ITEM 12 - Information
May 19, 2004

Briefing on the Transportation Research Board (TRB)
Review of TPB Modeling Procedures

Staff Recommendation: Receive briefing on the enclosed second letter TRB report reviewing the TPB travel demand modeling procedures and on the enclosed staff comments on the report.

Issues: None

Background: In April 2002, the TPB approved a process for conducting a review of the region's travel modeling procedures. The process called for the TPB to engage the TRB in appointing a review panel and overseeing the review process. The TRB began its analysis of the TPB modeling procedures in January 2003 and submitted its first letter report on September 8, 2003. The analysis has been completed with the submission to TPB of the second letter report on May 10, 2004.

May 10, 2004

The Honorable Christopher Zimmerman
Chairman
National Capital Region Transportation Planning Board
Metropolitan Washington Council of Governments
777 North Capitol Street, NE, Suite 300
Washington, DC 20002

Dear Chairman Zimmerman:

This letter is the second report of the Transportation Research Board's (TRB's) Committee for Review of Travel Demand Modeling by the Metropolitan Washington Council of Governments (MWCOG). The committee, which was appointed by the National Research Council to undertake this review, includes scholars and practitioners who collectively are familiar with metropolitan planning organization (MPO) modeling practices in many areas of the country. The committee's membership is presented in Attachment 1.[1]

In a letter of May 8, 2002, Mr. Phil Mendelson, acting as Chairman of the National Capital Region Transportation Planning Board (TPB, a constituent unit of MWCOG), requested that TRB undertake this study. That request describes the present study as part of TPB's ongoing program to upgrade its travel forecasting methods and respond to federal guidance on modeling in air quality nonattainment areas.

The specific scope for that study is described in the Statement of Task approved by the Governing Board of the National Research Council on October 9, 2002. The Statement of Task specifies that the committee will "perform review of the state of the practice of travel demand modeling by the Transportation Planning Board (TPB) of the Metropolitan Washington Council of Governments." The Statement of Task is presented in Attachment 2.

The committee undertook to provide guidance on five specific elements listed in this statement of task:

- The performance of TPB's latest travel model (Version 2) in forecasting regional travel,
- The proposed process for merging the latest travel model outputs to produce mobile source emissions,
- TPB's proposed direction of future travel demand model upgrades,
- Travel survey and other data needed to accomplish future model upgrades, and
- The detail (grain) of travel analysis zones that should be developed for future upgrades.

[1] Biographical information is available at http://www4.nas.edu/webcr.nsf/CommitteeDisplay/SAIS-P-02-07-A?OpenDocument.

The committee's initial letter report, dated September 8, 2003, addressed the first two items.[2] This second letter addresses the last three items and other matters raised in a work program document that TPB presented to the committee. That document is included here as Attachment 4.[3]

In the course of preparing this report, committee members met as a group several times by teleconference and held a face-to-face meeting and teleconferences with TPB staff.

The committee's observations presented in this letter report have been reviewed independently under the procedures of the National Research Council by individuals selected for their diverse perspectives and technical expertise.

We begin this letter as we did our first report, by stating our principal observations. We then proceed to explain the background and bases for these observations and other comments the committee offers to assist TPB.

Principal Observations

As we noted in our first letter, despite some four decades of experience with the use of travel demand models in transportation planning, there are few universally accepted guidelines or standards of practice for these models or their application. Any assessment of these models, their performance, and the current state of transportation demand modeling practice relies primarily on professional experience and judgment.

Nevertheless, most transportation professionals will agree that improvements in demand modeling have been and continue to be made. These improvements have come from at least three sources. First, we have enhanced our understanding of factors that influence travel demand and have been able to apply that understanding to formulate models that represent the relationships among these factors in more realistic ways. Second, the power and flexibility of computers available for modeling have increased dramatically at the same time that their cost has fallen, allowing us to apply computationally more complex and data-intensive modeling methods. Finally, we have substantially enhanced our capabilities for data collection and database management.

The state of transportation modeling practice today is marked by continuing evolutionary modification of the widely applied "four-step model" and development of revolutionary new models that are beginning to be applied in analyses of transportation policy matters. New "activity-based" or "tour-based" models and microsimulation of traffic flows using less aggregated data and providing more spatial and temporal detail promise substantial improvements in our ability to account for the influence of such factors as time of day, congestion, and travelers' socioeconomic characteristics. These new models will improve our ability to represent the influence of investment decisions, traffic control strategies, and other public policy variables on regional travel patterns, which will in turn enhance our ability to

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[2] The committee's first letter report is available at http://trb.org/publications/reports/mwcogsept03.pdf. The second report will be available at http://trb.org/publications/reports/mwcogapril04.pdf.
[3] The document is a staff proposal and not an officially approved TPB work program.

estimate air pollution emissions and other aspects of the region's well-being.

These new models, the committee agrees, are likely to be used widely within the next decade. Several MPOs have begun to adopt the new formulations. While the capabilities of the new models are being perfected and their application grows more widespread, many agencies may continue to rely on four-step modeling and seek to improve their existing modeling practices.

An important implication of this situation is that MPOs must allocate their resources to strike an appropriate balance between maintaining their current models and preparing for the migration to new practices. That balance will change as time passes. Within this context, the committee makes the following points:

1. TPB's proposal to develop a comparative analysis of modeling practices employed by other MPOs with similar characteristics may be useful but will be a challenging undertaking. (page 5)
2. TPB's efforts to improve model calibration and validation statistics through improved representation of transit and highway network supply characteristics—such as refinements of volume-delay functions, free-flow speed and capacity values, linkages of transit speeds to highway speeds, and network coding—are steps in the right direction. (page 6)
3. TPB's proposals to develop new model components to represent truck and commercial vehicle trips are a reasonable application of methods successfully adopted by other MPOs. The committee suggests that collection of new traffic classification counts begin as soon as possible and that model development work be initiated without waiting for completion of these counts. (page 7)
4. The committee is encouraged by TPB's plan to work with the region's transit agency and others to find a method to represent bus speeds in future years. (page 8)
5. The committee recognizes that the practice of using K-factors and other arithmetic adjustments to improve four-step models' ability to represent base-year travel observations is not uncommon, but continues to find TPB's use of such correction factors to be excessive. TPB should proceed aggressively with its plan to document the logical basis and need for these adjustments. (page 8)
6. Having previously questioned TPB's feedback procedures to estimate transit and highway network travel times, the committee agrees that TPB's proposed exploration of alternatives to its rule-based heuristic approach for approximating equilibrium conditions and current representation of highway-transit composite times in distribution and mode choice is helpful. The committee notes that there are accepted feedback algorithms for obtaining convergence of travel times. (page 10)
7. The committee believes that time-of-day link volumes estimated in the four-step model process should be more directly linked to TPB's postprocessing procedures. TPB should develop postprocessing procedures that maintain consistency with the agency's four-step travel demand modeling procedures. (page 11)

With regard to other questions TPB posed, the committee offers the following points:

8. While large survey sample sizes generally yield statistically more precise estimates of

important modeling parameters, large surveys can be expensive. For the purposes of model calibration, surveys that incorporate selective sampling of stratified populations can be more effective and efficient than those that entail larger random samples. (page 14)

9. The committee believes that TPB's proposal to consider a nested logit model is appropriate. However, determining the specific nesting structure requires extensive empirical analysis. The committee recommends that TPB also consider other discrete-choice model formulations that allow more flexible representation of competition among different transportation modes. (page 12)
10. The committee agrees that TPB should actively monitor the progress of early adopters of new models and take appropriate action to ensure that the agency's modeling meets current standards of good practice. At the same time, TPB should maintain balance in its work programs to achieve shorter-term objectives of producing forecasts required to meet agency responsibilities. (page 12)
11. Many factors influence the appropriate number and size of analysis zones to be used in modeling. The committee can offer only general comments, within the context of the scope of this study and the specific information available, concerning the grain size of TPB's zone system. (page 13)
12. The committee commends TPB's plan to conduct a new regional household survey and offers a number of comments on details of the proposed survey. (page 14)

Background

The committee's first report stated eleven points concerning its assessment of the performance of TPB's travel demand models. Six of these points, which questioned or suggested changes in various aspects of TPB's models, are addressed directly in the work program document TPB prepared for the committee. Other points in the first report addressed matters on which the committee substantially agreed with TPB's procedures.

TPB's work program document proposes work elements for the model development program organized in five parallel "tracks," reflecting TPB's historical approach to advancing its travel models:

> Track 1—Application: Improvement of the currently adopted model set to produce adequate forecasts while enhanced models are in development.
> Track 2—Methods development: The incorporation of advanced practice in travel demand modeling that can be made operational in the next few years.
> Track 3—Research: Keeping abreast of research developments in areas of travel modeling, surveying, data (GIS) maintenance practices and integration, and simulation.
> Track 4—Data collection: The implementation of data collection designed to meet the needs of Tracks 1, 2, and 3.
> Track 5—Maintenance: Documentation of the current modeling applications, including recent improvements in software and data requirements. This track includes an ongoing effort to train staff in the use of current and updated application procedures.

The document also poses a number of questions soliciting the committee's advice on several matters concerning modeling strategy and data collection.

The following sections present the committee's findings and conclusions, first on the points of concern raised in the committee's initial report and addressed in the work program document and second on TPB's questions. The latter questions include matters of travel surveys and model granularity cited in the scope of the study initially presented to the committee.

Throughout this letter, we have not followed the structure of TPB's proposed work program but do make reference to specific elements of the program in our comments.

The committee remarked generally that the five tracks for model development are a reasonable organization for the agency's work program but voiced concern that activities identified by such terms as "methods development" or "research" may be viewed by some people as not likely to contribute immediately to an MPO's day-to-day operations. These activities then are more difficult to justify in budgeting discussions and are targeted for funding cutbacks when budgets become tight. Strong leadership and commitment are needed to maintain such an active model development program, to ensure that progress is maintained on all tracks, and to ensure that the results from the program are promptly incorporated into the production models used for travel demand forecasting.

An awareness of what is being done at other MPOs can be valuable to technical staff and senior managers responsible for providing such leadership and commitment. While the models most MPOs use embody similar logic and assumptions, there are no widely accepted guidelines explicitly delineating best practices or even presenting a comprehensive comparison of various regions' practices. TPB has undertaken to collect information from other MPOs with similar characteristics[4] for comparative analysis of modeling practices and demand estimation results. However, TPB reports that progress has been hampered by difficulty in obtaining detailed and comparable current documentation on the various MPOs' modeling practices. The committee anticipates that this effort will continue to be challenging.

TRB, with sponsorship from the U.S. Department of Transportation, is undertaking a study to gather information and prepare a synthesis of practice on metropolitan area travel demand modeling. The study should be useful to TPB in determining modeling practices at other MPOs.

Comments on TPB Proposals Responding to Previous Committee Assessments

TPB's discussion of proposed work elements includes responses to six areas of concern mentioned by the committee in its first letter report: model validation, travel estimation for trucks and commercial vehicles, bus network representation, uses of adjustment factors, applications of feedback through mode choice in reaching final travel estimates, and

[4] TPB lists eleven peer MPOs and includes preliminary results of the analysis in the work program's Appendix A.

procedures in postprocessing for estimating hourly highway traffic volumes and speeds. The committee considers each of these areas in turn.

Improving Model Validation

The committee commented in its first report that statistical measures indicated that base-year modeled link volumes do not match observed traffic counts and transit ridership as closely as the committee would typically expect in model validation. TPB's work program document addresses this concern primarily in the highway and transit validation work element (1.A.). This work element entails several steps intended to improve the match between modeled and actual link volumes, including network enhancements to better reflect actual conditions (1.A.1), short-term modeling improvements (1.A.2), longer-term modeling improvements (1.A.3), and testing of the SUMMIT model for use as a diagnostic tool (1.A.4).[5]

TPB refers to staff's continuing efforts to achieve improvements in validation statistics. It cites as examples recent applications of its model set to study travel demand in specific regional corridors, where improved statistics have been achieved. TPB attributes these improvements to the use of refined free-flow speed and capacity values, a refinement of the zonal area–type assignments, adjusted link volume-delay functions, and improvements related to network coding. TPB believes that improvements such as these can be of benefit to the regional model. The committee finds these results encouraging and proposes that TPB staff continue to evaluate whether systematic adjustments of the sort used in these corridor studies may lead to improved highway assignments on a regional level. However, adjustments of selected link impedances merely to correct over- or underassigned volumes should be avoided.

With regard to the match between estimated base-year and observed transit ridership, TPB has outlined several short-term enhancements to its current model package, such as incorporating existing sub–mode choice and rail access mode choice models, relating bus travel times to highway link times, and evaluating the weighting of in-vehicle and out-of-vehicle travel times in transit route choice. The committee was encouraged by the interest shown by the region's principal transit agency (WMATA). It hopes that other agencies similarly will recognize the value of TPB's model development activities and cooperate in supplying traffic and passenger counts and other operational data, and in collaborative data collection efforts.

TPB proposes to investigate the new SUMMIT mode choice software being developed with Federal Transit Administration (FTA) support. The use of SUMMIT for projects seeking to qualify under FTA's New Starts program has typically revealed problems in three areas: the physical and operating plans for the alternatives; errors in network coding; and fundamental limitations, errors, and other weaknesses in the mode choice model. The activity of modifying the mode choice model code to produce data files compatible with SUMMIT input requirements exposes these problems, making the SUMMIT software an excellent diagnostic tool as well as a means for estimating total user benefits of a transit improvement. User benefits are computed at the upper level of the mode choice model, so it can be equally applicable to multinomial or nested logit model formulations.

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[5] Titles and reference numbers for subtasks are presented in TPB's schedule charting the timing of planned work elements (Figure 1 of the TPB document) and are included in discussion of the primary work element.

The committee agrees that these enhancements, along with the longer-term recalibration and restructuring of the agency's mode choice model, should yield benefits. Overall, these various efforts to improve model validation are commendable. In addition, the committee has the following comments, which may be useful to TPB in the validation portion of its work program.

TPB's reported error statistics (%RMSE) comparing highway counts and link volumes may be somewhat overstated because of small numbers of observations in some of the tabulated link count categories. The values in some cases also appear to include links in large buffer zones outside the MWCOG study area, which could add to the overstatement of error. The committee proposes that TPB staff revise the categories used in these tables and not include links in large buffer zones in the computations.

The committee notes that TPB completes a relatively small number of iterations of the equilibrium highway-assignment algorithm and does not indicate a criterion for determining how many iterations may be appropriate. The committee believes that improvements in base-year highway link volume validation through additional iterations may be possible. Some testing of how the number of iterations affects fitting results could be included in TPB's model maintenance work track. In such testing, the number of iterations may be limited by monitoring some standard measure of convergence.[6]

Truck and Commercial Vehicle Travel

The committee commented in its first report that combining business and commercial trips in the non-home-based trip category is not advisable. The committee was concerned that commercial vehicle travel is influenced by factors fundamentally different from those influencing personal travel and was not persuaded by TPB's explanations with regard to the use of light-duty trucks for commuter travel in the region.

TPB has proposed, in the business and commercial trips work element (1.B.), to develop a set of truck and commercial vehicle models and thereby to separate the modeling of commercial and personal travel. The approach proposed is similar to that used by the Baltimore Metropolitan Council (BMC) and entails use of truck and commercial vehicle traffic classification counts to adjust base commercial vehicle trip tables. Other MPOs have used similar procedures to update their truck and commercial vehicle forecasts. The committee finds this proposal encouraging as a near-term solution, but it is concerned that model development work is scheduled to commence only after a series of classification counts are conducted in 2006 (work element 1.B.2). The committee recommends that new counts be collected sooner, if at all possible, to accelerate this work activity's completion.

Documentation provided by BMC indicates that link counts from 550 locations in the Baltimore region and an additional 50 locations in the Washington region for 2000 were used to adjust the base truck trip table and estimate a commercial travel trip table. BMC staff report that other counts are available from the Maryland State Highway Administration. The

[6] One widely used measure is calculated as [Σ (link volume*link time) – Σ (O-D volume*minimum path time)].

committee surmises that some truck count data currently available in the MWCOG study area[7] would allow work on the truck and commercial vehicle trip tables to begin before additional classification counts are collected. The committee recommends that preliminary work be scheduled to examine the availability and coverage of truck counts, to support early updating of the TPB truck and commercial vehicle trip tables. Other techniques suggested in the literature might also be helpful in accelerating this work.[8]

With regard to our earlier discussion of the likely evolution of travel demand models, we note that the type of model being proposed is fairly crude. Over the longer term, the committee anticipates that TPB will find it appropriate to upgrade its truck and commercial travel modeling through a more behavioral approach. TPB should consider conducting a survey of commercial firms, stratified by types and volume of goods shipped, to provide a stronger basis for model development. Truck and commercial vehicle trips entering and departing the region, as well as through trips, may be estimated from a cordon intercept survey.

Bus Network Characterization

The committee commented in its first report that TPB's use of fixed bus speeds and other coding details in its networks may misstate the influence of transit in estimates of future trip distribution and mode choice. TPB acknowledges the committee's concern and plans to work with the region's transit agency and others to find a method for representing bus speeds in future years (work element 1.C.).

The committee finds TPB's plan encouraging and notes that some agencies use estimated highway travel times from traffic assignment to modify bus travel times employed in mode choice and trip distribution modeling. Network coding for express and major line-haul bus lines on freeways and major arterials, in the committee's view, certainly should reflect future congestion levels and travel times. However, care is needed in linking the underlying network of local and feeder bus schedules to less reliable assignment travel times on minor arterials and local streets.

As we noted with regard to model validation, TPB proposes to investigate FTA's SUMMIT software as a tool for assessing transit network quality. The committee agrees that this is a worthwhile activity.

Use of Adjustment Factors

The committee discussed TPB's use of adjustment factors in trip generation, trip distribution, and mode choice in its first report. TPB's work program document includes an element to minimize the use of adjustment factors (1.D.) that entails work of two types. TPB staff plan first to document more fully the bases for the various adjustment factors currently used and actually commence to do so in the work program document.[9] The committee appreciates this

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[7] Truck volumes must be submitted for Highway Performance Monitoring System sections, for example.

[8] For example, see *Quick Response Freight Manual*, prepared for the Federal Highway Administration, Office of Planning and Environment Technical Support Services for Planning Research, by Cambridge Systematics, Inc., with Comsis Corporation, and University of Wisconsin–Milwaukee, DTFH61-93-C-00075, September 1996.

[9] The work program document's Appendix D cites four principal reasons for using adjustment factors: substantial underreporting of nonwork travel in travel surveys, aggregation errors associated with trip production

effort and agrees that the work should continue.

The second type of work TPB proposes is a sensitivity analysis to investigate whether the use of factors can be reduced. TPB's schedule indicates that trip generation, trip distribution, and mode choice will be tested and may be modified. To the extent that this work results in reduced use of factors, the committee finds this effort to be positive as well.

As indicated in our first report, we recognize that the use of adjustment factors is not uncommon. However, justification for the use of such factors is based on current conditions. There is little theoretical basis for anticipating that such adjustments will remain constant. The effect of a physical barrier may change as development patterns shift over time, and jurisdictional barriers can be readily altered by changes in local tax policies, school characteristics, and real estate values. When primary model estimates (trips, interchanges, and mode share results) are heavily factored, future estimates of these quantities will often reflect the factors more than they do the underlying behavioral relationships embodied in the models. This result is particularly likely when large factors are applied to modeled trips and trip interchanges that initially are small values but are projected to become much larger in future forecasts. The committee notes 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. The committee recognizes that professionals may reasonably differ on what represents "extensive" or "excessive" use of adjustment factors but continues to believe that TPB's modeling relies unduly on adjustment factors.

The committee agrees, therefore, that TPB should not only document clearly its reasons for applying each adjustment to its current models, but also periodically review those reasons and confirm that they remain valid. TPB should examine whether applied factors remain applicable and consistent with the assumptions underlying forecasts of future travel patterns. TPB should conduct sensitivity tests to assess the magnitude of the combined influence of factors applied in all stages of the four-step model. Otherwise, even though the adjustments are apparently justifiable, as they become more extensive they could weaken the fundamental behavioral logic of the modeling process and threaten its ability to provide defensible forecasts.

The committee found the newest information presented in Appendix D of TPB's work program to be helpful in understanding some of the adjustments being made, but questions remain. The Potomac River and jurisdictional boundaries in the Washington region, for example, may skew travel patterns. Trips originating in a zone near such a perceived barrier may be more likely to terminate in a zone on the same side of the barrier, as compared with otherwise equally attractive destinations on the other side of the barrier. Arguably, the classic and most clearly justifiable use of adjustment factors (in this case, K-factors) is to adjust interzonal impedances for zonal pairs that have the barrier between them. The committee was puzzled, however, that links between Montgomery and Fairfax Counties, for example, appear to require no K-factors, despite their separation by the Potomac River, while factors are

models, inadequacies of explanatory variables to account for important factors influencing travel patterns, and limited geographic scope of travel survey data compared with the region within which travel is forecast.

abundantly applied to other intercounty links.

Speed Feedback Incorporating Mode Choice

The committee commented in its first report that TPB's feedback of highway and transit times to trip distribution bypasses mode choice and is not typical of good modeling practice in regions with significant transit services and ridership. TPB has proposed in its speed feedback work element (1.E.) to review speed feedback practices of other MPOs and to conduct sensitivity analyses to determine whether changes in procedures will improve modeling results. Sensitivity analyses conducted as part of TPB's proposed work program explore the consequences of introducing additional feedback iterations as well as including mode choice in the feedback computations. The analyses indicate that including mode choice in the feedback does indeed influence transit travel forecasts, and TPB suggests adjustments that might be made in the model application.

The committee found these analyses and suggested adjustments to be helpful. However, the committee suggests that clearer explanations of the bases for judging the adequacy of the feedback procedure might help to explain its influence on travel forecasts.

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. There is a theoretical basis for the algorithm, and it has been proved mathematically to converge to consistent link times.[10]

TPB's work plan document, in contrast, describes a heuristic approach that approximates equilibrium conditions. The committee notes that the number of iterations used in TPB's procedures appears small, and it did not find adequate documentation of how close the final assignment times are to convergence. Furthermore, the committee observes that average regional speed is not a good measure of convergence. It is possible for the regional average speed to remain nearly constant without achieving reasonable convergence in zone-to-zone travel times.

The committee proposes that TPB use the equilibrium algorithm. Because network analyses can be unreliable under severe conditions of congestion, experimentation with alternative feedback approaches may be useful.[11] The committee suggests that TPB test different methods for weighting highway and transit times to produce a composite travel time for distribution. It may be more effective to weight transit times by the mode share in the

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[10] This and alternative feedback algorithms are evaluated by Boyce, D. E., Y.-F. Zhang, and M. R. Lupa in Introducing "Feedback" into Four-Step Travel Forecasting Procedure Versus Equilibrium Solution of Combined Model, *Transportation Research Record 1443*, TRB, National Research Council, Washington, D.C., 1994, pp. 65–74.

[11] See, for example, Boyce, D., B. Ralevic-Dekic, and H. Bar-Gera, Convergence of Traffic Assignments: How Much Is Enough? *Journal of Transportation Engineering*, Vol. 130, No. 1, Jan.–Feb. 2004, pp. 49–55; and *Incorporating Feedback in Travel Forecasting: Methods, Pitfalls and Common Concerns*, Report DOT-T-96-14, Comsis Corporation, Silver Spring, Md., and Federal Highway Administration, Washington, D.C., March 1996.

interchange than to calculate an origin-destination composite time that weights the transit time by the regional transit mode share. The former approach should increase the model's sensitivity to transit improvements by increasing the importance of transit in trip distribution for those interchanges with a high transit mode share while reducing its importance for those interchanges with negligible transit trips.

Traffic Speed and Volume Estimation for Air Pollution Emissions Estimation

The committee commented in its first report that TPB's procedure for estimating hourly traffic volumes and speeds for air quality modeling was questionable. The postprocessing procedure entails two steps: first, aggregating peak- and off-peak-period traffic assignments to a 24-hour total that is redistributed to hourly periods as a percentage of daily volume; and second, adjusting the initially estimated hourly volumes as necessary to meet link hourly capacity constraints. The second step is referred to as "peak spreading."

The committee expressed two concerns in its first letter. The first is that 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. The second is that TPB's peak-spreading method may create unintended emissions impacts. TPB's work plan addressed the second concern with additional sensitivity analysis but did not comment on the committee's first concern. We have elaborated on this first concern with a set of computations discussed in the following paragraphs and Attachment 3.

To compare the differences between time-of-day distributions of traffic produced by the four-step model with those produced by the postprocessing procedure, the committee conducted a simple analysis. We compared the peak-period traffic volumes from TPB's four-step model with the peak-period volumes estimated by the hourly profiles used in TPB's postprocessing. The analysis results are shown graphically in Attachment 3.

The ratio of peak-period to daily traffic estimated in TPB's postprocessing is necessarily a single number for each of the categories of links defined for the postprocessing procedure. The ratio estimated by the four-step model can vary.

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. A simple method for accomplishing this would be to allocate volumes proportionally within each time period (i.e., the percentages of hourly volume within a time period sum to 100 percent).

TPB staff have been aware of this issue and noted the possible need for hourly volume distributions as a percentage of the period volume instead of as a percentage of the daily volume.[12] 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.

Response to TPB's Questions to the Committee

The committee's responses to questions posed in TPB's proposed work program document are given in the following sections. The questions address matters associated with items in the study's initial scope or raised during the course of committee discussions with TPB staff.

Nested Logit Models in Mode Choice

TPB asked what level of survey sampling would be needed to support a nested logit model choice formulation of the size and structure TPB proposes. TPB asked further whether the committee could suggest a different structure that might be less difficult to estimate and calibrate. The nested logit formulation is often an effective tool for travel demand estimation, and software exists for its estimation. Determining the specific nesting structure requires extensive empirical analysis.

While the estimation of nested logit models may require fewer observations of data, they often require higher-quality data in terms of information obtained per observation.[13] The committee suggests that TPB consider other currently available discrete choice formulations that might be more flexible in representing the behavioral characteristics of competition among transportation modes. Explanations of such formulations are available in the literature.[14] Matters of survey sampling are addressed below (page 14).

Alternatives to the Four-Step Model

In the work program TPB presented to the committee, TPB asked what direction the committee might suggest that TPB take with respect to the development of tour- and activity-based models. As we explained earlier in this letter, the committee anticipates that microsimulation, tour-, and activity-based models will be increasingly used within the coming decade for travel demand modeling at MPOs.

These alternative formulations are being adopted now in some MPOs' modeling practices.

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[12] See Metropolitan Washington Council of Governments memo file from Mike Freeman on Development and Recommendations of Hourly Distributions of Daily Traffic Volume, Aug. 27, 2002.

[13] Meyer, M. D., and E. J. Miller, *Urban Transportation Planning: A Decision-Oriented Approach* (2nd ed.), McGraw-Hill, 2001, p. 303. In addition, some practitioners have encountered problems with overspecification; the problem is explored by Bierlaire, M., T. Lotan, and P. Toint in On the Overspecification of Multinomial and Nested Logit Models due to Alternative Specific Constraints, *Transportation Science*, Vol. 31, No. 4, 1997, pp. 363–371.

[14] See, for example, Bhat, C. R., Random Utility-Based Discrete Choice Models for Travel Demand Analysis, in *Transportation Systems Planning: Methods and Applications* (K. G. Goulias, ed.), CRC Press, Boca Raton, Fla., 2003.

The work of these early adopters will benefit the profession as a whole as well as the stakeholders in those specific agencies' travel demand forecasting. The committee recommends that TPB actively monitor the early adopters' progress and appreciates TPB's efforts to learn more about such models.

We note that these new models can be formulated and estimated on the basis of TPB's existing survey data, although data collection with survey instruments designed to support such models can enhance the result. For example, collecting in-home activity information and using 2-day activity diaries may produce useful results. Agencies that have conducted such surveys—for example, the San Francisco Bay Area Metropolitan Transportation Commission—may be helpful sources of advice.

The committee recognizes that responsible agency officials must ensure that the agency's ability to produce forecasts suitable for decision making in the region is not compromised. However, it is important that TPB keep abreast of developments in new approaches to modeling and maintain the currency of the agency's practices.

Grain Size in Travel Modeling

In the scope of work presented to the committee at the start of the study and in its recent work program, TPB asked the committee to comment on the grain of travel analysis zones. TPB staff have commented in meetings with the committee that zone size is an issue particularly with regard to estimation of pedestrian and other nonmotorized travel and transit usage in areas of higher-density development.

Many people suggest that larger numbers of smaller zones—a finer-grained representation of the region—will produce better travel demand forecasts. However, as zone size is reduced, data requirements increase. Software and computing resources available to the agency often control the maximum number of zones that is practical for regional analysis.

In general, zone sizes should take into account how grain size will influence variables important to the policy questions the model is to address. Grain size should be fine enough to provide a robust basis for making decisions, but not so fine as to result in excessive data and computing costs.

That said, some practitioners suggest rules of thumb. For example, the number of zones actually used in designing a model is likely to be at least equal to the number of census tracts in the study area. The number should be sufficiently fewer than the practical maximum (e.g., considering data costs and computational resources) to allow for an expansion of the number of zones later for special studies and to subdivide zones to account for major land developments.

Local factors will affect the preferred grain size of the analysis zone structure. For example, how is access to transit handled in the models? How many paths between zones are loaded in each model run? What is the geographic basis for the zone system? Answers to such questions are important in this context. TPB staff might gain insights by reviewing the literature on the topic.[15]

Travel Surveys and Other Data for Travel Modeling

The scope of work presented to the committee at the start of the study called for commentary on travel survey and other data needed for future TPB model upgrades. In its work program document, TPB asked several questions concerning a proposed regional household travel survey. Overall, the committee commends TPB for its aggressive attention to maintaining the currency of its data.

<u>Trade-Offs of Increased Household Sample Size</u> TPB asked about factors to be considered in increasing its survey sample size from 5,000 to 10,000 or 15,000 households. Given the need for data to calibrate a mode choice model with several alternatives, it is probably necessary to think beyond random sampling of households in order to improve the efficiency of the survey.

<u>Sample Size for Model Development</u> TPB asked whether there is a "compelling need" to have a sample size greater than 10,000 households for model development. The committee recognizes that larger sample sizes will generally give statistically more precise estimates of important model parameters. Sample sizes generally may be determined by considering the statistical variation anticipated in the underlying population and the level of reliability needed to support robust decision making. The committee presumes TPB's situation is similar to that of other regions and on this basis finds it difficult to fault TPB's proposal to take a 15,000-household sample. Nevertheless, the committee encourages TPB first to identify the parameters with significant influence on policy decisions that are to be estimated from survey results and then to determine sample sizes necessary to yield reliable estimates of those parameters.

As we have commented in preceding sections, response rates are crucial.[16] The problem is to collect enough observations for households with (for example) transit trips to support reliable inference of causal relationships. The solution will likely depend less on the total number of households sampled than on how the survey is structured. The committee suggests that

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[15] For example, the following papers and reports may be helpful:
Khatib, Z., K.-T. Chang, and Y. Ou, Impacts of Analysis Zone Structures on Modeled Statewide Traffic, *Journal of Transportation Engineering*, Vol. 127, No. 1, Jan.–Feb. 2001, pp. 31–38.
You, J., Z. Nedovic-Budic, and T. J. Kim, A GIS-Based Traffic Analysis Zone Design: Technique, *Transportation Planning and Technology*, Vol. 21, 1997, pp. 45–68.
You, J., Z. Nedovic-Budic, and T. J. Kim, A GIS-Based Traffic Analysis Zone Design: Implementation and Evaluation, *Transportation Planning and Technology*, Vol. 21, 1997, pp. 69–91.
Wilbur Smith and Associates, *The Effect of Zone Size on Traffic Assignments*, Commonwealth Bureau of Roads, Melbourne, Australia, 1971.
Hanscom, E. W., and K. C. Sinha, *The Effects of Simplifying Traffic-Zone and Street-Network Systems on the Accuracy of Traffic Assignments in Small Urban Areas in Indiana*, Interim Report, No. FHWA/IN/JHRP-79/15, Purdue University, West Lafayette, Ind., 1979.
[16] Refer, for example, to *Special Report 277: Measuring Personal Travel and Goods Movement: A Review of the Bureau of Transportation Statistics' Surveys*, TRB, National Research Council, Washington, D.C., 2003. Low response rates can introduce systematic selectivity bias in the estimation of key parameters and bring about a waste of resources associated with simply increasing sample size in an attempt to reduce estimation errors.

stratified and choice-based sampling will be appropriate strategies for addressing this problem.

Sampling Households Outside Planning Area TPB asked whether there a “compelling need” to collect a minimum number of household samples for jurisdictions that are modeled but are beyond the TPB planning area. The committee sees no reason to collect household data from outside the planning area unless those households are anticipated to have unique and underrepresented characteristics that could have critical influence on travel demand projections.

Activity-Based Travel Diaries TPB asked whether there is a “compelling reason” to use activity-based travel diaries for future travel surveys and how the use of diaries would influence response rates and overall survey data quality. As explained previously, activity diaries are not needed as part of a survey to calibrate activity- and tour-based models. However, the activity-based travel diaries can provide useful information concerning in-home activities and joint activities pursued outside the home, which can enhance an activity-based model system.

Multiday Survey TPB asked about the value of a multiday survey, particularly with regard to survey response rate and data quality. An attractive feature of a multiday survey is the moderation of normal day-to-day variation in household travel activity. Reports in the literature suggest that a 2-day period may be optimal, and the committee observes that the marginal costs of gathering a second day are probably low. However, arguments might be made that a new survey should collect travel data on every day of the week, including weekends. The committee cannot offer a compelling reason for making decisions about such matters without additional information on survey costs and the plausible relationship of survey duration and variance in parameter estimates, but it notes that shifts in the patterns of travel by time of day and day of week may occur over the multiyear periods between major household travel surveys. TPB’s FY 2003 Unified Planning Work Program indicates that a sixth wave of data collection in the continuing longitudinal household travel survey is scheduled for spring 2004; the survey is intended to track and assess changes in travel behavior over time.

Random-Digit Dialing Sample Frame TPB asked about the value of continuing to use random-digit dialing (RDD) sample frames in light of declining response rates. As we have already commented, the committee agrees with TPB’s observation that declining response rates are a problem generally. We note also that a number of troublesome issues arise when household surveys rely on the initial recruitment call with RDD lists. For example, cell phones are an increasing proportion of telephone numbers, and the variety of ways cell phones are used pose problems for the RDD survey methodology. Increasing numbers of households are or will be on the “do not call” list or do not speak English as a primary language. Such trends are increasing the potential difficulties of recruiting travel survey respondents and avoiding sampling bias.[17]

[17] The National Research Council–appointed Committee to Review the Bureau of Transportation Statistics’ Survey Programs noted that survey methodologists generally are concerned about declining response rates and resulting bias in telephone survey results. For a variety of reasons, dial-up surveys are not likely to remain a

We nevertheless find the RDD sample frame to be a practical way of coupling household surveys with the computer-assisted telephone interview. The committee proposes that TPB explore recent applications of other survey design and recruitment methods. Some surveys, for example, have used mailing of introductory letters and other preparatory activities to improve response rates.

Global Positioning System Household Vehicle Add-On TPB asked about the costs and benefits of a Global Positioning System (GPS) household vehicle add-on subsample to the regional household survey. The committee has reservations about this technology and cannot recommend its use. However, the technology may record travel that is otherwise unreported or underreported and so may be justified as a small add-on as described in TPB's work program document. Reconciling GPS readings with travel diary and interview data may be very labor-intensive and yield relatively little information beyond what can be obtained by observing household vehicle odometer readings.

Year-Round Travel Survey TPB asked about the value of moving from a "typical season" to a year-round data collection strategy for future household surveys. The committee notes that year-round survey procedures will capture seasonal employment and the effects of school-year travel variation. Additional factoring will be required to convert such survey results into the typical-day format used in the traditional four-step model. In addition, year-round surveys require extra care in their design and execution to ensure that each subsample is representative and that the survey yields robust statistics.[18]

Concluding Observations

The committee has found TPB staff to be open in their discussion of the various matters we have addressed in this study. While many MPOs undertake to have a peer review of their modeling practices, these reviews are usually conducted within the confines of the agency by professionals selected by the agency's leadership. We commend TPB for requesting that the National Research Council appoint an independent TRB committee to conduct this review and for its responsiveness to the committee's several requests for additional information.

We appreciate this opportunity to assist TPB in dealing with the complex and sometimes controversial issues of travel demand modeling.

Yours very truly,

David J. Forkenbrock
Chair

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viable data-gathering technique in the long run, but replacement techniques are not yet adequately developed. See *Special Report 277*.

[18] For example, the American Community Survey (a U.S. Census Bureau activity; see http://www.census.gov/acs/www/) relies on annual waves of samples. While TPB's survey may be conducted over a shorter time period, the design issues (e.g., updating and data blending) could be similar.

Attachments

1. Committee Membership

David J. Forkenbrock (Chair), Director, Public Policy Center, and Professor, University of Iowa, Iowa City, holds appointments in Urban and Regional Planning and in Civil and Environmental Engineering. His research and teaching interests include analytic methods in planning and transportation policy and planning. He recently completed work as the principal investigator for National Cooperative Highway Research Program projects on Evaluation of Methods, Tools, and Techniques to Assess the Social and Economic Effects of Transportation Projects, and Effective Methods for Environmental Justice Assessment. He is a member of the College of Fellows, American Institute of Certified Planners, and a Lifetime National Associate of the National Academy of Sciences.

Chandra R. Bhat, Associate Professor, Department of Civil Engineering, University of Texas, Austin, is also the Associate Chairman of the Civil Engineering Department and the Fluor Centennial Teaching Fellow in Engineering. His research interests include land use and travel demand modeling, evaluation of the impact of transportation control measures on mobile emissions, activity pattern analysis, and use of nonmotorized transportation. He has authored or coauthored more than 40 papers on topics relating to travel demand forecasting published in peer-reviewed journals and has done work on improvements to travel modeling procedures for a number of MPOs, including Boston, Dallas–Fort Worth, Houston–Galveston, and Seattle. He chairs the TRB Committee on Passenger Travel Demand Forecasting.

William A. Davidson, Principal Consultant, PBConsult, San Francisco, California, directs the technical activities of the Systems Analysis Group. He has 31 years of experience in the field of travel demand model development and forecasting. He has developed complete travel demand model sets for many large metropolitan areas, including Los Angeles, Chicago, San Francisco, Houston, Cleveland, Las Vegas, Phoenix, St. Louis, Buffalo, Austin, and Dallas–Fort Worth. He is particularly known for his work in mode choice model development and has developed advanced-practice tour-based models in Houston and Columbus, Ohio. He worked for the Federal Transit Administration and the National Transit Institute to develop and teach a course on multimodal travel demand forecasting.

Ronald William Eash, Visiting Scholar, Transportation Center, Northwestern University, Evanston, Illinois, was a senior Technical Manager at the Chicago Area Transportation Study (CATS), the MPO for metropolitan Chicago, where he was responsible for the implementation of a regional travel forecasting model for northeastern Illinois. Features of this model included simulation of individual travel and mode choice decisions, incorporation of nonmotorized alternatives, and time-of-day traffic assignments for air quality conformity. He also developed the current CATS household trip generation model and has conducted numerous travel forecasting studies of transportation corridor alternatives.

Keith L. Killough, Principal, KLK Consulting, Los Angeles, California, has served on travel model improvement peer review panels in Los Angeles, Sacramento, Santa Cruz, San Diego, and Colorado Springs, and he is currently on the review panel for the federal

TRANSIMS project. He was the Manager of Planning and Development for the Los Angeles County Metropolitan Transportation Authority (MTA), which serves as transportation planner, coordinator, designer, builder, and operator for Los Angeles County. In this capacity, Mr. Killough was responsible for travel simulation modeling, geographic information systems, and strategic transportation planning and led the MTA Long-Range Plan updates in 1995 and 2001. He previously was Planning Manager at the Southern California Rapid Transit District and was responsible for implementation of the travel forecasting models used for the development of the Metro Red Line Project.

Debbie A. Niemeier, Professor, Civil and Environmental Engineering, University of California, Davis, is Chancellor's Fellow at UC Davis and Director of the UC Davis–Caltrans Air Quality Project, where she conducts research to assist the state and MPOs with speed correction factors, hot-spot modeling, and conformity. She has authored or coauthored more than 40 papers on transportation and air quality modeling published in peer-reviewed journals and is the author of the chapter "Mobile Source Emissions: An Overview of the Regulatory and Modeling Frameworks" in *Transportation Engineering Handbook: Planning Methods and Applications*. She is a licensed Professional Engineer. Prior to her tenure at UC Davis, she worked as an engineer for the Texas Department of Transportation and the City of San Marcos, Texas, and as a transportation project manager for T.Y. Lin International.

Mark L. Schlappi, Systems Analysis Program Manager, Maricopa Association of Governments, Arizona, is responsible for refining the MPO's forecasting models and producing travel forecasts for highways, transit, and bikeways. He was previously the transportation planner for Scottsdale, Arizona. He has worked on corridor improvement studies and goods movement studies, and he served on travel model peer-review panels for Las Vegas and Salt Lake City.

2. Statement of Task

This project will perform review of the state of the practice of travel demand modeling by the Transportation Planning Board (TPB) of the Metropolitan Washington Council of Governments. The review panel will provide guidance on:

1. The performance of the TPB's latest travel model (version 2) in forecasting regional travel;
2. The proposed process for merging the latest travel model outputs to produce mobile source emissions;
3. The TPB's proposed direction of future travel demand model upgrades;
4. Travel survey and other data needed to accomplish future model upgrades; and
5. The detail (grain) of travel analysis zones that should be developed for future upgrades.

Sponsors: Metropolitan Washington Council of Governments

3. Comparison of Period-Specific Link Volumes Projected by the Travel Model and Postprocessing Procedure

To gain greater insight into the degree to which TPB's postprocessing procedure hourly traffic volume estimates are consistent with the period-specific link volumes projected by the four-step model, the committee compared the two sets of estimates.

1. Using the travel demand link-volume estimates (provided by MWCOG in file AMPMOP051.ASC), we calculated the following for freeways and arterials:

$$\text{Daily volume}_{link} = \text{PM volume}_{link} + \text{AM volume}_{link} + \text{off-peak volume}_{link}$$

Percentage of daily volume in each peak period:[19]

$$\%\ \text{AM volume}_{link} = (\text{AM volume}_{link} / \text{daily volume}_{link}) * 100$$
$$\%\ \text{PM volume}_{link} = (\text{PM volume}_{link} / \text{daily volume}_{link}) * 100$$

2. We computed the equivalent percentages of daily volume in each period that would be estimated by using the postprocessing link profile method (e.g., from Table 4 in the postprocessing report[20]):

	AM Freeway	AM Arterial	PM Freeway	PM Arterial	Even Freeway	Even Arterial
AM period[21]	28.3%	31.0%	11.7%	12.0%	18.9%	20.4%
PM period[22]	13.9%	15.8%	27.3%	28.5%	19.5%	20.7%

3. We plotted histograms of the %AM and %PM found in Step 1 by facility type and peaking profile. These histograms (Figures 4-1 through 4-6) show the frequencies of the percentages of daily volumes falling in each period using the travel demand estimates. The vertical bold line on each histogram represents table results of Step 2, the percentage of daily volume that would be assigned to the peak period for each link on the basis of the postprocessing method. The numbers of links falling into each category are shown in Table 4-1.

[19] The same steps would be used for the off-peak period.
[20] Metropolitan Washington Council of Governments, *Description and Validation of the Version 2.1/TP+/MOBILE6 Emissions Post-Processor*, March 21, 2003.
[21] AM period: hours 7, 8, 9 (Table 4).
[22] PM period: hours 17, 18, 19 (Table 4).

PROFILE * FACCODE Cross-tabulation

		FACCODE						Total
		1	2	3	4	5	6	
PROFILE	1	728				114	204	1046
	2		1904	1073				2977
	3				1122			1122
	4	485				64	231	780
	5		2219	1608				3827
	6				2041			2041
	7	1034				299	248	1581
	8		2525	1312				3837
	9				977			977
Total		2247	6648	3993	4140	477	683	18188

Table 4-1 Number of links in the TPB network (FACCODE = 1 for freeways, 2 and 3 for arterials, 4 for collectors, 5 for expressways, and 6 for freeway ramps; profiles start at 1 in Table 4 of the postprocessor document, starting from the left).

Figure 4-1 Freeways—classified as AM link.

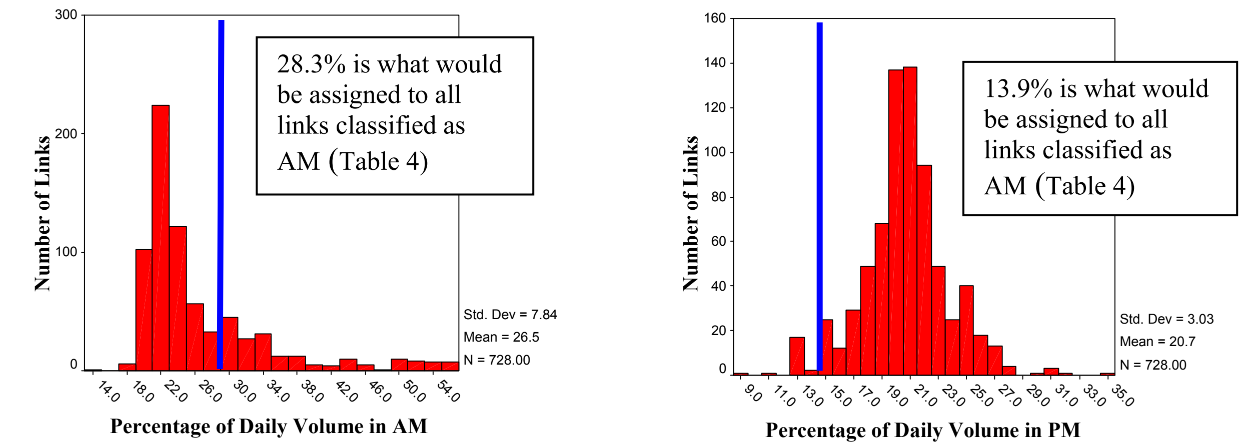


Figure 4-2 Freeways—classified as PM link.

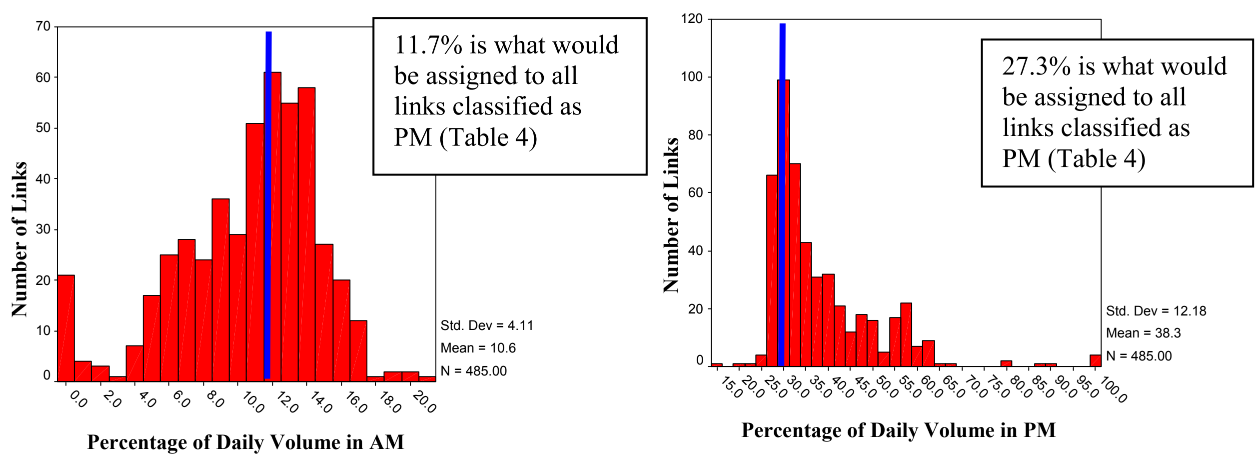


Figure 4-3 Freeways—classified as "even" link.

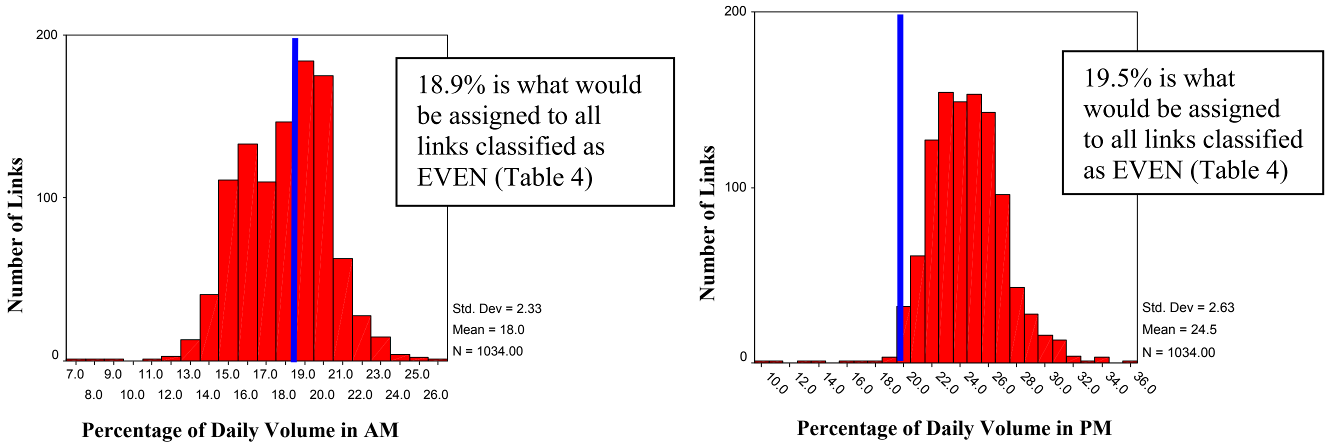


Figure 4-4 Major/minor arterials—classified as AM link.

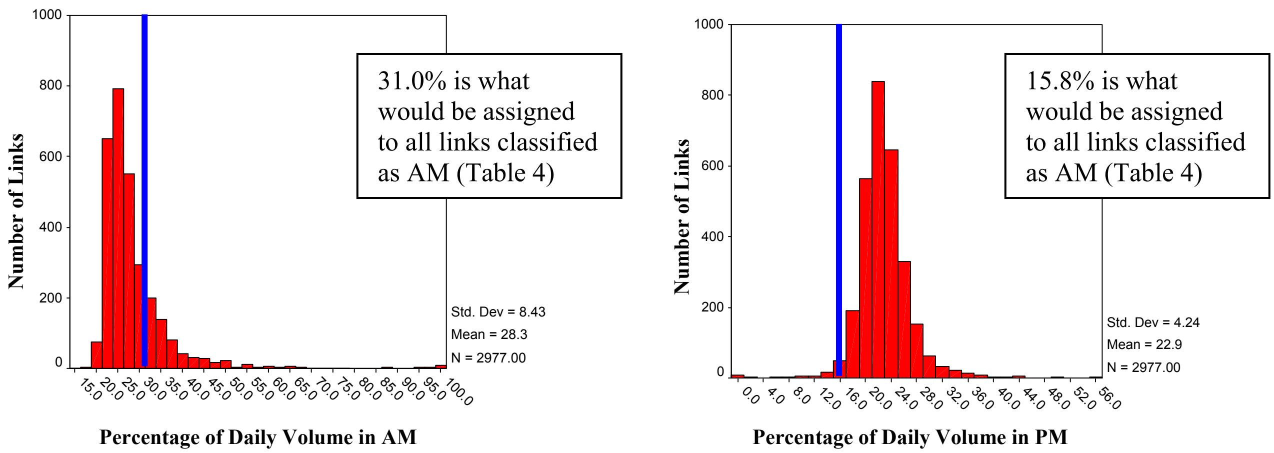


Figure 4-5 Major/minor arterials—classified as PM link.

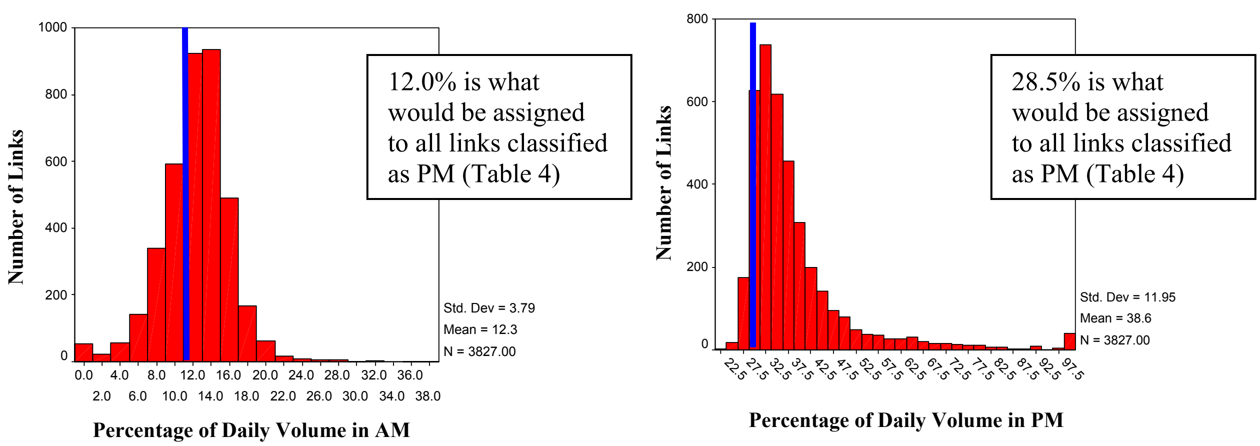
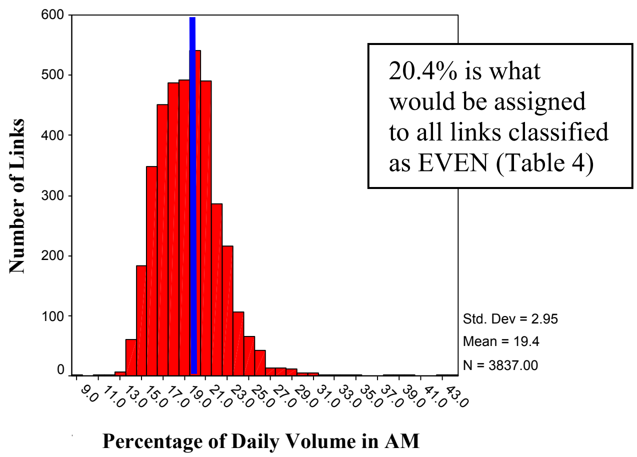
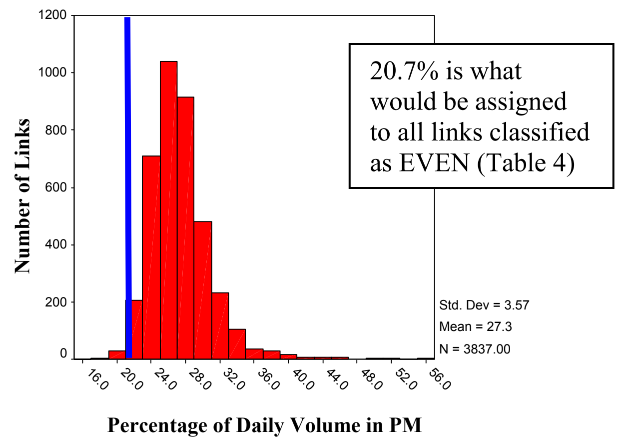


Figure 4-6 Major/minor arterials—classified as "even" link.





4. Work Program Document

Descriptions of Proposed Work Elements for the TPB Models Development Program to (a) Address Concerns Raised by the TRB Committee's First Letter Report and (b) Advance the State of Modeling Practice in the Metropolitan Washington Region, National Capital Region Transportation Planning Board, Washington, D.C.: Metropolitan Washington Council of Governments, December 24, 2003 (with appendices). Appendices will be available at http://trb.org/publications/reports/mwcogapril04app.pdf.

Descriptions of Proposed Work Elements for the TPB Models Development Program to

a) Address Concerns Raised by the TRB Committee's First Letter Report

b) Advance the State of Modeling Practice in the Metropolitan Washington Region

December 24, 2003

National Capital Region
Transportation Planning Board
Metropolitan Washington Council of Governments
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Proposed Work Elements for the TPB Models Development Program

Introduction

The TRB Review Committee indicated during the September 12, 2003 telephone conference with TPB staff that it would be very helpful to them to review proposed work program elements from the TPB staff as the panel prepares its second letter report. Dr. David Forkenbrock's letter of September 18, 2003 to Dr. Ronald Kirby further articulated the requested information as follows:

> *"Detailed descriptions of work-program elements that … (TPB) staff proposes to undertake to (a) address concerns raised by our first letter report and (b) advance the state of modeling practice in the Metropolitan Washington region. We very much hope that these descriptions will be fairly explicit and detailed and will include your anticipated schedule for undertaking the work. Additionally, we hope that these descriptions will include consideration of MWCOG's strategy for mobilizing resources in the region to accomplish the work-program elements."*

This document describes TPB staff's proposed outline of work elements in the models development program over the next four and a half years. This time frame extends from the second half of the current fiscal year (FY-2004) until the end of FY-2008. The work elements were developed in response to the TRB committee's recommendations in the first letter report, as well as to meet immediate TPB planning study objectives while continuing to implement incremental improvements to TPB modeling practices.

The TRB Committee's First Letter Report and TPB Staff Comments

On September 8, 2003 the TRB Committee released its first letter report reviewing the state of the practice of travel demand modeling by the TPB, and on the same date TPB staff released a set of comments on the TRB review developed during a brief comment period on an advance copy of the TRB report.

The TRB Committee noted in its first letter report that with regard to travel demand models:

- "…there are few universally accepted guidelines or standards of practice for these models or their application." (TRB first letter report, 2003, p. 2);
- "…any assessment of these models and their performance must rely primarily on professional experience and judgment."(p. 2)

- "The committee's findings are based upon its experience in regions with populations, institutional complexity, travel patterns, and air quality planning requirements comparable to those of the metropolitan Washington area." (p. 2)
- "The committee did not attempt to identify a vigorously defined agency peer group, but the committee's members agreed that TPB's practices may be appropriately compared with those of MPOs in, for example, Boston, Chicago, Dallas/Ft. Worth, Miami, Philadelphia, Phoenix, and other regions." (p. 7) ; and
- "It is not within either the scope of this study or the limitation of the time and resources available to the committee to conduct a thorough review of practices of MPOs around the country. In both this letter and its deliberations generally, the committee is relying primarily on members' experience and judgment." (p. 8)

The TPB staff comments of September 8, 2003 note that the TPB staff, like the TRB Committee, is handicapped by a lack of specific, up-to-date information on the practices currently being employed by a peer group of other MPOs. To address this issue, TPB staff has begun an effort to collect information from the MPOs suggested by the TPB Committee as well as five additional metropolitan areas, bringing the total to eleven: Atlanta, Boston, Chicago, Dallas/Ft. Worth, Detroit, Houston, Miami, Philadelphia, Phoenix, San Francisco, and Seattle. The results of this effort to date are provided as Appendix A to this document.

The information-gathering effort on the eleven peer MPOs has relied upon documentation that is readily available on web-sites, or from off-the-shelf materials available through the mail. While some very useful information has been obtained through this effort, as reported in Appendix A, there are some issues for which specific additional information requests will be needed, including direct conversations with modeling staff in the individual agencies. It is anticipated that such additional information requests will be made as the TPB models improvement work program proceeds over the coming year.

The TRB Committee organized its observations on the TPB travel models under eleven points presented in a section titled "Principle Observations." The TPB staff comments noted that there are five of these observations with which TPB staff is in agreement, and which do not require further attention. There are three observations by the TRB Committee which the TPB staff agrees offer potential for improvement in the modeling process that can be addressed by TPB staff:

> *3. Statistical measures indicate that base-year modeled link volumes do not match observed traffic counts and transit ridership as closely as committee members would typically expect in model validation.*
>
> *5. TPB's inclusion of the home-based shopping trip (HBS) category in trip generation is commendable. Combining business and commercial trips in the non-home-based trip (NHB) category is not advisable.*
>
> *6. The use of fixed bus speeds in TPB networks may misstate the influence of transit in estimates of future trip distribution and mode choice.*

Finally, there are three observations by the TRB Committee which the TPB staff believes require further consideration and discussion between the TRB Committee, TPB staff and other interested parties:

> *7. TPB's extensive use 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.*
>
> *8. TPB's feedback of highway and transit times to trip distribution bypasses mode choice and is not typical of good modeling practice in regions with significant transit services and ridership.*
>
> *10. The TPB's procedure for estimating hourly traffic volumes and speeds—aggregation of peak-and-off-peak period traffic assignments to a 24-hour total that is then redistributed to hourly period—is questionable, because the final emission estimates are not strictly based upon assigned peak and off-peak link volumes and speeds. Testing will be needed to determine the procedure's effects on emissions estimates.*

Each of the above six observations by the TRB Committee is addressed in turn in the work elements proposed for the TPB models development program outlined in this document. TPB staff already has developed some additional information and conducted some sensitivity tests to address each of these observations. Additional research on practices of other MPOs is expected to suggest further alternative methods which can be tested and evaluated as the TPB work program proceeds over the coming year.

The TPB Models Development Program

TPB staff has historically envisioned the models development program as a series of five parallel 'tracks' upon which the travel forecasting methods would advance over time. Operating concurrently, the following tracks provide useful context for staging modeling improvements:

- **Track 1 – Application**: Improvement of the currently adopted model set to produce adequate forecasts while enhanced models are in development.

- **Track 2 – Methods Development**: The incorporation of advanced practice in travel demand modeling that can be made operational in the next few years.

- **Track 3 – Research**: Keeping abreast of research developments in the areas of travel modeling, surveying, data (GIS) maintenance practices and integration, and simulation.

- **Track 4 – Data Collection**: The implementation of data collection designed to meet the needs of tracks 1, 2, and 3.

- **Track 5 – Maintenance**: Documentation of the current modeling applications, including recent improvements to software and data requirements. This track also includes an ongoing effort to train staff in the use of current and updated application procedures.

Activities aimed at improving the current application method now known as the Version 2.1/TP+, Release C model and the emissions post-processor constitute the Application track (Track 1). These would occur most intensively in the near-term and would include sensitivity tests and validation checks of the model. These types of activities could potentially lead to parameter adjustments and/or structural modifications to the application model based on an assessment of the various model checks.

The development of an enhanced model in the longer term, i.e., either a more advanced four-step travel model, or possibly a 'successor' application to the present four-step process is the focus of the Methods Development track (Track 2). The phasing of activities in this track is heavily dependent upon the selected model specification and data collection schedule (Track 4) required to support the enhanced model.

Activities associated with an ongoing review of emerging travel modeling approaches that could inform long-term model improvements constitutes the Research track (Track 3). These activities take several forms, including participation in modeling conferences, reviews of the literature, and information gathering from relevant websites.

The Data Collection track (Track 4) requires resources which are equal to or greater than those expended in models development. Several travel surveys have been conducted during the past ten years which supported the models development work element. These have included a household travel survey (1994), continuing panel surveys during the past five years, an external auto survey (1994), an internal truck survey (1996), external truck surveys (1996 and 2003), Metrorail ridership surveys (1994 and 2002), a regional on-board bus survey (2000), and the 2000 Census Journey to Work. Given the vintages of some of these surveys, it is envisioned that a new round will be needed during the balance of this decade, costing several million dollars in total when all pre-survey and post-processing elements are included. Additional funding will be required to conduct all of the desired survey activities. Increases in federal planning funds under the reauthorization of the federal transportation program and state SPR funding are considered the most likely sources for this funding. Should the TPB conclude that a departure from the traditional four-step travel demand modeling practice should be undertaken in Track 2, there would be substantial implications for the structuring of surveys, including associated costs and staging.

The Maintenance track (Track 5) is another ongoing work activity that formalizes technical documentation and training with respect to incremental updates and modifications to the travel modeling procedures. The objective is to provide up-to-date training and dissemination of materials for the current application of the travel demand models in any given year.

The proposed multi-year program in models development below addresses these five tracks. As part of the application track, TPB staff proposes to investigate issues raised by the TRB Committee in its first letter report. The activities are mapped in a series of timelines shown in Figure 1.

Figure 1 Multi-year staging of models development activities

	FY-04		FY-2005				FY-2006				FY-2007				FY-2008			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1. Application Track																		
A. Highway & Transit Validation																		
1) Network enhancements to better reflect actual conditions	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
2) Improve transit modeling: Short term	■	■	■	■														
- Transit assignment: Migrate transit sub-models to TP+																		
- Make bus speeds a function of link delay																		
- Consistent treatment of travel time weights through model																		
3) Improve transit modeling: Longer term		■	■	■	■	■	■	■	■	■								
- Develop nested logit mode choice model																		
- Update procedures for calculation of bus & rail fare matrices																		
- Ability to constrain demand at park-and-ride lots																		
- Inclusion of PNR parking costs in mode choice process																		
- Revise method used to code auto-access to transit links																		
4) Testing of SUMMIT model for use as a diagnostic tool	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
B. Business and Commercial Trips																		
1) Design models, counts, surveys	■	■	■	■	■	■												
2) Implement counts, surveys							■	■	■	■	■	■						
3) Calibrate models													■	■	■	■		
4) Refine medium- and heavy-duty truck models													■	■	■	■		
C. Bus Speeds in TPB Networks (See Item 1.A.2)	■	■	■	■	■	■	■	■	■	■								
D. Minimize the use of adjustment factors in the model																		
1) Documentation of existing factors	■	■																
2) Trip generation	■	■	■	■	■	■	■	■	■	■	■	■	■	■				
- Develop workers-in household model																		
- Develop one or more special generator models																		
3) Trip distribution	■	■	■	■	■	■	■	■	■	■								
- Short-term changes to gravity model																		
- Long term: Move to destination choice model																		
4) Mode choice	■	■	■	■	■	■	■	■	■	■								
- Test model w/o adjustment factors																		
- Move to nested logit mode choice model (See item above)																		
E. Speed feedback																		
1) Test: Include mode choice in each iteration of speed feedback	■	■	■	■	■													
2) Test: Include post-processor in speed feedback process	■	■	■	■	■													
F. Emissions post-processor																		
1) Sensitivity tests	■	■	■	■	■													
2) Update code	■	■	■	■	■													
G. Incremental refinement of Version 2.1 C model																		
1) Version 2.1 D *	■	■	■	■														
2) Version 2.1 E					■	■	■	■										
3) Version 2.1 F									■	■	■	■						
4) Version 2.1 G													■	■	■	■		
5) Version 2.1 H																	■	■
2. Methods Development Track																		
A. Continue development of airport choice/ground access model			■	■	■	■	■	■	■	■	■	■	■	■				
B. Develop tour-based and/or activity-based travel model			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
C. Grain of analysis zones			■	■	■	■	■	■	■	■								
D. Data, software, hardware, and training requirements	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
3. Research Track	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
4. Data Collection Track **																		
A. Household travel survey																		
1) Survey design	■	■	■	■														
2) Data collection					■	■	■	■										
3) Processing and cleaning									■	■	■	■	■	■	■	■		
4) Final report																	■	■
B. Auto external survey																		
1) Data collection							■	■	■	■								
2) Processing, cleaning, and final report											■	■	■	■				
C. Analysis of census data	■	■	■	■	■	■												
D. Regional transportation clearinghouse	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
5. Maintenance Track	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Notes:

* Version 2.1D model includes updates from Intercounty Connector (ICC) study and TRB-recommended improvements that can be done in short term.

** Level of survey data collection is a function of future federal funding levels

Application (Track 1)

In formulating Application track work elements TPB staff has considered the observations made in the first letter report and has shared the concerns with stakeholders in the region. One key stakeholder, WMATA, has requested that TPB consider additional improvements relating to transit modeling. Consequently, the Application track elements reflect a combination of near term improvements occurring over the next four and a half years, taking into account both TRB and WMATA recommendations regarding model requirements. The planned improvements will lead to incrementally improved model versions (2.1D, 2.1E, etc.) that are expected to be brought into production at the end of each *calendar* year. While TPB staff seeks to consider all recommendations for improving technical methods on a yearly basis, staff maintains that each new version must undergo internal review to assess its performance for forecasting.

The essential elements of the Application track relate to highway and transit modeling validation (with an emphasis on improving transit models), business and commercial trip modeling improvements, minimizing model adjustments, considering structural modifications to modeled feedback linkages, and testing the mobile emissions post-processor. A more specific description of work elements follows below.

1.A Highway and Transit Validation

The TRB Committee observed that "modeled link volumes do not match observed traffic counts and transit ridership as closely as committee members would typically expect in model validation." Ongoing TPB staff efforts are aimed at achieving improvements in these matches. A prime example of such improvements are model refinements resulting from local project planning work in the ongoing Inter-County Connector (ICC) study in Maryland, as described in Appendix B. TPB staff has been working with local consultants on a number of topics to improve the model performance in the study subarea. The study team has investigated, for example, the use of refined free-flow speed and capacity values, a refinement of the zonal area type assignments, adjusted volume-delay functions for certain facility types, and improvements relating to network coding. The activities have not only resulted in an improved performance within the subarea, but have also had beneficial effects in the model performance in neighboring counties. TPB staff feels that the regional model can take advantage of the lessons learned from this project planning work, and that similar refinements can be made through collaborative efforts with local consultants working on other project planning studies in the region.

Element 1.A.1 will focus on implementing network coding refinements, such as those considered in the ICC study area, to other areas in the regional network system. Elements 1.A.2 and 1.A.3 indicate that transit modeling improvements will be implemented on both a short-term basis, including improvements the TPB staff feels can be addressed immediately to serve current planning needs, and a longer-term basis, where more advanced techniques will be implemented. The short term improvements will include the development of pre-existing transit sub-models, linking highway network speeds to transit speeds, and reviewing in-vehicle and out-of-vehicle weighting used in the development of transit paths. In the short term, two models, a sub-mode split model which estimates the shares of rail-related and bus-only transit trips, and a mode-ofarrival model which estimates the shares of access modes at Metrorail stations, will be migrated to the TP+ platform. These models will be estimated using information contained in the 1994 HTS and the 1994 Metrorail Survey. The longer-term improvements will focus on the development of a nested logit model for the region, and supporting sub-tasks, including enhancing the development of transit fares, improving the representation of PNR lot-to-zone connections, and considering the PNR lot supply to moderate auto-access demand.

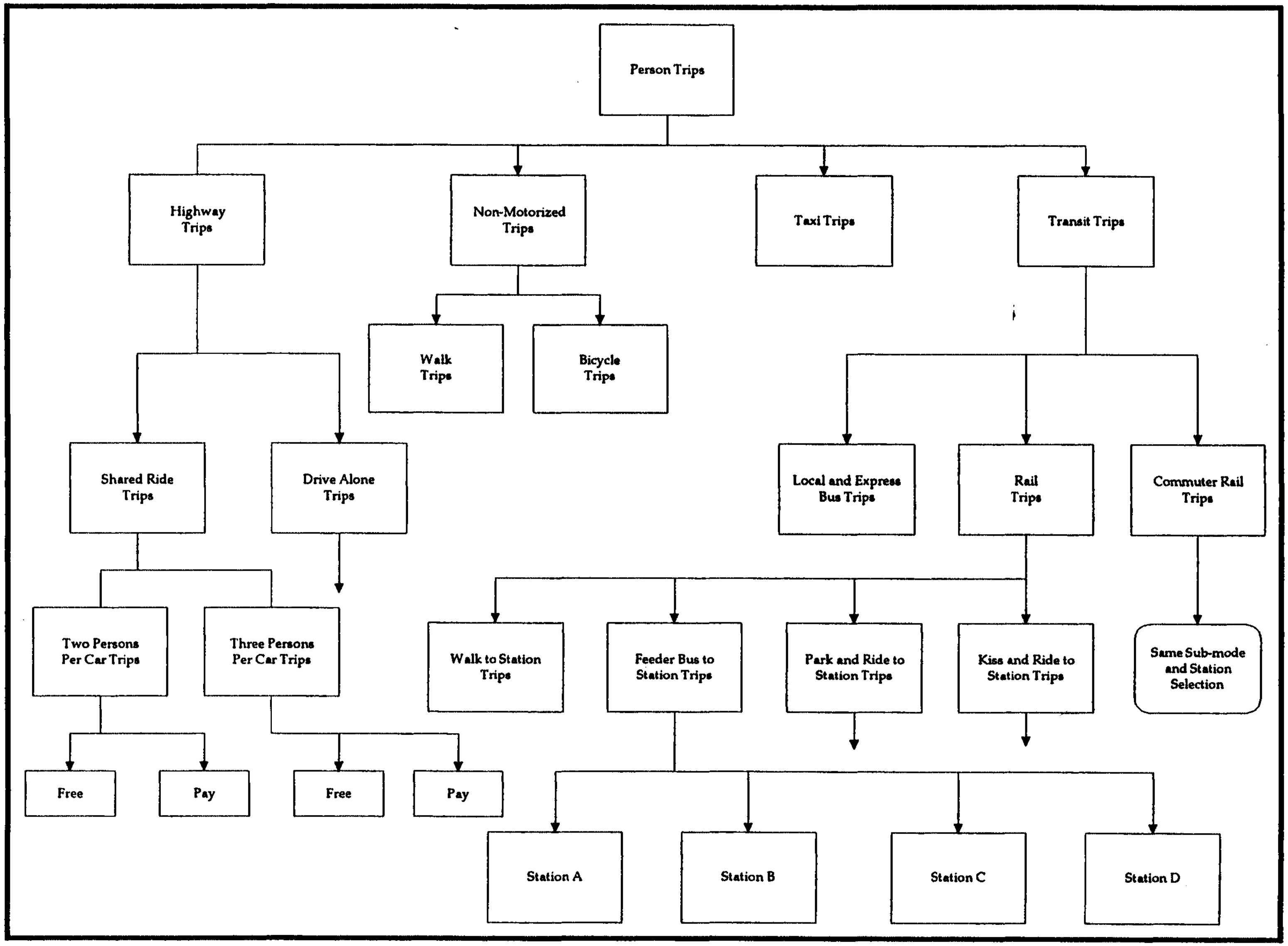
A conceptual diagram of a potential nested logit mode choice model is shown in Figure 2. This structure was the focus of models development for the Dulles Corridor Study several years ago. In that effort, the model coefficients were not developed using statistical packages, but were instead developed using information from other studies. Further, available survey information contained only limited data on the mode choice selection with respect to station and access mode, and the statistical package ALOGIT was found to be inadequate to handle the size nest shown in Figure 2. TPB staff would like the TRB Committee to comment on the level of survey sampling that would be needed to accommodate this model structure during estimation / calibration. Alternatively, the TRB Committee might suggest a different structure that would be less difficult to estimate / calibrate.

TPB staff will also investigate utilizing a newly developed transit analysis package developed by FTA, the SUMMIT program (element 1.A.4). The package is currently in development as a potential tool for assessing transit benefits associated with proposed transit improvements. SUMMIT also holds promise as a quality control device for transit network coding. It may also be used to identify problems associated with other modeling steps beyond mode choice. TPB will work to integrate SUMMIT with the regional mode choice model.

The model validation effort will be undertaken to assess the accuracy of highway and transit simulations using the most recent sources of observed data. It is anticipated that highway ground counts corresponding to calendar year 2002 will be available to check daily screenline crossings and regional VMT. Hourly traffic data from Maryland databases will also be obtained to assess highway performance by time period. Transit validation checks will be accomplished using the 2000 Regional Bus On-Board Survey and the 2002 Metrorail On-Board Survey. (The bus on-board survey incorporates most, but not all, of the major operators in the Washington, D.C. region.)

The TRB Committee has commented in the first letter report that, “ The goodness of fit for transit passenger volumes is normally conducted in more detail than systemwide averages and cordon crossings. Additional comparisons by subarea, district interchange, corridor, and rail line and station are typically performed….” TPB staff has historically examined Metrorail assignments in detail after the application of the transit sub models. In contrast, bus trip patterns have not received as much scrutiny beyond a review at jurisdiction levels, due to limitations in local bus data. The 2000 regional on-board bus survey is the first of its kind since 1972. It is hoped that this will allow a more detailed comparison of bus trip patterns produced in the modeling process. A more detailed discussion of the proposed effort in highway and transit validation is provided in Appendix B.

Figure 2
Structure of the Regional Model Mode Choice Model



1.B Business and Commercial Trips

As is the case in many metropolitan areas, the structure of the commercial truck models employed by TPB were developed many years ago, and have been informed by the results of internal and external truck surveys periodically. Most recently, an external truck survey was undertaken for the region in spring and summer 2003, and the information is being tabulated this fall. Post-processing including logic checking, geocoding, and factoring is scheduled to be undertaken during the balance of FY-2004. The last internal truck survey was conducted in 1996 and did not produce a useable dataset for updating the truck models.

The TRB Committee noted that TPB subsumes the estimation of light truck travel in the NHB trip purpose and does not recommend this approach. TPB has responded that until a better means of estimating light truck trips can be developed, there is no choice but to use the NHB trip purpose as a placeholder.

At the urging of the TRB Committee, TPB staff has begun to investigate truck modeling practice in other metropolitan areas. Staff is reviewing the approach adopted in 2002 by the Baltimore Metropolitan Council and has obtained a complete set of model documentation. A description of the Baltimore commercial vehicle model development, together with a summary of truck model development, is presented in Appendix C. This effort to develop a full set of truck models using a synthetic travel pattern derived from classification counts offers promise, given the increased difficulty with internal truck surveys.

For the balance of FY-2004 staff plans to complete its review of modeling practice in this area and develop a design for updating models, including the development of a set of classification counts which could be used to develop a synthetic "survey" trip pattern, in conjunction with the recently completed external truck survey (element 1.B.1). During FY-2006, as part of travel monitoring work program activities, a series of classification counts should be conducted (element 1.B.2). The budget for this effort will need to be funded from sources outside the planning funds in the UPWP, possibly tapping state SPR funding in D.C., Maryland, and Virginia. Assuming completion of the counting program during FY-2006, the development of synthetic trip patterns would commence in FY-2007 with model calibration to follow (element 1.B.3). It is envisioned that the models development work program would provide the resources needed for the design in FY-2004 and the calibration phase in FY-2007/2008 (element 1.B.4). The product would be models providing separate forecasts of light, medium, and heavy trucks.

1.C Bus Speeds in TPB Networks

The TRB Committee has observed, "The use of fixed bus speeds in TPB networks may misstate the influence of transit estimates in future trip distribution and mode choice." TPB staff has begun investigating how other MPO's relate bus speeds to congested highway link speeds. TPB staff will work with WMATA and state and local transit agencies to identify a method for representing bus speeds in future years (including expanded services and running way improvements), and integrate the method into the Version 2.1 model. Documentation of the selected method and related modeling changes will be produced during the second half of FY-2004.

1.D Minimize the Use of Adjustment Factors

The TRB Committee has commented that "TPB's extensive use 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." TPB staff disagrees with the statement that the fundamental behavioral logic is undermined, and has undertaken a review of practice in several major MPOs. TPB staff plans to more fully document the use of these factors (element 1.D.1) in the modeling process, which staff feels reflect, not undermine, the behavioral patterns that cannot be adequately portrayed by a travel demand model structured around time and cost variables. TPB staff maintains that the number of trip interchanges employing adjustment factors is not extensive in the Version 2.1C model, but will undertake a sensitivity analysis to see if reductions could be made (elements 1.D.2 through 1.D.4). Documentation of these activities will be completed during the balance of FY2004. A detailed discussion of adjustment factors currently used in the Version 2.1/C model is provided in Appendix D.

1.E Speed Feedback

The TRB Committee has commented that "TPB's feedback of highway and transit times to trip distribution bypasses mode choice and is not typical of good modeling practice in regions with significant transit services and ridership." In September 8, 2003 comments on the TRB Committee's first letter report, TPB staff disagreed with the TRB Committee on this point, and referenced the one-year process of review and sensitivity analysis which provided the basis and rationale for the current TPB approach.

TPB staff was mindful in developing its "speed feedback" process of section 93.122(b)(1)(v) in the August 15, 1997 EPA conformity rule amendments which addresses this issue:

> "Zone to zone travel impedances used to distribute trips between origin and destination pairs must be in reasonable agreement (emphasis added) with the travel times that are estimated from final assigned traffic volumes. Where use of transit currently is anticipated to be a significant factor in satisfying transportation demand, these times should also be used in modeling mode splits"

It is important to note that while this section of the conformity rule requires "reasonable agreement" between travel times used in the various steps of the travel modeling process, it does not prescribe any particular technique for implementing "speed feedback". The appropriate test for whether or not this requirement is being met is to compare the travel times that are estimated from the final assigned traffic volumes with the travel times that are used in the trip distribution and mode split steps conducted earlier in the sequential trip distribution/mode choice/traffic assignment procedure.

TPB staff has examined the results of some sample applications of the TPB's speedback procedure to assess the level of agreement achieved between the various steps in the modeling process. This examination has focused in particular on running additional iterations of the modeling process to assess whether there are any significant differences between the speeds associated with final assigned traffic volumes for successive iterations of the modeling process. The results of this examination are reported in Appendix E to this document.

The standard application of the Version 2.1C model set involves four sequential iterations referred to as pump-prime, base, first, and second iterations. The pump-prime iteration develops an initial set of highway skims (peak and off-peak). The outputs of this pump-prime iteration are then used as inputs to the base iteration that includes running all of the sequential steps of the modeling process, including mode choice. An appropriate test for "reasonable agreement" of speeds through the process is to compare the outputs of the pump-prime iteration, which are used in the base iteration as inputs to both distribution and mode split, with the outputs of the "second iteration." If reasonable agreement is not achieved, the outputs of the second iteration can be used as inputs to a new base iteration which will rerun both distribution and mode split.

The results of the examination reported in Appendix E suggest that if the inputs to the pump-prime iteration are based on recent modeling results for the year being analyzed, the outputs of the pump-prime (which serve as inputs to the base) compare well with the outputs of the second iteration. If the inputs to the pump-prime iteration are based on modeling results from a much earlier year than the year being analyzed (e.g., using 1994 results as input to pump-prime for a 2025 analysis) the agreement between the inputs to the base and the outputs of the second iteration is not as good. In this latter case, using the output of the second iteration as input to a new base iteration (including distribution, mode split, and assignment) and then conducting "additional" first and second iterations appears to provide much better agreement between the inputs to the base iteration and the outputs of the second iteration.

In summary, it appears that good agreement between the speeds in distribution, mode choice, and final traffic assignment in the current TPB Version 2.1C procedure can be assured either by choosing pump-prime input speeds from earlier modeling results for a year close to the year being analyzed, or by using pump-prime input speeds developed from earlier years and running additional iterations.

TPB staff plans to review the speed feedback practices employed in several other large metropolitan areas, and to conduct other sensitivity analyses with the current Version 2.1 C procedure, including attempting to cycle back through mode split with each iteration and testing alternative forms of the impedance function for trip distribution. This activity will be completed during FY2004, including documentation of the analysis and a recommendation to implement a change to the modeling process if significantly improved procedures are identified.

1.F. Emissions Post-processor

The TRB Committee has observed that "the TPB's procedure for estimating hourly traffic volumes and speeds – is questionable ---- Testing will be needed to determine the procedure's effects on emissions estimates." The TRB Committee's first letter report did not provide any specific suggestions for sensitivity tests to be conducted on the TPB's emissions estimation procedures. However, in its detailed comments the TRB Committee seemed particularly concerned about the TPB procedure for establishing volumes, speeds and emissions estimates for links and time periods which are found to be over capacity after the first set of hourly distributions is developed: "the impact of peak-spreading procedures on emissions is very difficult to predict for links that are over-capacity for extended periods."

For links and time periods which are over capacity after the first set of hourly distributions is developed, the link volume/capacity ratio exceeds 1.0 at level of service E, and the link is operating under unstable flow conditions. A procedure is needed to represent these unstable flow conditions for the purposes of emissions calculations. TPB staff has conducted some sensitivity tests employing alternative procedures for addressing over-capacity links and time periods for freeways. The results of these tests are shown in Table 1 for the years 2005 and 2015 for the Washington Metropolitan Statistical Area.

The "base" example in Table 1 represents the TPB's current procedures in which volumes are set at freeway capacity (as determined in look-up tables for different freeway types), and the speed is set using standard speed flow functions corresponding to the maximum of the pre - and post-spread hourly volumes.

The "Test 1" example in Table 1 reduces volumes for all over-capacity links and time periods by 22 percent of the freeway capacity used in the base case to reflect the fact that recurring congestion may reduce flow rates below freeway capacity. The speed in this test is set to correspond to the post-spread volume reflecting congested conditions.

The "Test 2" example in Table 1 reduces volumes for all over-capacity links and time periods to match corresponding flow rates observed in the Skycomp aerial freeway monitoring report for the Washington region. The speed is set to correspond to the post-spread volume under congested conditions.

The "Test 3" example sets the volume to the appropriate freeway capacity as in the base case, but then sets the speed to correspond to the post-spread hourly volume rather than to the maximum of the pre-and post-spread volumes as used in the base case.

In the sensitivity tests reported in Table 1, VOC and NOx emissions generally move in opposite directions as different procedures are employed: VOC emissions decrease from left to right across the table, while NOx emissions increase. This is due to the interplay between the shapes of the VOC and NOx curves, and the differences between the procedures with regard to setting the final volumes and speeds for over-capacity links and time periods. The absolute differences in the emissions estimates in these tests are less than one percent of the base case estimates except for Test 1, where the reductions in NOx estimates were 1.3 and 1.2 percent of the base

Table 1 Emissions Post-Processor Sensitivity Analysis

2005 MSA Summary

		Test 1	Base	Test 2	Test 3
		Freeway capacity reduced by 22%; Freeway speed based on 'standard' speed-flow function using the post-spread hourly volume.	*Freeway capacity unadjusted; speed based on 'standard' speed-flow function using the maximum pre-/post- spread hourly volume.*	*For V/C > 1.0 volume adjusted to Skycomp-estimated flow rate. Freeway speed based on 'standard' speed-flow function using the post-spread hourly volume.*	*Freeway capacity unadjusted; Freeway speed based on 'standard' speed-flow function using the post-spread hourly volume.*
Freeways Only	VMT	50,022,000	50,022,000	50,022,000	50,022,000
	Speed (mph)	55.6	57.2	57.9	58.7
	Diff. WRT Base	*-1.6*	*N/A*	*0.7*	*1.5*
	VOC (tons)	13.2	13.2	13.1	12.9
	Diff. WRT Base	*0.0*	*N/A*	*-0.1*	*-0.3*
	NOx (tons)	87.6	90.3	90.8	91.2
	Diff. WRT Base	*-2.7*	*N/A*	*0.5*	*0.9*
All Facilities	VMT	126,454,000	126,454,000	126,454,000	126,454,000
	Speed (mph)	38.7	39.3	39.6	40.0
	Diff. WRT Base	*-0.6*	*N/A*	*0.3*	*0.7*
	VOC (tons)	46.8	46.8	46.7	46.5
	Diff. WRT Base	*0.0*	*N/A*	*-0.1*	*-0.3*
	NOx (tons)	199.4	202.1	202.6	203.0
	Diff. WRT Base	*-2.7*	*N/A*	*0.5*	*0.9*

2015 MSA Summary

		Test 1	Base	Test 2	Test 3
		Freeway capacity reduced by 22%; Freeway speed based on 'standard' speed-flow function using the post-spread hourly volume.	*Freeway capacity unadjusted; speed based on 'standard' speed-flow function using the maximum pre-/post- spread hourly volume.*	*For V/C > 1.0 volume adjusted to Skycomp-estimated flow rate. Freeway speed based on 'standard' speed-flow function using the post-spread hourly volume.*	*Freeway capacity unadjusted; Freeway speed based on 'standard' speed-flow function using the post-spread hourly volume.*
Freeways Only	VMT	59,737,000	59,737,000	59,737,000	59,737,000
	Speed (mph)	54.9	56.5	57.2	58.1
	Diff. WRT Base	*-1.6*	*N/A*	*0.7*	*1.6*
	VOC (tons)	7.0	7.0	7.0	6.8
	Diff. WRT Base	*0.0*	*N/A*	*0.0*	*-0.2*
	NOx (tons)	28.1	28.9	29.1	29.2
	Diff. WRT Base	*-0.8*	*N/A*	*0.2*	*0.3*
All Facilities	VMT	146,521,000	146,521,000	146,521,000	146,521,000
	Speed (mph)	38.4	39.1	39.4	39.8
	Diff. WRT Base	*-0.7*	*N/A*	*0.3*	*0.7*
	VOC (tons)	23.3	23.3	23.3	23.1
	Diff. WRT Base	*0.0*	*N/A*	*0.0*	*-0.2*
	NOx (tons)	64.8	65.6	65.8	65.9
	Diff. WRT Base	*-0.8*	*N/A*	*0.2*	*0.3*

case estimates for 2005 and 2015 respectively. Since running emissions represent less than half of total mobile emissions for VOC in both 2005 and 2015, and about 86 and 83 percent for NOx for 2005 and 2015 respectively, these tests generally show relatively small changes in mobile emissions estimates in all of the cases.

In a conformity determination approved by the TPB on December 17, 2003 mobile emissions estimates for milestone years 2005, 2015, 2025, and 2030 were significantly below mobile emissions budgets recently found to be adequate by EPA. The analyses supporting both the mobile emissions estimates for milestone years and the mobile budgets were conducted using the current Version 2.1 C travel model and post-processing procedures referenced in this document, in conjunction with EPA's MOBILE6 emissions model. The emissions budgets and estimates for 2005 and 2015 were as follows (in tons per day):

	2005		**2015**	
	VOC	**NOx**	**VOC**	**NOx**
Budgets	98.1	237.4	98.1	237.4
Estimates	97.4	234.7	48.3	79.3
Budget Adherence Margin	**0.7**	**2.7**	**49.8**	**158.1**

Additional emissions reductions in 2005 of 4.0 tons per day of VOC and 8.3 tons per day of NOx were documented based on off-line estimates of the benefits associated with transportation emissions reduction measures, bringing the total adherence margins for 2005 to 4.7 tons per day for VOC and 11.0 tons per day for NOx. The changes in mobile emissions estimates for 2005 and 2015 shown in the sensitivity tests in Table 1 that represent increases in emissions are quite small relative to the adherence margins documented in the TPB's December 17, 2003 conformity determination.

Having evaluated the procedures and results shown in Table 1, TPB staff believes that the Test 2 method may be more conceptually appealing than the base case method, and is considering incorporating this method into future production versions of the post-processor. TPB staff is also planning to conduct same comparisons between the time-of-day distributions resulting from the post-processor and distributions observed from permanent count stations located throughout the Washington metropolitan area. TPB staff plans to assess whether the post-processing methodology might be useful in providing improved time-of-day distributions for traffic modeling and analysis, in addition to being used for estimation of mobile emissions as is the case in currently adopted TPB procedures.

TPB staff plans to seek information on emissions estimation procedures employed in other metropolitan areas over the coming year, and to conduct additional sensitivity tests as appropriate. If significantly improved procedures are identified, they will be incorporated into future updates to the TPB's adopted procedures.

1.G Incremental Refinements to the Version 2.1C Model

This is a global activity to integrate the latest refinements emerging from the ongoing program, as these can be made ready for production modeling (i.e., air quality conformity of the TIP and Plan, and project planning studies). As indicated in Figure 1, a new label (Version 2.1D, 2.1E, etc.) would be affixed to the production model as these refinements are incorporated into the regional modeling process. While the timeline suggests an annual update, the update might occur at irregular intervals, as warranted by the refinements.

Methods Development (Track 2)

The activities in the methods development track are associated with the development of a 'next generation' of travel forecasting procedures using the current state of the art in modeling, including improvements to the existing four-step model or the implementation of more advanced approaches such as tour-based models. There are several areas where the current four-step approach possibly could be enhanced. These include the implementation of an airport ground access model, a shift to tour-based or activity-based models, and the development of a more detailed zone structure.

2.A Continue Airport Ground Access Model Development

The Washington region has three major airports: Dulles International, Baltimore-Washington International, and Ronald Reagan Washington National. The existence of three airports poses a complex situation in attempting to forecast airport ground access by mode. Fortunately, there is an ongoing program to collect ground access travel data at approximately two-year intervals. Staff activities during FY-2004 include the review of these data and investigation of ground access modeling practices in other metropolitan areas. It is envisioned that development of a model specification and calibration file could be undertaken in FY-2005 with the goal of implementing a production model during FY-2006. A more detailed discussion of the proposed effort in airport ground access model development is provided in Appendix F.

2.B Tour-based and Activity-based Models

Two emerging trends in regional travel forecasting models are tour-based models and activity-based models. Nearly all activity-based models include tour modeling, but a tour-based model does not necessarily include activity modeling. A traditional household travel survey, like the 1994 COG/TPB Household Travel Survey, would support development of either traditional trip-based models or the newer tour-based models. By contrast, development of an activity-based model of travel would require that a special activity-based household travel survey be conducted. The main benefit of conducting an activity-based household travel survey is that it could be used to develop all three model types, i.e., trip-based, tour-based, and activity-based models. The principal drawback is that the survey instruments for activity-based surveys tend to be more elaborate, which can lower survey response.

Tour-based models have been used in European countries, such as Sweden and the Netherlands, for a number of years. By contrast, their use in the U.S. is a more recent phenomenon. One of the first operational tour-based models in the U.S. was developed by Cambridge Systematics, Inc. for Boise, Idaho in 1995. It dealt only with auto trips. Boise discontinued using it, because the town did not have the staff to maintain it.

Three tour/activity models are currently in use:

- New Hampshire statewide model (1997), tour-based model
- Portland, Oregon (1998), activity-based model developed by Mark Bradley. Portland's model was enhanced in 2001.
- San Francisco County (2000), tour-based and activity-based

Several urban areas are considering tour- and/or activity-based models: Cincinnati, Dallas, Denver, and Seattle. A recent TMIP-supported peer review panel recommended that the Denver Regional Council of Governments (DRCOG) move away from its traditional four-step model and move toward activity-based modeling, including a tour-based approach to trip making. Similarly, a separate TMIP-supported peer review panel recommended that the Cincinnati MPO (Ohio, Kentucky, Indiana Regional Council of Governments: OKI) move toward tour-based models (Urban Transportation Monitor 2003). In a recent (2001) model review for the Puget Sound Regional Council, a peer review panel led by Cambridge Systematics, Inc. recommended that PSRC move toward both tour-based and activity-based models.

In tour-based models, a tour is generally defined as a series of trips starting and ending at a given place. For example, a home-based work tour starts and ends at home and the "primary activity" of the tour is work. Every tour can have zero, one, or more "intermediate stops." Each tour is eventually decomposed into its component trips, which get assigned to a network, using standard travel modeling software packages, such as TP+ or TransCAD. In activity-based models, instead of beginning with trip generation, the model generally begins with a generation of daily activity patterns. From activity patterns, tours are developed, which later get broken down into trips.

TPB staff would like the TRB Committee to suggest directions that might be taken in the TPB methods development track during the next several years with regard to tour-based and activity-based models.

2.C Grain of Analysis Zones

TPB staff would like the TRB Committee to comment on the grain of travel analysis zones. The present 2,191-zone structure covers a 7,000 square mile region. There are 1,972 internal zones, 47 external stations, and 72 spare zone numbers available for corridor detailing. This structure was dictated by limitations in the DOS-based MINUTP software TPB staff had been using. The allocation of zones reflected an allocation by the TPB Travel Forecasting Subcommittee which took into consideration the following:

- the need for more detailed zones around transit stations;
- the need to reflect an expansion of the urbanized area within the region; and

- the need to add jurisdictions to the modeled region reflecting the EPA-designated non-attainment boundary.

Considerable time and energy were expended in getting this 2,191-zone structure in place in 1994. The resulting zone structure was a compromise which addressed each of the three needs. The zone allocation impacted network coding, model estimation, and demographic projections of population, households, and employment in COG's Cooperative Forecast.

With the migration to a Windows-based software, notably TP+, the constraint on number of zones is removed. The three needs identified above remain. TPB staff also recognizes that the present zone structure results in zones that are larger than desirable, in downtown Washington as well as in the outer suburbs, which inhibits transit and highway assignments.

2.D Data, Software, Hardware, and Training Requirements

Before embarking on the development of enhanced models, there are several preparation activities that will need to be considered. It will be important to anticipate data requirements necessary to support the enhanced modeling approach. New types of required information may not be readily obtained using conventional data collection techniques. The software and hardware requirements to support the newer models will also need to be funded and put into place. Staff development and training will also need to be addressed. It is envisioned that the use of GIS-aided procedures will play an increasingly important role in the development of model enhancement plans.

Research (Track 3)

Activities in the research track are important to an ongoing models development program, but are sometimes neglected. Keeping abreast of modeling practice is facilitated by participation in the Transportation Research Board, the AMPO Travel Modeling Subcommittee, the Travel Model Improvement Program, and ITE. Additionally, literature reviews are facilitated by access to MPO and other websites.

Data Collection (Track 4)

4.A Regional Household Travel Survey

Staff has identified three potential options for conducting a new regional household travel in 2004/2005. In Appendix G, a series of important questions that could affect the design and conduct of this new regional household travel survey are posed to the TRB Committee. Staff would like to review and discuss the TRB Committee's responses to these questions with the Travel Forecasting Subcommittee of the TPB Technical Committee before making a final decision on what may be a once in a decade opportunity to collect needed new household travel survey data for future models development activities.

The first option would be to conduct a new regional household travel survey similar to the 1994 COG/TPB Household Travel Survey. This survey would be a trip-based survey designed to support further refinement and validation of the COG/TPB Version 2.1 four-step travel forecasting model. Data collection for this survey would occur in two phases in the fall of 2004 and the spring of 2005. A completed sample size of 2,500 households would be obtained in each survey data collection phase for a total sample size of about 5,000 households. This sample would be stratified by major jurisdiction with the total number of samples allocated to each jurisdiction roughly proportional to each jurisdiction's relative share of regional households. Slight exceptions to this proportional allocation of survey samples would be in the District of Columbia and in lower density outlying semi-rural jurisdictions. District households would be over-sampled by one-third to ensure a sufficient number of sample households residing in higher-density urban areas well served by transit in the overall regional sample. Also, a minimum completed sample size of 150 households would be established for the outlying semi-rural jurisdictions regardless of their proportionate share of regional households to ensure an adequate number of samples for analysis from this jurisdictional area-type. This sample allocation plan would result in approximately 1,000 completed samples in the District of Columbia, 250-300 samples each in the other inner core area jurisdictions of Arlington and Alexandria, 500-700 samples in each of the three major Beltway jurisdictions, 250-300 samples in each of four outer suburban jurisdictions, and about 150 samples in each of two outlying semi-rural jurisdictions in the TPB planning region.

A Computer-Assisted Telephone Interviewing (CATI) survey methodology would be used for this new household travel survey and employ random digit dialing techniques (RDD) to develop the geographically stratified sample of households to be contacted. Households in the RDD sample with published telephone numbers would be identified and sent pre-survey letters explaining the purpose of the travel survey, informing them that someone will be calling them shortly and encouraging their participation. Initial survey recruitment calls would be made in an attempt to contact all potentially eligible households drawn in the RDD sample regardless of whether or not the household has a published telephone number. A minimum of seven call attempts on at least 5 different days would be made to reach and recruit each potentially eligible household to participate in the household travel survey. When a potentially eligible household is reached an initial screener interview would be conducted to obtain some basic information about the household and attempt to elicit the household's participation in the survey. Households agreeing to participate in the travel survey would be sent travel diaries for each member of the household age 5 and older to be completed for a randomly assigned travel day. Travel day trip diary information and personal characteristic data for each household member would then be retrieved via diary retrieval interviews and recorded into the CATI system.

Planned survey quality control and response enhancement procedures for this survey would include: (1) pre-survey letters to households with published phone numbers, (2) use of experienced, well-trained multi-lingual survey interviewers, (3) use of refusal conversion techniques, (4) survey reminder cards and calls, (5) a 1-800-Help Line, (8) use of trip rostering techniques and (7) limited use of proxy interviews.

It is anticipated that this first option for a new regional household travel survey could be designed to fit within expected UPWP budget levels over a two fiscal year period.

The second option for the conduct of a new regional household travel survey would be very similar to the first option, except that it would also include a GPS household vehicle tracking add-on sub-sample. This add-on sub-sample would recruit approximately 200 households who had agreed to participate in CATI to also agree to carry GPS tracking devices in their household vehicles on their travel survey day. Household respondent vehicle trip reports recorded in the CATI would then be compared with the vehicle tracking records recorded using the GPS device. In this manner the GPS add-on sub-sample would provide a direct measure of survey respondent vehicle-trip underreporting and misreporting of vehicle trip details because the GPS tracking would also provide direct measures of trip starting and ending times as well as very accurate measures of trip distances.

It is estimated that such a 200 household GPS tracking add-on sample would increase travel survey costs by about $100,000 and require some increase in UPWP funding for this add-on sub-sample.

The third option would be the conduct of a large-sample methodologically enhanced activity-based regional household travel survey requiring additional funding from sources outside the planning funds in the UPWP. Methodological enhancements would include: (1) development of a GIS-based housing unit sampling frame that would enable selections of travel survey sample households by area type; (2) development of a multi-modal data collection survey methodology that permits household recruitment and diary retrieval by mail, telephone, Internet and in-person contacts; (3) a GPS add-on sub-sample; and (4) a follow-up survey of non-responding households and household members. It is estimated that such an enhanced survey would cost on the order of 3 to 5 million dollars for a 10,000 to 15,000 household sample and would require significant pre-testing of the design enhancements.

Staff believes that there is considerable merit in the third option worth the substantially higher costs, given that this would be a once in a decade opportunity for improving the quantity and quality of data for model development in the metropolitan Washington region. Staff currently plans to begin the design of such a large-sample methodologically enhanced regional household travel survey and to seek additional funding from sources outside the planning funds in the UPWP. Staff is very interested in the TRB Committee's responses to the questions in Appendix G and its comments on the three options for a new regional household travel survey that are currently under consideration.

4.B Auto External Survey

This project will obtain information on auto travel to and through the modeled region by persons living in areas beyond the external travel cordon for the modeled area. Information on the origin and destination of the external auto trip, the trip purpose, the number of persons in the vehicle, number of vehicles regularly used by the trip maker's household, and the Potomac River Bridges that may be crossed will be obtained via a very short, mail-out/mail back postcard questionnaire.

4.C Analysis of Census Journey to Work Data

This project will obtain, tabulate, and analyze Census Journey to Work data collected in the 2000 Census. This work activity will include tabulation and analysis of Summary File 3 (SF 3), the Public Use Microdata Sample (PUMS) and the Census Transportation Planning Package (CTPP 2000). Place of work geocoding for the CTPP 2000 will be used by comparing it to COG's small area TAZ-level employment data and developing place of work adjustment factors, if necessary. Trip conversion factors will be developed to convert CTPP 2000 worker flow data into Home-Based Work (HBW) commuting trips consistent with the definitions used in COG/TPB travel forecasting model. After applying appropriate HBW conversion factors a TAZ-level data file will be built for use in travel model validation and refinement efforts.

The CTPP 2000 data tabulations and analysis will also be used to review the current 2191-TAZ areas system and to suggest updates and refinements to it, especially in geographic areas that currently have large TAZs.

4.D Regional Transportation Data Clearinghouse

Staff will update TPB's Regional Transportation Data Clearinghouse databases with updated traffic volumes and transit ridership data as well as transportation-related data from the 2000 Census. Formal arrangements with local, state, WMATA, and other regional agencies will be continued and expanded to transfer new data to and from the Regional Transportation Data Clearinghouse. The necessary database and communications infrastructure needed to incorporate better access to ITS and other more detailed traffic volume and speed data will also be developed.

Maintenance (Track 5)

The Maintenance track is envisioned to be an ongoing work element in the models development program focused on documentation and training. Documentation of technical methods is viewed as a critical component of the models program for several reasons. A detailed summary of calibration and validation procedures are important for understanding the model design and the relative importance of specific variables used in each step of the process. Defining input variables and guidelines for applying the travel model in writing minimizes opportunities for misuse and misspecification of the model. The technical users are now only one segment of the community demanding information on the regional modeling process. Elected officials, interest groups, and private citizens are increasingly eager to obtain modeling information. In response, the TPB allows technical information to be accessed directly over the internet. As scrutiny of the TPB travel models has increased in recent years, it has become clear that well prepared documentation fosters public buy-in to the regional planning process and minimizes the opportunities for legal challenges.

Documentation activities will address the application of the current travel model, modeling updates that have been implemented during the year, and progress made in the Methods

Development and Research tracks. TPB staff has prepared a number of special summaries and sensitivity tests of the Version 2.1/C model at the request of the TRB review panel during FY-2003 and FY-2004. These materials will be packaged together as part of FY-2004 documentation.

The ‘regionally adopted model’ is commonly sought to serve the needs of project planning work conducted by local transportation agencies. Training in the application of the regional model will therefore be an on-going staff activity, particularly as the model incrementally evolves over time.

METROPOLITAN WASHINGTON COUNCIL OF GOVERNMENTS
Local governments working together for a better metropolitan region

May 13, 2004

Dr. David Forkenbrock
Chairman
TRB Committee for Review of Travel
Demand Modeling by the
Metropolitan Washington Council of Governments
Transportation Research Board
500 Fifth Street, N.W.
Washington, D.C. 20001

Dear Dr. Forkenbrock:

Staff of the National Capital Region Transportation Planning Board (TPB) has been provided an advance copy of the second letter report by the TRB review committee on travel demand modeling in the Washington region, which was released on May 10, 2004. This letter provides comments by the TPB staff on the TRB Committee second letter report, as well as on the overall review by the TRB Committee.

As noted in the TRB Committee's second letter report, the TRB review of the TPB's travel demand modeling process was requested in a letter of May 8, 2002 from the then Chairman of the TPB, Councilmember Phil Mendelson of the District of Columbia, as part of TPB's ongoing program to upgrade its travel forecasting methods. The Statement of Task agreed upon by the TPB and TRB, and approved by the National Research Council, specified that the TRB Committee will "perform review of the state of the practice of travel demand modeling by the Transportation Planning Board (TPB) of the Metropolitan Washington Council of Governments. The review panel will provide guidance on:

1. The performance of the TPB's latest travel model (version 2) in forecasting regional travel;

2. The proposed process for merging the latest travel model outputs to produce mobile source emissions;

3. The TPB's proposed direction of future travel demand model upgrades;

4. Travel survey and other data needed to accomplish future model upgrades; and

5. The detail (grain) of travel analysis zones that should be developed for future upgrades."

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The TRB Committee's first letter report, dated September 8, 2003, addressed the first two work items. The TPB staff was provided an advance copy of this first letter report, and provided detailed comments on the report in a letter dated September 8, 2003 to the TRB Committee Chairman, Dr. David Forkenbrock.

At the request of the TRB Committee, the TPB staff prepared a document outlining the TPB's proposed work elements for models development which the Committee could use in addressing the remaining three work items of the Statement of Task. This document, dated December 24, 2003, is titled "Descriptions of Proposed Work Elements for the TPB Models Development Program to (a) Address Concerns Raised by the TRB Committee's First Letter Report; and (b) Advance the State of Modeling Practice in the Metropolitan Washington Region." The document addressed explicitly each of six observations made by the TRB Committee in its first letter report, three of which TPB staff agreed offered potential for improvement in the modeling process, and three of which TPB staff believed required further consideration and discussion.

The TRB Committee has included the proposed TPB work program document of December 24, 2003 as Attachment 4 to its second letter report, and has provided a discussion of each of the six topics addressed in the TPB's proposed work program. This letter prepared by TPB staff provides comments on the TRB Committee's discussion of each of the six topics in turn: improving model validation, truck and commercial vehicle travel, bus network characterization, use of adjustment factors, speed feedback incorporating mode choice, and traffic speed and volume estimation for air pollution emissions estimation. The TPB staff letter then provides comments on the section of the TRB Committee's report which provides responses to questions posed in the TPB's proposed work program document of December 24, 2003. Finally, the TPB staff letter provides some overall observations on the TRB review, followed by a brief conclusion.

TPB Comments on TRB Committee's Six Discussion Topics

(1) Improving Model Validation

TPB staff is in general agreement with the TRB Committee's discussion of this topic. Significant improvements in model validation have been achieved in a current project planning study through use of refined capacity and free flow speed values in area type and facility type cross-classes; better delineation of area type codes using aerial photography; refined volume-delay functions for certain critical links; and refinement of zone centroid connections in geographic areas of particular interest and policy focus. The success of this approach has led to an effort by TPB staff to strengthen coordination between regional travel demand modeling efforts and corridor and sub-area studies being conducted throughout the region. State and local transportation agencies as well as the regional transit agency have been receptive to and supportive of this effort, which TPB staff believes will lead to improved performance of the regional travel demand model as well as improved technical analysis at the corridor and sub-area level.

At the conclusion of the section on improving model validation, the TRB Committee includes a brief discussion of the TPB's application of "the equilibrium highway-assignment algorithm", as follows:

"The committee notes that TPB completes a relatively small number of iterations of the equilibrium highway-assignment algorithm and does not indicate a criterion for determining how many iterations may be appropriate. The committee believes that improvements in base-year highway link volume validation through additional iterations may be possible. Some testing of how the number of iterations affects fitting results could be included in TPB's model maintenance work track. In such testing, the number of iterations may be limited by monitoring some standard measure of convergence."

The equilibrium assignment process used in the TPB's travel demand modeling procedures employs two overall principles:

1) User Equilibrium - Travelers are assumed to select a route so as to minimize their personal travel time. User equilibrium exists when travelers cannot improve their travel time by changing their route. User equilibrium therefore exists when the travel time on all routes between a given origin/destination (O/D) pair is equal, and that O/D travel time is less than or equal to that of any unused route.

2) System Optimal Flows – Preferred routes are those that minimize the total system travel time. System optimal route flows are reached when no traveler can switch to an alternative route without increasing the total system travel time.

The equilibrium algorithm is not deterministic, but rather operates as a series of individual network assignment executions which ultimately 'hone in' on an optimal end-state. At the end of each assignment, the speed is adjusted, vehicle-hours are calculated at the link level, and a global weighting function is developed and applied to the current link volume. The weight is developed as a function of the system hours of travel resulting from the current assignment and the previous iteration assignment. The volume weighting adjusts the link time such that the system vehicle hours of travel produced in the next assignment will continue to reduce. Closure of the process occurs when the global change in link volumes between successive iterations is small. In general, the number of iterations required for closure is directly related to the degree of congestion that exists in a given assignment.

The equilibrium assignment procedure in the TPB's software (TP+) allows for flexibility in the number of assignment iterations that are completed. The user can either specify a maximum number of iterations or let the software decide when a reasonable stopping condition is met. Table 1 shows the default convergence conditions presently used by TP+. Under default conditions, if any of the convergence criteria on Table 1 are met at a particular iteration prior to the maximum number of iterations, the algorithm will terminate the execution.

Table 1: Equilibrium Assignment Convergence Conditions in TP+

Convergence Parameter	Parameter Description	Default Value
GAP	Specifies the cutoff point based upon the relative difference in system cost (volume * cost) between two iterations	0.005
AAD	Specifies the cutoff point based upon the average absolute difference in volumes between two iterations	0.500
RAAD	Specifies the cutoff point based upon the relative average absolute difference in volumes between two iterations	0.005
PDIFF	Specifies the cutoff point based upon the fractional portion of links whose change in volume (between two iterations) is less than the value of PDIFFVALUE	1.000
PDIFFVALUE	Specifies the value to be used with PDIFF	0.000
RMSE	Specifies the cutoff point based upon the root mean squared error of the differences in volumes between two iterations	0.100

Sensitivity tests run by TPB staff have found that 10 iterations are sufficient for convergence for the off-peak period, but the AM and PM assignments require as many as 18 iterations to close under default parameter conditions. The Version 2.1D model currently in beta testing includes a maximum of 20 iterations as a result of these findings.

TPB staff is very interested in pursuing the suggestion of the TRB Committee that "*some testing of how the number of iterations affects fitting results could be included in the TPB's model maintenance work track.*" Do the additional iterations required to meet the convergence criteria noted above really improve the root mean square error (RMSE) values comparing modeled link counts with observed traffic counts, or would fewer iterations (and less computing time) suffice? This is an issue TPB staff would like to investigate with additional sensitivity testing.

Another related question on equilibrium assignment concerns whether truly comparable results can be obtained for different transportation alternatives if the number of iterations of the equilibrium assignment is different for each case. Might some of the differences found between the alternatives be due to the equilibrium assignment procedure itself, rather than the alternatives? TPB staff has encountered this issue, for example, in developing accessibility measures for different highway alternatives in a major planning corridor, and the issue has also been raised with regard to the application of the SUMMIT model currently being introduced by the Federal Transit Administration (FTA). In a recent 2004 article referenced by the TRB Committee entitled "*Convergence of Traffic Assignments: How Much Is Enough?*" Boyce, Ralevic-Dekic, and Bar-Gera propose and test a new algorithm designed to achieve more rapid convergence of the equilibrium assignment process. This is a promising area for further research, development, and implementation.

(2) Truck and Commercial Vehicle Travel

In response to the TRB Committee's comments on this topic in its first letter report, TPB staff has engaged consultant assistance to undertake the approach adopted by the Baltimore Metropolitan Council (BMC) to improve the representation of light commercial trucks in the TPB travel forecasting procedures. The additional classification counts will be undertaken as soon as a satisfactory survey design is developed and funding can be allocated to support data collection and analysis. Whether use of truck count data currently available for the Washington region would allow work to begin on improving truck forecasts before new data are collected, as the TRB Committee suggests, is a question TPB staff will put to the consultant.

While the TRB Committee finds the approach described above *"encouraging as a near-term solution"*, the Committee characterizes this approach as "*fairly crude*," and states that "*over the longer-term, the TPB will find it appropriate to upgrade its truck and commercial travel modeling through a more behavioral approach."* Toward this end, the Committee states that "*TPB should consider conducting a survey of commercial firms, stratified by types and volume of goods shipped, to provide a stronger basis for model development."*

TPB staff agrees with the TRB Committee that ideally a more behavioral approach to modeling light commercial trucks would be desirable, and has in fact attempted to pursue such an approach in the relatively recent past. An effort to collect the kind of data recommended by the TRB Committee was made in the early 1990s, but the response rates were so low that the data were essentially unusable. It was the difficulty in obtaining such data, together with the need to distinguish commercial vehicles from personal travel vehicles in observed data, that led TPB to drop its separate model for light trucks in the late 1980s, and to move to the current procedure of including such travel in the non-home-based trip category. Similar experience with this kind of data collection effort has been reported to TPB staff by other large Metropolitan Planning Organizations (MPOs). TPB staff doubts that these difficulties in data collection for light commercial trucks can be overcome, and consequently is currently not optimistic about the prospects for the TRB Committee's recommendation regarding a more behavioral approach to modeling light commercial trucks.

(3) Bus Network Characterization

TPB staff is proceeding with a concentrated effort to address the question of representation of bus services in future years. While the TPB's use of regularly updated bus schedule information throughout the region provides an accurate description of near-term bus services for travel modeling purposes, three aspects of bus services in the out-years are not explicitly addressed at present:

1) The effects of growing congestion on bus speeds and schedules;

2) The potential benefits of measures to improve bus speeds and schedule reliability, such as signal priority systems, removal of on-street parking during peak service hours, and providing bus-only lanes and queue jumpers; and

3) The addition of new bus service to provide shorter headways and expanded route coverage, particularly in rapidly growing areas in the inner and outer suburbs.

TPB's current travel modeling procedures for the out-years include detailed network coding for additions to the rail network and related changes in bus services, as well as for some new bus services in growing areas, but to a large degree the procedures use the most recent bus schedules as surrogates for the three key aspects of new bus service listed above. Explicit policy and planning criteria are needed to address these key aspects, and detailed network coding should be included to reflect these criteria for out-year travel forecasts. TPB staff is currently working with a committee of regional and local highway and transit planning staff to develop these needed improvements in the representation of transit services for future years.

TPB staff appreciates the TRB Committee's caution with regard to "*linking the underlying network of local and feeder bus schedules to less reliable assignment travel times on minor arterials and local streets.*" TPB staff is concerned that any technique to automatically link bus speeds to highways speeds produced from the traffic assignment procedure could cause instability and inaccuracy in the representation of bus services, even on higher level arterial roadways. TPB staff intends to take a comprehensive approach to this issue, addressing all three of the above key aspects to future bus speeds collectively, with an increased policy and planning focus used to guide the technical representation of bus services in the travel forecasting procedures.

(4) Use of Adjustment Factors

TPB staff believes that there will always be some inter-jurisdictional influences on travel patterns in the Washington region (and in other complex regions) which cannot be fully described by the time and cost variables in the four-step travel demand modeling process without the use of adjustment factors. However, TPB staff agrees with the TRB Committee that the use of adjustment factors should be fully documented, the bases for the use of these factors should continually be reviewed, and efforts should be made to minimize the number and magnitude of such factors. TPB staff has attempted to adhere to these principles in the past, and will continue to do so.

TPB staff recognizes the TRB Committee's concern that these inter-jurisdictional influences on travel patterns may change over time. The TRB Committee states that "*the effects of a physical barrier may change as development patterns shift over time, and jurisdictional barriers can be readily altered by changes in local tax policies, school characteristics, and real estate values.*" TPB staff would argue that the major influences for which adjustment factors have been used have been relatively stable over time, certainly in comparison to other important factors like household size and labor force participation by women, for which significant changes have occurred that were difficult to anticipate. Nevertheless, the caution about the use of adjustment factors where significant changes are possible over time is valid, and should be heeded by all travel modeling professionals.

Since the proposed work program was transmitted to the TRB Committee on December 24, 2003, TPB staff has undertaken a thorough review of each K-factor applied in the Version 2.1C model as development of the Version 2.1D model has progressed. The basis for this examination was the opportunity afforded by the changes in capacity/speed lookup parameters and a revised freeway volume/delay function that have been introduced with the Version 2.1D model. The result has been the elimination of nine K-factors in the Version 2.1D model, with thirteen others being "dampened" (i.e., their values more closely approach 1.0 than corresponding factors in the Version 2.1C model). A second review of the remaining K-factors is being undertaken in the wake of adjustments being made to estimated 2000 employment after comparisons with the 2000 Census data. (Significant adjustments are being made to the year 2000 employment estimates for several outlying jurisdictions, and modest adjustments are being made for inner jurisdictions.)

At the conclusion of the section on adjustment factors, the TRB Committee raised a specific question regarding the use of adjustment factors in the Washington region:

"The committee found the newest information presented in Appendix D of TPB's work program to be helpful in understanding some of the adjustments being made, but questions remain. The Potomac River and jurisdictional boundaries in the Washington region, for example, may skew travel patterns. Trips originating in a zone near such a perceived barrier may be more likely to terminate in a zone on the same side of the barrier, as compared with otherwise equally attractive destinations on the other side of the barrier. Arguably, the classic and most clearly justifiable use of adjustment factors (in this case, K-factors) is to adjust interzonal impedances for zonal pairs that have the barrier between them. The committee was puzzled, however, that links between Montgomery and Fairfax

Counties, for example, appear to require no K-factors, despite their separation by the Potomac River, while factors are abundantly applied to other intercounty links."

The reason that the TRB Committee was puzzled by this particular adjustment factor application is that the physical barrier effects on trip patterns have been addressed not through the use of K-factors, but through the addition of time penalties stratified by trip purpose and income level (as documented in Tables 5 through 8 in Appendix D of the TPB's work program document of December 24, 2003.) These time penalties were developed as an integrated part of the gravity model F-curve calibration process, using data from the household travel survey. The calibration involved running the model for several iterations, using a gamma distribution fitting technique to arrive at a "smoothed" F-function, which allowed observed trip length profiles to be matched. These time penalties are used to address physical barriers on trip patterns, and were introduced while iterating through the F-curve calibration process. K-factors were introduced during application of the travel demand for the entire modeled area, after the F-factor calibration had been completed.

In summary, TPB staff agrees with the TRB Committee's recommendation that the use of adjustment factors should be fully documented and continually reexamined in the travel demand modeling process, and, in keeping with historical practice at TPB, will continue to do so each time the models are updated and new data are introduced.

(5) <u>Speed Feedback Incorporating Mode Choice</u>

TPB staff appreciates the constructive suggestions made by the TRB Committee for addressing this issue, which has been the subject of extensive sensitivity analyses by TPB staff, both when the procedure was first developed in the mid-1990s and more recently during the development of the Version 2.1D model. As described in the TPB staff's comments on the TRB Committee's first letter report, TPB staff has found (and continues to find) that allowing major variations in highway speeds during the speed feedback process to modify distributions containing large percentages of rail and HOV trips (which are independent of highway speeds) creates a "hysteresis effect" in which unrealistic reductions occur in final estimated levels for transit and HOV on priority lanes.

The TRB Committee provides references which address feedback and equilibrium assignment. TPB staff has reviewed these references (one of which contains documentation of the TPB's experience with this issue) and found them to be very relevant and helpful. As discussed under the earlier section entitled "Improving Model Validation", TPB staff is currently using an equilibrium algorithm for traffic assignment, but is not applying this approach through trip distribution and mode choice as proposed in the 1994 article by Boyce, Zhang and Lupa in Transportation Research Record 1443. TPB staff will continue to investigate whether improved equilibrium algorithms should be incorporated into the TPB travel forecasting process, and whether such algorithms can be provided by the TPB's software vendor.

The TRB Committee also suggests that "*TPB test different methods for weighting highway and transit-times to produce a composite travel time for distribution.*" TPB staff agrees that the current use of a regional weighted average of highway and transit travel times in trip distribution is a primary issue to be addressed in further sensitivity testing of the speed feedback process. In the near-term, TPB staff has described in its work program document of December 24, 2003 the results of sensitivity tests using the TPB's current procedure with different "pump-prime" assumptions for highway speeds, as well as re-running the entire modeling process to ensure that speeds are consistent throughout the modeling process. This analysis has indicated that good agreement between speeds in distribution, mode choice, and final traffic assignment can be assured either by choosing pump-prime input speeds from earlier modeling results for a year close to the year being analyzed, or by using pump-prime input speeds developed from earlier years and running additional iterations of the entire process.

The TRB Committee makes a particular point that "*average regional speed is not a good measure of convergence. It is possible for the regional average speed to remain nearly constant without achieving reasonable convergence in zone-to-zone travel times.*" The Committee seems to be under the impression that TPB staff is using average regional speed as a measure of convergence for the speed feedback process, which is not the case. TPB staff is well aware of the importance of obtaining "*reasonable convergence in zone-to-zone travel times*" as a means of assuring consistency throughout the four-step modeling process, and in developing the final model version has ensured that at least 95 percent of final zone-to-zone link speeds are within 2 mph of the speeds used in the prior iteration of the process. While region-wide and jurisdiction-wide speeds were listed in Appendix E of the TPB's December 24, 2003 work program document, these speeds were not the basis for determining convergence of the speed feedback process. TPB staff will include information on zone-to-zone link speed convergence in future documentation of the travel forecasting procedures.

TPB staff believes that a thorough evaluation of this complex issue requires more analysis of the various sensitivity tests already conducted, as well as additional sensitivity tests and analyses. A greater understanding is needed of the interaction between trip distribution, mode choice, and traffic assignment as variations in highway speeds are fed back through this sequential process in an effort to achieve an equilibrium solution.

(6) <u>Traffic Speed and Volume Estimation for Air Pollution Emissions Estimation</u>

In this section the TRB Committee states that in the TPB Travel forecasting process "*the post-processing procedure entails two steps: first, aggregating peak and off-peak-period traffic assignments to a 24-hour total that is redistributed to hourly periods as a percentage of daily volume; and second, adjusting the initially estimated hourly volumes as necessary to meet link hourly capacity constraints.*" The Committee states that two concerns were expressed in its first letter concerning the post-processing, and that "*TPB's* *work plan addressed the second concern with additional sensitivity analysis but did not comment on the committee's first concern."*

The TRB Committee's first concern is stated as follows: *"TPB's aggregation of peak and off-peak travel model estimates to 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."* The Committee provides a simple analysis which *"compared the peak-period traffic volumes from TPB's four step model with the peak-period volumes estimated by the hourly profiles used in TPB's post-processing"* and "*found differences between the two sets that are in many cases strikingly large and skewed."*

The TPB staff did comment on this first concern in its comments of September 8, 2003 on the TRB Committee's first report. TPB staff pointed out that the TRB Committee's characterization of the first step of the post-processing procedures did not recognize that links are categorized into three peaking classes and three functional classes (nine distributions in all) based on the period-specific link volumes produced by the travel models, and that the default hourly distributions used for these nine classes are based on empirically observed distributions for the most recent years available for the Washington region. A detailed description of these procedures is provided in a memorandum to the file by TPB staff member Michael Freeman dated August 27, 2002. A copy of this memorandum was provided to the TRB Committee, and is referenced by the Committee toward the end of the Committee's discussion of this topic in the second letter report. The Committee's second letter report does not mention these specific procedures for developing and applying initial hourly distributions, which together constitute the first step of the TPB's post-processor. TPB staff has included Mr. Freeman's memorandum in full as Attachment A to this letter.

Mr. Freeman's memorandum describes the analysis of the most recent time of day Highway Performance Monitoring System (HPMS) data available from a total of 7,882 observations in the Washington region which formed the basis for the nine time-of-day distributions used in the first step of the post-processing procedure. The memorandum also describes the procedure used for defining the three "Collapsed Functional Classes" and three "Peaking Classes" used, and the criteria through which period-specific link volumes produced from the travel model were used to assign links to the nine categories. While the TPB's adopted procedure applies the nine time-of-day distributions directly to reaggregated 24-hour volumes from the travel model, as noted by the TRB Committee Mr. Freeman's memorandum also recognizes that "the available observed data could be used to stratify the volumes from the three time periods into hourly volume, instead of stratifying daily volume directly into hourly volume." This latter alternative was considered by TPB as the procedure was being developed.

The TRB Committee states that "*the estimates of hourly volumes and speeds must be associated directly with the time-of-day (am, pm, off-peak) travel model output. A simple method for accomplishing this would be to allocate volumes proportionally within each time period (i.e. the percentages of hourly volumes within a time period sum to 100 percent).* It is not clear to TPB staff how the TRB Committee proposes to "*allocate volumes proportionally within each time period";* there are many such allocations that *"sum to 100 percent."* The option considered by TPB staff was to use the empirically-derived distributions to allocate volumes to each hour within the am peak, pm peak, and off-peak periods, and then to use the second step of the procedure to spread volumes from overloaded time periods to proximate time periods for each link.

In analyzing the output of the travel model by link and by the three time periods, however, TPB staff found, as the TRB Committee has noted in its analysis, that the volumes assigned to the two peak three-hour periods and to the eighteen-hour off-peak period by the travel model did not always match well with the observed distributions. In particular, as the TRB Committee's analysis demonstrates, the travel model tends consistently to assign too high a proportion of daily traffic to the pm peak period. This may be attributed in part to the fact that the travel model is calibrated on average regional time-of-day distributions based on 1994 survey data by travel purpose and mode, and does not adjust these distributions over time. This comparison indicates that rather than avoiding post-processing procedures, the overall modeling process would be enhanced through feeding back time-of-day observations from the post-processor to the demand model. While this may not be an issue for metropolitan areas where peak periods are short and little peak spreading is occurring over time, travel monitoring in the Washington region over time shows that the peak period is spreading steadily as traffic congestion worsens. In order to better reflect this phenomenon in the emissions post-processor, TPB staff decided to apply the observed distributions for the nine link categories to 24-hour link volumes rather than the period-specific link volumes.

Further research and sensitivity testing on this first step of the post-processor would be worthwhile. Mr. Freeman's memorandum suggests, for example, that because the observed time-of-day distributions for arterial, collection and local functional classes were very similar, these classes could be combined. In contrast, more refined distributions might be sought for freeways, where unique peaking characteristics can occur at major bottlenecks, and on portions of the system that carry a high percentage of traffic traveling through the region rather than within the region. Currently these variations are subsumed into the three time-of-day distributions used for freeways. More extensive time-of-day data will be needed, however, if this approach to refined freeway distributions is pursued.

In combination, the two steps of the TPB's post-processor integrate the behavioral elements of the travel demand model with time-of-day specific aspects of traffic conditions observed in the Washington area. The post-processor provides much more realistic hourly speed estimation than can be obtained by relying solely on the speeds for the three-hour am peak, the three-hour pm peak, and the eighteen hour off-peak periods which are provided by the travel demand model. This more realistic speed estimation is essential for estimation of emissions by motor vehicles, which are extremely sensitive to speeds.

TPB staff would like to continue to refine these procedures through the use of observed time-of-day distributions to improve the ability of the travel model to forecast peak-spreading and time-of-day volumes over time. This is an aspect of determining equilibrium conditions that is becoming increasingly important in the Washington region as congestion on major roadways spreads to more areas of the network and to more time periods throughout the day. The phenomenon is complex, however, and time-of-day traffic data are limited. Peak-spreading can be influenced by localized factors such as staggered work hours which are not well-represented in data used to calibrate the travel model. TPB staff believes, for example, that the tendency of the travel model to assign too much volume into the peak period for travel leaving the metropolitan core area may be due in large part to the fact that the federal government has an extensive program of staggered work hours, which in practice is subsumed into the regional time-of-day distributions used to calibrate the travel model.

Response to TPB's Questions to the Committee

In the December 24, 2003 TPB work program document TPB staff posed a number of questions to the TRB Committee regarding certain elements of the work program. The TRB Committee has provided responses to these questions under the following headings: nested logit models in mode choice; alternatives to the four-step model; grain size in travel modeling; and travel surveys and other data for travel modeling.

TPB staff greatly appreciates the responses provided by the TRB Committee in this section of the report. The responses address specifically the areas identified by the TPB staff, and provide very useful views on both the theoretical and practical aspects of each area addressed. TPB staff is in general agreement with the views and recommendations expressed by the TRB Committee throughout this section, and will make full use of this information as these various areas are pursued in the TPB models development work program over the next few years.

Overall Observations on the TRB Review

The level of interest by policy-makers and stakeholder groups in the data inputs, structure, and outputs of travel forecasting procedures in the Washington region has increased significantly over the past few years. Limited funding for adding new highway and transit capacity, and increased sensitivity to air quality and other environmental and social impacts of transportation facilities, has brought new scrutiny to highway and transit project proposals as well as measures to better manage both demand and supply aspects of the transportation system. Extensive public comment on the TPB travel modeling procedures led to the May 8, 2002 request to the TRB from TPB Chairman Phil Mendelson for an "arms-length" review of the TPB procedures.

The review conducted by the TRB panel (with excellent support from TRB staff) covered the entire scope of the TPB travel modeling procedures, and focused in considerable depth on issues which the TRB Committee felt were in need of attention. TPB staff provided considerable additional documentation requested by the TRB Committee throughout the review process, and a number of face-to-face meetings and teleconferences were held. The TRB Committee's two letter reports, and TPB staff comments on those reports, demonstrate that a great deal of attention was focused on certain highly technical aspects of the modeling process because of their perceived importance to the provision of the information needed by decision-makers and stakeholders.

In addition to the observations provided by the TRB Committee on particular aspects of the TPB's travel demand modeling process, TPB staff believes that the overall observations made by the TRB Committee on current documentation and understanding of state of the practice in travel demand modeling were an especially valuable part of this review, both for the TPB and for the travel demand modeling community as a whole. In the TRB Committee's first letter report, the following observations were made:

- "*- -there are few minimally accepted guidelines or standards of practice for these models or their application;"*
- "*any assessment of these models and their performance must rely primarily on professional experience and judgement;"* and
- "*the committee's findings are based upon its experience in regions with populations, institutional complexity, travel patterns, and air quality planning requirements comparable to those of the metropolitan Washington area"*

The TRB Committee's second report states:

> " *An awareness of what is being done at other MPOs can be valuable to technical staff and senior managers responsible for providing such leadership and commitment. While the models most MPOs use embody similar logic and assumptions, there are no widely accepted guidelines explicitly delineating best practices or even presenting a comprehensive comparison of various regions' practices. TPB has undertaken to collect information from other MPOs with similar characteristics[4] for comparative analysis of modeling practices and demand estimation results. However, TPB reports that progress has been hampered by difficulty in obtaining*

[4] TPB lists eleven peer MPOs and includes preliminary results of the analysis in the work program's Appendix A.

> *detailed and comparable current documentation on the various MPOs' modeling practices. The committee anticipates that this effort will continue to be challenging.*
>
> *TRB, with sponsorship from the U.S. Department of Transportation, is undertaking a study to gather information and prepare a synthesis of practice on metropolitan area travel demand modeling. The study should be useful to TPB in determining modeling practices at other MPOs."*

TPB strongly supports the need for the synthesis of practice on metropolitan travel demand modeling to be undertaken by the TRB with sponsorship from the U.S. Department of Transportation. TPB staff believes that this study will help to provide a greater understanding of the issues which must be addressed by the practitioner community, particularly those relating to data-gathering difficulties (as for light commercial trucks), behavior which is changing gradually over time (as for peak spreading and telecommuting), and behavior which is difficult to represent in a sequential modeling structure (as for speed feedback).

As described in earlier sections, TPB staff has found that substantial improvement can be made in the performance of the TPB travel demand modeling process through the development and use of more refined inputs to the model, including more specific capacity and free flow speed values; refined volume-delay functions for certain critical links; additional zone centroid connections in geographic areas of particular interest and policy focus; and, perhaps most importantly, improved estimates of employment by traffic analysis zones. TPB staff appreciates the TRB Committee's support for these efforts to improve the inputs to the modeling process, which are sometimes neglected in favor of efforts to refine the structure of the models. From a practitioner's perspective, a strong focus on the quality of model inputs as well as model structure is essential to improving model performance and interpreting model results.

Conclusion

The TPB staff believes that the TRB Committee's review of the TPB's travel demand modeling procedures has been a very productive and valuable undertaking. TPB staff greatly appreciates the level of interest and commitment demonstrated by the TRB Committee, and the willingness of the Committee to pursue areas of concern through additional discussion with TPB staff and the review of additional materials and analyses focused on those areas. TPB staff particularly appreciates the excellent support provided by the TRB staff in ensuring that opportunities were provided as needed for discussion and exchange of materials between the TRB Committee and TPB staff throughout the review.

In addition to pursuing improvements to specific areas of the TPB travel modeling process as a result of this review, TPB staff intends to strongly support the synthesis of practice on metropolitan travel demand modeling which TRB will be undertaking with sponsorship of the U.S. Department of Transportation. This synthesis should be very valuable to all of the participants in metropolitan travel demand modeling, whether from the research, consultant, software, practitioner, policy-maker, or stakeholder communities, and should help to overcome the difficulties encountered during this review by both the TRB Committee and TPB staff in assessing the current state of the practice in a peer group of large metropolitan planning organizations.

TPB staff will also strongly support opportunities for greater communication and closer working relationships between representatives of the research, consultant, software, and practitioner communities to ensure that practitioners are aware of and can take full advantage of new techniques as they become available, and that the developers and providers of these new techniques have a full appreciation of the policy and program priorities, resource availability, and data issues which must be addressed by the practitioner community. The concluding sentence of the 1994 article by Boyce, Zhang, and Lupa referenced by the TRB Committee succinctly captures this collaborative approach to moving forward in the travel demand modeling field:

> “ *It behooves us all – planning agency practitioners, software developers, federal program managers, and academics – to work together to ensure that the next generations of travel forecasting methods benefit rapidly from research findings, practical experience, and advances in computing technology”*

In closing, the TPB staff again expresses its appreciation to the TRB Committee and the TRB staff for conducting a very thorough and in-depth review of the TPB travel demand modeling process.

Sincerely,

Ronald F. Kirby
Director, Department of
Transportation Planning

Memorandum

ATTACHMENT A

Date: August 27, 2002

To: File

CC: Ron Kirby, Mike Clifford, Jim Hogan, Ron Milone, Mark Moran, Hamid Humeida, Daivamani Sivasailam, Bob Griffiths

From: Michael Freeman CMF
Transportation Engineer

Subject: Development and Recommendations of Hourly Distributions of Daily Traffic Volume

Introduction:

Purpose

The purpose of this study is to develop recommendations for hourly volume distributions that can be applied to every link of the Version 2 network. These distributions are necessary to develop hourly volumes to be input into the MOBILE 6 model for the next air quality conformity analysis.

Methodology

The following steps were implemented to develop the hourly distributions:

- Data organization
  - Identify data observations: Each unique occurrence of location, date, and direction with 24 continuous hours of volume data was identified as an observation. Observations were identified independently for MD and VA data sets.

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- Classify each observation: Two classification variables were created with three possible values each. Therefore, each observation could be assigned one of nine possible classification combinations.

- Statistical Analysis

  - Calculate the distribution of daily volume by hour for each data set.

  - Calculate means and 90% confidence intervals: For each of the nine class combinations, the mean with confidence intervals was calculated for each hour.

  - Compare statistics of MD and VA datasets and consider combining into one regional dataset.

Available Data

Although data from the District of Columbia was not available before the completion of this study, MWCOG was able to obtain HPMS hourly traffic volume data from MDSHA and VDOT. Each dataset identified every count station's location, direction, date, roadway functional classification, and hourly traffic volumes. DC is expected to release hourly traffic volume data later this year. When we receive the data, we can include them in a new regional analysis.

Data Organization

The volume data was classified in a manner that can be implemented with the Version 2 network. A cursory analysis indicated that possible correlations could exist between the distributions by functional classification and distributions by relationships between volumes for AM Peak, PM Peak, and Daily volumes that are forecasted in the Version 2 travel demand model. Two categorical classes were created to provide more realistic distributions based upon link characteristics. These categorical classes are Collapsed Functional Class and Peaking Class.

Collapsed Functional Class

Figure 1 identifies the relationship between the three Collapsed Functional Classes, HPMS data provided by the state agencies, and MWCOG's Version 2 travel demand model.

FIGURE 1: FUNCTIONAL CLASSES

<table>
<tr><th>HPMS Functional Class</th><th>Collapsed Functional Class</th><th>Version 2 Network Functional Class</th></tr>
<tr><td>Rural Interstate</td><td rowspan="3">Freeways/Expressways</td><td>Freeways</td></tr>
<tr><td>Urban Interstate</td><td rowspan="2">Expressways</td></tr>
<tr><td>Urban Freeways and Expressways</td></tr>
<tr><td>Rural Other Principal Arterial</td><td rowspan="4">Arterials</td><td rowspan="2">Major Arterials</td></tr>
<tr><td>Rural Minor Arterial</td></tr>
<tr><td>Urban Principal Arterial</td><td rowspan="2">Minor Arterials</td></tr>
<tr><td>Urban Minor Arterial</td></tr>
<tr><td>Rural Major Collector</td><td rowspan="5">Collectors/Locals</td><td rowspan="5">Collectors</td></tr>
<tr><td>Rural Minor Collector</td></tr>
<tr><td>Rural Local</td></tr>
<tr><td>Urban Collector</td></tr>
<tr><td>Urban Local</td></tr>
</table>

Peaking Class

In the current post processor, each network link is assigned an orientation attribute of inbound, outbound, or circumferential. Generally, the distributions assigned to the inbound links have pronounced peaks in the morning. Conversely, the outbound links' highest volumes occur in the evening. The circumferential links have two peaks of approximately the same magnitude occurring in the AM and PM peak hours. The links are assigned the orientation attribute based solely on geographic orientation.

In an effort to account for different peaking characteristics for links near activity centers in the outer suburbs, ***a Peaking Class was defined to replace the orientation class used in the version 1 post processor.*** The peaking class is determined from the following attributes that are forecasted for each link of the Version 2 model:

- V_{AM} = the sum of observed volumes of the three hours beginning at 6 AM, 7AM, and 8AM.
- V_{PM} = the sum of observed volumes of the three hours beginning at 4PM, 5PM, and 6PM.
- V_{TOTAL} = The total 24 hour volume forecasted for the link.

Each peaking Class is defined below in Figure 2.

FIGURE 2: PEAKING CLASS DEFINITIONS

Peaking Class	Condition
AM	$7.5\% < \frac{V_{AM} - V_{PM}}{V_{TOTAL}}$
EVEN	$-7.5\% \le \frac{V_{AM} - V_{PM}}{V_{TOTAL}} \le 7.5\%$
PM	$\frac{V_{AM} - V_{PM}}{V_{TOTAL}} < -7.5\%$

DATA CLASSIFICATION SUMMARY

The three Peaking Classes and three Collapsed Functional Classes result in nine class combinations. The number of unique location/date/direction distribution occurrences included in the analysis are summarized in Figure 3 below:

FIGURE 3: FREQUENCY OF OBSERVED DISTRIBUTIONS

			Peaking Class							
			AM		EVEN		PM		TOTAL	
Collapsed Functional Class	Freeways & Expressways	MD	174	*2.2%*	414	*5.3%*	245	*3.1%*	833	*10.6%*
		VA	37	*0.5%*	180	*2.3%*	57	*0.7%*	274	*3.5%*
		Region	**211**	***2.7%***	**594**	***7.5%***	**302**	***3.8%***	**1107**	***14.0%***
	Arterials	MD	511	*6.5%*	998	*12.7%*	1149	*14.6%*	2658	*33.7%*
		VA	230	*2.9%*	453	*5.7%*	569	*7.2%*	1252	*15.9%*
		Region	**741**	***9.4%***	**1451**	***18.4%***	**1718**	***21.8%***	**3910**	***49.6%***
	Collectors & Locals	MD	248	*3.1%*	380	*4.8%*	631	*8.0%*	1259	*16.0%*
		VA	290	*3.7%*	545	*6.9%*	771	*9.8%*	1606	*20.4%*
		Region	**538**	***6.8%***	**925**	***11.7%***	**1402**	***17.8%***	**2865**	***36.3%***
	TOTAL	MD	933	*11.8%*	1792	*22.7%*	2025	*25.7%*	4750	*60.3%*
		VA	557	*7.1%*	1178	*14.9%*	1397	*17.7%*	3132	*39.7%*
		Region	**1490**	***18.9%***	**2970**	***37.7%***	**3422**	***43.4%***	**7882**	***100.0%***

As shown in the above table, 4750 observations were included in the MD dataset and 3132 observations were included in the VA dataset. ***Combined, these result in a total of 7882 observations for the region.*** Each state's dataset contained at least 37 observations for each of the nine class combinations, resulting in acceptable sample sizes for analysis.

STATISTICAL ANALYSIS

Confidence Intervals

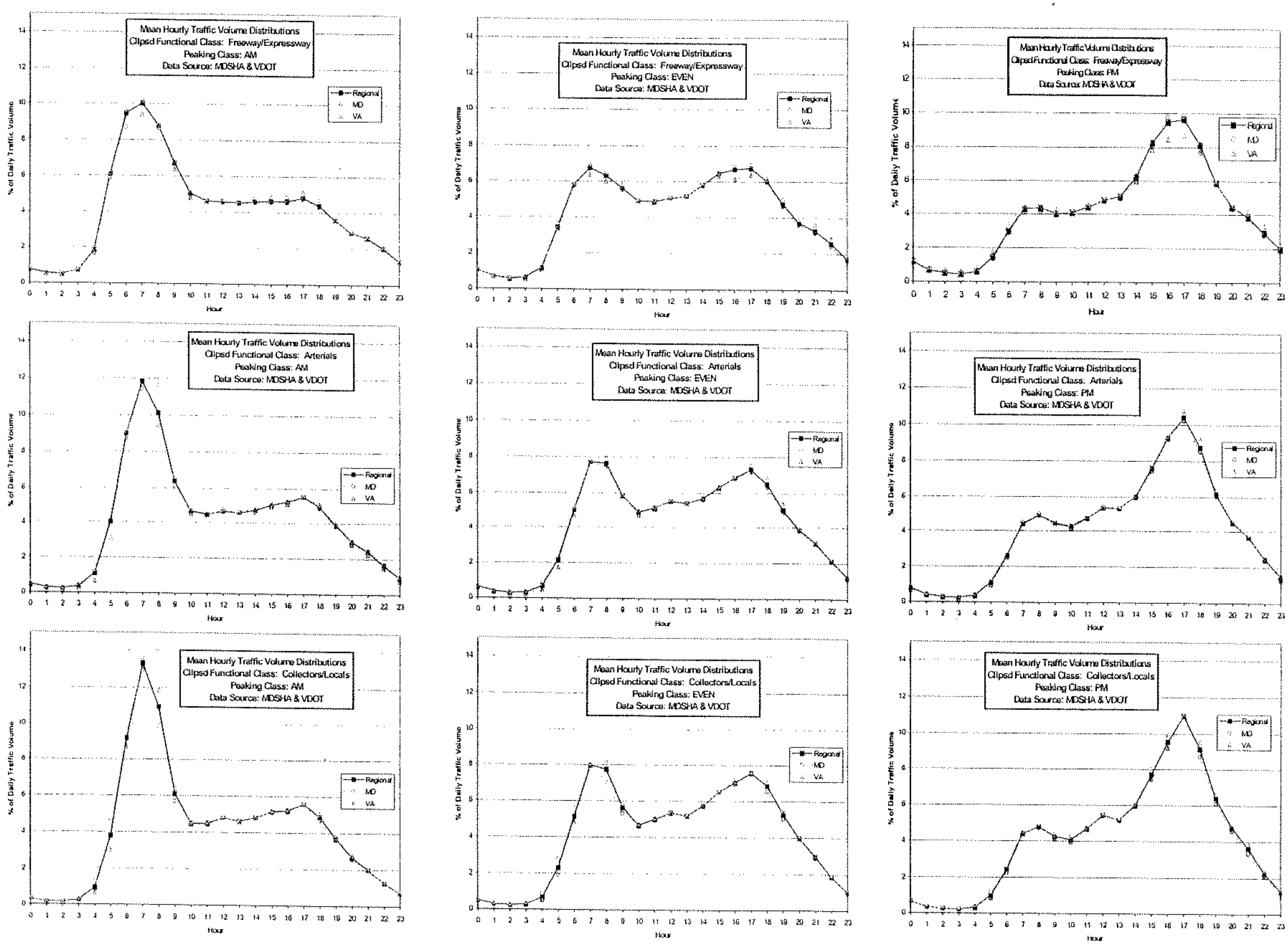
For each dataset (MD, VA, and Regional), the mean (% of daily total) of each hour for each class combination was calculated, along with the 90% confidence interval. The highest confidence interval range of 1.3% occurred with the VDOT dataset, Freeway/Expressway collapsed functional class, and AM peaking class. We are considering this an acceptable level of statistical error for the purposes of calculating hourly volumes within the Version 2 post processor. The means and confidence intervals are provided in graphical form in the appendix.

Regional Distributions

Figure 4 includes graphs of hourly volume distributions for each of the nine class combinations. Each hourly mean is plotted for Virginia, Maryland, and the Regional total datasets. ***There is very little difference between the datasets for most hours of the day.*** Maximum differences of approximately two percent occur between Virginia and Maryland during some of the peak hours. After observing these low differences among the results for each state, ***we decided to combine all of the data into a regional dataset to be applied over the entire network.*** These regional distributions are provided in tabular form in Figure 5.

FIGURE 4:

MEAN HOURLY VOLUME DISTRIBUTIONS BY STATE AND REGION



NOTE: A FULL PAGE VERSION OF EACH OF THE NINE GRAPHS IS PROVIDED IN THE APPENDIX

FIGURE 5:
RECOMMENDED DISTRIBUTION OF DAILY VOLUME BY HOUR

	COLLAPSED FUNCTIONAL CLASS								
	FREEWAYS/EXPESSWAYS			ARTERIALS			COLLECTORS/LOCALS		
	PEAKING CLASS			PEAKING CLASS			PEAKING CLASS		
HOUR	AM	EVEN	PM	AM	EVEN	PM	AM	EVEN	PM
0	0.758	1.022	1.169	0.490	0.642	0.780	0.337	0.507	0.645
1	0.541	0.693	0.677	0.301	0.379	0.419	0.195	0.297	0.336
2	0.511	0.577	0.502	0.250	0.288	0.288	0.176	0.232	0.251
3	0.708	0.648	0.441	0.374	0.316	0.244	0.285	0.294	0.207
4	1.856	1.176	0.610	1.091	0.688	0.387	0.959	0.686	0.334
5	6.123	3.431	1.449	4.048	2.175	1.103	3.804	2.310	1.000
6	9.488	5.805	3.011	9.020	5.069	2.603	9.206	5.153	2.452
7	10.022	6.769	4.305	11.834	7.724	4.454	13.334	7.985	4.430
8	8.804	6.330	4.381	10.128	7.639	4.965	10.938	7.748	4.811
9	6.735	5.645	4.030	6.373	5.852	4.489	6.106	5.656	4.257
10	5.075	4.930	4.095	4.703	4.933	4.300	4.499	4.683	4.093
11	4.622	4.903	4.421	4.527	5.174	4.794	4.513	5.013	4.721
12	4.596	5.086	4.844	4.713	5.556	5.387	4.813	5.359	5.453
13	4.528	5.191	5.076	4.635	5.436	5.344	4.639	5.203	5.204
14	4.605	5.812	6.251	4.798	5.717	6.025	4.849	5.743	5.989
15	4.645	6.477	8.268	5.087	6.337	7.593	5.171	6.513	7.701
16	4.637	6.702	9.493	5.265	6.859	9.303	5.233	7.033	9.537
17	4.845	6.753	9.659	5.551	7.301	10.417	5.579	7.571	11.003
18	4.399	6.029	8.159	4.988	6.490	8.768	4.915	6.847	9.153
19	3.610	4.756	5.897	3.899	5.068	6.167	3.719	5.316	6.409
20	2.914	3.700	4.461	2.962	3.875	4.550	2.700	3.986	4.778
21	2.612	3.277	3.868	2.401	3.130	3.671	2.012	2.985	3.656
22	2.033	2.568	2.939	1.637	2.118	2.471	1.298	1.854	2.290
23	1.333	1.717	1.996	0.926	1.232	1.476	0.717	1.025	1.289
SUM	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

ADDITIONAL ISSUES / FOLLOW-UP WORK TASKS

The following issues related to the application of hourly traffic distributions will be addressed in the future.

- *Develop hourly distributions while keeping the Version 2 peak period volume distributions intact:* The distributions of this analysis are stratifications of daily volume. However, the Version 2 model will forecast volumes for three time periods: (6AM-9AM), (4PM-7PM), and (all remaining hours). As forecasted volumes from the Version 2 model become available, the distributions of these three time periods should be compared with the data that were used in the preparation of this analysis. If appropriate, the available observed data could be used to stratify the volumes from the three time periods into hourly volume, instead of stratifying daily volume directly into hourly volume.

- *Combining arterials, collectors and locals functional classes into one collapsed functional class:* For this analysis, arterials were grouped into a collapsed functional class and collectors and locals were grouped into a second collapsed functional class. However, the resulting distributions for these two collapsed functional classes were very similar. By combining these classes, the distribution calculations could be simplified by reducing the number of link classes from nine to six.

- *Local Functional Classification Distributions:* Collector and local functional classifications were grouped into one collapsed functional class for the analyses documented in this memo. However, it may be more appropriate to develop separate distributions for use in the Version 2 post processor. Currently, the highway network of MWCOG's travel demand model does not include roadways with local functional classifications. The local vehicle miles of travel (VMT) is forecasted by performing "off-line" calculations using output from the travel demand model. Since collector and local VMT are forecasted with different methods in the post processor, separate distributions should probably be used.

INTERIM RECOMMENDATIONS

Until the outstanding issues are addressed, it is suggested that the distributions provided in Figure 5 be used for other cursory applications (e.g. execution of preliminary MOBILE 6, calibration of Version 2 Demand Model). In order to apply the distributions, each link of the Version 2 highway network will need to be classified into one of the nine distribution classes based upon the previously defined classification variables identified below:

I. Collapsed Functional Class
   a. Freeways / Expressways
   b. Arterials
   c. Collectors / Locals

II. Peaking Class
   a. AM Peaking
   b. Even Peaking
   c. PM Peaking