environmental defense
finding the ways that work

1875 Connecticut Avenue NW
Washington, DC 20009

July 8, 2004

Chairman Chris Zimmerman
Chair, Transportation Planning Board
Metropolitan Washington Council of Governments
777 North Capitol Street, N.E., Suite 300
Washington, DC 20002-4290

RE: Need for Timely Action To Correct Problems In Washington DC Area Travel Models

Dear Chairman Zimmerman:

Need to Improve TPB Models to Address Time-of-Day and Pricing Issues. At the June 16, 2004 meeting of the Metropolitan Washington Transportation Planning Board (TPB), the TPB staff acknowledged that the TPB travel models need to be improved with regard to: (1) estimating the impacts of transportation pricing on travel behavior and (2) estimating the effects of changes in travel time and cost on the "spreading of the peak" and the time-of-day of travel by the region's residents and visitors. We agree this is an urgent need.

A substantially accelerated work effort is needed to address these issues before the TPB models will be adequate to provide a fair and legally defensible foundation for decision-making, especially with regard to any transportation projects or transportation plan changes that entail consideration of time-of-day road pricing, such as the conformity analysis for the InterCounty Connector and proposed Express Toll Lanes or High Occupancy Toll Lanes on the Capital Beltway, I-95, and other various roads in Virginia and Maryland. The region has adequate data to re-estimate a better set of models in the near term, but has thus far lacked willingness at the staff level and among some decision-makers to commit resources to accomplish this needed task. Failure to take action on this puts future decisions on a potentially shaky and legally contestable foundation.

Adjustments to Models Inadequate to Address Deeper Problems: Avoiding Arbitrary and Capricious Decisions. The adjustments being made by TPB staff and consultants to replace overly used "travel model adjustment factors" with new "employment adjustment factors" and to refine the traffic assignment element of the model cannot alone address deeper inconsistencies and problems embedded in the basic structure of the travel model, and indeed have introduced new serious problems in the model, for example producing underestimated travel speeds on a much larger share of roadway links. New adjustment factors may superficially reduce some of the base year observed traffic volume simulation errors, but only a more thorough overhaul and re-estimation of the travel models can produce a scientifically validated modeling system.

A model which is highly inconsistent internally – for example in how much traffic is assumed to occur during peak hours or how much people value their time in making travel choices – is quite vulnerable to being "gamed" to produce whatever results are sought by the decision makers. It is likely to produce unreliable estimates of transportation system and project performance and impacts. Decisions justified by such models risk being dismissed as arbitrary and capricious, especially when the decisions intimately involve significant factors for which the base year model produces very poor results, such as the effects of time-of-day pricing.

To summarize key elements of the transportation conformity regulations, Sec. 93.122(b)(1):

> *"Network-based travel models…must be validated against observed counts (**peak and off-peak, if possible**)…analyzed for reasonableness and compared to historical trends and other factors, and the results must be documented; …network-based travel model assumptions must be documented and **based on the best available information**; … a capacity-sensitive assignment methodology must be used, and emissions estimates **must be based on a methodology which differentiates between peak and off-peak link volumes and speeds and uses speeds based on final assigned volumes;** …travel impedances used to distribute trips between origin and destination pairs must be in reasonable agreement with the travel times that are estimated from final assigned traffic volumes; …Network-based travel models **must be reasonably sensitive to changes in the time(s), cost(s), and other factors affecting travel choices;** …**Reasonable methods in accordance with good practice** must be used to estimate traffic speeds and delays in a manner that is sensitive to the estimated volume of travel on each roadway segment represented in the network-based travel model."* [emphasis added]

We believe there is strong evidence that the MWCOG travel models fail to satisfy a number of these criteria. The peer review of MWCOG's travel models, prepared by the National Academy of Sciences' Transportation Research Board (NAS/TRB) and transmitted in two letters, dated September 8, 2003 and May 10, 2004, provide ample evidence of problems in the models and reaffirm concerns that had been raised by an independent consultant review of the TPB travel model Version 2.1, which we commissioned, contained in the report, *More Sprawl, More Traffic, No Relief: An Analysis of Proposed Potomac River Crossings,* October 2002.

Transmittal of Citizen's Guide to Critiques of the TPB Travel Model. The NAS/TRB peer review report letters are however rather technical. Thus, we asked our independent travel modeling expert to prepare the attached document, *A Citizen Guide to Critiques of the Metropolitan Washington Area Travel Model: What Does it All Mean?* We provide this to help translate these issues into layperson's language. We request this attachment be included in the letters received to the TPB, to the TPB Citizen's Advisory Committee, and distributed to the TPB Technical Committee and TPB Travel Forecasting Subcommittee.

New Evidence of Gross Inconsistency in How TPB Model Treats Tolls and Value of Time. Given the importance of tolling issues in the Washington, DC, region's upcoming transportation plan update and environmental reviews for the InterCounty Connector, HOT lanes, and toll express lane proposals, we have also had our consultant look in depth at the way that the Value of Time is treated in the TPB Version 2.1D model. What our consultant uncovered is unsettling,

and provides further new evidence of the need for a quick comprehensive re-estimation of the TPB travel models to ensure better internal consistency before these models are applied for these important new planning and environmental decisions.

In toll modeling, the most important variable is the Value of Time. If travelers are assumed to have a high Value of Time, they will be willing to pay high tolls to save a small amount of time. If they are assumed to have a low Value of Time, they will be reluctant to pay high tolls unless time savings are great. The Value of Time assumed will dramatically affect toll roads usage, toll revenues, and changes in traffic on other roads. It is critical that Value of Time assumptions in the TPB model be documented fully.

The Value of Time is also very important in estimating transit ridership. With low Value of Time, the model assumes that transit riders are mostly "captive", and the transit ridership will be little affected by, or inelastic, with respective to transit speed and frequency. With high Value of Time, transit ridership will be much more sensitive to, or elastic, to time and frequency, and simulate the mode shifts of "choice" riders who can switch from autos.

The Value of Time assumptions should be identical in both cases. In Version 2.1D of the TPB travel demand model, they are not. The Value of Time used for modeling toll roads in the trip distribution and assignment steps is much higher than the Value of Time used in modeling transit in the mode choice step. This is demonstrated below for the home-based work trips and single-occupant vehicles, but the problem extends across all trip types.

The last full documentation of the model is for Version 2.1C.[1] It documents a value of $2.78 (1980 dollars) for in-vehicle time in the mode choice model (Exhibit 6.7, p. 6-10). This is equivalent to approximately $6.20 in 2003 dollars. It justifies this number as follows:

> *The rule of thumb for work trips is that the calculated Value of Time should be between 25% and 50% of the prevailing wage rate … Value of Times coming from work mode choice models should be between $2.47 and $4.94 in 1980 dollars.* (p. 6-8)

In Version 2.1D, the in-vehicle time coefficient was reduced.

> *The in-vehicle travel time coefficient in the HBW mode choice model has been changed from 0.03556 to 0.02128 to obtain an out-of-vehicle coefficient/in-vehicle coefficient ratio of 2.5.*[2]

While this change appears to have been made for reasons unrelated to questions about toll modeling or Value of Time, it has a direct effect on Value of Time for home-based work trips in the model. Instead of the documented value of $2.78 (1980 dollars) as discussed above, the new Value of Time is $1.66 in 1980 dollars or $3.72 in 2003 dollars, which equates to 17% of the prevailing wage. *The new Value of Time is below the acceptable range discussed in the*

[1] Metropolitan Washington Council of Governments. "COG/TPB Travel Forecasting Model Version 2.1/TP+, Release C, Calibration Report, DRAFT, December 23, 2002.
[2] Milone, Ron. Memorandum to file re "Transmittal of Version 2.1D (DRAFT #16) Model, April 8, 2004.

documentation excerpt quoted above. It is well below recommendations by U.S. DOT that 50% of the prevailing wage rate be used.[3] *The new TPB model value is about 1/3 of that called for in the U.S. DOT guidance.* On the other hand, a Value of Time of $8.80 (1980 dollars) is assumed for single-occupant work trips in the assignment step of the TPB model. This is 93% of the prevailing wage rate and much higher than the U.S. DOT recommendation. It is 5-½ times as much as is assumed in the mode choice model. This is likely to bias the results in favor of toll roads relative to transit.

TPB Should Take Account of Recent Research on Value of Time in Refining its Modeling to Evaluate Toll Lane and Transit Strategies. There is a growing body of research on the value of time, based on measurements taken from operating High Occupancy Lanes in southern California and elsewhere. Studies suggest the Value of Time exhibits a distribution from person to person and from trip to trip depending on trip purpose and the time of day. This research should be considered in improving, applying, and interpreting the TPB travel models as they are used to consider toll strategies.

A 2002 paper by Ken Small, Cliff Winston, and Jia Yan[4] estimated the value of time and the value of reliability of travel time and how this varied among different income groups and under different conditions in Southern California. They found a median value of rush-hour time, estimated from actual travel behavior, of $21.46/hour (2000 dollars), with a range from a low of $11.47/hour to $29.32/hour. They estimated the value of travel-time reliability during rush hours at $19.56 (with a range from $6.26 to $42.80/hour). Adding the two medians (value of travel time plus value of reliability) produces a value very close to the peak toll rate charged during rush hours on the State Road 91 Express Lanes in Orange and Riverside County California during the time period when the survey data were collected. These studies further suggest the TPB model Value of Time may be too low across the board, but especially in the mode choice model, again suggesting a built in quantitative bias of the TPB Version 2.1 model against transit strategies and in favor of highway solutions.

Internally Consistent Value of Time Should be Used in the TPB Model. As work is done to improve the TPB model's treatments of tolls, this work should insure consistent treatment of the Value of Time between modes and across model steps while accounting appropriately for differences in the value of time between different income groups and for different trip purposes, and perhaps at different times of day. It appears likely that the "improvement" to the Version 2.1D model set for release by TPB on July 23, 2004 will remain highly internally inconsistent in its treatment of the Value of Time, poorly calibrated to observed time-of-day travel data, and ill-supported by evidence of its capacity to simulate observed traveler behavior in this or other regions. Timely improvement to the TPB models should be accomplished before they are used to evaluate time-of-day tolling on projects such as the ICC, the Capital Beltway, I-95, I-270, and other roads for which electronic tolling is being considered.

---

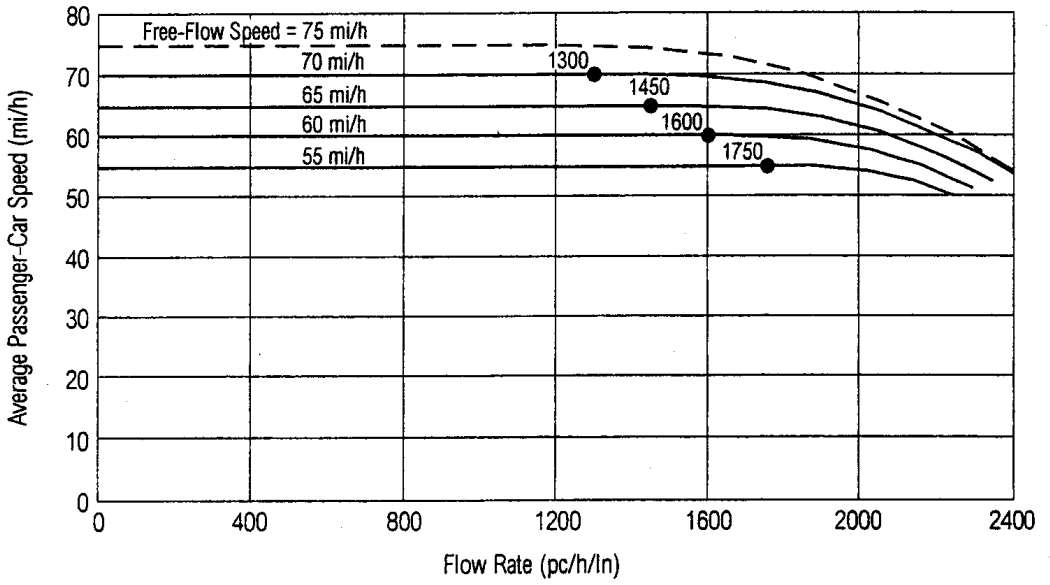
[3] Kruesi, Frank E, Assistant Secretary for Transportation Policy, U.S. Department of Transportation. Memorandum re "Departmental Guidance of Valuation of Travel Time in Economic Analyses", April 9, 1997.

[4] Small, Kenneth A., Clifford Winston, and Jia Yan, "Uncovering Motorists' Preferences Using Revealed and Stated Preference Data," Dept. of Economics, Univ. of California at Irvine (Oct 2001). Presented to American Economic Association, Jan. 2002.

Version 2.1D Model Changes Have Introduced New Problems in the Model. The underlying problems in the model discussed in the *Citizen's Guide* can only be addressed through a top-to-bottom overhaul of the model. Instead, there has been an attempt to address the problems superficially. These changes may improve some measures of performance, but they are moving the model further from reality.

Modeled road speeds are much lower in Version 2.1D than in Version 2.1C due to changes in assumed free-flow speed, free-flow capacity, and the shape of the delay function. For freeways in area type 5 and 6 (suburban) carrying 2000 vehicles per lane per hour, Version 2.1D calculates a travel speed of 33.5 m.p.h. (half of free-flow speed). As shown in the graphic below (which also was included in our first 2002 model critique), the calculated speed should be in the range of 60-65 m.p.h. or twice as much.

EXHIBIT 13-2. SPEED-FLOW RELATIONSHIPS FOR BASIC FREEWAY SEGMENTS



Source: *Highway Capacity Manual*. Washington DC: Transportation Research Board, 2000.

Errors of this magnitude make the model useless for planning freeways or tollways The model will overestimate delay, and overestimate any benefits of increased roadway capacity. Use of toll roads will be overestimated because the time savings will appear to be greater than they are. The model may also underestimate NOx emissions which are relatively high for high-speed freeways.

TPB Models Should Be Brought Up To Best Practice Standards. The TPB should immediately work with its partners to program adequate resources to improve the TPB travel models to deal with the issues discussed above and ensure continuing independent oversight of the travel model development and applications process in the metropolitan Washington Region. To paraphrase a TPB member at the June 16, 2004 meeting, "let's make it a priority to improve our regional transportation models and get them to the cutting edge," rather than just "updating them as resources permit." Most of the federal transportation funding that comes to the metro area is flexible funding that can be used to improve data collection, modeling, and analysis. And investments in better analysis tools can yield huge payoffs in better decisions that produce more

efficient transportation systems and better travel choices, while better protecting our environment and public health.

Sincerely,

Michael Replogle
Transportation Director
Environmental Defense

Attachment: *Norm Marshall,* A Citizen Guide to Critiques of the Metropolitan Washington Area Travel Model: What Does it All Mean?, *June 2004, Environmental Defense, Washington, DC*

cc:
Mr. Phil Shucet, Virginia DOT Commissioner
Mr. Neal Peterson, Maryland State Highway Administrator
Senator Barbara Mikulski
Senator Sarbanes
Rep. Chris Van Hollen
Rep. Wynne
Regional Administrator, FHWA
Regional Admininstrator, FTA
Regional Administrator, EPA

A Citizen Guide to Critiques of the Metropolitan Washington Area Travel Model:

What Does it All Mean?

June 15, 2004

By Norm Marshall
Smart Mobility, Inc.

Prepared for Environmental Defense

ENVIRONMENTAL DEFENSE
finding the ways that work

EXECUTIVE SUMMARY

The National Capital Region Transportation Planning Board (TPB) is responsible for long-term transportation planning and for air quality conformity. To perform these functions, MPOs develop complex transportation models. There is a danger that the model becomes just a “black box”; a tool to which few have access, and which elected officials come to trust because it is complicated to understand and staff assure them that the model is sound.. The model is too important for this. Just as it has been remembered after financial scandals that “transparency” is essential to the proper workings of financial markets, “transparency” is equally important to developing public policy, investing public funds in transportation, and assuring the public’s health. Just as public corporate accounting methods and assumptions are subject to periodic audits and oversight, so too should metropolitan transportation modeling be subject to close independent scrutiny to ensure the integrity of the process and its assumptions. Both can have a huge impact on our communities, economy, health, and quality of life.

We independently reviewed the TPB model twice in 2002. Later in 2002, the TPB requested that the Transportation Research Board, a branch of the National Academy of Sciences, convene an expert panel to review the TPB model. This committee has submitted two review letters in fall 2003 and spring 2004. Through this process, the TPB model has been significantly improved. However, some important issues remain unresolved.

These unresolved issues with the TPB transportation and air quality modeling include:

1) The model does a poor job of matching traffic counts. For example, the model underestimates the heaviest traveled roads, freeways carrying over 100,000 vehicles per day, by an average of 23,000 vehicles – which is much greater than accepted standards. Put in terms of the usual time-of-day patterns of traffic, this "error" is the rough equivalent of missing a full congested lane of peak hour traffic on each of these roads!

2) The model relies too heavily on ad hoc “adjustment factors” that the TRB review committee has said: “undermines the fundamental behavioral logic of the four-step modeling process.” These are essentially fudge factors that are insensitive to changes in travel time and travel cost, and hide the induced traffic that is produced by widening or building new highways, as well as dampening the traffic reduction benefits of investments that improve public transportation, walking, and bicycling.

3) The transportation model is run in a manner that does not properly balance its books to produce sound, consistent, and repeatable estimates of travel time and traffic flows. In technical terms, it fails to reach equilibrium conditions. This likely causes the model to overestimate future traffic volumes on congested roadways. Therefore the model overestimates the need for additional roadway capacity.

4) The transportation model consistently produces very large errors in estimating how many cars and transit riders travel during morning and evening rush hours when compared with actual counts of traffic and transit riders. This means the model produces significant errors in estimating congestion, travel time delay, and how

people will respond to changes in highways, transit, and travel costs.. This undermines the credibility of any analyses done with the model. There is a fundamental disconnect between the assumptions used for air quality analysis and the estimates of travel produced by the transportation model. This has until now been ignored by TPB staff, but is of great concern to the TRB review committee and us because it means the models cannot be trusted to produce reliable estimates of traffic, congestion delay, emissions, or the differences between various alternative transportation investments and scenarios.

5) TPB staff recently have found errors of 20 percent or more in base year employment estimates. The household and employment inputs are the foundation of travel demand modeling and affect all outputs. These problems have until now been covered up by the extensive use of adjustment factors that directly affect the model's estimates of travel and traffic. Indeed, this finding confirms that the overall TPB model is in need of further fundamental re-estimation and re-calibration, with far less reliance on adjustment factors and far more attention to the factors that influence the amount and character of traffic in various times of the day, as well as other neglected factors, such as pedestrian friendliness of neighborhoods.

All of the issues discussed above are interrelated. A regional transportation model is a complex representation of a complex system. An error in one output variable can be a symptom of underlying errors in a different part of the model. Addressing all of the issues will require a more thorough reworking of the TPB transportation model than staff have undertaken to date.

Without correcting these problems, the region cannot be confident that the planning efforts underlying billions of dollars of public investments are valid, or whether air quality standards crucial to the public health will be achieved. The Transportation Planning Board should support further continuing independent oversight of the TPB model development and applications program in coming years to ensure timely progress to address these issues, as well as accelerated investment in improving these modeling tools that are used for regional planning, project planning studies, and environmental reviews.

Introduction

All United States regions with 50,000 people or more are required to have Metropolitan Planning Organizations (MPOs). In the Washington D.C. region, the MPO is the National Capital Region Transportation Planning Board (TPB), housed at the Metropolitan Washington Council of Governments (MWCOG). The TPB's planning area covers the District of Columbia and surrounding jurisdictions in Maryland and Virginia.

MPOs are responsible for long-term transportation planning and for air quality conformity. In its transportation planning function, TPB is responsible for assuring that billions of dollars in transportation investments are made wisely, i.e. that the investments result in the greatest benefits to the region in terms of mobility, accessibility, and quality of life. In its air quality conformity process, TPB is responsible for assuring the public's health.

To perform these functions, MPOs develop travel demand models that match existing traffic and transit ridership, and forecast traffic and transit ridership in the future. In order to improve model performance, especially at the edges of the planning area, the model includes bordering areas in Maryland, Virginia and West Virginia. The long-range transportation plan models a bundle of roadway and transit projects to test the benefits of doing this over doing nothing, and to assure that the planned projects will not cause air pollution problems. The model also is used to evaluate major roadway and transit projects individually. For example, the TPB travel demand model currently is in use in developing the Environmental Impact Statement (EIS) for the Intercounty Connector (ICC) in Maryland.

The TPB's ability to fulfill its responsibilities rests heavily on the strength of the travel demand model. Does the model accurately reflect current traffic and transit ridership? This is a necessary but not sufficient requirement. The more difficult test is: Will the model properly translate alternative transportation and land use scenarios into different future travel forecasts?

Travel demand modeling is a very complex undertaking. The models include thousands of roadway links, transit links, and complex representations of population and employment. There is a danger that the model becomes just a "black box"; a tool to which few have access. The model is too important for this. There is a lot of judgment embodied in transportation modeling, and a wide range of forecasts is possible depending on which judgments are made. Just as it has been remembered after financial scandals that "transparency" is essential to the proper workings of financial markets, "transparency" is equally important to developing public policy and investing public funds in transportation.

Given the complexity of regional transportation models, it is essential that independent reviewers examine the model, and that these reviews are made available to the public. Reviews are needed periodically because the model is continually being updated. Updates of the TPB model have been especially frequent over the past two years – due in part as a response to concerns raised in recent model reviews.

We reviewed the TPB model twice in 2002 – Version 1 submitted to TPB in January 2002[5] and Version 2 submitted to TPB in November 2002.[6] In 2002, the TPB requested that the Transportation Research Board, a branch of the National Academy of Sciences, convene an expert panel to review the TPB model. This committee has submitted two review letters. The first, submitted in September 2003, reviewed Version 2.1C of the model.[7] The second, submitted in May 2004, reviews Version 2.1C with some reference to work on the draft 2.1D version.[8] The TRB committee confirmed several of the important issues raised earlier in our reviews.

Through this process, the TPB model has been significantly improved. However, some important issues remain unresolved. The table below summarizes both the progress made to date, and the work remaining to be done.

Status of TPB Travel Demand Model Issues Raised 2002-2004 by SMI and TRB

Issue	Identified	Ver. 1	Ver. 2	2.1C	2.1D
1. equilibrium assignment	SMI-1, SMI-2			✓	✓
2. ultimate capacity/not LOS C	SMI-1, SMI-2		✓	✓	✓
3. realistic speed-delay functions	SMI-1		✓	✓	✓
4. multiple times of day	SMI-1		✓	✓	✓
5. non-motorized trips improvement	SMI-1, SMI-2				
6. need to match traffic volumes better	SMI-2, TRB-1				
7. over reliance on K-factors and other adjustment factors	SMI-2, TRB-1, TRB-2				
8. better feedback process	SMI-2, TRB-1, TRB-2		partly	partly	partly
9. time of day/air pollution postprocessing	SMI-1, TRB-1, TRB-2				
10. improved bus speeds	TRB-1, TRB-2				
11. composite road/transit times in feedback process	TRB-1, TRB-2				

"✓" indicates that issue has been resolved
Note: Version 2.1D still in draft form without complete documentation

The review documents have been aimed primarily at other modelers and use technical language. This report is focused on communicating the key issues in some of the unresolved areas to the layperson. Specifically, it focuses on #s 6, 7, 8 and 9 which have been raised by both the TRB reviewers and by us, and which remain unresolved. More technical information on these issues can be found in the review documents cited and in TPB's responses.

[5] Smart Mobility, Inc. *A Critique of Transportation Planning Board Travel Demand and Air Emissions Models,* Revised January 2002
[6] Smart Mobility, Inc. *More Sprawl, More Traffic, No Relief: An Analysis of Proposed Potomac River Crossings,* October 2002.
[7] Letter from David J. Forkenbrock, Chair, Transportation Research Board's Committee for Review of Travel Demand Modeling by the Metropolitan Washington Council of Governments to Peter Shapiro, Chairman, National Capital region Transportation Planning Board, dated, September 3, 2003.
[8] Letter from David J. Forkenbrock, to Christopher Zimmerman, Chairman, National Capital region Transportation Planning Board, dated, May 10, 2004.

In addition, a new issue has recently been raised by TPB staff – inconsistency in employment data, and how this inconsistency should be addressed. We discuss this issue as well, and then offer some concluding comments as to how all of these issues may be interrelated.

For each issue, this report addresses the following issues:

1) What is the issue about?
2) Why is it important?
3) What is the current status of the issue?
4) What should be done?

Matching Traffic Volumes Better

What is the issue about?

Each significant roadway in the region is modeled explicitly, with weekday traffic volumes assigned to it by the model. A basic test of regional transportation models is how well they match traffic counts. There are published standards for a set of statistical measures commonly used to evaluate regional transportation models.

Why is it important?

Coming at the end of the complex "four step model" process, these traffic assignments provide a useful indicator of how well the entire model chain is performing. While a good fit with base year data does not assure that the model will produce accurate traffic forecasts, there can be no confidence in model forecasts when a model doesn't match base year traffic counts well – either in modeling major future investments such as the Intercounty Connector, or in estimating future air pollution emissions.

What is the current status of the issue?

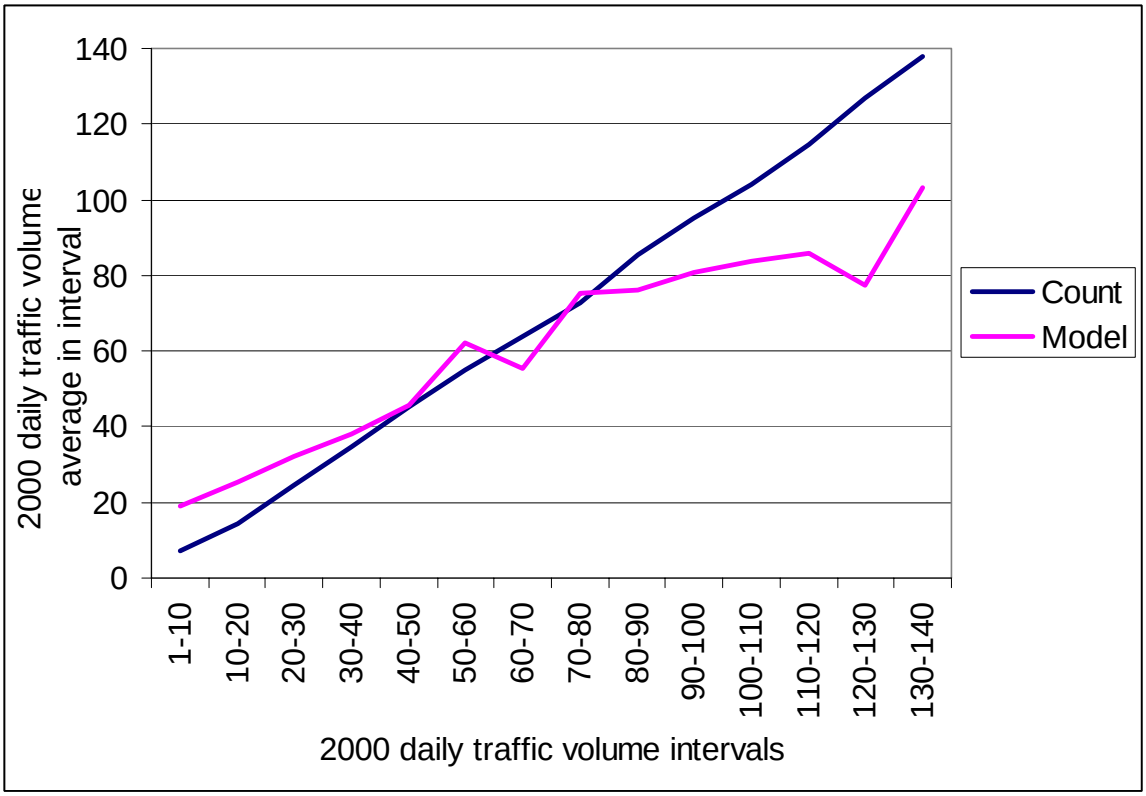
For each of the model versions, TPB has published statistical comparisons of model outputs with traffic counts from the year 2000.

The TRB review committee criticized the Version 2.1C model because the statistical measures indicate that estimated link volumes did not match observed traffic counts as closely as the committee would expect in model validation. Specifically, the committee found that 8 of 33 facility type traffic volume classes had percent Root Mean Square Error (RMSE) values that were unacceptable. Comparing the results of the 2.1D model versus the 2.1C model, the percent RMSE values by volume class improved in 23 of the 41 total classes. However, 18 worsened and 7 would still be found unacceptable by the TRB committee. The RMSE for all links compared has increased only slightly between Versions 2.1C and 2.1D, from 51.91 to 51.69 (where 0 is perfect fit).

An RMSE of more than 51 represents a lot of large errors for individual roadway links. The Version 2.1D documentation presents summary statistics for model vs. count for 1,088 freeway

links, grouped into 14 classes depending on average daily traffic volume.[9] Freeway links are modeled more accurately, on average, than all roadway links; the RMSE for freeway links is 31.93. However, a graph of the data shows systematic bias in the assignment to freeways.

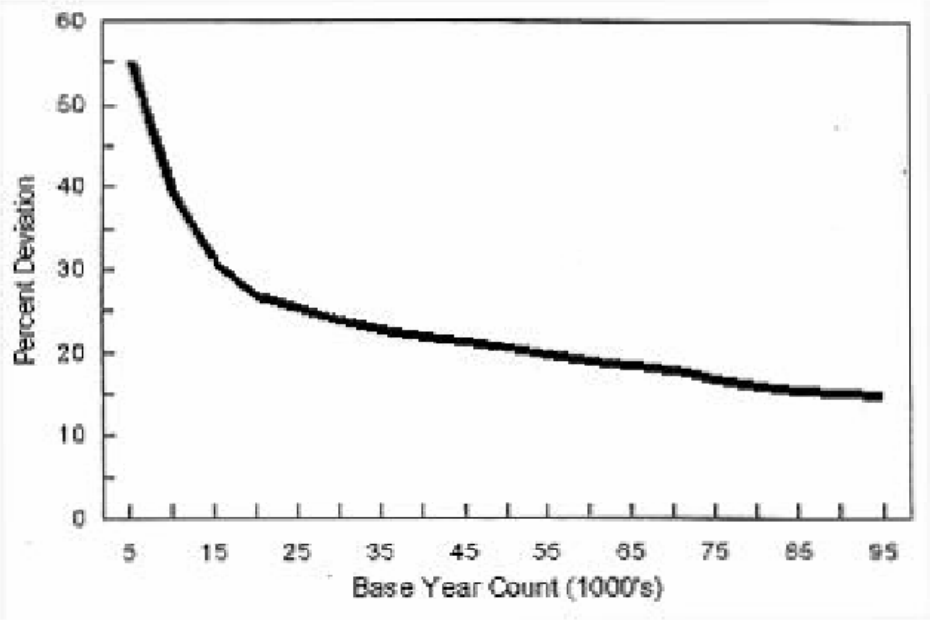
Version 2.1D 2000 Model vs. 2000 Counts, Freeway Links by Volume Group



Low-volume freeways are over-assigned in the Version 2.1D model and high-volume freeways are under-assigned. The errors are particularly great for links with over 100,000 daily traffic volumes. For these links the model error is an average of 21.4 percent or 23,000 vehicles per day. This average error is larger than the desirable error for a single link of about 15 percent as shown in the figure below, taken from a reference cited by the TRB review committee.

[9] Malone, Ron. Memorandum to Files concerning "Transmittal of Version 2.1D (Draft #16) Model, April 8, 2004.

Figure 7-4
Maximum Desirable Error for Link Volumes



Source: Barton-Aschman Associates, Inc. and Cambridge Systematics, Inc., *Model Validation and Reasonableness Checking*, prepared for Travel Model Improvement Program (TMIP) and the Federal Highway Administration (FHWA), February 1997

When a transportation model is presenting travel behavior well, the percentage errors will be smallest on the highest-volume roadways. The large errors for freeway links with over 100,000 vehicles per day make the TPB model unreliable for planning major roadways and for calculating air pollution emissions.

While we are reporting here for Version 2.1D, this is not a new problem. We noted the same problem in the original Version 2 in the fall of 2002, except that we commented on all model links and not just freeways. The table and text below are copied from that review.

Table 1: Daily 1994 VMT – Estimated versus Count

Count Range	Estimated VMT	Count VMT	% Difference
0 - 20,000	61,383,259	54,216,970	13%
20,000 - 40,000	29,351,014	29,494,240	0%
40,000 - 60,000	9,986,070	9,515,490	5%
60,000 - 80,000	4,923,946	5,196,100	-5%
80,000 - 100,000	8,728,344	9,421,070	-7%
100,000 – 120,000	8,823,471	9,866,850	-11%
120,000 – 140,000	208,882	290,920	-28%
Total	123,404,986	118,001,640	5%

> As seen in Table 1, the DCV2 model assigns too many vehicles to the low class facilities which have count volumes under 20,000 vehicles per day. The estimated volume on these roadways is 13 percent too high. In addition, the model is under-assigning vehicles to the high class facilities which have count volumes greater than 100,000 vehicles per day. The estimated volumes on the two high class facility types are 11 percent and 28 percent low respectively when compared against the count VMT. The evidence in Table 1 suggests that the DCV2 model is estimating too many trips and that on average the trips are too short.[10]

What should be done?

The roadway traffic assignments come at the very end of the complex "four step model" process. Therefore, they are influenced by every other model step. In Version 2.1D, it appears that the primary method being used to address this issue is adjusting traffic assignment parameters such as hourly capacity values and assumed free-flow speeds.[11] We think that this sort of tinkering is of limited value because the fundamental source of the problems lies upstream in other parts of the model. As stated in the fall 2002 review, the most likely explanation is that the model is estimating too many trips, which are on average, too short.

What is needed is a complete reworking of the TPB model that includes all four steps. This theme will be revisited throughout this report.

K-Factors and other adjustment issues

What is the issue about?

Regional transportation models use a four step modeling process:

1) Estimating trips from household and employment data,
2) pairing the origins and destinations together to form complete one-way trips,
3) determining the mode of travel (auto drive alone, carpool or transit), and
4) assigning the traffic to the roads.

Ideally, only system-wide parameters would be used. However, some models use local adjustment factors to better match base year conditions. A particularly significant class of adjustment factors in the TPB model are "K" factors. K-factors increase or decrease the flow between geographic subregions. The TPB model includes other types of local adjustment factors that interact with the K-factors in complex ways. For example, there also are county-to-county time penalties for some county pairs for particular trip types.

[10] Smart Mobility, Inc., October 2002, p. 5.
[11] Letter from Ronald F. Kirby, to David Forkenbrock, May 13, 2004, p. 2..

Why is it important?

Matching base traffic volumes is a necessary condition but not a sufficient one. The true purpose of the model is to develop realistic forecasts for future scenarios. If adjustments are "hardwired" in to fit a certain set of numbers, it is probable that the model will fail to reflect future differences properly.

In their first report, the TRB Review Committee stated that,

> TPB's extensive set of adjustment factors in trip generation, trip distribution, and mode choice to enhance the match between simulated and observed base-year data undermines the fundamental behavioral logic of the four-step modeling process.

Our fall 2002 review of the Version 2 model stated:

> Although the use of K-factors may improve model results in the base year, it also forces future model scenarios to be similar to the base year, thereby limiting model sensitivity. It is difficult to justify short-circuiting the model's ability to predict travel behavior in this way when analyzing various future build scenarios.

What is the current status of the issue?

In response to these criticisms, TPB has made some improvements in this area with the Draft Version 2.1D model. Specifically, the number of K-factors has been reduced from 68 to 59. Of the remaining 59, 13 have been reduced in magnitude and none have been increased. However, the number of zone pairs affected by these factors is still extremely large, and the myriad of time penalties and adjustment factors applied in trip generation and mode choice still remain.

The adjustment factors that remain are highly questionable. An example in Version 2.1D is a 7-minute time penalty on work trips from residences in Montgomery County to workplaces in Prince George's County. This time is added to the true travel time in evaluating the attractiveness. This is true even if the two locations are within 1 mile of each other. There is no plausible explanation for this, and it appears especially problematic when evaluating a proposal such as the Intercounty Connector. The TRB review committee wrote in its second letter that it continues to be "puzzled" by the use of K-factors in the model.

What should be done?

K-factors are used in regional transportation models to achieve a better fit with base traffic counts and other travel data. Therefore, it is ironic that the TPB model both uses K-factors more extensively than is common practice while simultaneously achieving a poor fit with traffic counts (as is documented above).

In our experience, the need for K-factors often is a symptom of other model problems. When K-factors are used, it is more difficult to root out the problems. The TRB review committee noted in their second letter that, "as a practical matter it is difficult to trace cause and effect when multiple model results are factored." "Some factors in the later stages of the four-step process may simply be compensating for factors applied in earlier stages." For example, if trip

rates are too high and trip lengths too low as discussed above, K-factors might help to improve model calibration somewhat, but such improvement would be limited because the root problems would remain.

As was found above, what is needed is a complete reworking of the TPB model that includes all four steps.

Feedback Process

What is the issue about?

The four-step modeling process treats a set of simultaneous decisions into a set of sequential decisions. Instead of deciding where to go, how to get there, and what roads to take all in one step, the four step modeling process calculates this as 3 separate steps. This introduces error into the process because at the beginning of the four step process, roads may appear uncongested and longer trips are encouraged. However, when the longer trips are loaded onto the network, there is more congestion than was assumed. Good modeling practice feeds the congested travel times back into the earlier steps of the modeling chain, repeating the process until an equilibrium condition is approximated.

Why is it important?

Models lacking feedback or with incomplete feedback overestimate travel on congested roadways, and therefore overestimate congestion and the need for expanded or new roadway capacity. Model feedback also is required by the Clean Air Act Amendments to assure that air pollution emissions are properly estimated.

What is the current status of the issue?

The TRB review committee criticizes the TPB model Version 2.1C feedback process as an "heuristic approach" that falls short of best practice. The committee's second letter (p. 10) states:

> The committee notes that there is a well-known algorithm for establishing equilibrium among trip distribution, mode choice, and assignment. The algorithm is applied by iterating through distribution, mode choice, and assignment, successively averaging link volumes over all completed iterations, computing new link travel times using the resulting average link volumes, building new paths and travel times between origin-destination zones, and then returning for another iteration.

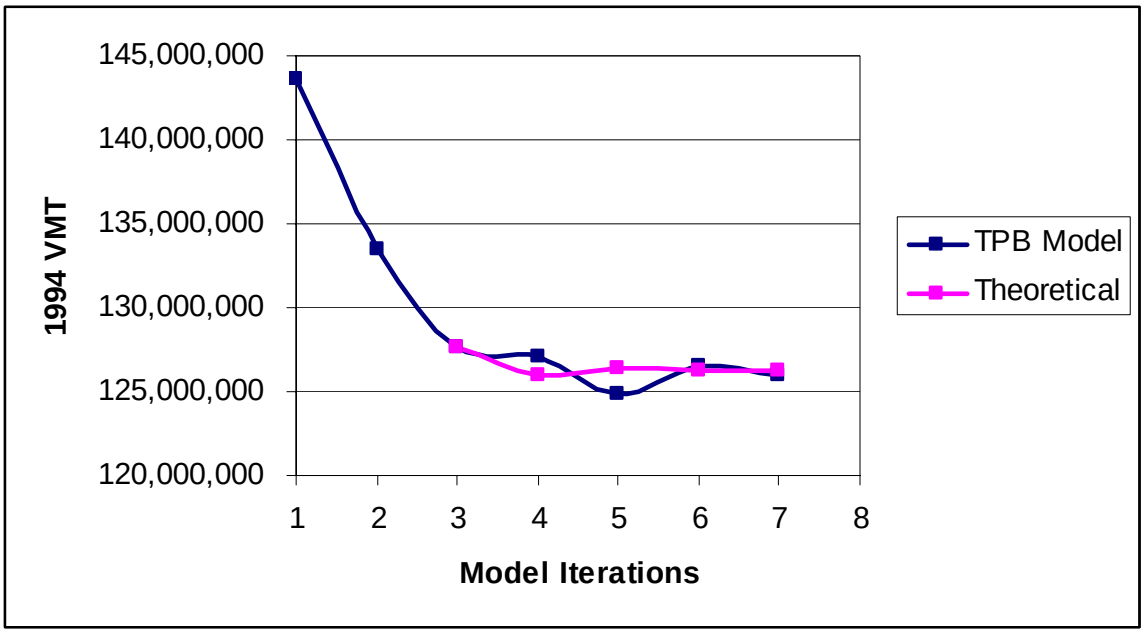
TPB's response to the TRB review committee letter questions whether equilibrium can be achieved within TP+, the commercial software used with the TPB model. We have implemented the Method of Successive Averages (MSA), which satisfies the requirements outlined by the TRB review committee, within TP+ in our Baltimore Vision 2030 modeling work.[12] More information on MSA can be found in *Incorporating Feedback in Travel*

[12] Our Baltimore modeling report is an appendix to the *Complete Vision 2030 Report* from http://www.baltometro.org/Vision2030.html. Our report begins on p. 163 of the pdf file.

Forecasting: Methods, Pitfalls, and Common Concerns dated March 1996, done for the federally-managed Travel Model Improvement program.

In TPB Version 2.1D, the number of model chain iterations was increased from four to seven. In addition, the mode choice module is now run twice instead of only once as in 2.1C. However, in our analysis of Version 2.1D #16, we found than even regional vehicle miles of travel (VMT) have not reached equilibrium at the end of the modeling process.

Version 2.1D 1994 Vehicle Miles of Travel(VMT) by Feedback Iteration



The blue line shows the VMT profile for the 1994 base year 2.1D model. The percent difference between the VMT at iteration six and iteration seven is still approximately half a percent. Based on our experience with the MSA version of the model, we would expect the difference in VMT between the last two iterations to be less than a tenth of a percent. Not applying the mode choice model in each feedback iteration (as is recommended by the TRB review committee) appears to be destabilizing the convergence and limiting any benefit of additional feedback iterations.

What should be done?

The Method of Successive Averages (MSA) feedback should be implemented.

Time of Day / Air Pollution Estimates

What is the issue about?

The TPB transportation model includes separate estimates of roadway traffic for different times of the day, including the weekday morning and afternoon peak periods and these are key to evaluating the real-world congestion levels, travel time delay, and quality of travel conditions and choices experienced by the traveling public. No traveler experiences "average daily travel time" but day after day, millions of people face congested morning and evening rush hour

conditions, and the less taxing experience of travel that avoids the rush hours. It is the differences between these conditions by time-of-day that shape the real choices made by people in real time, determining when, how, and where they travel.

Why is it important?

Transportation planning analysis is focused on meeting mobility needs during morning and afternoon peak travel conditions. Air pollution estimates are done for hourly time periods based on traffic volumes and speeds. Emissions vary by travel speed, so moving traffic from one time period to another will affect the emissions calculations. Even if the transportation model accurately matches daily travel, it will be inadequate for project analysis and air quality conformity analysis if the model cannot model time-of-day traffic properly. If the modeled distribution of trips by time-of-day varies significantly from the real work pattern, it will cause significant errors in estimates of congestion, travel time delay, and the response of travelers to changes in the quality and cost of highway and public transportation choices. Such errors will mask induced traffic impacts of new highways and make it difficult or impossible to fairly evaluate strategies that entail significant differences in the time-of-day travel cost, such as High Occupancy Toll (HOT) lanes.

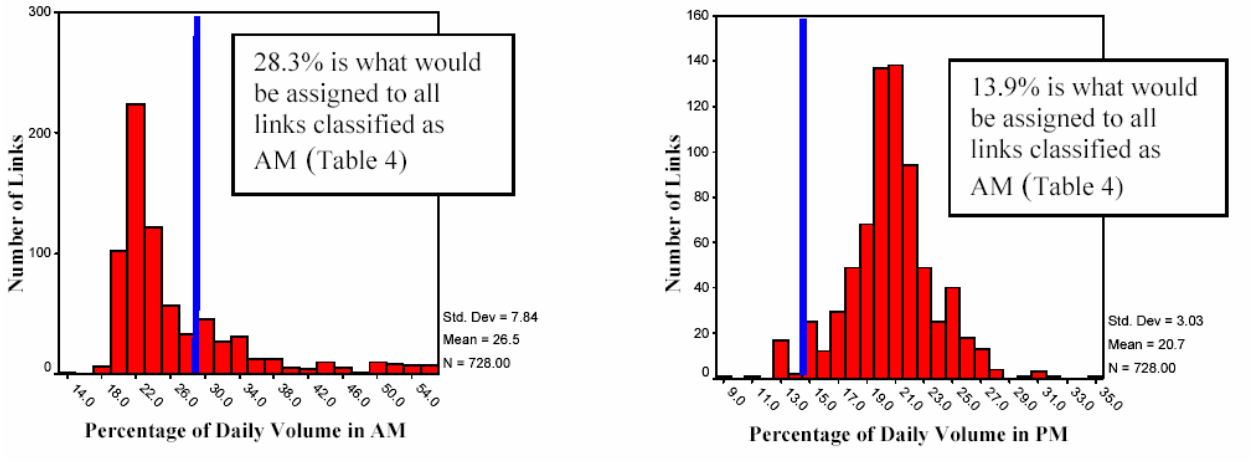
What is the current status of the issue?

The TRB review committee has raised serious issues with the TPB treatment of time-of-day traffic and time-of-day emissions estimates.

> TPB's aggregation of peak and off-peak travel model estimates to a 24-hour volume and subsequent redistribution to hourly estimates based on a percentage of daily volume essentially dissociates the hourly volumes, and subsequently the final emissions estimates, from the peak and off-peak projections produced by the four-step model. (p. 11)

TPB models traffic for different time periods, including a morning peak period and an afternoon peak period. However, when doing air emission analysis by hour of the day, it first aggregates the transportation model outputs to a 24-hour period. The TRB review committee has demonstrated that the air emission "postprocessing" results are inconsistent with the transportation model outputs. The graphic below is the first of many prepared by the TRB Review Committee to make this point.

Figure 4-1 Freeways—classified as AM link.



From TRB review committee second letter, p. 20.

The graphics are for Freeway links only, and for those Freeway links coded as peaking in the morning peak hour. The graph on the left shows the morning peak period and the one on the right shows the afternoon peak period. The red bars show the distribution of daily traffic assigned to the peak period by the transportation model. The blue line shows the distribution assumed in air emission postprocessing. Compared to the transportation model, the postprocessing routine assumes much more traffic in the morning peak period and much less traffic in the afternoon peak period.

The TRB review committee's findings from this analysis are:

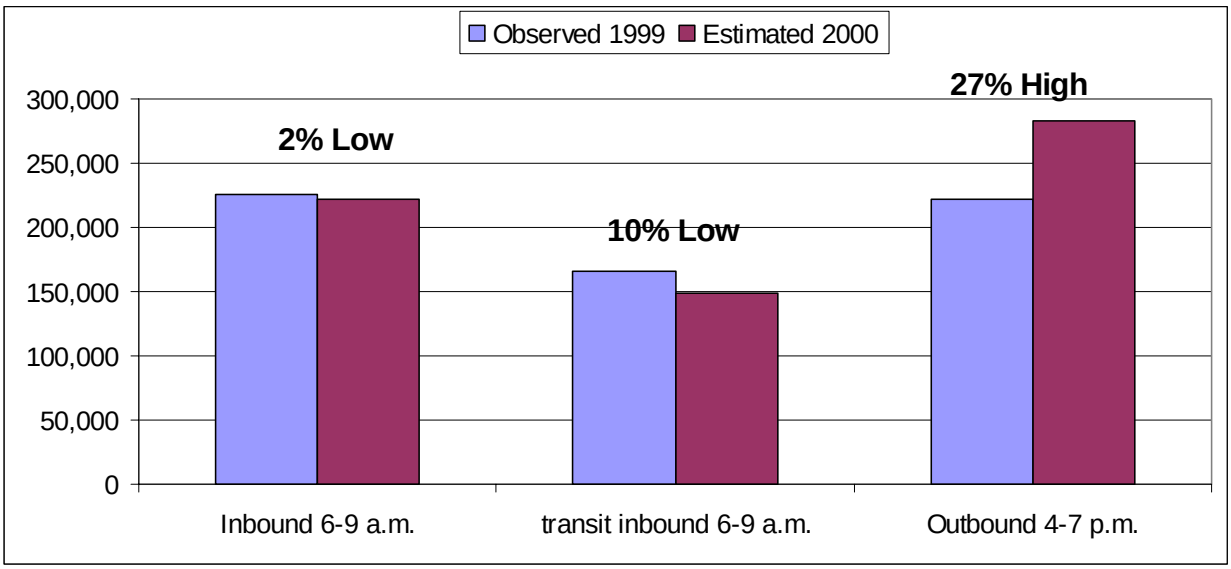
> Ideally, the ratios of peak-period to daily traffic produced by the four-step model would be tightly clustered in a balanced distribution around the single-number estimate used in the postprocessing procedure. However, we found differences between the two sets that are in many cases strikingly large and skewed. The current postprocessing procedure undermines the relationship that ought to exist between the hourly volumes used for mobile source emissions estimates and the AM, PM, and off-peak volume estimates produced by TPB's four-step model.
>
> The estimates of hourly volumes and speeds must be associated directly with the time-of-day (AM, PM, off-peak) travel model output…
>
> The committee asserts that such an effort is necessary to produce hourly volumes for the mobile source emissions process that are credibly linked to travel demand estimates and should be included in TPB's work program. (p. 11-12)

The TRB Review Committee is rightly arguing that the transportation model should more accurately allocate daily traffic to individual links by time period than any global percentage. However, before the air pollution emissions estimate are based directly on the transportation model, the allocation of traffic by time period in the transportation model should be improved.

Earlier TPB analysis showed that, despite the overuse of adjustment factors criticized by the NAS/TRB review, the previous TBP Version 2.1C over-predicted vehicles entering or leaving the Metro Core, during the PM peak period by 52 percent in 1994 and by 37 percent in 2000.

Documentation for Version 2.1D demonstrates that the model is under-assigning traffic to the morning peak period and continuing to over-assign traffic to the afternoon peak period.[13] Information is given for the Metro core and Beltway cordons only. These model results are shown in the following figures.

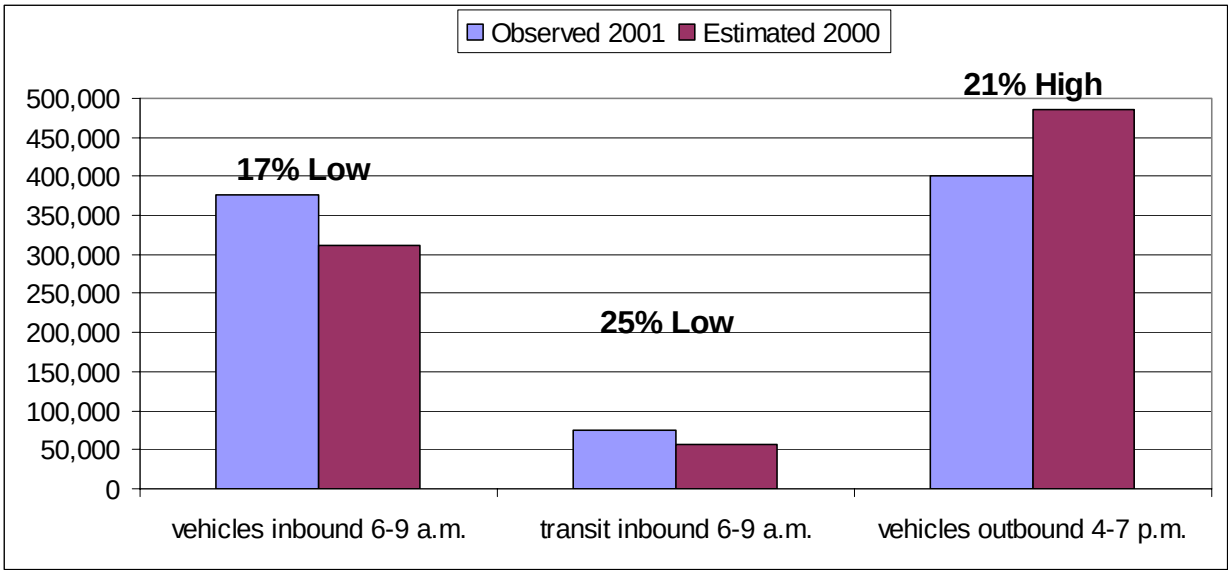
Version 2.1D Release #18 Peak Period Traffic Outputs vs. AM and PM Peak Period Traffic Counts and AM Peak Transit Ridership – Metro Core Cordon[14]



[13] Malone, Ron, Memorandum to Files concerning "Transmittal of Version 2.1D (Draft #16) Model, Tables labeled "Estimated and Observed Metro Core and Beltway Cordon Trip Crossings by Time Period", April 8, 2004,

[14] From handouts distributed by Ron Milone at the May 21, 2004 meeting of the TPB Travel Forecasting Subcommittee.

Version 2.1D Release #18 Peak Period Traffic Outputs vs. AM and PM Peak Period Traffic Counts and AM Peak Period Transit Ridership – Beltway Cordon



Note: transit comparison not available for afternoon peak period.

The model poorly estimates travel times in the peak period that are used to evaluate whether people will drive or take transit, where in the region they will travel, and how congested are the conditions faced by real world travelers now and in the future.

What should be done?

We concur with the recommendations of the TRB review committee to allocate the transportation model outputs to the air quality analysis hours, except that we also recommend that the time period allocations of the transportation model be improved first.

This serious mis-estimation of time-of-day travel means that the TPB Version 2.1 model fails to properly incorporate congestion feedback in the modeling process as required by federal planning regulations (CFR Title 40 Section 93.122). Unless this flaw is fixed, the model cannot fairly characterize the congestion and delay that shapes travel behavior in our region, and the response of travelers to changes in highway capacity like the ICC, HOT lanes, or Metro improvements. TPB should take immediate steps to address this problem before the model is used to evaluate the environmental or air quality impacts of these projects.

Employment Estimates

What is the issue about?

TPB staff recently determined that there are serious errors in the employment inputs, especially for the areas in the model where the inputs are supplied by the Baltimore Metropolitan Council rather than by the National Capital Planning Commission.

> The systematic jurisdictional differences in base year 2000 employment estimates identified in this analysis were on the order of 20% or more. Staff explained that these differences arose primarily from the different data sources used and the way in which these different data sources defined and measured employment. Because these systematic differences could significantly skew the pattern of trip origins and destinations generated by the travel demand forecasting models used by the TPB, staff recommended that a technical adjustment be made to the employment data when running these transportation models.[15]

Why is it important?

The excerpt above shows why this is important: "systematic differences could significantly skew the pattern of trip origins and destinations …" The household and employment inputs are the foundation of travel demand modeling and affect all outputs.

What is the current status of the issue?

There is no single perfect employment dataset. Data collected from payroll billings, called ES-202 or Bureau of Labor Statistics (BLS) data, are commonly used in regional transportation modeling. There are confidentiality issues in using these data, and also geocoding issues (making sure the workers are placed at the correct address), but data can be tabulated by transportation analysis zone (TAZ) and by employment type. TPB uses ES-202 data as the foundation for the inputs in most of the modeled area.

A major issue with ES-202 data is that it only includes "covered" employment, i.e. those employees who are covered by unemployment insurance. The Bureau of Economic Analysis (BEA) data supplements the ES-202 numbers with estimates for the missing categories. Some of the categories are particularly important in the modeled area including military, international organizations and foreign embassies, and state and local government (including Annapolis). While BEA data are designed to correct for the deficiencies in the ES-202 data, they are not available at a sub-county level.

Census Transportation Planning Package (CTPP) data are available at the transportation analysis zone (TAZ) level, but offer only crude information about type of employment. The CTPP data also have three other problems.

1) CTPP only includes one job for workers who work more than one job,
2) CTPP does not include employment location if worker didn't commute on survey day, and
3) CTPP based on geocoding of reported work location (with a potential for errors).

The current employment inputs in the TPB model are primarily based on ES-202 data with adjustments for non-covered employment. The TPB memo suggests that the BMC area inputs come from BEA data, but that doesn't appear to be the whole story because BEA data are not available at the TAZ level, and they do not match BEA totals at the county level.

[15] Griffiths, Rober E. Memorandum to TPB Technical Committee concerning "Travel Model Employment Data Adjustment Factors, dated May 7, 2004.

TPB proposes to address the employment problem by factoring the TAZ inputs so that the CTPP county totals are achieved. They propose dealing with the first two issues with CTPP data by making adjustments. There is an assumption that 1.6 percent of the workers were absent on the Census survey data. Then, estimates of multiple job holding by jurisdiction are applied. These range from a low of 7.4 percent in Alexandria to 13.0 percent in some outer counties, with an average of 2.08 jobs per worker with multiple jobs. The jurisdiction-specific rates are derived from the 1994 household travel survey. The economy has changed a lot since 1994 so this may introduce some errors.

The third issue, proper geocoding, has been a major issue in previous Census releases. As the 2000 CTPP data were just released this spring, national discussion about the quality of these data is just beginning. A recent posting on the Travel Model Improvement Program (TMIP) internet listserv is:

> The experience at Metro (Portland) is that CTPP journey to work, and the distribution of place of work are always very low for the CBD, high for the near CBD (across the Willamette, the major screenline). Metro does a lot of work getting an accurate ES202 data set, and directly surveying non-covered employees to get a good estimate. They also compare distributions with the household survey output. They are able to develop successful destination choice models with minimal k-factoring (none), which would suggest that they have a good worker allocation in terms of distribution.
>
> Bad geocoding, exacerbated by identical street names and addresses on both sides of the river (except for E-W designations-Westside= SW and NW, Eastside = SE & NE, is thought to be the culprit. In short, they have historically been unable to make any use of the CTPP for modeling. To the best of my knowledge, they have not considered using the 2000 CTPP. (Keith Lawton, June 4, 2004)

Keith Lawton is one of the members of the TRB review committee. Portland Metro is generally thought to have the best regional travel demand model in the U.S. Lawton's comments suggest that TPB should be cautious and do further checking before adjusting all of the employment inputs to the CTPP data.

A further reason for caution is demonstrated in the table below which summarizes 2000 ES-202, BEA, CTPP, and proposed TPB totals.

Comparison of 2000 BEA with CTPP and Proposed TPB Employment

Area Name	BEA	CTPP	TPB proposal	TPB-BEA
District of Columbia	703,841	671,700	743,600	39,759
Anne Arundel MD	248,955	225,100	253,400	4,445
Calvert MD	18,805	19,700	22,800	3,995
Carroll MD	51,151	48,700	54,800	3,649
Charles MD	39,436	36,200	41,900	2,464
Frederick MD	85,364	84,700	96,300	10,936
Howard MD	139,311	120,000	135,100	-4,211
Montgomery MD	495,235	420,900	473,800	-21,435
Prince George's MD	335,372	295,300	338,300	2,928
St. Mary's MD	39,186	40,177	46,600	7,414
Arlington VA	182,614	163,600	182,400	-214
Clarke VA	4,486	5,265	5,900	1,414
Fauquier VA	18,814	18,700	21,100	2,286
King George VA	10,348	9,900	11,100	752
Loudoun VA	94,017	79,200	90,500	-3,517
Fairfax, Fairfax City + Falls Church VA	635,010	546,600	615,300	-19,710
Alexandria (Independent City) VA	103,380	81,400	89,300	-14,080
Stafford VA	28,315	27,100	30,500	2,185
Prince William, Manassas + Manassas Park VA	117,711	106,300	119,700	1,989
Spotsylvania + Fredericksburg VA	50,746	46,326	52,200	1,454
Jefferson WV	14,184	14,172	16,000	1,816
Total	3,416,281	3,061,040	3,440,600	24,319

The differences between the TPB proposal (adjusted CTPP) and BEA are fairly large from jurisdiction to jurisdiction. The largest difference in percentage terms is for the City of Alexandria. BEA totals 103,380 for 2000 where the TPB proposal is 89,300. This difference of 14,080 equals 13.6 percent of the BEA employment.

It is important for the employment data to be consistent across TAZs, but it is unclear why the CTPP estimate for Alexandria would be more accurate than the BEA estimate. The CTPP data may have geocoding errors and must be factored to account for undercounted absent workers and multiple job holders. While no data source is perfect, it would appear to be more accurate to do the jurisdiction factoring with the BEA data.

What should be done?

As a short-term fix, the TAZ-level employment should be factored to the county-level BEA totals. Within the next year, the process of developing TAZ-level inputs should be reviewed and improved as necessary so that large county-wide adjustments will no longer be needed. Furthermore, this effort should be done in concert with a complete model overhaul that addresses the issues raised in the TRB and our critiques.

Interrelationships between the Issues

In an internet posting included above, Keith Lawton linked accurate employment inputs to the ability of Portland Metro to accurately model traffic in that region without use of K-factors. TPB's Robert Griffiths, in his memo discussing the employment data problems in the TPB model also suggests that improving the employment inputs: "may reduce and lessen the need for K-factors …" (p. 2)

In fact, all of the issues discussed above are interrelated. A regional transportation model is a very complex representation of a very complex system. An error in one output variable can be a symptom of underlying errors in a different part of the model.

A metaphor we use is that regional transportation model is analogous to being somewhere on the side of a mountain in a dense fog. We may think we have reached the summit because there is no higher ground nearby. This is similar to trying to fix problems with assigning traffic to roadway links by considering only changes in link capacity and speeds. The true summit cannot be reached without looking further afield. In the model, this is equivalent to throwing out the K-factors and other local adjustment factors and reworking the model more completely.

Summary

The TRB review committee process has identified serious problems with the TPB transportation modeling process. While some of these issues have been addressed, several significant issues have not. These include:

1) The model fits traffic count data poorly.
2) The model relies too much on K-factors, time penalties and other local area adjustments that limit the value of the model for forecasting.
3) The model needs improvement in its equilibrium process.
4) The model does a poor job of assigning traffic to peak time periods, and in translating traffic volumes by time period into air emissions.

In addition, TPB staff have recently identified serious errors in the employment inputs.

Without correcting these problems, the region cannot be confident that the planning efforts underlying billions of dollars of public investments are valid, or whether air quality standards crucial to the public health will be achieved.

For example, the model is in current use for evaluating the proposed Intercounty Connector. The model matches observed traffic counts poorly, being widely off the mark for freeways, especially for those with higher or lower than average freeway values. The model relies on K-factors that lack an underlying explanation, including K-factors that arbitrarily adjust traffic between Montgomery and Prince Georges Counties. The model fails to reach equilibrium, so that comparisons of alternatives may not be strictly "apples-to-apples." The model does not allocate traffic appropriately to peak morning and afternoon periods, so that measures of congestion will be incorrect. Furthermore, the allocation of traffic to hours for air quality modeling will not match the transportation model. With all of these problems, the model

outputs do not provide an acceptable basis for assessing the impacts and performance of projects such as the InterCounty Connector or Beltway toll lanes, or for making critical decisions about investing billions of dollars in transportation facilities across the region Nor does the model comply adequately with CFR Title 40 Section 93.122 requirements for appropriate congestion feedback.

TPB's staff have resisted addressing fundamental problems underlying the poor performance of the TPB transportation model. This resistance has been enabled by the hesitation of many Board and technical committee members to question TPB staff assertions about the adequacy of the TPB modeling process. This failure to address the problems has postponed the time when the Washington region can achieve the first class transportation and air quality planning capability that it sorely needs to adequately support air quality conformity analysis, environmental impact analysis, and other regional and project planning needs.

The discovery of the fundamental problems in employment data inputs offers an excellent opportunity for a thorough reconsideration of the model functioning while addressing the issues raised by the TRB and our model critiques.

This will require support and encouragement from the TPB Board**,** and a willingness to accept changes from past modeling results**, and a commitment of funding to enable an accelerated model redevelopment program, with ongoing independent expert oversight to guide the process**. Some of the timidity with which MPO staffs approach transportation modeling improvements is related to a fear that improved models may give different answers. This is of special concern in the area of air quality which is such an important issue in this region. A DC-area private consultant once said at a TRB meeting: "Let's face it; better model – worse emissions" to knowing laughter from his fellow modelers. We must accept that a better model will give better answers, and these answers may be different from those from past modeling.