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."

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) Speed Feedback Incorporating Mode Choice

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

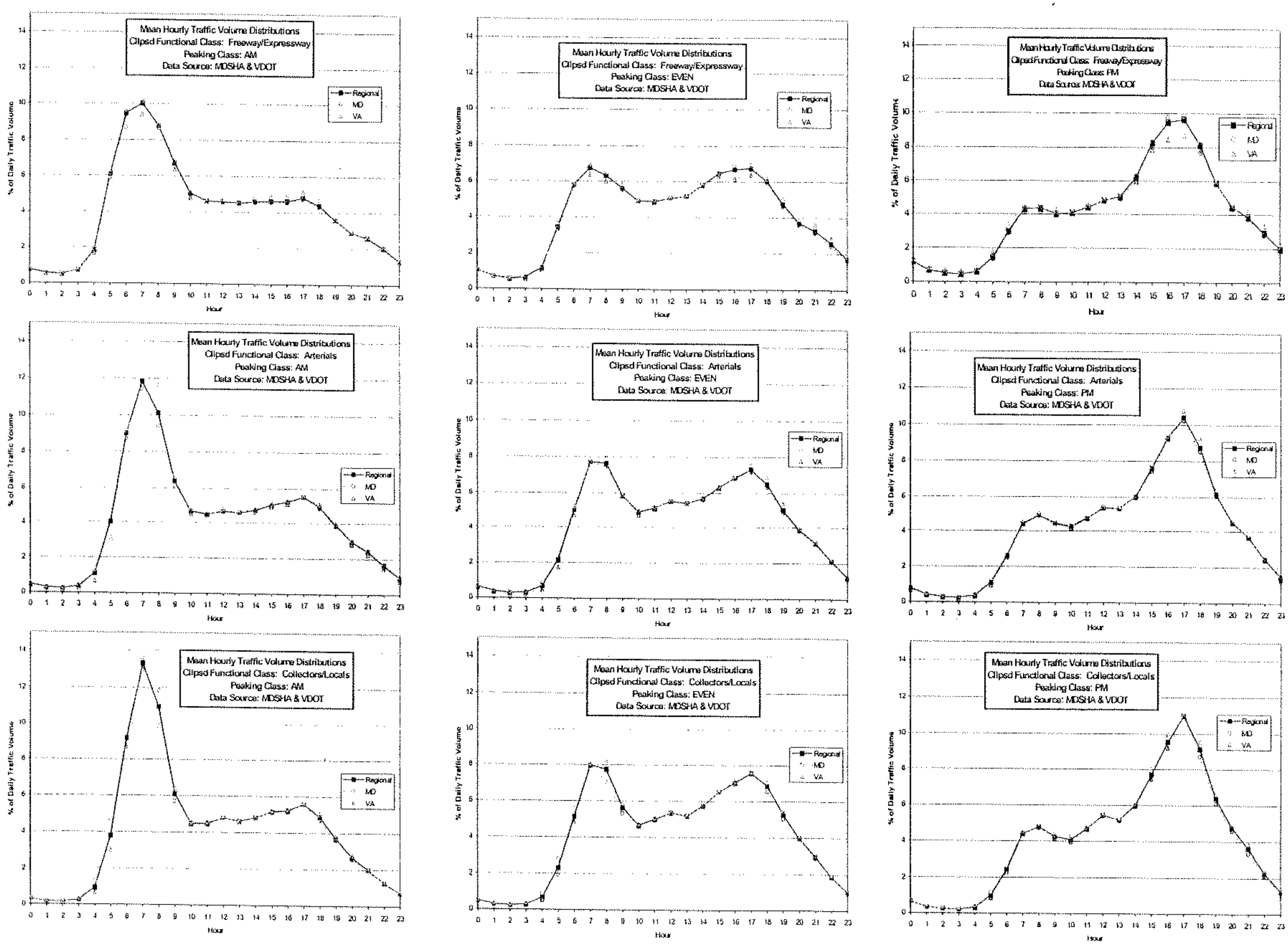
For each dataset (MD, VA, and Regional), the mean (% of daily total) of each hour for each class combination was calculated, along with the 90% confidence interval. The highest confidence interval range of 1.3% occurred with the VDOT dataset, Freeway/Expressway collapsed functional class, and AM peaking 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