Metropolitan Washington Council of Governments
National Capital Region Transportation Planning Board

Review of Managed Lane Forecasting Techniques

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Summary

The Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board (TPB) engaged Vanasse Hangen Brustlin (VHB) to review how MPOs around the United States evaluate proposals for High-Occupancy Toll lane (HOT lane) and managed lanes. This review focused on how travel demand modeling techniques are employed in these analyses and is summarized in this memo.

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. 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:

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 a separate memo. 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.

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 memo.

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 memo.

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 a separate memo. 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.

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