPB behind its peer agencies in terms of its ability to provide the best practices in modeling. With the data in place, TPB will have the flexibility to continue advanced model development at the pace it sees fit, including elements of activity-based models, while maintaining the high standards of the existing trip-based model for continuing support of work program activities.

Following the completion of the home interview survey, there are several options for TPB to begin an incremental approach to moving toward an activity-based model. The logical first step would be to convert the trip results of the home interview survey into tours. While it is possible to have a tour-based model that is not activity-based, an activity-based model must be tour-based. Following the creation of the tour dataset, TPB could begin designing and estimating a tour generation model. Another option would be for TPB to develop a detailed network assignment procedure similar to those used in the NYMTC and MORPC models. And another option would be to develop a population synthesizer module first; this is the approach being followed by ARC in Atlanta.

[49] Section 4-1.

To pursue any facet of the incremental approach, TPB may wish to consider formalizing a closer relationship with area universities to begin research into the development and application of an activity-based model for the Washington region.[50] Such relationships have proven beneficial to MPOs like NCTCOG in advancing modeling work in their metropolitan area.

Another option is for TPB to participate in (and if necessary lead) a joint program with other MPOs that will keep abreast of the current status of activity-based models. This joint project could document the success or failure of activity-based model development and application efforts by the early adopters of activity-based models. This same mechanism could be used to perform further research into how an activity-based model can be cost-effectively developed and applied by TPB and other MPOs. Such an effort could be jointly funded by MPOs throughout the country and be led by the Association of Metropolitan Planning Organizations (AMPO), the U.S. Department of Transportation, or another organization that serves MPOs. TPB already participates in both the TMIP listserv and the activity-based model coalition listserv, and such an effort has been discussed periodically in these forums. This joint program could guide the direction of any incremental approach to advanced model development.

[50] TPB's university partners must be representative of the National Capital Region, and have the expertise to contribute to a usable activity based model for the entire modeled area.

References

Anderson, R., Al-Akhras, A., Gill, N. & Donnelly, R., (2003) Implementation of a Tour-based Microsimulation Regional Travel Demand Model: Mid-Ohio Region. Paper for 9th TRB Conference on the Application of Transportation Planning Methods.

Anderson, R., Jiang, Z., & Parasa, C., 2006. Hardware Requirements and Running Time for the MORPC Travel Forecasting Model. Paper and Presentation for the Transportation Research Board (TRB) Innovations in Travel Demand Modeling conference

Arentze, T. A. & Timmermans, H. J., 2001. Albatross – a Learning-Based Transportation Oriented Simulation System http://www.infra.kth.se/tla/tlenet/meet5/papers/Timmermans2.pdf

Arentze, T. & Timmermans, H., 2005. The Sensitivity of Activity-Based Models of Travel Demand: Results in the Case of Albatross. http://www.iasi.cnr.it/ewgt/16conference/ID60.pdf

Arentze, T, Timmermans, H., Janssens, D., & Wets, G., 2006., Modeling Short-Term Dynamics in Activity-Travel Patterns: from Aurora to Feathers. Paper and Presentation for the Transportation Research Board (TRB) Innovations in Travel Demand Modeling conference

Castiglione, J, Hiatt, R., Chang, T. & Charlton, B., 2006 Application of a Travel Demand Microsimulation Model for Equity Analysis. Paper for the Transportation Research Board 2006 Annual Meeting.

Charlotte, NC, Department of Transportation, 2006. Metrolina Regional Model Documentation Excerpt (DRAFT).

Freedman, J., Castiglione, J., & Charlton, B., 2006. Analysis of a New Starts Project Using the San Francisco Tour-Based Model. Paper for the Transportation Research Board 2006 Annual Meeting.

Fox, J., Daly, A. & Gunn, H., 2003. Review of RAND Europe's Transport Demand Model Systems.

Gliebe, J., 2006., Linking Tour-Based Models with Microsimulation: the TRANSIMS Experience in Portland. Presentation for the Transportation Research Board (TRB) Innovations in Travel Demand Modeling conference

Outwater, M. & Charlton, B., 2006. The San Francisco Model in Practice: Validation, Testing, and Application. Paper and Presentation for the Transportation Research Board (TRB) Innovations in Travel Demand Modeling conference

Personal conversation with David Armstrong, NYCMTA Metro-North Railroad
Personal conversation with Yehoshua Birotker, Jerusalem (Israel) Transportation Masterplan Team.

Personal conversation with Kuo-Ann Chiao, NYMTC.

Personal and telephone conversation with Billy Charlton, SFCTA.

Personal conversation with Howard Slavin, Caliper Corporation.

Sabina, E., & Rossi, T., 2006. Using Activity-Based Models for Policy Decision Making. Paper and Presentation for the Transportation Research Board (TRB) Innovations in Travel Demand Modeling conference.

Schmitt, D., 2006., Application of the MORPC Micro-Simulation Model: New Starts Review. Presentation for the Transportation Research Board (TRB) Innovations in Travel Demand Modeling conference.

State of Florida, Department of Transportation, 2002., Report of the Florida Statewide Model Task Force Blue Ribbon Panel.

Stopher, P., 2005. Challenges to Using an Integrated Land-Use Transport Model in Australia. Presentation for the Oregon Integrated Models Symposium.

Telephone conversation with Robert Adams, NYSDOT.

Telephone conversation with Gordon Garry, SACOG.

Telephone conversation with Julie Kirschbaum, SFCTA.

Telephone conversation with Jennifer John, Portland METRO.

Xu, M., Taylor, M., & Hamnett, S., 2005. LUTDMM: An Operational Prototype of a Microsimulation Travel Demand System. Paper and Presentation for the 28th Australasian Transport Research Forum.