An Evaluation of Assignment Algorithms and Post-Processing Techniques for Travel Demand Forecast Models

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(Abstract)

The purpose of this research project was to evaluate the techniques outlined in the *National Cooperative Highway Research Program Technical Report 255 Highway Traffic Data for Urbanized Area Project Planning and Design (NCHRP-255)*, published in 1982 by the Transportation Research Board. This evaluation was accomplished by using a regional travel demand forecast model calibrated and validated for the year 1990 and developing a highway forecast for the year 2000. The forecasted volumes along the Capital Beltway (I-495/I-95) portion located in the State of Maryland were compared to observed count data for that same year. A series of statistical measures were used to quantitatively evaluate the benefits of the techniques documented in NCHRP-255.

The primary research objectives were:

- To critically evaluate the ability of a regional travel demand forecast model to accurately forecast freeway corridor volumes by comparing link forecast volumes to the actual count data.
- To evaluate and determine the significance of post-processing techniques as outlined in NCHRP-255.

The most important lesson learned from this research is that although it was originally written in 1982, NCHRP-255 is still a very valuable resources for supplementing travel demand forecast model output. The "raw" model output is not reliable enough to be used directly for highway design, operational analysis, nor alternative or economic evaluations. The travel demand forecast model is a tool that is just part of the forecasting process. It is not a turn-key operation, and travel demand forecasts cannot be done without the application of engineering judgment.

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1.0 INTRODUCTION

1.1 Project Scope

One of the key outputs of travel demand forecasting models is the projected highway volume forecast. Often times, these volumes need to have some type of post-processing in order for them to be useful for project planning needs. Post-processing refers to any activity that follows the execution of the travel demand forecast model run. It can be viewed as the fifth step in the traditional sequential four-step modeling process. Currently, the only guide for post-processing travel demand model forecasts is the technical report *National Cooperative Highway Research Program (NCHRP) Report 255 Highway Traffic Data for Urbanized Area Project Planning and Design*[1]. This report was published in 1982 and remains the only nationally recognized technical resource for post-processing.

The purpose of this research project was to evaluate the techniques outlined in NCHRP-255. In order to evaluate the benefits of NCHRP-255, a travel demand forecast model used for the Washington, D.C. Metropolitan Area from the year 1990 was used to develop forecasts for the year 2000. The most recent land-use data for the year 2000 was obtained from the Metropolitan Washington Council of Governments (MWCOG). Forecasted highway volumes were developed for the portion of the Capital Beltway Corridor (I-495/I-95) in the State of Maryland. The "raw" model link volume output and the post-processed model output for this portion of the Capital Beltway was compared to the actual year 2000 observed count data.

The primary research objectives are:

- To critically evaluate the ability of a regional travel demand forecast model to accurately forecast freeway corridor volumes by comparing link forecast volumes to the actual count data.
- To evaluate and determine the significance of post-processing techniques outlined in NCHRP-255.

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[1] Pedersen, N.J., and Samdahl, D.R., *Highway Traffic Data for Urbanized Area Project Planning and Design NCHRP Report 255*, Washington, D.C., Transportation Research Board, December 1982, Chapter 4.

In order to achieve the above primary objectives for this project, a benchmark had to be established to determine what is being done in the field today. As part of this step a basic literature search was performed to review the state-of-the-art and practice in project planning and travel demand model forecasting. This task involved reviewing the professional literature on post-processing and current travel demand forecast modeling improvements. As part of this step an effort was made to determine the significance of this project and the state of post-processing for travel demand forecast projections. Discussions were held with officials at MWCOG, with nationally recognized consultants in the field, as well as with other department of transportation and planning officials in the Washington, D.C. area.

The state-of-the-practice review revealed a lot of improvement in assignment algorithms since 1990 – the base year for the travel demand forecast model used for this project. So, as part of this project different assignment algorithms were tested as well as time-of-day factoring at the post-mode choice step in the modeling process. Different assignment algorithms were applied including an all-or-nothing algorithm, an incremental capacity restraint algorithm, and an equilibrium algorithm. Further modifications to the basic impedance equation were performed for two incremental capacity restraint algorithms and one for an equilibrium algorithm. Time-of-day assignment methodologies were applied utilizing both the basic incremental capacity restraint and the equilibrium assignment algorithms. The results of all the techniques were compared to the observed count data and the final post-processed results for links along the Capital Beltway.

In evaluating the post-processing techniques outlined in NCHRP-255, two other commonly applied post-processing techniques were also evaluated. In addition to these post-processing techniques, an alternative forecasting method was applied and evaluated. The two other post-processing techniques are incorporated in the NCHRP-255 methods. For practitioners who apply some type of post-processing technique to highway forecast, these two partial techniques are often the methods of choice and not the full NCHRP-255 link refinement method. Therefore, it was of interest to see if the other techniques yielded a better result than the “raw” model output and how the other techniques compare to the end product from the NCHRP-255 methodology.

1.2 Project Significance

This project is unique because it takes an older model set and applies the land-use for a future year that is now the present. There were no similar projects to this one identified in the literature nor identified by other professionals in the field. For this research project the model set was developed in the early 1990's. It was validated and calibrated for the year 1990 and used on major investment studies in the region. In developing a year 2000 travel demand forecast, 2000 land-use data, based on preliminary data from the 2000 census, was input into the model. The "raw" output traffic forecast projections were compared to the actual counts on a major freeway facility in the region.

The year 2000 land-use forecast from 1990 was not used because the objective of the project was not to determine the accuracy of the forecast from 1990, but to determine the benefits of post-processing. The 1990 forecast land-use for the year 2000 might not accurately reflect what has actually been developed. The 2000 land-use data applied for this research project reflected the data supplied to MWCOG by the area municipalities and supplemented by the Census 2000 data. The land-use is not a perfect picture of what is on the ground today, but it can be expected to be very close.

Travel demand forecast models (TDFM) produce projected travel demand based on the supplied land-use for a target year. The primary output from these models is traffic volumes. There are other important outputs in the process, but the basic outputs are still traffic volumes. These traffic volumes are used in many different applications including highway design, highway operations analysis, alternative selection, and project financial analysis. The accuracy of these traffic projections can be very important in determining project feasibility as well as purpose and need. Often times the projections are used to not only to develop potential toll revenue, but are also required for determining project financing and related bonding issues.

The model reflects the expected land-use, transportation network, and current travel behavior at the time it is developed. These elements can change by the time the forecast year is reached. Land-use is the most dynamic of these elements. Changes in the highway facility and regional economics result in unexpected development, especially in areas that do not have strong development and growth policies. Given this uncertainty, it is still important to produce accurate travel demand forecasts. Differences in highway forecasts can result in under built facilities, lower than expected revenue, and even poor decisions on infrastructure projects. There is a real importance in providing governmental and non-governmental agencies the most accurate traffic volume forecasts. This research project evaluates the current practices used to produce those forecasts.

1.3 Study Corridor

The study corridor for this project is the Capital Beltway, specifically the portion in the State of Maryland. The Capital Beltway is part of the national interstate system and it is designated as I-495 and I-95. As I-95 approaches Washington, D.C, it intersects the Capital Beltway. I–495 is the northwestern section of the facility and I-95 is the southeastern section. For this project the portion of the Capital Beltway incorporated both I-495 and I-95. The study area started at the American Legion Bridge and continued to the Woodrow Wilson Bridge. Both bridges cross the Potomac River - the Legion Bridge north of Washington, D.C. and the Wilson Bridge south of the city.

The Capital Beltway is the major freeway facility in the Washington, D.C. area. The American Legion Bridge carries roughly 222,650 vehicles per day, and the Wilson Bridge carries about 197,775 vehicles per day. There are other freeway facilities in the area, but they all feed into the Capital Beltway. The portion of the Capital Beltway used in this research project was approximately 40 miles in length and included 28 interchanges. It covered two counties - Montgomery County and Prince George's County. This section of the Capital Beltway intersects with the following major freeway facilities: I-270, I-95, Baltimore-Washington Parkway, I-595 (US 50), and I-295. The Capital Beltway was originally built in the 1960s. Figure 1-1[2] shows the geographic location of the study corridor and the major surrounding highway facilities.

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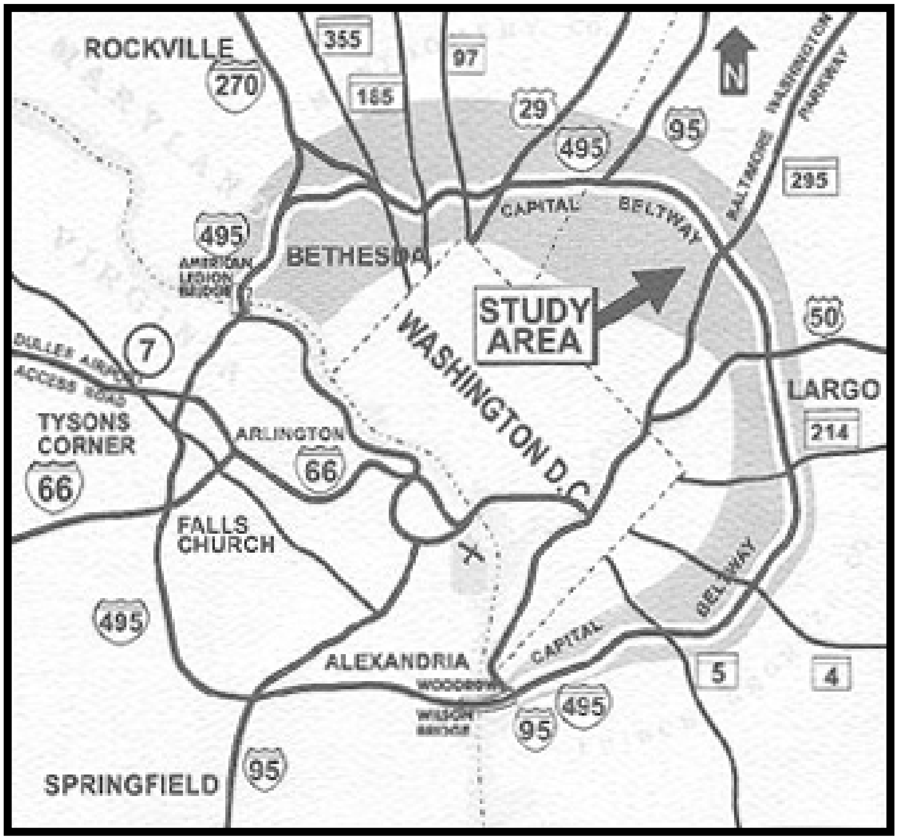
[2] Maryland State Highway Administration, *Capital Beltway Corridor* Study, Maryland State Highway Administration Web Site, Baltimore, Maryland, 2003.

Figure 1-1: Study Corridor



2.0 Literature Review

2.1 Overview

Comprehensive transportation planning in the United States started in the 1960s. Transportation planning activities had been conducted since colonial times, but in the 1960s the federal government took a proactive role. In 1961 the Bureau of Public Roads established the Office of Planning[3]. The Federal-Aid Highway Act of 1962 stated that for states to get federal aid for highway projects they must develop long-range transportation plans. These plans had to based on the 3 C's, which meant the plans must be continuing, comprehensive, and coordinated[4].

One of the results of this requirement was the creation of metropolitan planning organizations (MPOs). These organizations are required to develop long-range transportation plans that are updated and modified on a continuing basis, are comprehensive, and are coordinated between the jurisdictions that constitute the metropolitan area. As part of transportation planning process, it is the MPO that maintains a regional travel demand forecast model. This model serves as the basis for long-range transportation planning studies in the metropolitan area.

2.2 Development of Computerized Travel Demand Forecast Models

Computerized travel demand forecast models were first developed and applied in the 1960s. The first computerized travel demand forecast models were a battery of computer programs. There were two programs: PLANPAC and UTPS. PLANPAC was the first of these software programs, but in the 1970s it was improved to better address the needs of highway planners and take advantage of improvements in computer hardware developments. PLANPAC was developed and maintained by the U.S. Department of Transportation. UTPS was first developed by the U.S. Department of Housing and Urban Development and later became UTPS when the Urban Mass Transportation Administration took over the software's development[5].

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[3] Papacostas, C.S., and Prevedouros, P.D., *Transportation Engineering and Planning,* Englewood Cliffs, New Jersey, Prentice Hall, 1993, Chapter 7, p. 284.
[4] Weiner, Edward, Urban *Transportation Planning in the United States An Historical Overview*, Washington, D.C., U.S. Department of Transportation, 1992, pp. 41-44.
[5] Ibid, pp.115-116.

In the 1980s the microcomputer became more ubiquitous and accessible. As this new technology expanded became more available programs like UTPS were developed for the microcomputer. Software packages such as MinUTP and TRANPLAN replaced UTPS[6]. These software programs operated in a DOS environment and were able to incorporate the emerging improvements into the travel demand forecast modeling process. Both programs were developed by private companies. MinUTP was developed and maintained by COMSIS Corporation and TRANPLAN was developed and supported by the Urban Analysis Group. These software programs have now been replaced by TP+, which is developed and supported by Citilabs.

2.3 National Cooperative Highway Research Program Technical Reports

In 1978 the National Cooperative Highway Research Program (NCHRP) produced a technical report titled *NCHRP-187 Quick-Response Urban Travel Estimation Techniques and Transferable Parameters User's Guide*. This report presented a set of manual techniques and generalized parameters that could be used to perform transportation planning studies for smaller areas that were not necessarily part of a large metropolitan area. In the 1980s these techniques were incorporated into a software package called QRS. They were later updated in a software packaged called QRS II, which is no longer just a simple tool for sketch planning[7]. NCHRP-187 was recently updated with the release of *NCHRP-365 Travel Estimation Techniques for Urban Planning*. The updated technical report was published in 1998.

In 1982, the Transportation Research Board published *NCHRP-255 Highway Traffic Data for Urbanized Area Project Planning and Design*. One of the most important issues that NCHRP-255 dealt with was the application of travel demand forecast outputs from computerized models. NCHRP-255 provided, among other things, a set of procedures for refining link volume outputs directly from the model, as well as different methodologies for developing turning movements. This technical report recognized that direct model output was not suitable for project planning needs, and that techniques needed to be developed in order to post-process the "raw" results. As applied to link volumes, the procedure was termed "link refinement" or "link smoothing."

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[6] Comsis Corporation, *MinUTP Technical Manual*, Silver Spring, MD, Comsis Corporation, 1996, Introduction Chapter.

[7] Papacostas, C.S., and Prevedouros, P.D., *Transportation Engineering and Planning,* Englewood Cliffs, New Jersey, Prentice Hall, 1993, Chapter 9, p. 445.

NCHRP-187 presented a technique for distributing traffic between competing facilities. This procedure was later incorporated into NCHRP-255. The authors of NCHRP-255 were familiar with the procedure, having worked for the primary developer of the procedure. NCHRP-255 did not represent an addition to NCHRP-187. NCHRP-255 was a separate document that addressed the needs of practitioners who were using computerized travel demand forecast models. The same technique that is in NCHRP-187 was carried over to NCHRP-365, but no mention of NCHRP-255 and the refinement techniques presented in that report are mentioned in NCHRP-365.

2.4 NCHRP-255 Applications

NCHRP-255 was published in 1982 and has never been updated. The technical report is out of print and cannot be purchased from the Transportation Research Board. Even though it is out of print, it still remains the standard guide for post-processing the link volume outputs from computer-based travel demand forecast models. NCHRP-255 is an important document, but it is not used universally and few practitioners are familiar with the procedures and methods in the report. NCHRP-187 is much more recognized and referenced in the transportation planning textbooks.

Since 1990 there has not been one transportation publication about NCHRP-255. In 1989, the Institute of Transportation Engineers (ITE) published an article titled *Increasing the Relevance of Planning for Project Development and Engineering Design*. This article addressed the fact that NCHRP-255 was not being applied in the field. It stated[8]:

> "The FHWA's Office of Planning felt the NCHRP report filled a critical gap in the planning/project development linkage, but needed to be marketed to help enhance technology transfer and encourage the practical application of these procedures."

In order to address this problem, FHWA went on to develop a course that dealt with the applications of NCHRP-255. This course was taught by the National Highway Institute (NHI). It

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[8] Fleet, Christopher R., Osborne, A., and Hooper, Kevin G., "Increasing the Relevance of Planning for Project Development and Engineering Design." *ITE Journal*, May 1989, pp. 29-32.

incorporated a set of spreadsheet tools directly based on the methods and techniques documented in NCHRP-255. These basic spreadsheets are still used today, although the application software program has been changed.

In 1984 ITE formed a technical committee to assess the use of system-level, computer-model-generated traffic volume forecasts in project level engineering and design. As part of this effort the committee reviewed the use and application of the procedures presented in NCHRP-255. The committee published a report in 1990 concerning the application of NCHRP-255. The committee found that only 16 percent of the respondents stated that they apply the methods outlined in NCHRP-255, while 52 percent responded that they seldom or never use it. The remaining respondents were not aware of the report. Their conclusion was that the use of NCHRP-255 as a technical standard was limited[9]. That was the state-of-the-practice 13 years ago and not much has changed.

2.5 State-of-the-Practice

Throughout the 1990s there was little mention or documentation concerning the techniques and methods outlined in NCHRP-255. There has been a good deal of research and documentation of improvements to the traditional travel demand forecast modeling structure. The U.S. Department of Transportation, in cooperation with the U.S. Environmental Protection Agency and the U.S. Department of Energy, has established the Travel Model Improvement Program (TMIP). The purpose of the TMIP program is[10]:

1. To increase the ability of existing travel forecasting procedures to respond to emerging issues including environmental concerns, growth management, and lifestyle, along with traditional issues,
2. To redesign the travel forecasting process to reflect changes in behavior, to respond to greater information needs placed on the forecasting process, and to take advantage of changes in data collection technology, and

[9] ITE Technical Council Committee 6F-34, "Refinement of traffic Forecast: Practitioners and Procedures." ITE Journal, February 1990, pp. 43-47.
[10] Cambridge Systematics, Inc. and Barton Aschman Associates, *Short-Term Travel Model Improvements*, Washington, D.C., U.S. Department of Transportation, October 1994, p. i.

3. To integrate the forecasting techniques into the decision making process, providing better understanding of the effects of transportation improvements and allowing decisions makers in state governments, local governments, transit operators, metropolitan planning organizations and environmental agencies the capability of making improved transportation decisions.

In October 1994, the TMIP published a report titled *Short-Term Travel Model Improvements*. The report documented several potential improvements to the traditional urban travel demand modeling process. There was a section on instability of highway assignments in saturated networks. This section briefly touched on the problems concerning the application of an equilibrium assignment on a saturated network. The network was a dense grid-pattern of streets, and changes in one part of the network resulted in unexpected alternative paths far from the network change[11]. The report did not address the inherent problems in the assignment model that NCHRP-255 documented. In the report there is no mention of the need to post-process "raw" model results.

In March of 1996, TMIP published a report titled *Incorporating Feedback in Travel Forecasting: Methods, Pitfalls, and Common Concerns*. The purpose of this report was to address the emerging issues surrounding the need to incorporate the effects of congested network conditions into land-use development, trip distribution, and mode choice. One of the significant findings from the report was that[12]:

> "The implementation of the assignment-distribution feedback can produce different system-wide travel characteristics such as the average speeds and average trip length when there is congestion in the modeled networks. This result suggests that feedback may be essential to accurate forecasts when congestion exists."

Again this report failed to mention anything about the need to post-process the assignment output and the impact that feedback loops have on the accuracy of the assignment model. One of the

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[11] Cambridge Systematics, Inc. and Barton Aschman Associates, *Short-Term Travel Model Improvements*, Washington, D.C., U.S. Department of Transportation, October 1994, p. 12-3.
[12] Comsis Corporation, *Incorporating Feedback in Travel Forecacst Methods, Pitfalls and Common Concerns*, Washington, D.C., U.S. Department of Transportation, March 1996, p. 1.5.

essential outputs from the travel demand forecasting process is link volumes. If feedback was determined to be important for calculating link speeds, there should have been some mention of the pitfalls related to the assignment model and the corresponding need for post-processing of "raw" link outputs.

In October of 1997, TMIP published a report titled *Time-of-Day Modeling Procedures State-of-the-Art, State-of-the-Practice*. Given the growing need to use travel demand forecast models for not only transportation system design but also environmental analysis, there was an effort to incorporate improvements into the assignment model. The objective was to develop model outputs that were temporal as well as spatial[13]. This was done by assigning trips by purpose for certain times of the day. By assigning time-of-day trip tables it is thought that data can be taken directly from the model and used for project planning needs. Given the perceived benefits of time-of-day modeling there would not be a need to apply directional factors to average daily traffic volumes. Many academics and practitioners believe that time-of-day modeling produces better results. Time-of-day was determined to be important because the assignment of average daily traffic is not sufficient for the needs of the end user. The application of time-of-day procedures is thought to produce better assignments that can be used directly for project planning. The state-of-the-art and the state-of-the-practices did not contain any reference to NCHRP-255 and the need to post-process the "raw" results.

The National Highway Institute is part of FHWA and has a short course titled *Introduction to Urban Travel Demand Forecasting*. The course material workbook from August of 2000 provides a comprehensive reference and guide to the traditional four-step travel demand forecast modeling. The objectives of the course are[14]:

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[13] Cambridge Systematics, Inc., *Time-of-Day Modeling Procedures State-of-the-Art, State-of-the-Practice*, Washington, D.C., U.S. Department of Transportation, October 1997, pp. 2-1 – 3-18.
[14] National Highway Institute, *Introduction to Urban Travel Demand Forecasting – Participant Workbook*, Washington, D.C., U.S. Department of Transportation, August 2000, pp. 10-1 – 10-36.

To gain an introductory level understanding of:

- urban travel demand forecasting,
- how travel demand forecasting is used to support planning activities,
- new concerns and concepts in transportation planning and travel demand forecasting,
- knowledge of improvements to the travel demand forecasting process.

The workbook is divided in 14 sessions. There is a session on assignment as well as model validation procedures. There is no mention of the need for post-processing or any of the other concerns that were documented in NCHRP-255 pertaining to the use of computer-generated travel demand forecasts.

2.6 Project Significance

The Travel Model Improvement Program supports an electronic bulletin board. The purpose of this board is to allow practitioners and professionals in the field to exchange information and stay up-to-date with developments in the field. As part of this research project, two questions were posted on the board at separate times. The first question inquired about the state of use for NCHRP-255. The questions asked if any planning agencies still require the use of NCHRP-255. There were very few responses to the question. Planning agencies in the State of Maryland, Arizona, and Oregon responded that they still use the techniques and methods outlined in the report. The scope of their use was not determined, only that it is required in developing project planning forecasts. It appears that there is even less knowledge now concerning the techniques and methods outlined in NCHRP-255 than in 1990 when only 16 percent of respondents to an ITE survey stated that they use it.

The other question posted on the TMIP electronic bulletin board was whether anyone knew of a study similar to this research project. There were no replies, except that there had been a number of land-use studies done comparing the land-use forecast to the actual land-use that developed by the forecasts year. There have also been studies done comparing the original forecast to actual forecast for both highway and transit results. There were no replies from the board that a study like this one has been done before.

A search of transportation-related documents was done using the TRIS database as well as the ITE database. In neither database listed any other studies similar to this project. This project is unique in that it not only evaluates the techniques outlined in NCHRP-255, but also evaluates the results of using the actual land-use for a forecast year and inputting that into an older model set to develop forecasts for the known year that is not the model calibration or validation year.

There is always the chance that a study similar to this one has been done in the past and was not published. In order to make sure that was not the case for the Washington, D.C. Metropolitan Area the question was asked at a Travel Forecasting Subcommittee meeting of the Metropolitan Washington Council of Governments. In addition, travel forecasting professionals at the Maryland State Highway Administration, the Northern Virginia office of the Virginia Department of Transportation, Maryland-National Capital Park and Planning Commission, and leading consultants in the Washington, D.C. area were all asked if they knew of a similar study. It was determined that a study similar to this project has not been previously done. Additionally, all of the parties that were questioned showed real interest in seeing the results.

3.0 Methodology

3.1 Overview

The primary objective for this research project was to evaluate the benefits of post-processing techniques as outlined in the National Cooperative Highway Research Program (NCHRP) Technical Report 255, published by the Transportation Research Board. In order to determine the benefits of these techniques, a ten year-old travel demand forecast model (TDFM) was tested using the current land-use. The modeled results were then compared to the observed count data. The key tasks involved in the scope of research for this project were the following:

- To obtain the Regional Travel Demand Model Set from the year 1990.
- To compile count data for the Capital Beltway in the year 2000.
- To define and construct the cutlines for link refinements as outlined in NCHRP-255.
- To define a set of measures of effectiveness for the project evaluation.
- To execute the TDFM model run for the year 2000.
- To test and evaluate the different assignment algorithms.
- To derive peak hour forecasts and compare them to the observed count data.
- To apply time-of-day (TOD) factors to the trip tables and perform an assignment representative of the PM peak period.
- To evaluate the significance of the TOD assignment.

Each of these tasks had several sub-tasks and related activities. The compilation of the count data took the greatest amount of the time and effort. Familiarity and past experience with the MWCOG model set and related data helped make the modeling effort progress smoothly.

3.2 Travel Demand Model Set

Traffic forecasts were developed using a travel demand forecasting model (TDFM). The model was developed for the Washington, D.C. Metropolitan Area. The original 1990 model set was based on highway and transit networks with 1,478 zones. The model set used in this project was expanded to 1,674 zones. The additional zones resulted from splitting zones in Montgomery

County, Maryland. In addition to adding more zones, more links were coded in the highway network to better represent portions of Montgomery County.

Since the original development of the 1990 model set the model structure had been updated by MWCOG. The TDFM used in this research project was for the year 1990, but it incorporated later model structure improvements into the travel demand process. The model structure used for this research project represented a special status in MWCOG's TDFM model development program. This model was termed the "Hybrid Model." The Hybrid Model utilized the improvements from the update to the regional travel demand model – MWCOG's Version 1 Model. The Version 1 Model networks have 2,191 zones, the Hybrid Model which was developed for Stage IIb of the I-270/US 15 Multi-modal Corridor Study used 1,674 zone networks within the structure of the Version 1 Model algorithms.

The Hybrid Model structure was based on the Version 1 Model enhancements, an improvement to the previous regional model. The Version 1 Model reflected improvements resulting from data collected from 1990 CTTP and 1994 travel surveys. This data was used to evaluate and update the trip generation rates, trip distribution factors, and mode choice parameters. The Version 1 Model was validated for the year 1994 and released in October 1998. The Hybrid Model set was validated for 1990, and 1990 was designated as the base year for the model set.

The inputs for this research project into the process were:

- Year 2000 Land-Use (Cooperative Round 6.2 – July 2002).
- Year 2000 Highway and Transit Facilities.

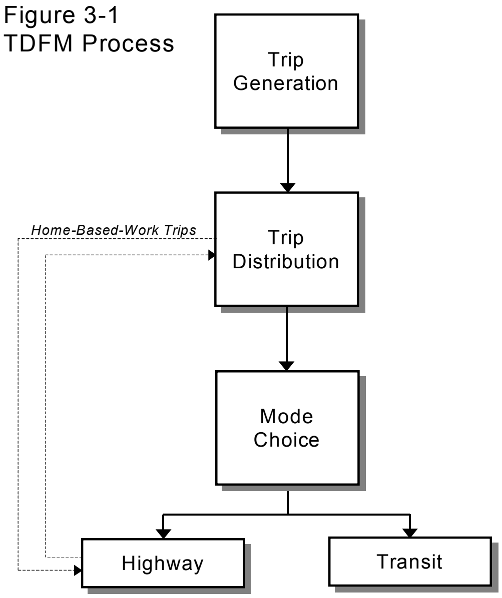
The Hybrid Model is structured around the traditional four step sequential demand forecasting process, with the added step of a feedback loop into trip distribution following the first assignment. Only auto-driver home-based work trips were fed back into the trip distribution model. Figure 3-1 shows the four step process and the incorporation of the feedback loop.

The first step in the four step process is the trip generation model. The trip generation model determines why a trip is made. For this model set the trip generation model develops trips based on six purposes. Four of the six trip purposes are at the person level, while the remaining two purposes are at the vehicle level. The following are the trip purposes:

- Home Based Work (HBW) – Person Trips.
- Home Based Shopping (HBS) – Auto Driver.
- Home Based Other (HBO) – Auto Driver.
- Non-Home Based (NHB) – Auto Driver.
- Medium Truck – Vehicle Trips.
- Heavy Truck – Vehicle Trips.

The trip generation model uses cross-classification and regression models for calculating trip attractions and trip productions. Trips are calculated at the district level and represent activities for the entire day. The trip productions and attractions are developed independently for each trip purpose. The trip production model is based on the number of households, vehicles per household, and area type. Trip attractions are calculated based on employment type and area type.

Figure 3-1
TDFM Process



In order to manage the data set in the environment in which the computer operates, the number of trips per district are calculated for both attractions and productions. The districts represent aggregated zones. There are a total of 293 districts for 1,674 zones. Since more is known about the production end, and housing is a more stable variable to forecast, attractions are balanced to productions at the district level. There is a set procedure developed to balance the internal attractions to productions. This process is applied on a regional basis.

The second step in the travel demand forecasting process is the trip distribution model. The trip distribution model is executed at the district level. Trip distribution takes the production and attraction data for each district and determines where the trip will travel. The result is a set of trip tables by purpose with production and attraction pairs by district.

Trip distribution utilizes a gravity model. The gravity model evaluates the attractiveness of a destination for a specific origin. Attractiveness is mainly a function of travel time, but friction factors are applied to spread the travel time trip distribution to match the survey data. Three sets of friction factors which are applied by purpose are used. These include internal, external interstate, and external arterial. There are four sets of K-factors used to adjust for socio-economic elements not accounted for by the friction factors. These factors are applied to HBW, HBO, HBS, and NHB trips. The friction factors and K-factors were developed in the original calibration of the Version 1 Model. MWCOG determined that the same factors were applicable for the Hybrid Model 1990 validation.

After trip distribution has been run, the district level trip tables are converted to zonal level trip tables. Home-based work person trips are fed into the mode choice model, while the other trip tables are converted to vehicle trips based on an auto-occupancy model. The mode choice model determines which mode work trips will use to get to and from their destination. Mode preferences are only developed for home-based work trips.

The mode choice model applies a two-tier logit model. The original model was developed in 1986 and was later updated in 1992. The first tier develops mode share for drive alone, transit, and share ride high occupancy vehicles (HOV). The second tier develops HOV-2 and HOV-3+. The mode choice model is applied to HBW production-attraction trip tables. All of the trip tables are converted to origin-destination trip tables prior to assignment.

The final step in the travel demand forecasting model process is trip assignment. There are two different assignments, one for highway trips and one for transit trips. The transit assignment is only done for project planning studies. The highway assignment is an incremental capacity restraint algorithm based on the BPR curves. The BPR curves represent a relationship between traffic volume and travel time or speed. As traffic volumes increase, travel time increases exponentially.

After the first assignment, a feedback loop is initiated. The feedback loop is applied to the HBW auto-driver trips. Travel times are computed based on the congested network, and HBW trip destinations are recalculated. The objective is to account for the effects of congestion on the employment location. After the feedback loop, a trip's travel time does not change. Rather, the work end may become closer to the home end. The result of the feedback loop is a change in trip length for HBW auto-driver trips, which reflects the impact of congestion on the work end location.

Although transit was not an explicit part of this project, the model does develop transit mode share during the mode choice step. The transit mode share calculation accommodates two types of transit trips: walk access and drive access. The determination of walk or drive access is based on the geography of the zone and the surrounding transit infrastructure. The percentage of walk and drive access from each zone is determined by the network coding, and then the mode choice model determines the access path. The access path must be either drive or walk. The final result is a set of trip tables for walk access and drive access. The transit assignment chooses the shortest time path, but transfer and wait time are penalized to better reflect real-world travel routes.

For the Hybrid Model a year 2000 transit network did not exist. In order to develop the transit path skims for the mode choice model, transit skims from the Version 1 model had to be converted to the 1,674 zone network used in the Hybrid Model. year 2000 transit skims were developed using the Version 1 model and converted to the 1,674 zonal structure using the zonal equivalence tables developed by MWCOG staff. The Version 1 networks represent an expanded geographic area. All of the transit service currently operating in the Washington, D.C. Metropolitan Area was within the network boundaries of the 1,674 zone Hybrid Model. Therefore, it was possible to convert the transit skims from one model structure to the other with minimal disruption in the modeling process.

The Hybrid Model runs on a MinUTP platform in a MSDOS environment. MinUTP was originally developed by COMSIS Corporation. The software development has stopped, and it is now supported by Citilabs. The Hybrid Model set utilized MinUTP versions 96b and 93b. Adjustments had to be made to the path statements throughout the modeling process. Added modifications had to be made to the computer's config.sys file and autoexec.bat files. Additionally, a memory manager program, in this case QEMM, was required for the running of the path skimming and assignment steps. MWCOG flow charts documenting the model process are included in the appendices of this report. The total run time for the model was about six hours. Each additional assignment took approximately 30 minutes per run.

3.3 Land-Use

The two basic inputs into the traditional four-step TDFM are land-use and the transportation network. Land-use is the most dynamic input in the TDFM process. Future modifications to the transportation network are usually known. Because of the need to have funds dedicated to get future network improvements and projects listed in the Constraint Long Range Plan (CLRP), future facility improvements can more easily be documented and incorporated in the TDFM, while land-use is dynamic and can change from expected future land-use forecasts. These changes can be related to regional economics, improved transportation facilities, zoning ordinances, as well as other less tangible impacts.

Although the Washington, D.C. area grew from 1990 to 2000, the forecast that would have been used in 1990 to develop year 2000 travel demand forecasts would not have accurately reflected what was actually on the ground in the year 2000. The land-use data used in the modeling process obtained from MWCOG's most recent land-use data, Cooperative Forecast Round 6.2, shows that from 1990 to 2000 households in the Washington, D.C. Metropolitan Area grew by 16.9 percent while total employment grew by 14.2 percent. The earlier Round IV Cooperative Land-Use Forecast from 1988 shows 5.2 prercent greater households than the actual year 2000 households for the eight core jurisdictions around Washington, D.C. For employment there is a 9.2 percent difference, with the 1988 land-use forecast showing approximately 263,000 more jobs than there actually were in 2000. Table 3-1 summarizes the land-use from the 1988 Cooperative Land-Use Forecast Round IV for the year 2000 and the actual land-use for the year 2000 from Round 6.2. Round 6.2 was provided by MWCOG in the summer of 2002.

Table 3-1: Year 2000 Land-Use Data Summary Round IV & 6.2

Jurisdiction	Households		Employment	
	IV	6.2	IV	6.2
District of Columbia	265,235	221,796	816,705	678,017
Montgomery County	338,998	314,922	574,995	532,665
Prince George's County	295,010	293,000	386,409	328,729
Arlington County	88,559	90,102	244,989	201,231
City of Alexandria	59,183	61,522	148,311	98,552
Fairfax County	377,216	366,248	534,463	565,112
Loundoun County	51,862	60,559	61,192	85,296
Prince William County	123,750	109,125	99,295	114,005
Total:	1,599,813	1,517,274	2,866,359	2,603,607

Source: MWCOG Round IV Technical Report - 1988 & MWCOG R6.2 Data Files - 2002

The Round 6.2 land-use was defined in terms of the 2,191 zone network. For the purposes of the Hybrid Model, the 2,191 zone structure had to be converted to the 293 districts used in the trip generation model. An equivalence table had been defined by MWCOG, but for external trips there was a need to factor back from 2020 to the year 2000. Based on growth patterns in the region, factors were applied to the 2020 external trip tables in order to calculate year 2000 external trip tables.

Figure 3-2 shows the number of jobs by zone for the year 2000 for Montgomery County, Prince George’s County, and Washington, D.C. Figure 3-3 shows the number of households by zone for the year 2000 for the same geographical area. Figures 3-4 and 3-5 show the density of jobs and households, respectively, by zone for the same geographic area. The density of jobs and households is provided in order to show where the central business districts and downtown areas are located.

Figure 3-2

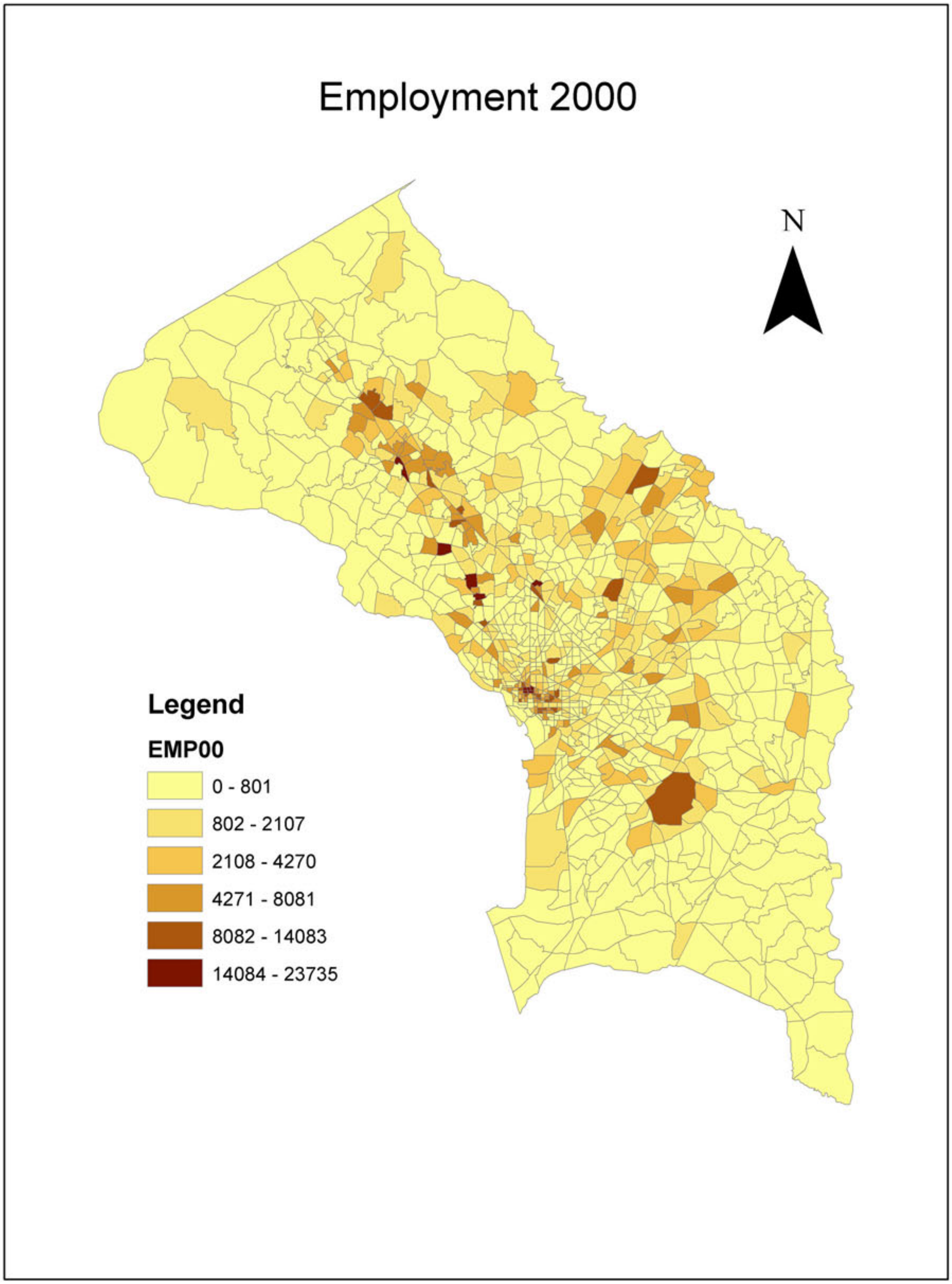

Employment 2000
N
Legend
EMP00
0 - 801
802 - 2107
2108 - 4270
4271 - 8081
8082 - 14083
14084 - 23735

Figure 3-3

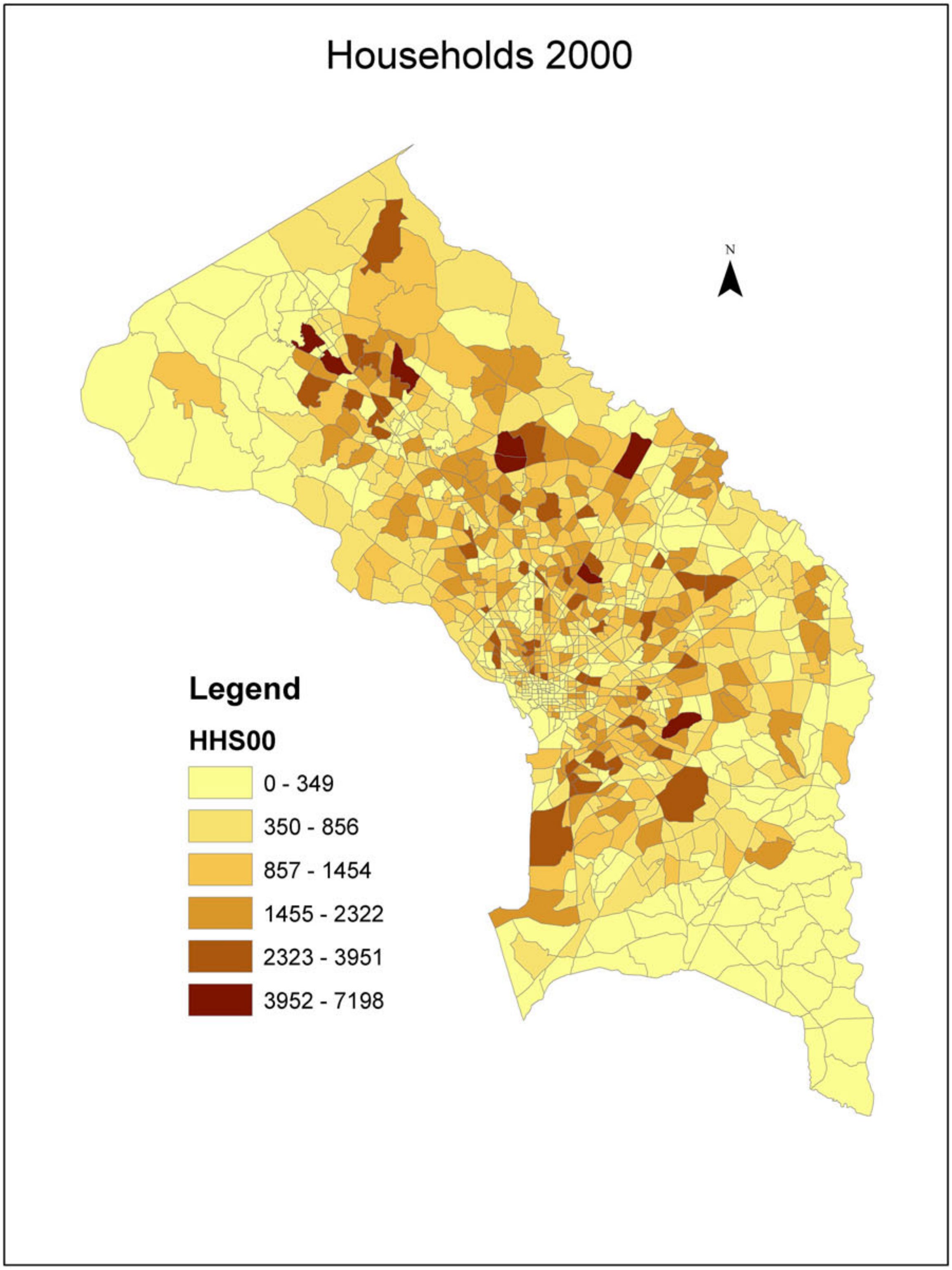
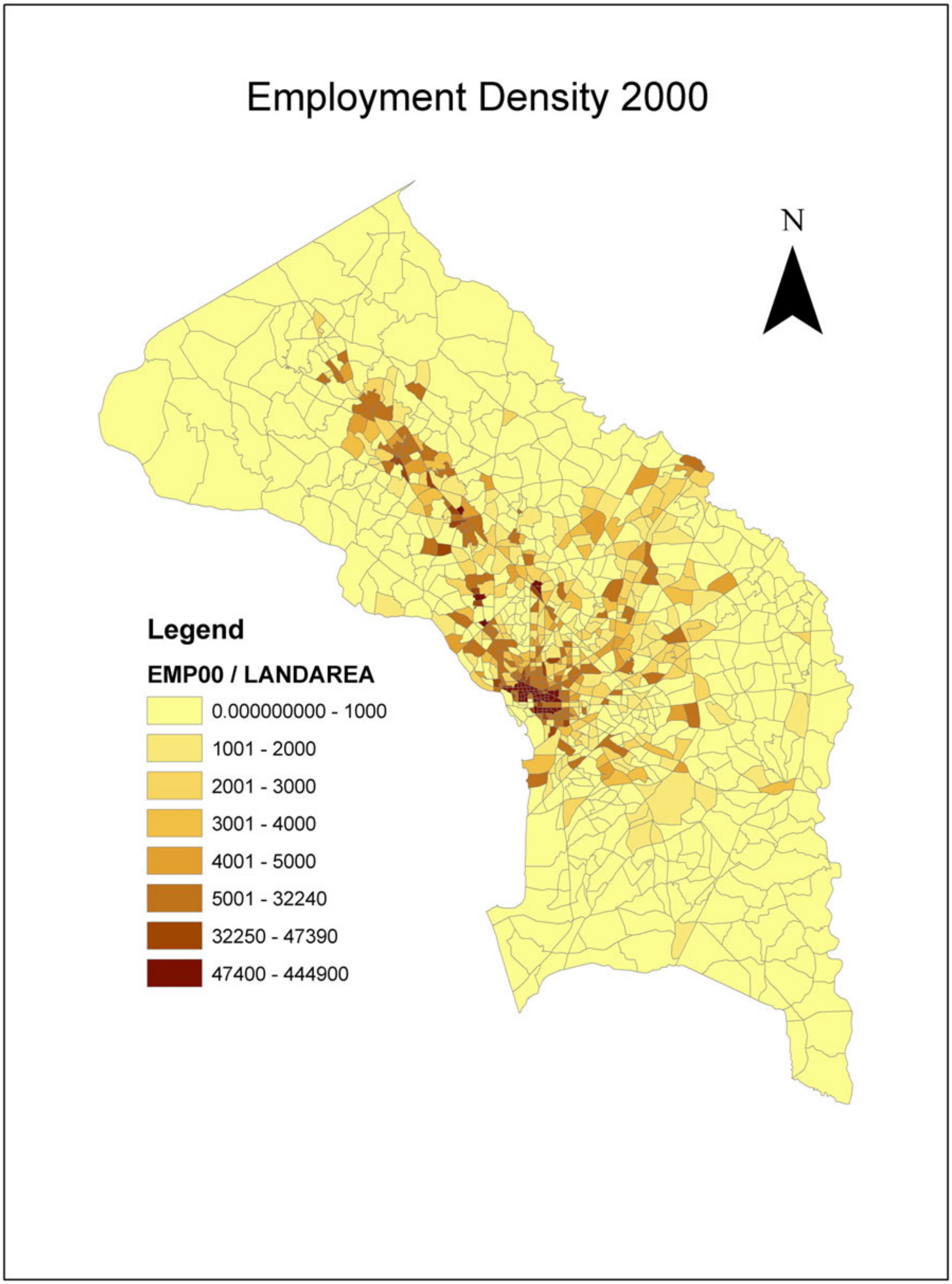
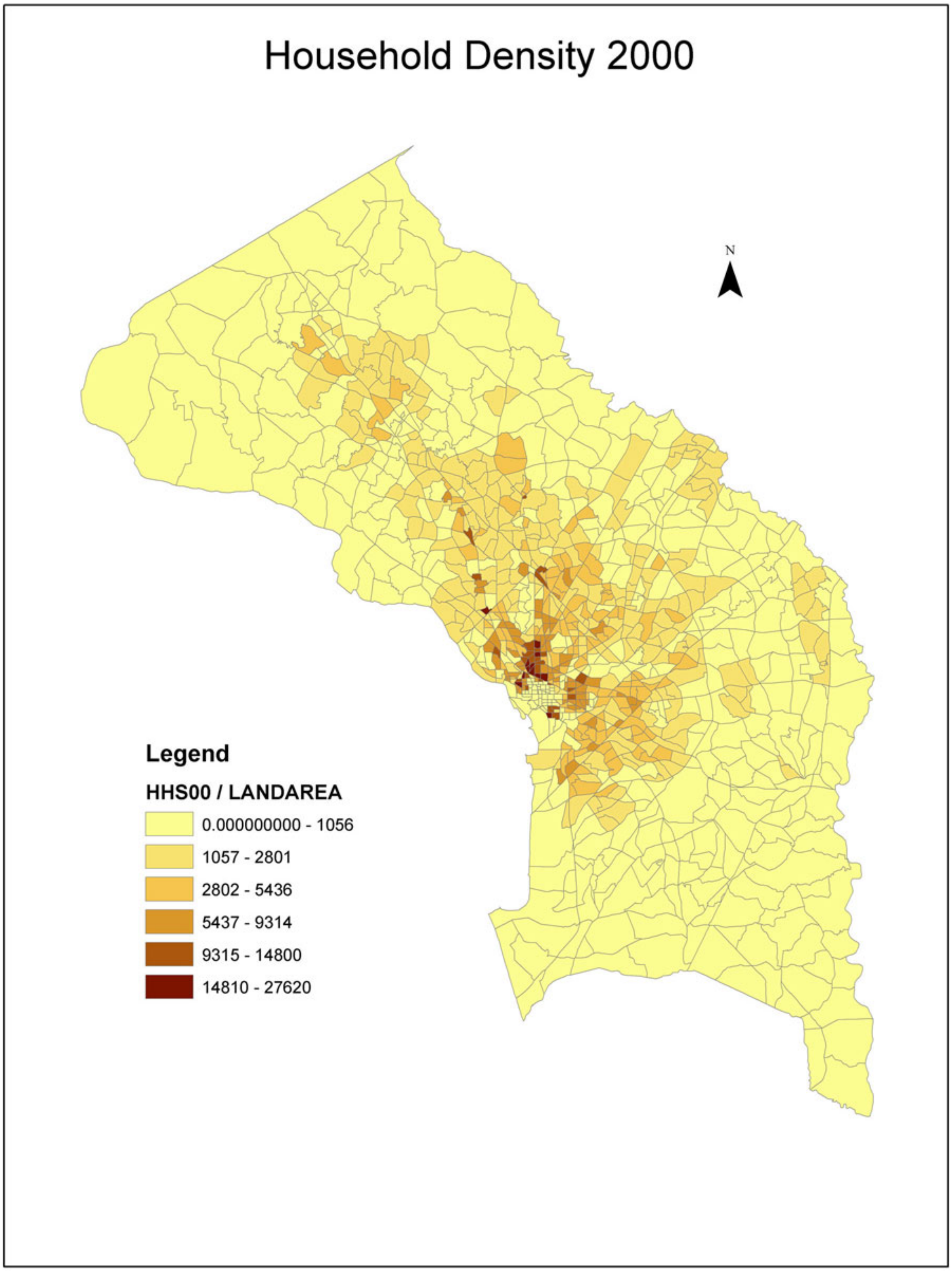

Households 2000
N
Legend
HHS00
0 - 349
350 - 856
857 - 1454
1455 - 2322
2323 - 3951
3952 - 7198

Figure 3-4



Employment Density 2000
N
Legend
EMP00 / LANDAREA
0.000000000 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 32240
32250 - 47390
47400 - 444900

Figure 3-5


Household Density 2000
N
Legend
HHS00 / LANDAREA
0.000000000 - 1056
1057 - 2801
2802 - 5436
5437 - 9314
9315 - 14800
14810 - 27620

3.4 Count Data Compilation

The compilation of the count data for this research project was a challenge. This project did not have a budget to collect data and relied on available sources for obtaining count data. These sources included the following data supplied by the Maryland State Highway Administration (SHA):

- SHA Traffic & Trends Publications
- SHA Traffic Monitoring Database
- SHA Capital Beltway HOV Corridor Study.

The *Traffic & Trends*[15] publication provided count data for permanent count stations throughout the State of Maryland. There are three operating stations along the Capital Beltway. There is one station near the northern Potomac River crossing, another station near the interchange for MD Route 650, and a third near MD Route 214 which is toward the southern end of the study corridor. Data was available from these stations for as far back as 1989, and provided by hour for an entire year. The data was also accessible via the internet through SHA's web site.

The other main data source was SHA's traffic monitoring database. This database is accessible via the internet through SHA's web site. The database has counts for most roads in the state for the previous three years. The counts are provided in different formats including 12-hour turning movement counts, vehicle classifications, and 24 hour volume counts. The counts are for varying times throughout a given year. These counts are not restricted to only a uniform data collection effort, but represent a clearinghouse for count data statewide.

The third source of data was material provided by SHA pertaining to the ongoing Capital Beltway HOV Corridor Study. This data included counts for all roads adjacent to the freeway as well as complete freeway system counts. The data was for daily and weekday peak hours. Although this data was very comprehensive it was not always consistent with other data sources. Counts performed at adjacent intersections during the same period did not always reflect the

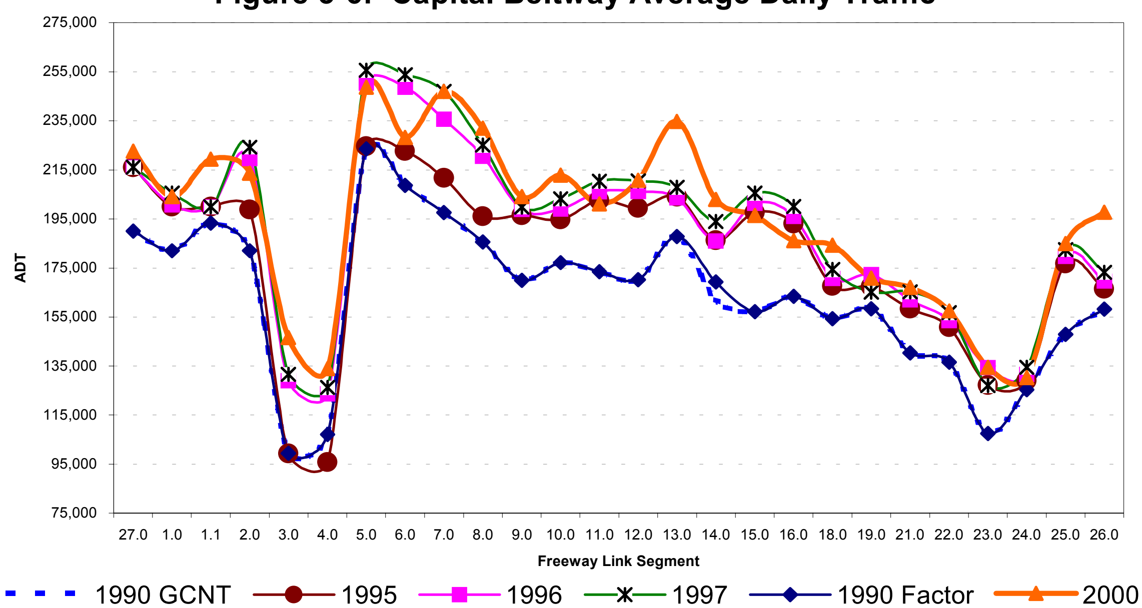
[15] *Traffic Trends 2000*, Maryland State Highway Administration, Baltimore, Maryland, 2001, pp.228-261.

same volumes. The data was used with other sources to provide balanced counts through the entire study corridor and on all arterial approach roads to Capital Beltway interchanges.

Count data needed to be reviewed and compiled for both 1990 and 2000. The TDFM highway network contained ground count data for most links in the network. The accuracy of this count data could not be determined, but for key links in the network it was consistent with patterns that were observed from varying data sources. There was some modification to the 1990 count data, but on the whole it was assumed to be reasonable for the purposes of making link refinements using the post-process techniques outlined in NCHRP-255.

It was critical to get the most accurate data for the year 2000 as possible. Since the basis of this research project is to compare the model results to the year 2000, the count data had to be consistent and reasonable. This was especially true for the actual freeway links on the Capital Beltway. Figure 3-6 shows a comparison of the count data for the year 2000 compared to previous years. The x-axis shows the freeway links starting at the American Legion Bridge and ending at the Woodrow Wilson Bridge.

Figure 3-6: Capital Beltway Average Daily Traffic



Although there still may be some questions concerning the count data, multiple sources were used to develop this data. In determining the most accurate count data for a specific link, preference was given to the volume published by SHA for the year 2000. These counts represent average annual daily traffic (AADT). Based on data provided in the *Traffic & Trends* there is a small difference in the AADT and average weekday daily traffic (AWDT). AWDT is more representative of what the model produces. This small difference, less than three percent, is a direct function of the nature of the Capital Beltway and the high demand on it.

For simplicity, AWDT link volumes produced from the model will be referred to as average daily traffic (ADT). The ADT link volumes, which are a direct output from the model, are supposed to represent the 30th highest traffic volume for design purposes. Based on data for the region, this is equivalent to a typical weekday in March or October.

3.5 Post-Processing Methodology

Post-processing refers to analysis performed after execution of the travel demand forecast model run. Post-processing activities are applied to both the highway and transit travel demand forecast model (TDFM) outputs to compensate for the limitations of the model. The TDFM used for this project produced average daily traffic (ADT) assignments. In order to develop design hour volumes, the ADT outputs were refined, and peak hour traffic projections were developed for the Capital Beltway and compared to observed year 2000 count data.

The travel demand forecasting model process is composed of four basic steps: trip generation, trip distribution, mode choice, and assignment. The assignment step involves determining what path trips will take to go from an origin to a destination. The post-processing techniques applied to the results of the highway assignment represent a set of procedures designed to compensate for limitations in the model network and the assignment algorithm.

Roadway networks are represented in a TDFM as nodes and links. For the TDFM used in this research project, the nodes serve to connect the links and are not coded with any specific characteristics. The links are coded with a set of attributes that represent specific roadway segments. These attributes include speed, capacity, and distance. The actual roadway segments have more attributes than these. A highway also has grade, turning radii, curve cuts, pavement conditions, and other geometric data that affect how the traffic flows. All of these characteristics cannot reasonably be incorporated into the TDFM highway assignment. The purpose of the TDFM network is to serve as an input for developing travel demand. The networks used in the TDFM process are not designed to be used as traffic operations analysis tools.

The assignment algorithm in the TDFM process is macroscopic. Software such as CORSIM uses microscopic assignments that better reflect traffic flow and operations. As a result of TDFM network limitations and the macroscopic characteristics of the assignment, certain adjustments must be made to trip paths. The highway network that is used in a TDFM is coarse and does not represent all the roads nor all the intersections or access points (e.g., curve cuts, driveways, etc.). Therefore, the results that are produced from the assignment need to be adjusted to compensate for the model's limitations. The post-processing refinement should not be viewed as a separate step in the TDFM process, but rather as an extension of the highway assignment.

For the Capital Beltway, there were two basic assumptions underlying the travel forecast refinement. These two assumptions were that traffic volumes would not decrease over time given the increase in surrounding land-use, and that the existing directional travel patterns would stay the same. When the final link adjustments and peak hour volumes were produced they were reviewed to check that these two basic assumptions were correct. If, in some cases, the assumptions were not met, factors influencing these assumptions were investigated to ensure that the forecasts were acceptable.

Highway post-processing involves the following three stages:

1. Refine Links (ADT)
2. Calculate Turning Movement (ADT)
3. Determine Peak Hour Turning Movements and Link Volumes (AM & PM Weekday)

Two elements were incorporated in the highway forecast's post-processing: the freeway system and the arterial approaches to interchanges along the Capital Beltway. The freeway system included all mainline links, C/D roads, and ramps.

For this research project, all post-processing activities for refining the highway link ADT volumes and developing ADT turning volumes involved procedures outlined in *NCHRP-255 Highway Traffic Data for Urbanized Area Project Planning and Design*[16], published by the Transportation Research Board. This technical report provided a set of procedures for smoothing the "raw" link volumes output directly from the TDFM process. These procedures were applied by using an Excel spreadsheet. Link vehicle flows were smoothed across parallel competing routes. These routes were grouped together and bisected by artificial cutlines. These cutlines served as the basis for refining the model output.

Cutlines were developed primarily perpendicular to the freeway. These cutlines were developed for each link between an interchange. There were a total of 27 major cutlines bisecting the Capital Beltway. Secondary cutlines were developed across interchange arterial approaches. Where two partial interchanges made one complete interchange, such as the adjacent interchanges at MD Route 337 and Forestville Road, they were combined and treated as one interchange. Therefore, there was no cutline located between these two interchanges. Since the two interchanges were treated as one interchange, turning movements were calculated and then the volume between the interchanges was calculated and assigned by hand.

Where cutlines could not be defined or were not applicable, single link adjustments were made to compensate for model limitations. Single link adjustments only represent corrections for over-estimation or under-estimation of link volumes when the model was validated. Single link adjustments were only applied for the bridges crossing the Potomac River.

In defining cutlines, NCHRP-255 provides some guidelines and tools. These cutlines were determined based on the local travel patterns of the surrounding network. The process used to

[16] Pedersen, N.J., and Samdahl, D.R., *Highway Traffic Data for Urbanized Area Project Planning and Design NCHRP Report 255*, Washington, D.C., Transportation Research Board, December 1982, Chapter 4.

develop the cutlines was iterative based on the deviation from the base year count. In some cases, cutlines were modified a few times before finally being applied for refining the model output. The process involved not only utilizing the guidelines outlined in NCHRP-255 but also performing an analysis of the relationship between the deviation percentages for a particular cutline's base year count and the base year simulation. For some of the cutlines, links were added or subtracted in order to achieve smaller deviations and better refinement results.

The spreadsheet used to refine the highway link volumes has two parts. The first part of the sheet accounts for bias in the modeling process. The bias is corrected by evaluating the difference in the validation or base year observed count and the model simulation. The second part of the spreadsheet redistributes vehicles across the cutline to compensate for limitations of the network and assignment. Data required for the spreadsheets includes the following:

- Base year traffic count
- Model output – link volumes for base year and future scenario
- Link capacity for base year
- Link capacity for future year

The base year counts used in the refinement sheets were for the validation year 1990. Considerable effort was applied to balancing all count data. This included balancing counts along the freeway as well as along facilities adjacent to the freeway. The freeway count data was evaluated based on other count data collected for the same freeway segment, in addition to the model ground counts, the travel patterns, the directional split, and the peak to daily percentages.

Link capacities are influenced by several factors. Some of these factors include the number of lanes, the facility type, and the area type. For the TDFM used in this study, capacity was given in terms of vehicles per hour and factored in the assignment process to reflect daily capacity. The hourly capacity is based on the area type and facility type. In the link refinement process the capacity is a major input into the redistribution of link vehicle flows. The TDFM produced ADT link volumes, so the link refinement was done at the ADT level. Since the refinement was at the ADT level, the capacity used in the spreadsheet represented daily capacity. The absolute value of the capacity was not as important as the relationship between the different capacities for each facility. The relativity of the capacity was important because it was used to help spread traffic volumes across competing facilities. For this project the following capacities were used:

- Freeway – 25,000 vehicles per day
- Expressway – 15,000 vehicles per day
- Major Arterial – 8,400 vehicles per day
- Minor Arterial – 7,000 vehicles per day
- Major Collector – 5,600 vehicles per day
- Minor Collector – 3,500 vehicles per day
- Local – 3,000 vehicles per day.

These capacity were derived for work done on the I-270 Multi-modal Corridor Study and work done on the US301 Corridor Study. Both studies were done by SHA and deal with highway facilities in the Washington, D.C. area.

The capacity factor used in the second part of the refinement process is a function of the future year capacity. In future year scenarios, the facility types and area types can change from the base year if there is a change in the roadway's operating characteristics. Adjustments to future year capacity are critical in determining proper estimates of traffic volume on each facility. These adjustments are impacted by changes in a facility's functionality, geometric design, class, and area.

Capacity is not the only factor used to redistribute the link flows. The other factor affecting the redistribution is a count-related factor that represents driver preference. The count factor is a function of the base year count. The count factor does not change in relationship to the "raw" or refined forecast volume.

Turning movements at the interchanges along the Capital Beltway were developed using the non-directional turning movement methodology outlined in NCHRP-255. For each interchange along the freeway, an estimated turning percentage was calculated using the sum of the existing turning movements divided by the total inflow volumes. This was used in conjunction with the refined approach link volumes to develop preliminary turning movements. These preliminary turning movements were then adjusted so that all of the interchange approach volumes balanced. Priority was given to the freeway, therefore the arterial approaches were allowed to fluctuate slightly. By allowing the arterial approach volumes to fluctuate against the freeway volumes, the entire interchange could be balanced. The rationale for holding the freeway links constant was based on the fact that the link refinement process for the freeway links was better than that for the arterial street approaches. This confidence in the freeway volumes was based on the overall performance of the refinement along the cutlines and the performance of the model simulation for the entire freeway facility.

Forecasted freeway link volumes were evaluated against historical trends as well as base year travel patterns. Future travel patterns were reviewed based on the proposed land-use and the location of the home trip end relative to the employment and shopping trip ends. The freeway is a dominant facility and ample data was available to test the reasonability of the forecast. This included the growth percentage along specific links, the annual growth compared to the household growth, the location of the travelshed, and the directional travel patterns.

In the balancing process, an overall decision hierarchy was developed based on the reasonability and the ability to evaluate the forecasts for certain types of highway facilities. This hierarchy guided the final turning movement balancing process. The adjustments to the turning movements reflected the current volumes, the surrounding land-use, and any roadway improvements. In general, turning movements were not expected to decrease for the forecast year. This was true in all cases except for interchanges where new facilities were being added or extensive land development was planned where there previously was little or no development in the base year. In these cases, specific turning movements could be less than base year count volumes, but the overall approach volume will still show an increase over the base year.

Peak hour traffic projections are an important part of any corridor study and the corresponding analysis. Therefore, for this research project peak hour volumes were derived from the ADT volumes for the Capital Beltway. The peak hour projections represented average weekday traffic forecasts for both the morning and evening peak hours. A spreadsheet was designed and applied to assist in this process. The underlying objective was to develop a hierarchy of roadway characteristics and use that as a guide for determining the reasonability of peak hour projections.

For the freeway system, the mainline peak hour volumes were a function of the ramp volumes. The freeway facility was divided by direction into two separate facilities – the Outer loop and the Inner loop. A starting peak hour volume was calculated at the first link of each loop. The entering peak hour volume reflected the 1990 base year directional volume peak to daily relationship.

Once the starting mainline volume had been calculated, then ramp peak hour projections were developed and the downstream link volumes were calculated based on the entering and exiting volumes at the upstream interchanges. Peak hour ramp volume projections were calculated based on the existing peak to daily percentages for each ramp. The modifications to the base year ramp peak to daily percentages were based on the following criteria:

- Existing patterns had to remain the same (except in locations where new facilities were added or large changes in the land-use were proposed).
- Future ramp volumes had to be greater than existing volumes (except in locations where new facilities were added or large changes in the land-use were proposed).
- The freeway non-directional peak to daily percentages had to be reasonable when compared to existing percentages, historical trends, and similar data for other freeway facilities.
- The peak to daily directional splits had to be reasonable based on existing patterns historical trends, and similar data for other freeway facilities.

Preliminary peak hour ramp volumes were developed for each loop of the Capital Beltway. The Inner loop was treated independently from the Outer loop. The freeway facility was then examined as a whole, and the overall characteristics of the forecast were judged for reasonability. By developing the initial directional volumes independently and then reviewing the system in its entirety, the process provided built-in quality control measures. There were several levels of checks and balances. The basic level was for the individual movement, where the projected forecast volume was compared to existing volume. The second level was for the directional facility (e.g., Inner, Outer) where the peak to daily percentages along the directional mainline links was reviewed for reasonability. The third level was for the system as a whole, where the non-directional peak to daily percentages and directional splits were reviewed for reasonability. Once the process moved on from the lowest level, which was the ramp or individual link, to the highest level, which was the system as a whole, the end product was a freeway system forecast that was plausible. If there was a question about the forecast at a specific segment, the rationale for that projection could easily be described, as could the impact on the entire system resulting from modifying that specific segment projection.

Reasonability tests included changing the peak to daily directional percentages and then determining the effects downstream. It was assumed that travel patterns would remain, for the most part, similar to base year patterns. Therefore, it was judged that the lowest acceptable peak to daily percentage for non-directional travel along the Capital Beltway was 6.0%, and the directional split could not change the travel pattern.

Figure 3-7 summarize the post-processing methodology applied for the full refinement of the “raw” model output. The process starts with the ADT from the model and finishes with the peak hour derivations. File names adjacent to the process steps (e.g., `xxx_pkhrs.xls`) refer to data file naming conventions used in the process.

3.6 Assignment Algorithm Evaluation and Testing

The point of this research project is to determine whether there is any benefit in using the techniques outlined in the technical report NCHRP-255. In order to perform this task, an older travel demand model set had to be run for a current year for which observed count data was available. In running the TDFM, there was also an opportunity to test different assignment algorithms and determine whether they could yield better results than the post-processed “raw” model output. There had also been short-term improvements in the state-of-the-practice for assignment algorithms since the TDFM set used in this project was developed. The nature of this project provided an opportunity to incorporate and test some of those improvements.

The TDFM set used in this project applied an incremental capacity restraint algorithm. The trip tables were combined, and then four equal quarters were assigned consecutively. After each quarter was assigned, the link travel times were recalculated using the standard BPR impedance equation.

The following equation is the BPR impedance formula:

$$t_c = t_o\,3\left(1 + \alpha\,\frac{V}{C}^{\beta}\right)$$

t_c = congested travel time

t_0 = initial travel time

V = link volume

C = link capacity per hour basis

The base or validation assignment had $\alpha = 0.15$ and $\beta = 4$. These values are generally accepted as representative of level of service (LOS) "C" conditions. The rationale being that planning activities should be performed for LOS "C" conditions. In actuality, for large urban areas with severe congestion, the Federal Highway Administration (FHWA) will tolerate LOS "D" as an acceptable level of service[17]. Even thought the Washington, D.C. region suffers from severe congestion and most project planning is done for LOS "D" conditions, the validation model set used in this project still had the LOS "C" coefficients for the BPR equation.

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[17] I-270/US 15 Multi-Modal Corridor Study Draft Environmental Impact Statement and Section 4(f) Evaluation, Maryland Department of Transportation, Baltimore, Maryland, May 2001, Chapter 5.

The capacity used in the BPR equation is representative of an hour vehicle flow. Therefore, the link volumes must be factored to reflect an hourly volume versus a daily volume. A ten percent factor is applied to the link volumes the for purpose of calculating the change in link impedance. Ten percent is a general peak-to-daily factor and is liberally applied only for the purpose of estimating the change in the link travel time.

The capacity is also representative of different facility and area types. The model network does not include intersection control nor the impact that control has on vehicle delay and the corresponding travel time. The capacity given to a link in the model has to represent an average capacity for that type of facility in that type of area. For example, given that the maximum capacity for an intersection is about 1,800 vph per lane[18], when two arterials meet each would be assumed to be given 50 percent of the available green time. In an hour, that would represent 900 vph per lane for each approach. In a given TDFM network, such an arterial link would be coded as having a capacity of 900 vph per lane. The link capacity takes into account the impact of delay resulting from the intersection control. These coded capacities are a function of the area type and facility type. They are usually developed based on Highway Capacity Manual procedures and measured saturation flow rates in the field.

In the initial ADT level evaluation, the incremental capacity restraint algorithm was applied for three different assignments. The first application was for the base case, which was the prescribed procedure in the original TDFM development. The second and third applications represented modifications to the BPR α and β coefficients. The incremental capacity restraint algorithm was modified as a test case because it was the part of the 1990 validation TDFM set. These modifications represented improvements in the TDFM process since the development of the 1990 model set.

After application of the incremental capacity restraint algorithm, an all-or-nothing (AON) assignment was performed. An AON assignment assigns all trips to the shortest path. There is no

[18] Highway Capacity Manual 2000, Transportation Research Board, Washington, D.C., National Research Council, 2000, pp. 15-1 – 16-35.

recalculation of the link impedance based on link volumes. AON assignment is not generally applied in highway assignments. It is still used in transit assignments because of the characteristics of transit capacity and lack of alternative routes. The purpose in applying the AON assignment for this research project was to quantitatively evaluate the assignment compared to other algorithms and test the model structure for expected results. By definition the AON assignment would be expected to over-simulate the freeway links on the Capital Beltway. These links have the highest free-flow speed in the transportation network; therefore, without updating link travel times, no congestion trips would take advantage of the facility's performance level. It was expected that the AON results would show higher than observed volumes for the year 2000 and produce the highest traffic volumes when compared to the other assignment algorithms.

Since the model set used for this project was developed, the application of the equilibrium assignment algorithm has become the standard[19]. Part of this project's objective is to evaluate and compare the different assignment algorithms as well as the improvements to them over the past ten years. Based on this evaluation it was determined that it was prudent to apply an equilibrium assignment algorithm. This research project provided an opportunity to quantitatively evaluate the differences in the equilibrium assignment versus the incremental capacity restraint assignment for an actual regional travel demand forecast model set. Unlike other tests of the equilibrium assignment, it was not related to a calibration effort and, hence, provided a unique chance to perform such an evaluation.

The objective of an equilibrium assignment is to disperse traffic across a network so that all paths between origin and destination zones are equal in travel time. The equilibrium assignment process applied here used fixed weights in determining the iteration average for travel impedance recalculation. Equilibrium was reached when the difference in travel times was less than 3.5% across all origin and destination zone pairs. The 3.5% was determined to be the acceptable level based on the industry standard[20].

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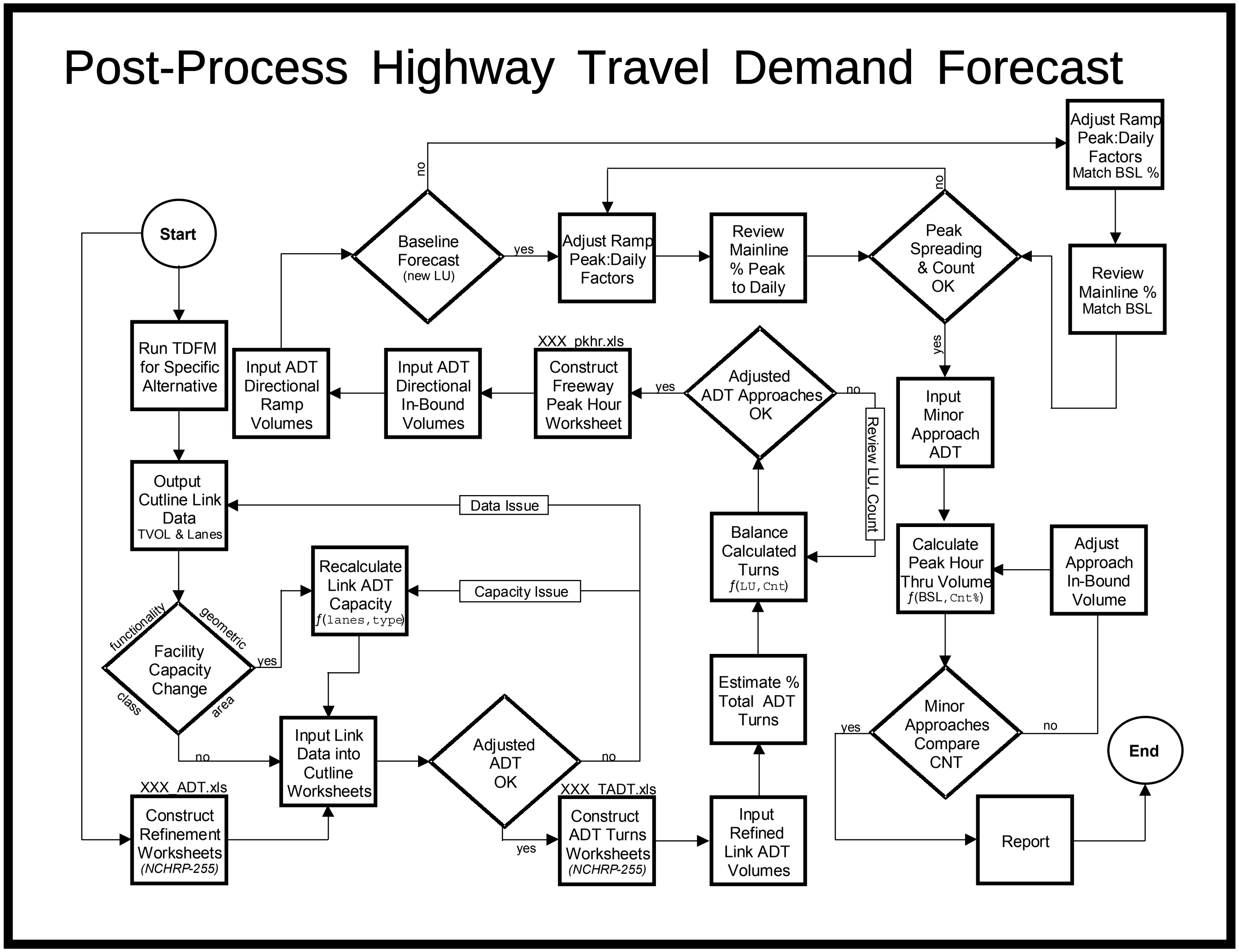
[19] Milone, Ronald, *COG/TPB Travel Forecasting Model Version 2.1/TP+, Release C User's Guide*, Washington, D.C., Metropolitan Washington Council of Governments, December 2002, pp. 1-4 – 1-8.
[20] Comsis Corporation, *MinUTP Technical Manual*, Silver Spring, MD, Comsis Corporation, 1996, pp. Assign-32.

Figure 3-7


Post-Process Highway Travel Demand Forecast
Start
Run TDFM for Specific Alternative
Output Cutline Link Data TVOL & Lanes
Facility Capacity Change
functionality
geometric
class
area
yes
no
Recalculate Link ADT Capacity f(lanes, type)
Input Link Data into Cutline Worksheets
Adjusted ADT OK
XXX_ADT.xls
Construct Refinement Worksheets (NCHRP-255)
XXX_TADT.xls
Construct ADT Turns Worksheets (NCHRP-255)
Input Refined Link ADT Volumes
Estimate % Total ADT Turns
Balance Calculated Turns f(LU, Cnt)
Adjusted ADT Approaches OK
Review LU, Count
XXX_pkhr.xls
Construct Freeway Peak Hour Worksheet
Input ADT Directional In-Bound Volumes
Input ADT Directional Ramp Volumes
Baseline Forecast (new LU)
Adjust Ramp Peak:Daily Factors
Review Mainline % Peak to Daily
Peak Spreading & Count OK
Adjust Ramp Peak:Daily Factors Match BSL %
Review Mainline % Match BSL
Input Minor Approach ADT
Calculate Peak Hour Thru Volume f(BSL, Cnt%)
Adjust Approach In-Bound Volume
Minor Approaches Compare CNT
Report
End
Data Issue
Capacity Issue

The objective of an equilibrium assignment is to disperse traffic across a network so that all paths between origin and destination zones are equal in travel time. The equilibrium assignment process applied here used fixed weights in determining the iteration average for travel impedance recalculation. Equilibrium was reached when the difference in travel times was less than 3.5% across all origin and destination zone pairs. The 3.5% was determined to be the acceptable level based on the industry standard[21].

Over the past ten years there have been many improvements to the modeling process. Some of these improvements have come in modifications to the BPR equations used for link impedance calculations. As part of the assignment algorithm testing and evaluation, modifications to the BPR equation based on state-of-the-practice were incorporated and applied here. The first modification to the BPR equation was based on changing the α and β coefficients to better divert traffic and spread it across competing facilities. Spreading traffic across competing facilities is one element of the post-processing techniques outlined in NCHRP-255. For this application, the base incremental assignment algorithm was applied with revised BPR coefficients. The BPR coefficients for this test were $\alpha = 0.80$ and $\beta = 6.0$. These parameters came from research done by CATS in Chicago, IL, and documented in a report by New York City MPO (NYMTEC)[22]. The results of this procedure were not positive and it was not repeated with the equilibrium algorithm.

The second modification test applied only the revised β coefficient and left the $\alpha = 0.15$[23]. This produced more favorable results and was also applied using the equilibrium algorithm. Figure 3-8 shows the different BPR functions used in the project.

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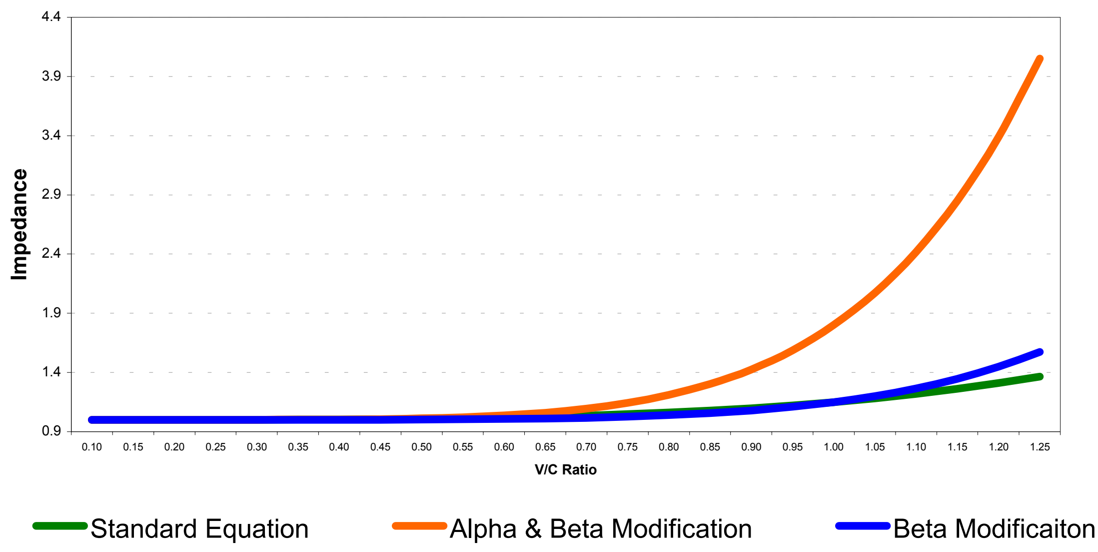
[21] Comsis Corporation, *MinUTP Technical Manual*, Silver Spring, MD, Comsis Corporation, 1996, pp. Assign-32.
[22] Parsons Brinckerhoff Quade & Douglas, Inc., *Transportation Models and Data Initiative for the New York Metropolitan Transportation Council Technical Memorandum 1.7.X Highway Network Development Guide*, New York, New York Metropolitan Transportation Council, March 1995, pp.1-3.
[23] Horowitz, Alan J., *Reference Manual Quick Response System II for Windows Version 5*, Milwaukee, WI, Center for Urban Transportation Studies, University of Wisconsin – Milwaukee, 1997, pp.104 – 140.

Figure 3-8: BPR Equations



3.7 Post-Processing Evaluation and Testing

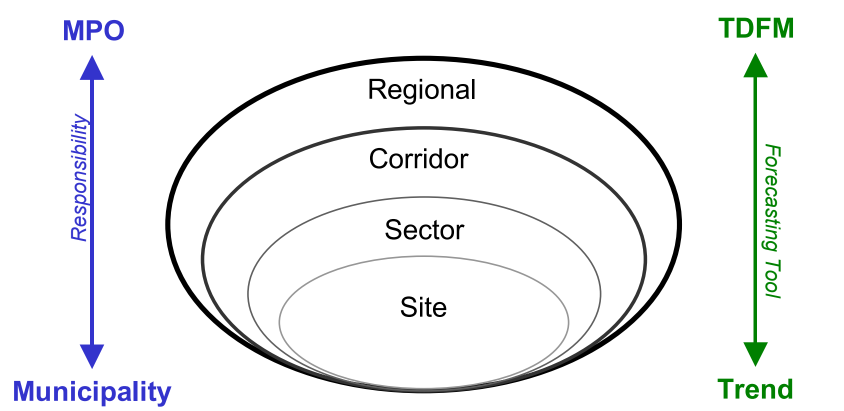
An incremental capacity restraint algorithm was the default assignment algorithm used in the TDFM set. All post-processing activities were based on the "raw" link volumes resulting from the default assignment. There were three post-processing techniques applied for this project. All three of the techniques involved link refinement of "raw" model output at the ADT level. The full post-process was outlined earlier in this chapter and the link refinement and turning movement calculations methodologies were taken directly from NCHRP-255. The two other post-processing techniques applied for evaluation purposes were derived from NHCRP-255 and represent parts of the prescribed post-processing methodology. These partial techniques are currently used by some practitioners in the field.

A fourth test was made to evaluate a different procedure for developing future traffic volumes. This procedure simply involved applying a growth rate compounded annually to the count data for 1990 to calculate a ten year forecast for the year 2000. The growth rate was determined by averaging three permanent count stations along the Capital Beltway portion located in the State of Maryland. This data was taken from the years 1989 through 1991. The result was a 3.93

percent annual growth rate. That was then compounded over ten years to produce a year 2000 forecast.

This method was selected because it is a common method used to forecast traffic projections for traffic impact studies and other similar level of transportation studies. Figure 3-9 shows the different levels of transportation studies and the range of tools used to develop forecasts. For short term studies, such as traffic impact studies, factoring can be an appropriate tool. But, for larger area studies and longer range planning, it is thought that travel demand forecast modeling often provides a better forecast. For this project, applying a compounded growth rate allowed for a quantitative evaluation to be performed. This was done by comparing the difference in the TDFM results to the annual compound growth factor and the observed count data.

Figure 3-9: Levels of Transportation Planning Studies



The two other post-processing techniques are based on adjustments to the "raw" link volume output from the model. These techniques do not attempt to redistribute traffic across competing facilities similar to the procedure documented in NCHRP-255. The first of these techniques will be referred to as the bias correction. This is the first part of the link refinement procedure outlined in NCHRP-255[24]. It involves taking the base year simulation and count volumes and applying a ratio adjustment and difference adjustment to the future year link simulation volume. The following equations represent the adjustments respectively:

$$RATIO = (COUNT/A_b) * A_f$$

$$DIFFERENCE = (COUNT - A_b) + A_f$$

A_b = Base Year Link Simulation
A_f = Future Year Link Simulation

To obtain the final refined link volume, the ratio and difference adjustments are averaged together. This technique only accounts for the bias in the modeling process and does not account for the coarseness of the network and limitations of the assignment algorithm. Since it is used by practitioners in the field and is less demanding than the full refinement methodology it was of interest to evaluate how it compared to the full refinement methodology. The full refinement methodology requires more data and takes more time to perform. If this method produces equal or better results it might be more valuable and useful than the full refinement.

The second alternative post-processing technique used by some practitioners in the field is the application of only the ratio adjustment. As with the bias adjustments, it is easier to apply than the full refinement methodology. It was determined to be a worthwhile experiment to quantitatively evaluate these partial techniques against each other as well as compare them to the "raw" model output and the full refinement process.

3.8 Time of Day Modeling

In October 1997 the Travel Model Improvement Program published a report on time of day (TOD) modeling procedures[25]. This report represented the state-of-the-practice and state-of-the-

[24] Pedersen, N.J., and Samdahl, D.R., *Highway Traffic Data for Urbanized Area Project Planning and Design NCHRP Report 255*, Washington, D.C., Transportation Research Board, December 1982, Chapter 4.

art. The report outlined the inadequacy of assigning daily trips and the need to develop peak period assignments for operational as well as environmental analyses. As part of this research project, a PM peak period assignment was performed using both an incremental capacity restraint assignment and an equilibrium assignment. The TOD method applied for this project was to factor the trip tables by purpose prior to the final highway assignment. The PM peak period was defined as a three hour period between the hours of four and seven in the evening.

In order to develop PM peak period trip tables factors had to be applied to the trip tables prior to the final assignment. These factors were taken from the latest version of the MWCOG travel demand forecast model – Version 2.1c. Table 3-2 summarizes the factors taken for the year 2000 model set directly from the Version 2.1c TDFM. These factors were applied to the production and attraction trip tables along with factors to convert them into origin and destination vehicle trip tables. The trip tables were assigned using the above-noted algorithms and compared to the observed count data for the year 2000.

<table>
<tr><th colspan="4">Table 3-2: PM Peak Period Time-of-Day Factors</th></tr>
<tr><th colspan="2">Purpose</th><th>Production End</th><th>Attraction End</th></tr>
<tr><td rowspan="2">HBW – Home Base Work</td><td>(auto-driver)</td><td>2.78%</td><td>63.29%</td></tr>
<tr><td>(HOV)</td><td>3.04%</td><td>72.39%</td></tr>
<tr><td colspan="2">HBS – Home Based Shopping</td><td>20.69%</td><td>31.49%</td></tr>
<tr><td colspan="2">HBO – Home Based Other</td><td>21.42%</td><td>28.54%</td></tr>
<tr><td colspan="2">NHB – Non Home Based</td><td>26.97%</td><td>26.97%</td></tr>
<tr><td colspan="2">Medium Truck</td><td>15.2%</td><td>15.2%</td></tr>
<tr><td colspan="2">Heavy Truck</td><td>13.0%</td><td>13.0%</td></tr>
<tr><td colspan="2">External Trips</td><td>11.0%</td><td>11.0%</td></tr>
</table>

Along with factoring the trip tables, the capacity factor in the assignment algorithms had to be adjusted to reflect the peak period versus the hourly capacity used in the BPR equation. A factor

[25] Cambridge Systematics, Inc., *Time-of-Day Modeling Procedures State-of-the-Art, State-of-the-Practice*, Washington, D.C., U.S. Department of Transportation, October 1997, pp. 2-1 – 3-18.

of 0.40 was applied to relate the peak hour capacity used in the impedance calculation to the three hour peak period.

PM peak hour volumes for the Inner Loop and Outer Loop of the Capital Beltway were developed from the TOD evening peak period assignment. Based on historical data at the permanent count stations the PM peak hour was determined to be 34 percent of the PM peak period. This was consistent for the shoulder years around the year 2000. It should be noted that if the TOD assignment was really being done for the year 2000, the TOD percentage by purpose would have been based on 1990 data, and the peak hour to peak period percentage would have been based on 1990 volumes. By using the year 2000 data for the year 2000 it provided a bias in favor of the model simulation representing the observed count data.

3.9 Measures of Effectiveness

The basis of this project was to evaluate the forecast against the observed count data along the Capital Beltway. There were two levels of analysis, the first was at the daily level and the second was at the peak hour level. The model produces daily link volumes, so a greater effort with respect to the primary objectives was performed for comparing and evaluating the ADT volumes along the Capital Beltway segments for the portion of the freeway facility located in Maryland. For the peak hours, the mainline and the ramp volumes were evaluated.

For the ADT volumes, there were two tools used in the analysis. The primary tools were statistical tests to quantitatively compare the results of the assignment algorithms and post-processing techniques against the observed count data. The two main statistics used in this evaluation were the percent root mean square of the error (RMSE)[26]. The other statistic applied here was the standard error of regression (S_E)[27].

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[26] Barton-Aschman & Associates, Inc. and Cambridge Systematics, Inc., *Model Validation and Reasonableness Checking Manual*, Washington, D.C., U.S. Department of Transportation, 1997, p. 94.
[27] Dickey, John W., *Metropolitan Transportation Planning*, Washington, D.C., Scripta Book Company, 1975, pp. 538 – 541.

The RMSE is calculated using the following equation:

$$\% \text{ RMSE} = \frac{\sqrt{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2/(n-1)}}{\sum_{i=1}^{n} y_i/n}$$

The standard error of regression is calculated using the following equation:

$$S_E = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n - 2}}$$

y_i = observed count

$\hat{y}_i$ = forecast volume

n = number of observation (number of links)

Both of these statistics measure the difference between the observed data point and the forecast or modeled data point. The RMSE is a standard statistic measure used in validation efforts for travel demand forecast models. There are standards defined for what is acceptable in terms of validation criteria. FHWA states that freeway links should be with in +/- 7 percent of the ADT observed count data[28]. This target applies to the base year validation and is applied to all freeway facilities as a whole, rather than individual links. When evaluating the results for the assignment algorithms tested for this project, even though the 1990 model set was calibrated and validated, some links along the Capital Beltway did not meet the seven percent target. The Capital Beltway is just one freeway facility in the Washington, D.C. area, and for this project only the 40 miles located in the State of Maryland were evaluated.

The second tool used to evaluate the ADT assignment and post-processing results was a set of graphs. There were two types of graphic tool used to evaluate how well the model and post-processing related to the observed data. The first types of charts plotted the ADT volumes by

[28] Barton-Aschman & Associates, Inc. and Cambridge Systematics, Inc., *Model Validation and Reasonableness Checking Manual*, Washington, D.C., U.S. Department of Transportation, 1997, pp. 94 - 98.

link for the different assignment algorithms and then for the different post-processing techniques. On each of these charts the observed count data was represented with the corresponding "raw" forecast or refined volumes. The x-axis represented the individual links along the Capital Beltway by cutline. The links start at the American Legion Bridge and finish at the Woodrow Wilson Bridge. The y-axis showed the ADT volumes. These types of charts were very good for identifying the more accurate assignment procedures and post-processing techniques. It quickly provided a comparison of the different techniques and identified those links where some procedures and techniques were more accurate than others

The second type of graphic tool was scatter plot charts. The scatter plots provided a picture of how well a specific assignment algorithm or post-processing technique matched the observed count data. The x-axis represented the simulation or forecast volume and the y-axis represented the observed count data. If the forecast and data matched perfectly, the data point would fall on a 45 degree line from the origin. If the data point was above this line, it represented an under-simulation; and below this line represented an over-simulation.

Related to the scatter plots, a trend line analysis was done to measure the difference in slope and the coefficient of determination (R^2). The trend line analysis fit a line to the data points on the scatter plot. The trend line had to pass through the axis origin point (0,0). By forcing the line through the origin point the slope could be measured against the perfect match line, $y = x$. The trend line's R^2 was also calculated to determine how close the points on the scatter plot were from the calculated trend line. It is important to remember that the R^2 was not related to how well the points fit the perfect match line $y = x$, but rather how dispersed the points were to fitting the trend line. The higher the coefficient of determination the closer the points were to the trend line and the better an equation representing the trend line could be used to represent those points.

The peak hour evaluation was not as uniform as the ADT evaluation. Peak hour volumes were derived from the full refinement methodology along the Capital Beltway study portion for both the AM and PM peak hours. For the PM peak hour TOD assignment, forecast were used to derive an additional PM peak hour forecast. The RMSE statistic was calculated for all of these scenarios. For the volumes derived from the full refinement, mainline volumes as well as ramp movements were included in the calculation of the RMSE. For the TOD-related volumes only the mainline volumes were included. Ramp movements were later approximated for the TOD related peak hour volumes but were not included in the RMSE calculations.

Similar to the ADT analysis, two types of graphic tools were used to evaluate the observed count data versus the forecast data. The AM and PM peak hour volumes were plotted by link with the count data for both the Inner Loop and the Outer Loop. Additionally, scatter plots were also done for the mainline, the ramps with volumes greater or equal to 1,500 vph, and the ramps with less than 1,500 vph. For the TOD derived PM peak hour volumes, the plots show data for the mainline volumes for the equilibrium assignment as well as the incremental capacity restraint assignment.

The graphic tools and statistical tools showed that the TOD-derived PM peak hour volumes produced from the incremental capacity restraint assignment were less accurate than the results from the equilibrium assignment. Therefore, only the PM peak hour volumes derived from the TOD equilibrium assignment were carried forward to the next step of analysis.

The next step of peak hour analysis was only carried forward for the PM peak hour Inner Loop volumes. Level of service was calculated for the entire Inner Loop. This was an approximately 40 mile-long freeway corridor. LOS was calculated for each mainline section, weave section, merge section, diverge section, and ramp roadway. This was done for the PM peak hour using the observed count data, the full refinement forecast, and the equilibrium TOD forecast.

In addition to the LOS analysis, an economic analysis was completed for the Inner Loop PM peak hour volumes. This included the above listed scenarios. Table 3-3 lists the unit cost parameters used in the economic analysis. These were the default values from the applied traffic operations model. The LOS and economic analysis was performed using FRESYS software[29]. FRESYS software was developed in the 1990s to analyze freeway system operations using a deterministic approach that also addressed the issue of operational problems such as queue spill back.

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[29] Penic, Michael, *FRESYS Freeway System Analysis Program*, Version 1.5, Silver Spring, Maryland, 1994.

The rationale for performing the LOS and economic analysis was to determine what effect the difference in observed versus forecast volumes would have on real types of decisions related to planning studies. The measures of effectiveness used in this analysis would be key inputs into the design of improvements as well as alternative selection. This type of analysis provided some measure of the sensitivity between the final forecasts and the observed data.

Table 3-3: Unit Cost Parameters			
Vehicle Cost	fuel	1.25	USD/gallon
	oil	1	USD/qt
	tires	125	cost/set (4)
	repair	125	cost/visit
	depreciation	12500	per veh
Passenger Cost	travel	5	USD/hr
	delay	7.5	USD/hr
Pollution Cost	CO impact	0.02	USD/gram
	HC impact	0.01	USD/gram
	NOx impact	0.01	USD/gram

The PM peak hour for the Inner Loop was selected for this detailed analysis because it represented a higher congestion level. The PM peak volumes are typically higher in critical choke points. The Inner Loop facility generally experiences higher demand in critical areas during the afternoon peak hour. This critical section is from the American Legion Bridge to east of the interchange at MD Route 97.

4.0 RESULTS

4.1 Overview

The purpose of this research project is to evaluate the techniques outlined in NCHRP-255. In order to evaluate whether there are any benefits to these techniques, a travel demand forecast model for the Washington, D.C. Metropolitan Area from the year 1990 was used to develop forecasts for the year 2000. The most recent land-use data for the year 2000 was obtained from the Metropolitan Washington Council of Governments (MWCOG). Forecasted highway volumes were developed for the portion of the Capital Beltway Corridor (I-495/I-95) in the State of Maryland. The "raw" model link volume outputs and the post-processed model outputs for this portion of the Capital Beltway were compared to the actual year 2000 observed count data.

The primary research objectives are:

- To critically evaluate the ability of a regional travel demand forecast model to accurately forecast freeway corridor volumes by comparing link forecast volumes to the actual count data.
- To evaluate and determine the significance of post-processing as techniques outlined in NCHRP-255.

4.2 Assignment Algorithms Evaluation

The first part of this research project was to evaluate three different assignment algorithms. The assignment is the last step in the traditional four-step travel demand forecast model (TDFM) and it attempts to establish the paths that trips will take from an origin to a destination. The TDFM set used for this project was calibrated and validated using an incremental capacity restraint assignment algorithm. Since this type of algorithm was used to establish the creditability of the model structure, it was the primary type of assignment algorithm applied for this project. The other algorithms were measured against this base incremental capacity restraint algorithm. The other two assignment algorithms that were evaluated as part of this project included an equilibrium algorithm and an all-or-nothing (AON) algorithm.

The TDFM set used for this project was created in the early 1990s by the Metropolitan Washington Council of Governments (MWCOG). It was based on the regional TDFM for the Washington, D.C. Metropolitan Area and was increased from 1,478 zones to 1,674 zones. It covered an area from the Pennsylvania border to south of Prince William County, Virginia. Based on the state-of-the-practice and the model development by MWCOG over the past ten years, modifications to the incremental capacity restraint and equilibrium algorithms were performed as part of this research project. The modifications involved alteration to the impedance equation used to recalculate travel time. In total, there were six different assignment runs. These assignments produced daily traffic volumes – average daily traffic (ADT). Forecasted traffic volumes along the portion of the Capital Beltway that lies in Maryland were compared to observed count data for the target year of 2000. The base year for the model set was 1990, so the research presented here represented a ten-year forecast.

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

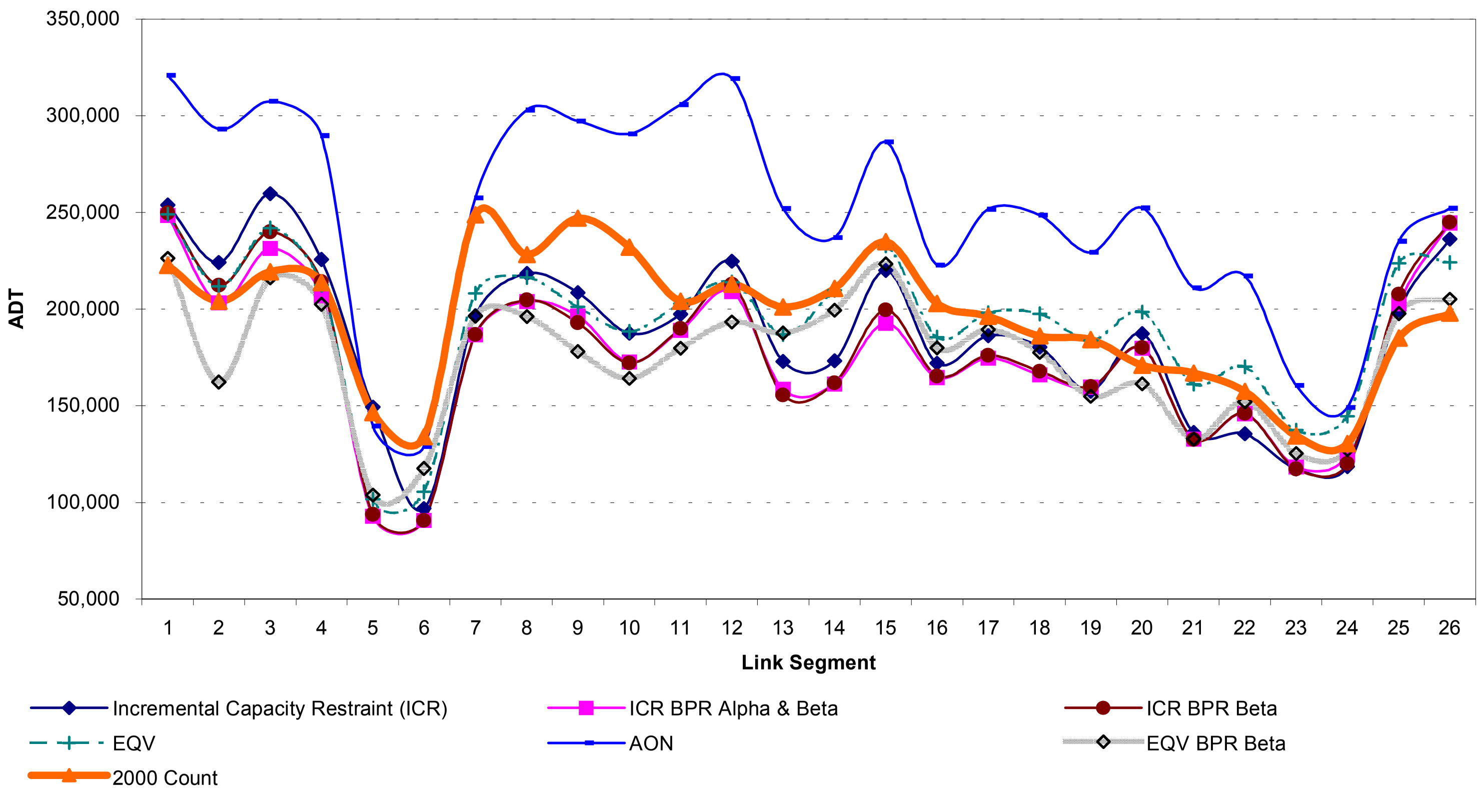
The trend line analysis was related to the scatter plots which showed observed link data versus simulation link data for all data points in the set. The trend line analysis fitted a line to the data points, but forced the line through the origin point (0,0). If the simulation data was a perfect match to the observed count data, the trend line would have a slope of one (i.e., $y = x$). Therefore, the critical measure for the trend line analysis was the comparison of the slope of the trend line to the perfect match of $y = x$ and the slope equal to one. The coefficient of determination (R^2) was also calculated for the fitted trend line. The R^2 only represented how well the trend line fitted the points, and it did not represent how well the simulation matched the observed data. Table 4-1 summarizes the results of the assignment algorithms for links along the Capital Beltway.

Table 4-1: Summary of Assignment Algorithm Evaluation				
Algorithm	**RMSE**	**Standard Error of Regression** (1 X 10^3)	**Trend Line y-intercept (0,0)**	
			R^2	**Slope**
Incremental Capacity Restraint	13.9%	28.15	0.376	1.029
All or Nothing	31.6%	64.06	0.576	0.078
Incremental Capacity Restraint (BPR α & β adjustments)	17.3%	35.08	0.211	1.088
Incremental Capacity Restraint (BPR β adjustment)	17.4%	35.32	0.145	1.076
Equilibrium	11.8%	24.03	0.525	1.003
Equilibrium (BPR β adjustment)	14.8%	30.03	0.570	1.105

In addition to the measures presented in the above table, a series of graphs were used to help evaluate the results of each assignment. The first type of chart simply plotted the volume by link segment for a specific series against the ADT. The second types of charts were scatter plots done for each assignment. The scatter plots showed how well the specific algorithm forecast results matched the observed count data for that specific link. The y-axis represented the observed count data and the x-axis represented the simulation or forecast volume. Figure 4-1 shows the ADT by link for all of the different assignment algorithms. It shows the observed count series as well as the different assignment series.

All of the algorithms, except for the AON assignment, matched the count reasonably well. It was expected that the AON assignment would result in an over-simulation. The AON acted as would have been expected, and this served to confirm that the model assignment process was working. If the AON did not result in an over-simulation, that might have been indicative of a network coding problem. The AON served a dual purpose here, the first was as a benchmark for the other assignment algorithms and the second as a quality control measure.

Figure 4-1: Assignment Results Capital Beltway Average Daily Traffic



The remaining assignment algorithms results were all about the same. There was one point where all of the forecast results increased while the count decreased. This could be a result of construction on the Beltway in this location during the year 2000. The model network would not reflect the effects of construction, even if it were a long-term project.

The base assignment, which was the incremental capacity restraint algorithm, produced reasonable results. The RMSE for this assignment was 13.9 percent. The results for this assignment did not show any particular relationship concerning over-simulation to capacity on the Capital Beltway. The assignment over-simulated at the river crossings, but for most of the corridor it under-simulated. The over-simulation in the vicinity of the river crossing could be a result of network supply. There are only a few river crossings, and they represent choke points in the system. Based on the Capital Beltway results, it would appear that the model was not as successful in simulating the traffic flow from Maryland to Virginia as compared to other links along the Capital Beltway.

Figure 4-2 shows the scatter plot for the incremental capacity restraint (ICR) assignment. The under-simulation is apparent on the plot. Most of the data points fall above the diagonal axis line y = x. The trend line analysis resulted in a slope of 1.029. This is reasonably close to 1.0, but the corresponding R^2 showed very little correlation. Overall, the assignment produced relatively good results.

The AON assignment results showed a pattern of over-simulation. The RMSE was 31.6 percent, which was the highest RMSE compared to the other assignment algorithms. Figure 4-3 shows the scatter plot results from the AON assignment. Except for two data points, all of the links were over-simulated, as could be expected from this type algorithm. The trend line analysis showed a 0.078 slope showing further evidence of the over-simulation. The Capital Beltway is surrounded by other major and minor arterials, as well as collector facilities, in a dense suburban setting. Given the high speed on the freeway versus the surrounding street network, most trips used the freeway even if this meant backtracking and traveling excessive distances past the destination zone. In reality, when there is a high level of congestion on the Capital Beltway short trips are expected to utilize the arterial network. As expected, the AON algorithm did not represent travel in a mixed urban setting where multiple alternative routes exist. Compared to the incremental capacity assignment, the AON is a poor substitute.

Figure 4-4 shows the scatter plot results for the equilibrium assignment algorithm. The equilibrium algorithm is designed to spread traffic across all competing routes. It stops once all travel paths between an origin and destination pair have equal travel time. When this TDFM set was developed, equilibrium was not the accepted assignment algorithm used by MWCOG. Only the latest TDFM set released by MWCOG in December 2002 uses an equilibrium assignment[30].

The equilibrium assignment algorithm showed the lowest RMSE for all of the tested algorithms. The RMSE was 11.8 percent, and the trend line analysis resulted in a slope of 1.003. The R^2 was not much different from the incremental capacity restraint results at 0.525. Although marginally better than the base assignment algorithm, it did take longer time to execute the equilibrium assignment. The amount of time was about ten minutes longer, or roughly a 30 percent increase. Given the improved results, the time difference was not substantial. As with all of the assignments, the river crossings were over-simulated by the equilibrium assignment. For the river crossings, it did not perform any worse or better than the bulk of the other assignment algorithms.

Figure 4-5 and Figure 4-6 show the scatter plot results from modifications to the impedance equation using an incremental capacity restraint algorithm. Figure 4-5 shows results representing modifications to both the α and β coefficients. Figure 4-6 shows the results for modifications to only the β coefficient. Both tests showed root mean square errors of 17 percent. The trend line analysis yielded slopes of 1.088 and 1.076, respectively. In both cases the model under-simulated the corridor volumes. The modifications to the impedance equation are supposed to divert traffic from over-congested facilities and spread the demand more evenly through the network. In this case the volumes were prematurely spread.

[30] Milone, Ronald, *COG/TPB Travel Forecasting Model Version 2.1/TP+, Release C User's Guide*, Washington, D.C., Metropolitan Washington Council of Governments, December 2002, pp. 1-4 – 1-8.

Figure 4-2: ICR Comparison of Count to Simulation Year 2000

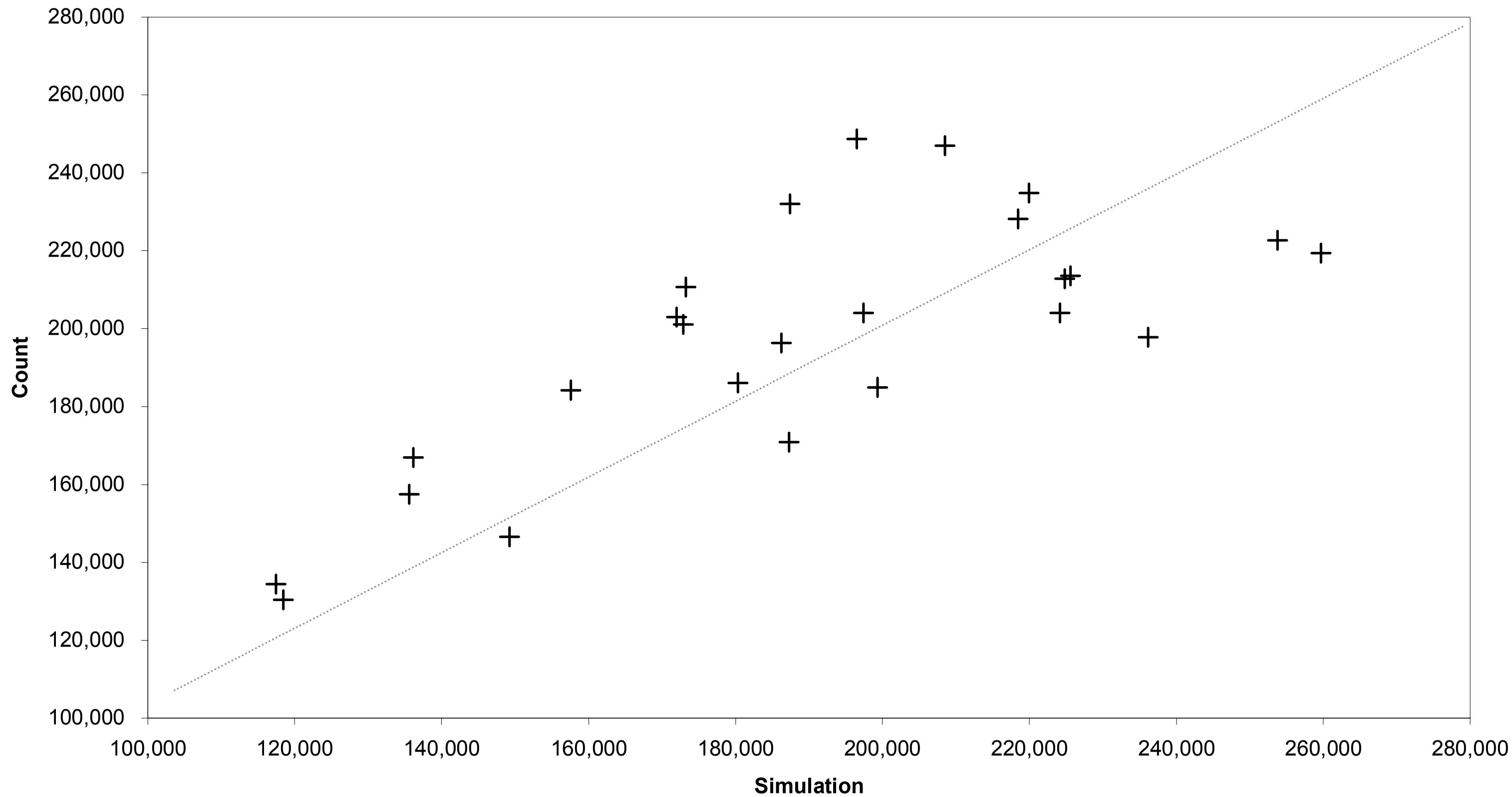


Figure 4-3: AON Comparison of Count to Simulation Year 2000

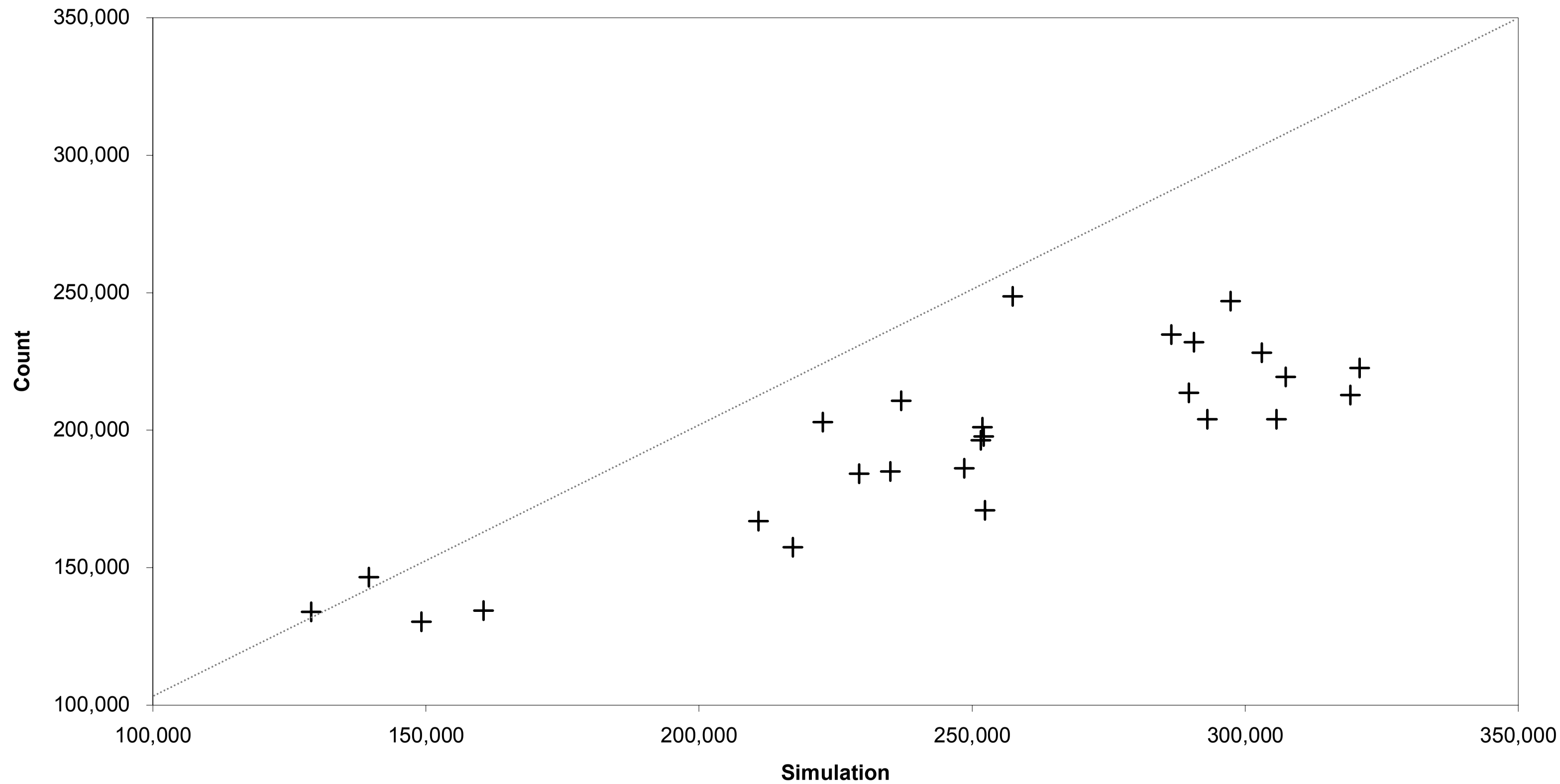


Figure 4-4: Equilibrium Comparison of Count to Simulation Year 2000

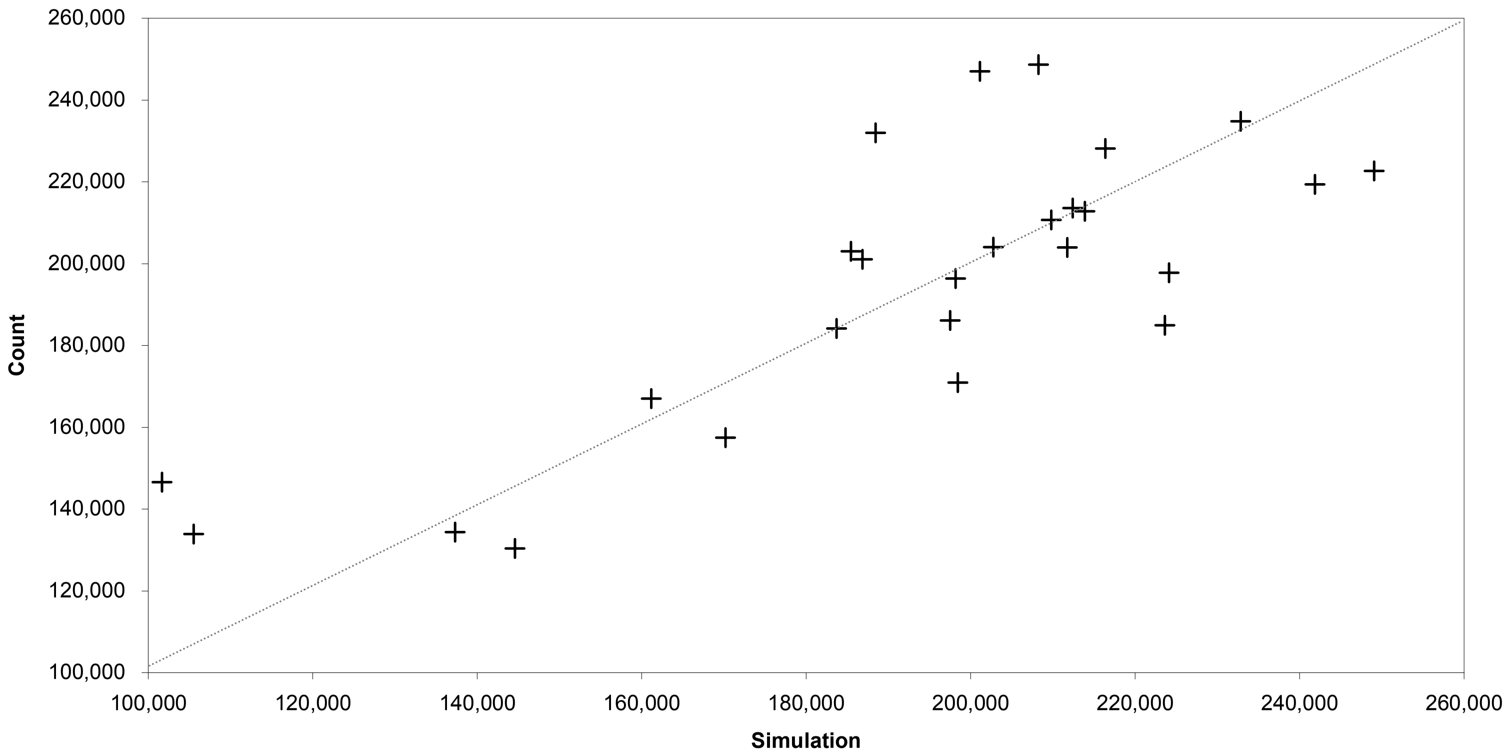


Figure 4-5: ICR BPR Alpha & Beta Modification Comparison of Count to Simulation Year 2000

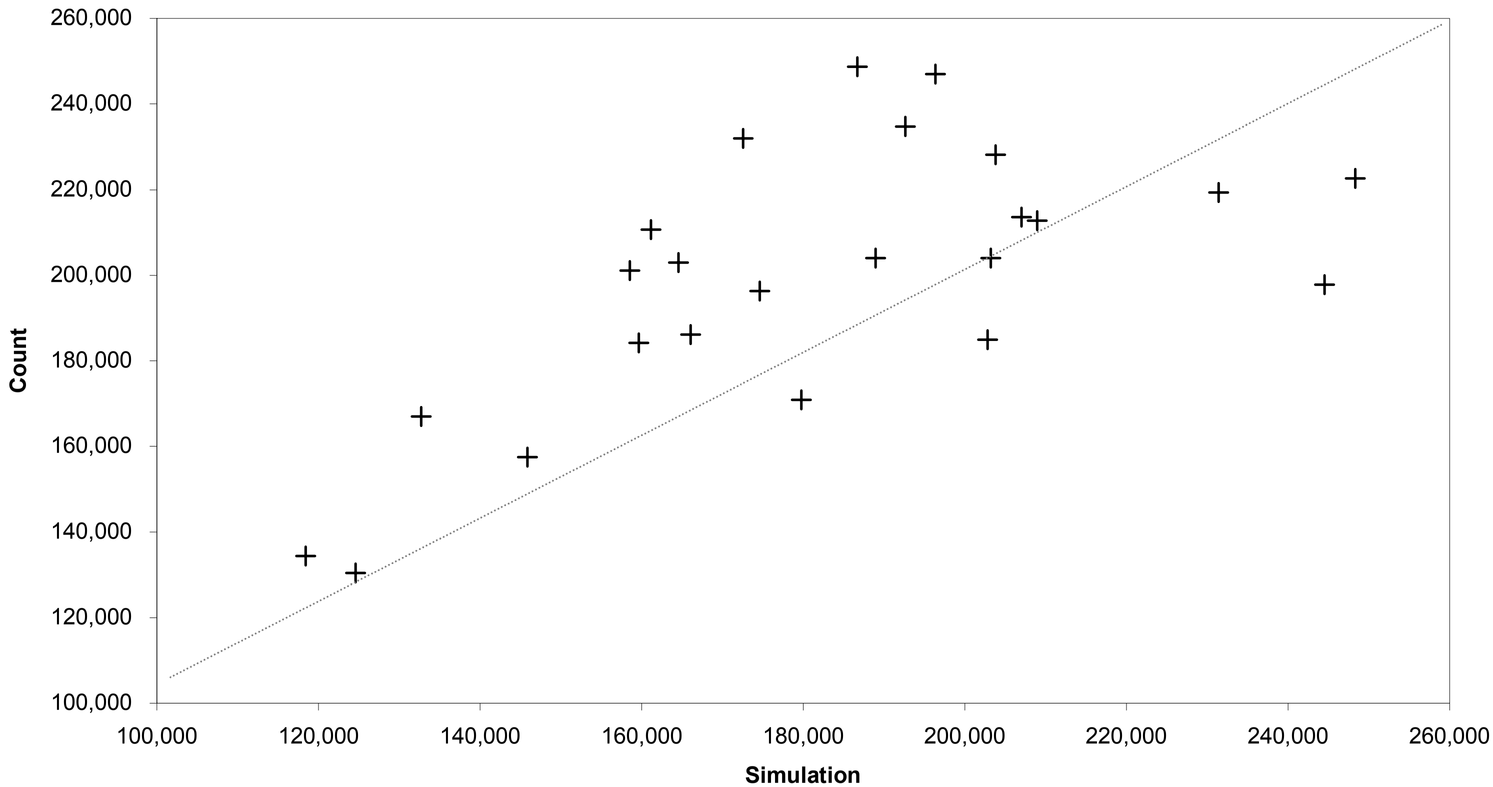


Figure 4-6: ICR Beta Modification Comparison of Count to Simulation Year 2000

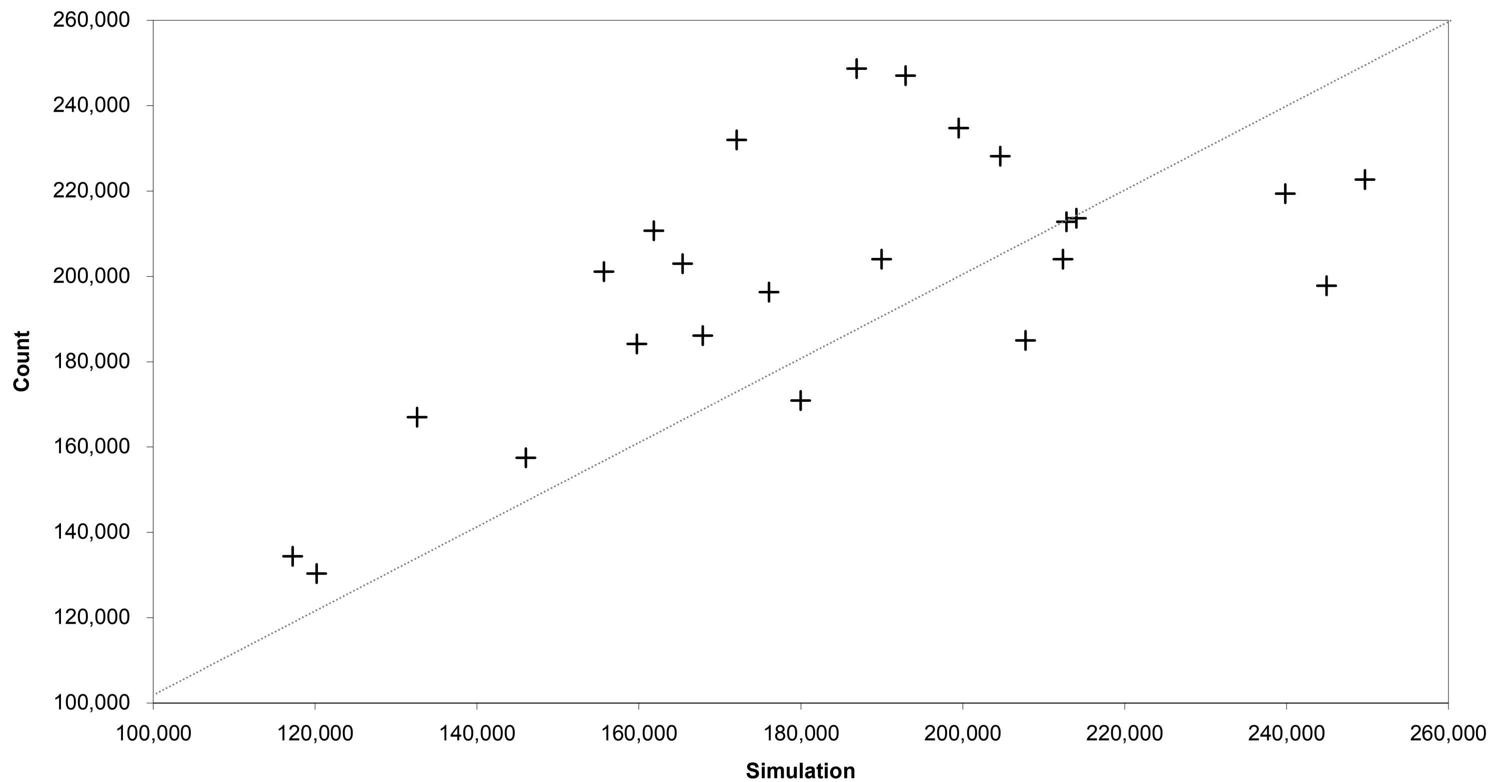


Figure 4-7: Equilibrium Beta Modification Comparison of Count to Simulation Year 2000

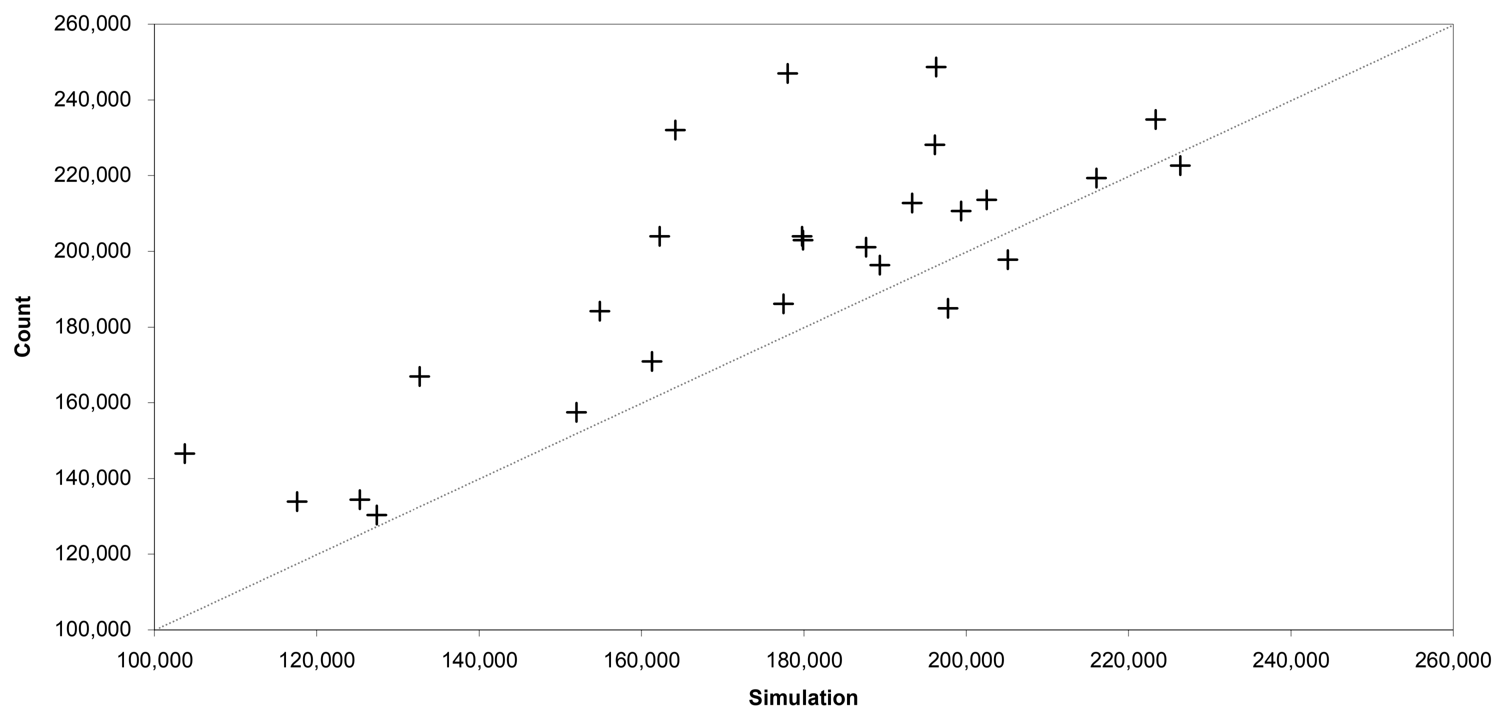


Figure 4-7 shows the scatter plot results of a β coefficient modification to the impedance equation applied using an equilibrium assignment. The RMSE was 14.8 percent and the trend line analysis produced a slope of 1.105. Although the assignment results were better than the modified incremental capacity restraint assignments, it was not as good as the base assignment nor the unmodified equilibrium assignment. A conclusion could be made that the basic relationships in the model when it was calibrated should not be adjusted for future year scenarios. If the model is calibrated using the standard impedance coefficients, it is not beneficial to adjust them for future year runs without knowing the effect for the calibration run.

4.3 Post-Processing Techniques Evaluation

Post-processing refers to analysis performed after execution of the travel demand forecast model run. Post-processing activities are applied to both the highway and transit travel demand forecast model (TDFM) outputs to compensate for the limitations of the model. For this research project, three different post-processing techniques were applied to the "raw" model results. The "raw' results refer to link volumes developed using the base assignment which employed an incremental capacity restraint algorithm.

The three post-processing techniques applied to the "raw" model output are all documented in NCHRP-255. All three of the techniques produce refined link volumes. The full refinement represents the technique outlined in NCHRP-255 for refining link volumes from a computerized travel demand forecast model. This procedure is documented in Chapter Four of the technical report. The two other techniques are derived from the full refinement. They represent parts of the full refinement. The first technique compensates for the model bias. This technique applies two types of corrections: one is the difference adjustment and the other is ratio adjustment. The results of both adjustments are averaged. This bias adjustment is the first part of the full refinement process. The bias correction is often used when a cutline cannot be defined, but many times practitioners used it independently of the full refinement.

The second partial technique, which is used by practitioners in the field, is to only apply the ratio adjustment. The idea is that the TDFM is used to develop growth factors from the base year to the future. It requires the same amount of data as the bias correction, but it only requires a single computation. Part of this research effort is to see if there is a benefit to the full refinement procedure given the data requirements and time to perform it. By looking at three different post-processing methods, a quantitative comparison can be made between them, and an assessment of their value to the processes can be measured.

As part of evaluating the different assignment algorithms and different post-processing techniques, a third method to forecast link volumes was evaluated. This method involved applying an annual growth factor to the links and compounding it over a ten year period. This method is often employed when traffic impact studies are done. Usually, a historical growth rate is taken from the preceding years. The same was done in this case, so data from 1989, 1990, and 1991 was taken to establish a growth rate. This rate was then applied to the 1990 link volumes and compounded over a ten year period to develop year 2000 forecast.

The same statistical measures used to evaluate the assignment algorithms were used for the post-processing evaluation. As with the assignment algorithm comparison, the 2000 observed data was compared to the post-process forecast results by link. Table 4-2 presents a summary of these measures. The first two rows contain the results for the base year incremental capacity restraint assignment and the equilibrium assignment. These two algorithms yielded better results than the other algorithms and are included in the table for comparison to the post-processing results.

Except for the annual growth rate technique, all of the other methods produced better results than the assignment algorithms. The full refinement technique produced the lowest RMSE at 5.7 percent, compared to the equilibrium assignment of 11.8 percent. The ratio adjustment produced slightly better results than the bias adjustment. This is interesting because the bias adjustment represents the ratio and difference adjustments. The difference adjustment was not tested as part of this evaluation, but from the above results it can be inferred that the ratio adjustment is a better technique than the difference adjustment.

Table 4-2: Summary of Post-Processing Techniques Evaluation				
Algorithm	**RMSE**	**Standard Error of Regression** (1 X 10^3)	**Trend Line y-intercept (0,0)**	
			R^2	**Slope**
Incremental Capacity Restraint	13.9%	28.15	0.376	1.029
Equilibrium	11.8%	24.03	0.525	1.003
Full Refinement	5.7%	11.62	0.918	1.030
Bias Adjustment	6.9%	13.98	0.883	1.037
Ratio Adjustment	6.6%	13.39	0.895	1.036
Annual Growth Rate	25.2%	51.12	0.885	0.805

The trend line analysis showed that, except for the annual growth rate technique, all of the post-processing techniques produced better trend lines. Although the slopes might be slightly better for some of the assignment algorithms, the data points for the post-processing techniques all were fairly close to the trend line. The R^2 values were all much closer to 1.0 than the assignment algorithm results. The results shown in the summary table demonstrate that there is a real benefit to post-processing over taking the "raw" model results.

Figure 4-8 shows the results of these four techniques. It can easily be seen from the graph that the annual factored growth over-predicted the year 2000 forecast. The other methods were much more accurate and the difference between them is less. It is important to notice that toward the southern end of the study corridor, where the demand is lower, the full refinement technique better matched the observed count. The other two methods are only the first part of the full refinement. The second part of the full refinement technique redistributes traffic across a defined cutline. For links that are not over-saturated, the bias and ratio adjustments do not completely compensate for the coarseness of the highway network and the limitations of the assignment process. If there were more under-saturated links in the corridor, the full refinement technique might have produced a greater differential between the bias and ratio adjustments.

Figure 4-9 shows the scatter plot for the full refinement process. Many of the data points are located on or immediately adjacent to the perfect match line y = x. Very few data points were over-simulated. Most of the error was related to under-simulation at the ADT level. At both river crossings the data showed much better results than the “raw” assignment results.

Figure 4-10 and Figure 4-11 show the scatter plots for the bias and ratio adjustments. These scatter plots show very little difference between the two techniques. The ratio adjustment yielded slightly better results for the corridor, but the improvement was very small.

Figure 4-12 shows the scatter plot for the annual factored growth. As with Figure 4-8, it can clearly be seen that this method over-simulated the corridor. In the early 1990s the Capital Beltway was experiencing rapid growth in traffic. As the decade progressed, the traffic growth started to taper off and approach more reasonable levels given the land-use development in the surrounding area and the capacity limitations of the facility. In 1990 this might not have been predictable, and by using the historical traffic growth the resulting forecast would be too high. The results of this method show the importance of travel demand forecast models. Over a fifteen or twenty-year forecast period, the factored growth would have been completely unrealistic.

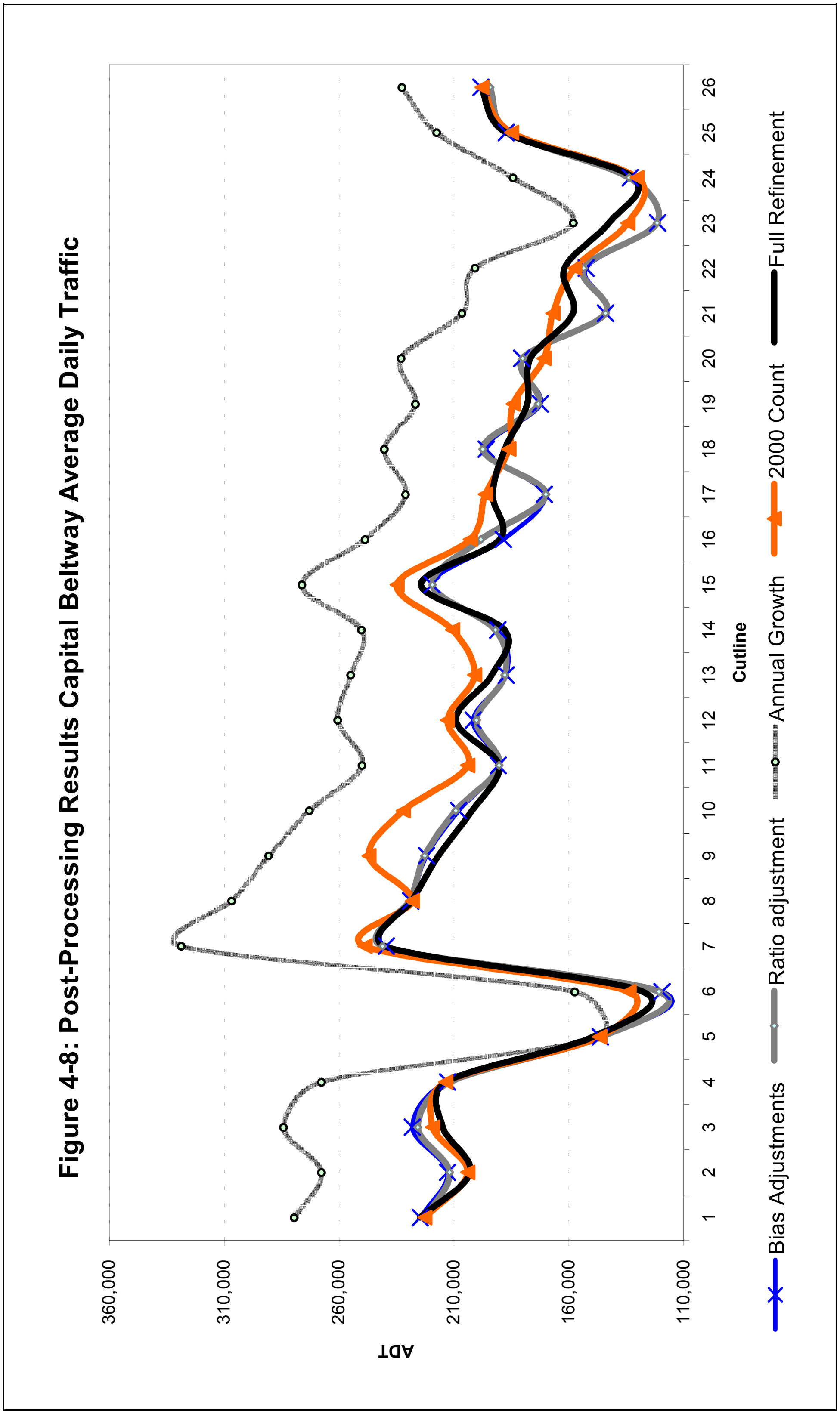


Figure 4-8: Post-Processing Results Capital Beltway Average Daily Traffic
ADT
360,000
310,000
260,000
210,000
160,000
110,000
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
Cutline
Bias Adjustments
Ratio adjustment
Annual Growth
2000 Count
Full Refinement

Figure 4-9: Full Refinement Comparison of Count to Simulation Year 2000

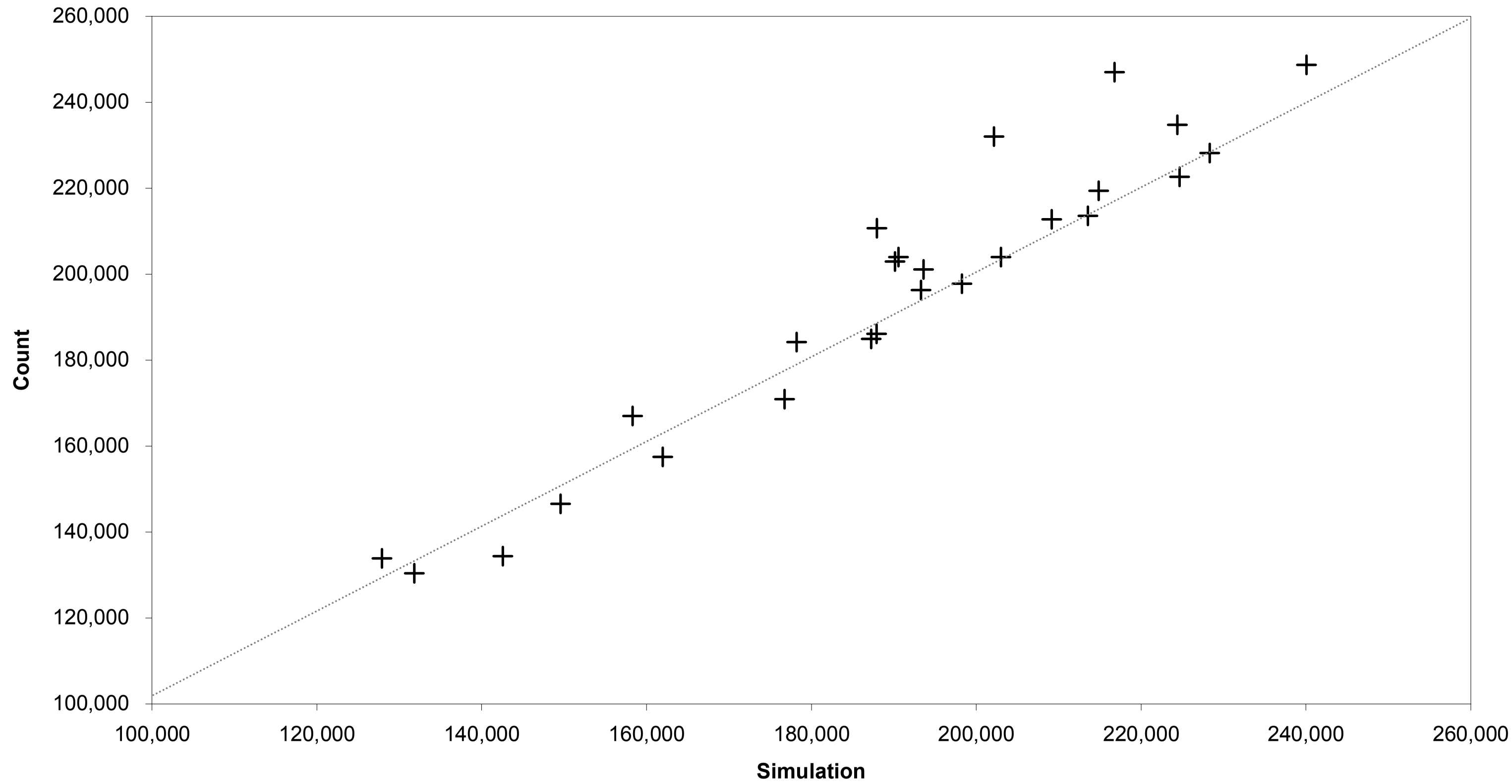


Figure 4-10: Bias Adjustment Comparison of Count to Simulation Year 2000

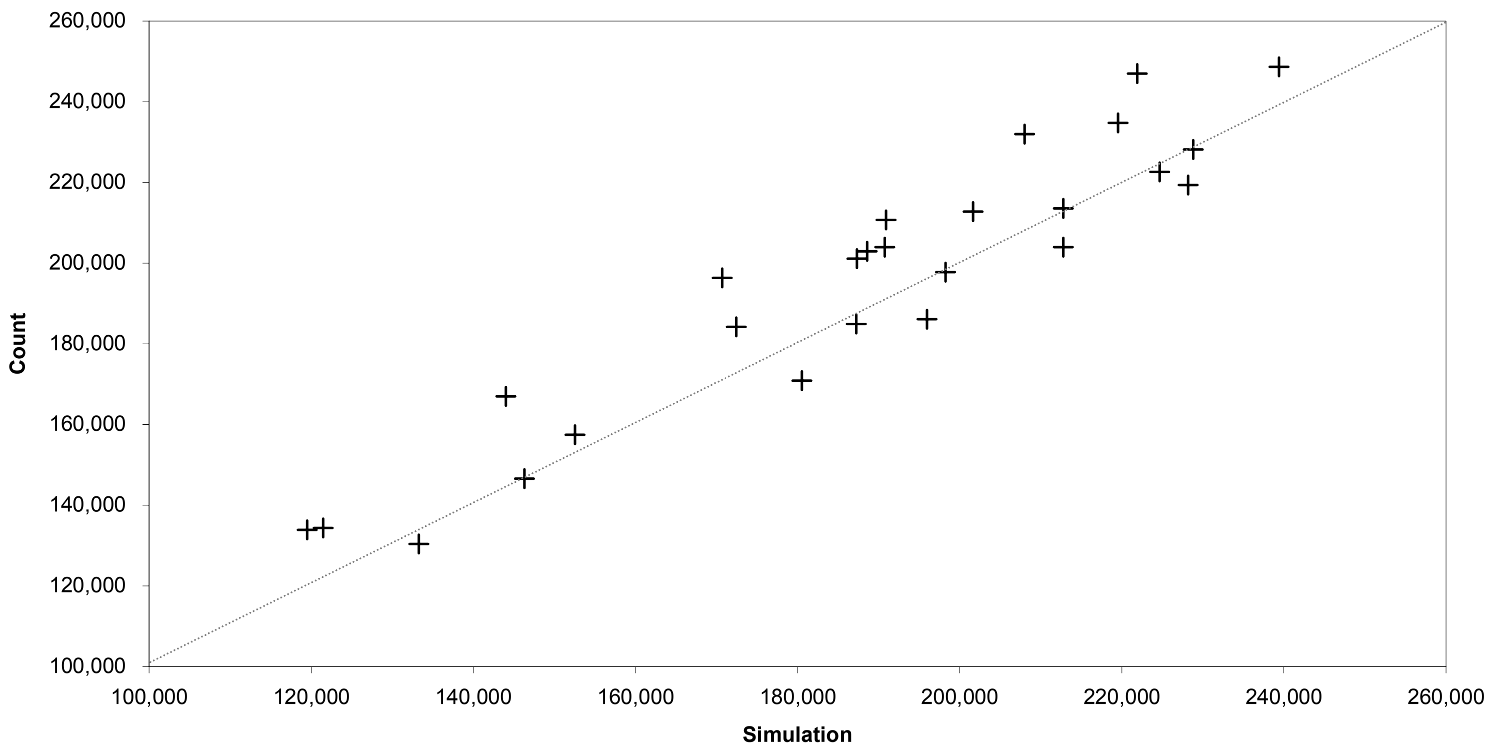


Figure 4-11: Ratio Adjustment Comparison of Count to Simulation Year 2000

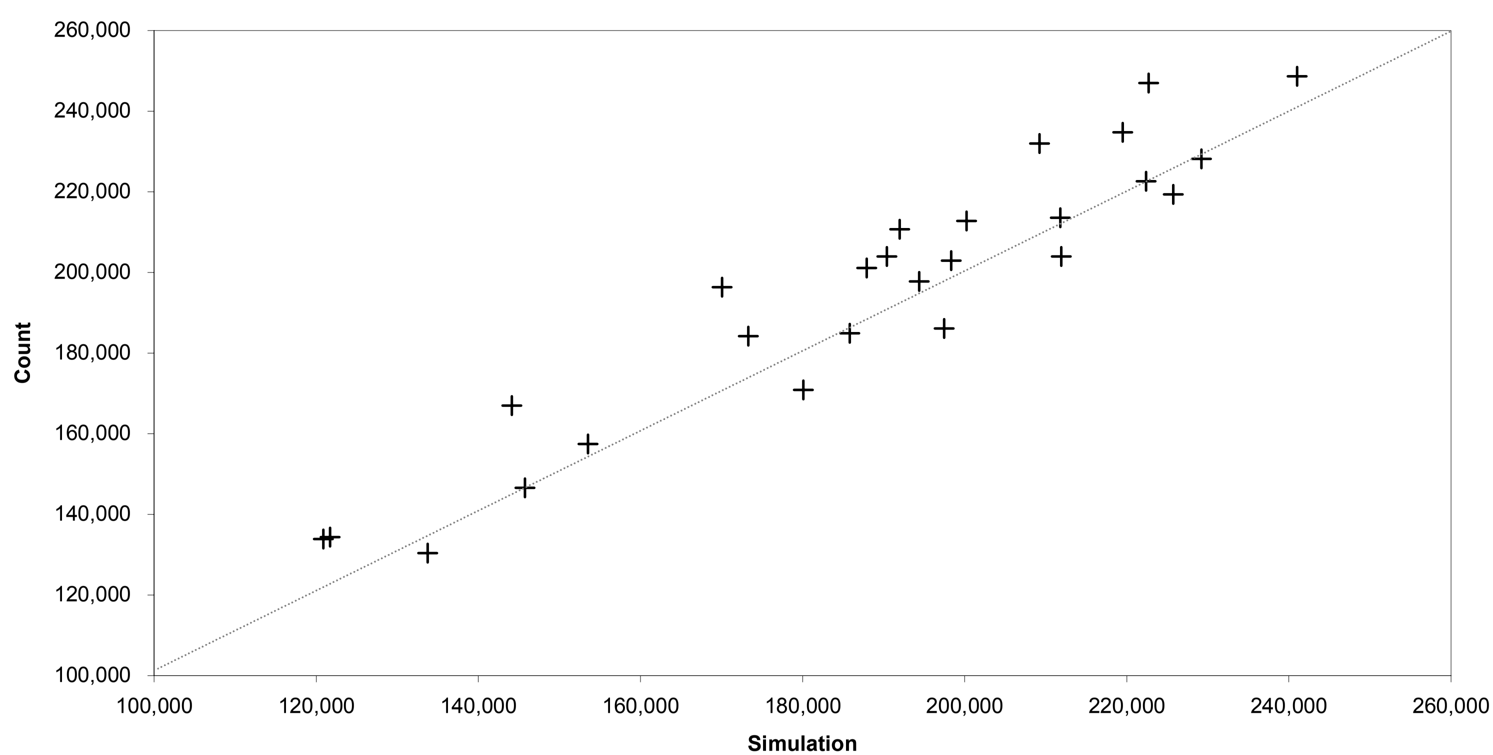
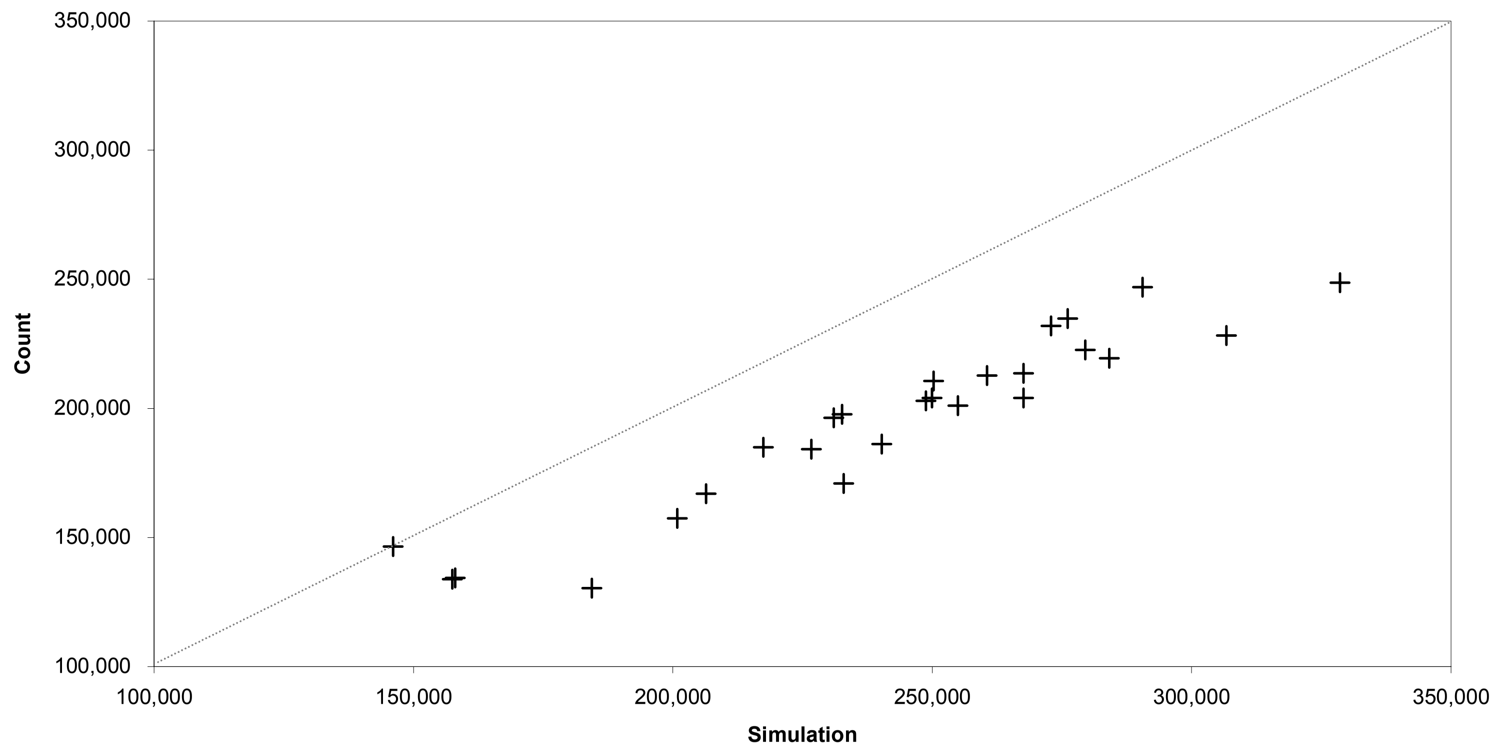


Figure 4-12: Annual Growth Comparison of Count to Simulation Year 2000



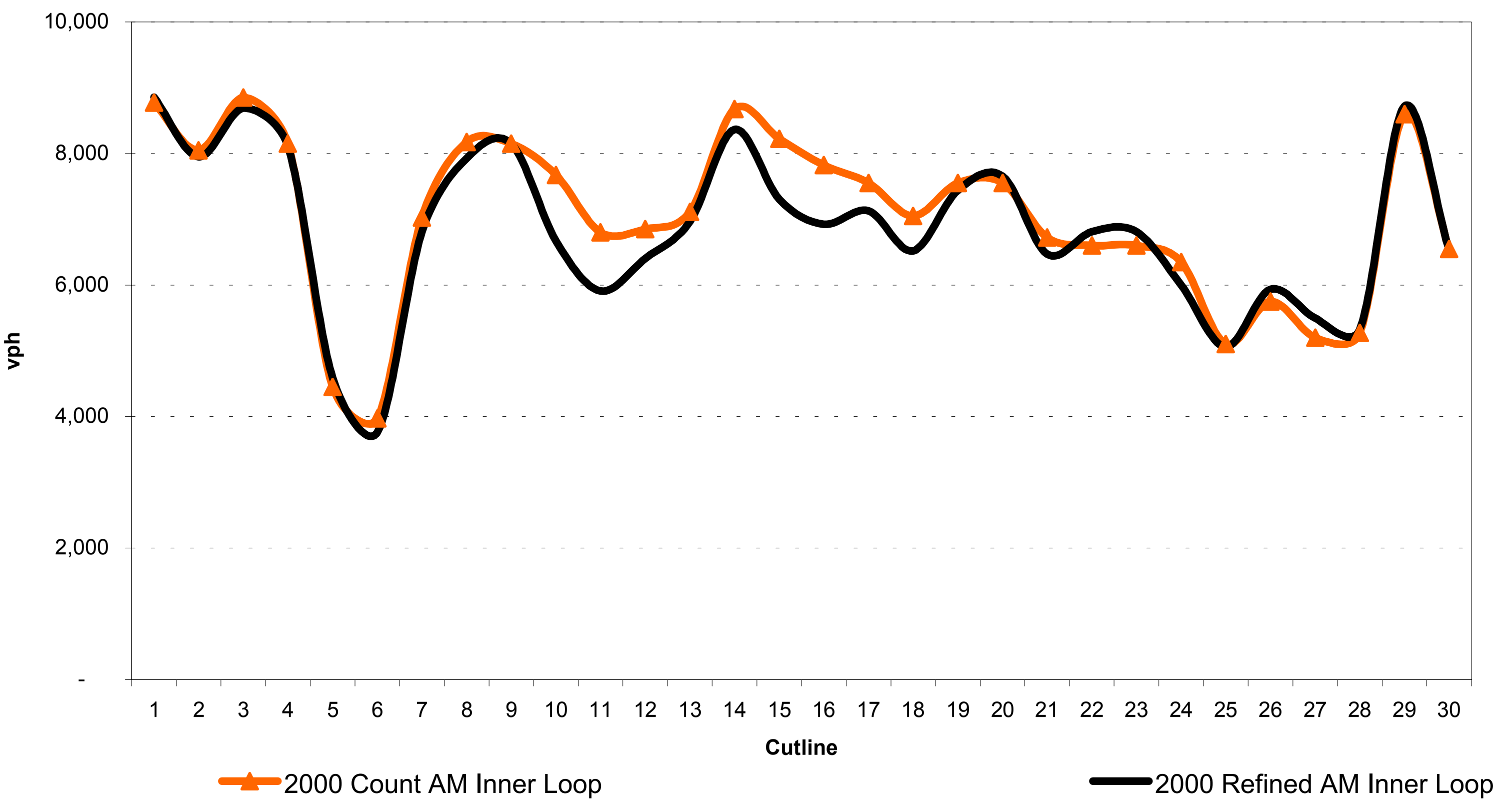
4.4 Peak Hour Derivation Evaluation

In project planning studies there is often a need to develop weekday peak hour projections for both the morning and evening peak hours. As part of this research project, peak hour volumes were derived from the ADT projections for the study corridor. The peak hour projections were based on the existing peak to daily percentages. The fully refined ADT volumes served as the input for the peak hour derivation. As part of this effort ADT turning movements had to be developed for all of the interchanges using the fully refined ADT volumes. The derivation of the peak hour projections was based on manipulating the ramp volumes to obtain a specific peak to daily percentage on the freeway facility by direction. Several levels of checks and balances play into this process with the end result being a peak hour forecast that is hopefully reasonable. One of the objectives of this research project is to quantitatively measure the accuracy and reasonability of these projections.

The Capital Beltway was divided into two separate facilities — the Inner Loop and the Outer Loop. The percent root mean square error was calculated for the mainline links and the ramps (turning movements) for both the AM and PM peak hours. There was no distinction made for the Inner or Outer Loops in this calculation. For the AM peak hour the RMSE was 4.2 percent on the mainline and 15.7 percent for the ramps. For the PM peak hour the RMSE was 4.1 percent on the mainline and 12.1 percent for the ramps.

Figure 4-13 shows the link volumes by segment versus the vehicle per hour for the AM peak hour on the Inner Loop. Figure 4-14 shows the link volumes by segment versus the vehicle per hour for the AM peak hour on the Outer Loop. Figure 4-15 shows the link volumes by segment versus the vehicle per hour for the PM peak hour on the Inner Loop. Figure 4-16 shows the link volumes by segment versus the vehicle per hour for the PM peak hour on the Outer Loop. The y-axis on these graphs represents the vehicles per hour (vph) and the scale is marked for every 2,000 vph. The 2,000 vph is representative of the capacity for a lane of traffic. Each interval represents another lane.

Figure 4-13: AM Peak Hour Inner Loop Capital Beltway Mainline Peak Hour Volumes



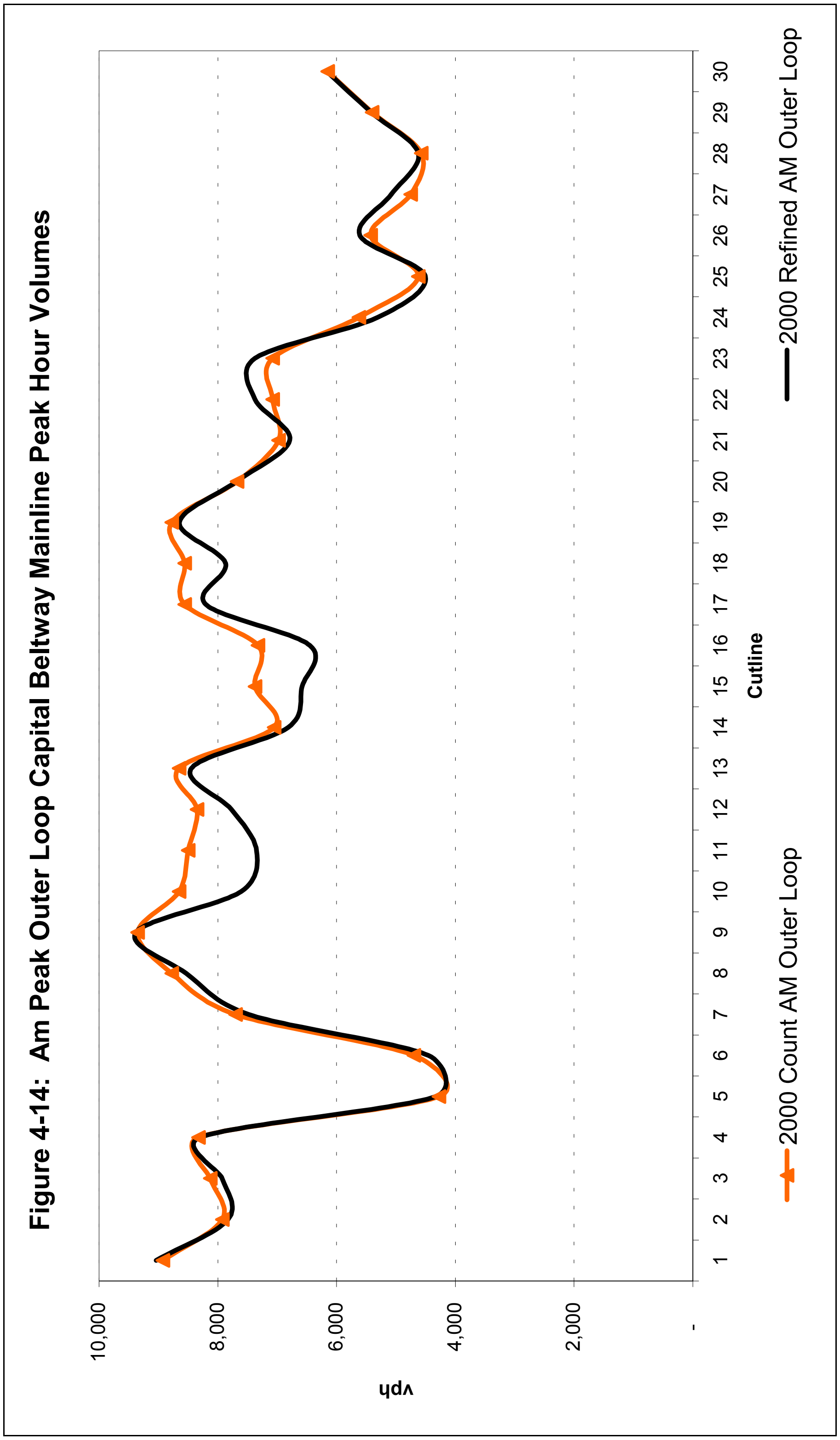


Figure 4-14: Am Peak Outer Loop Capital Beltway Mainline Peak Hour Volumes

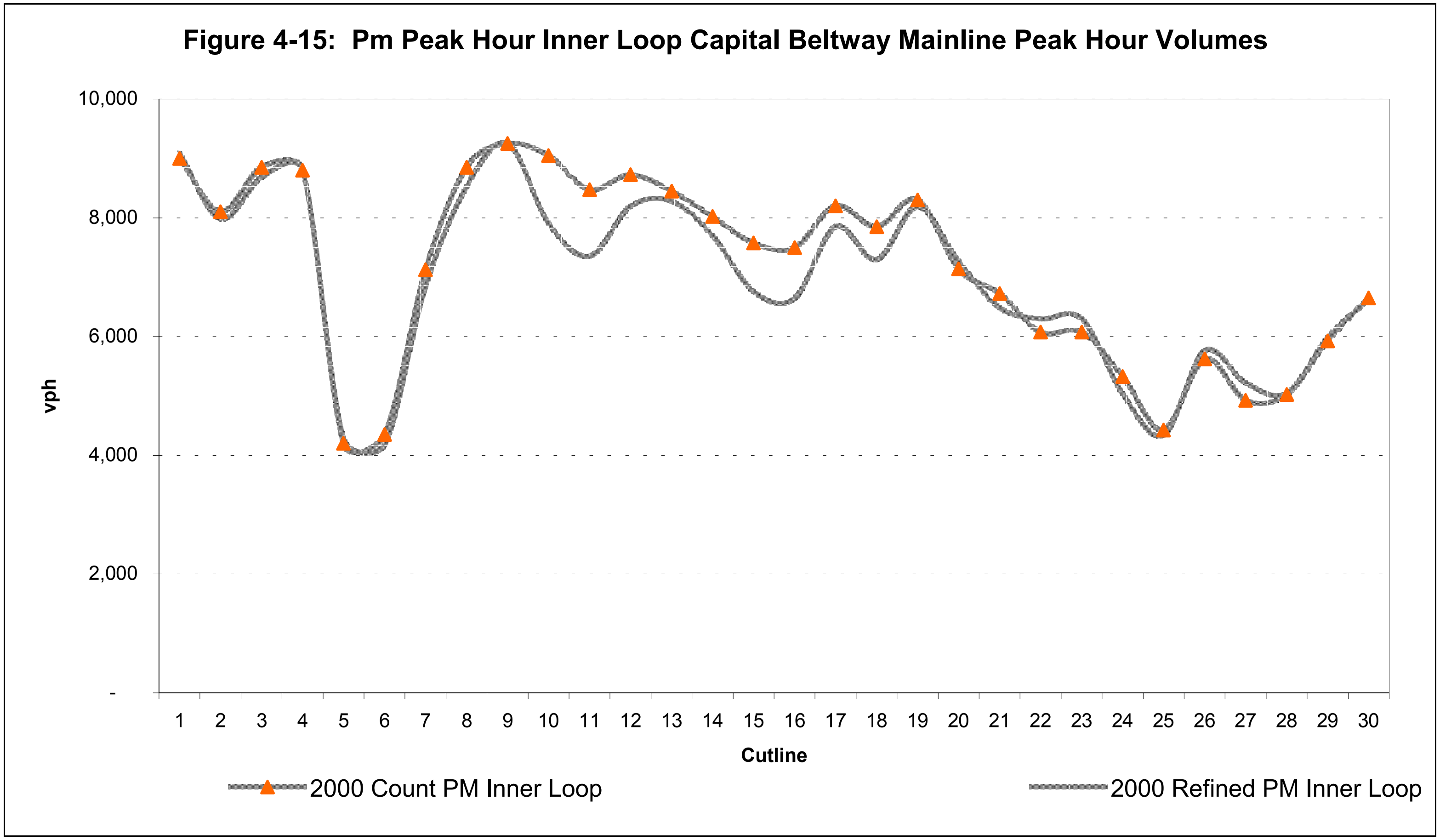
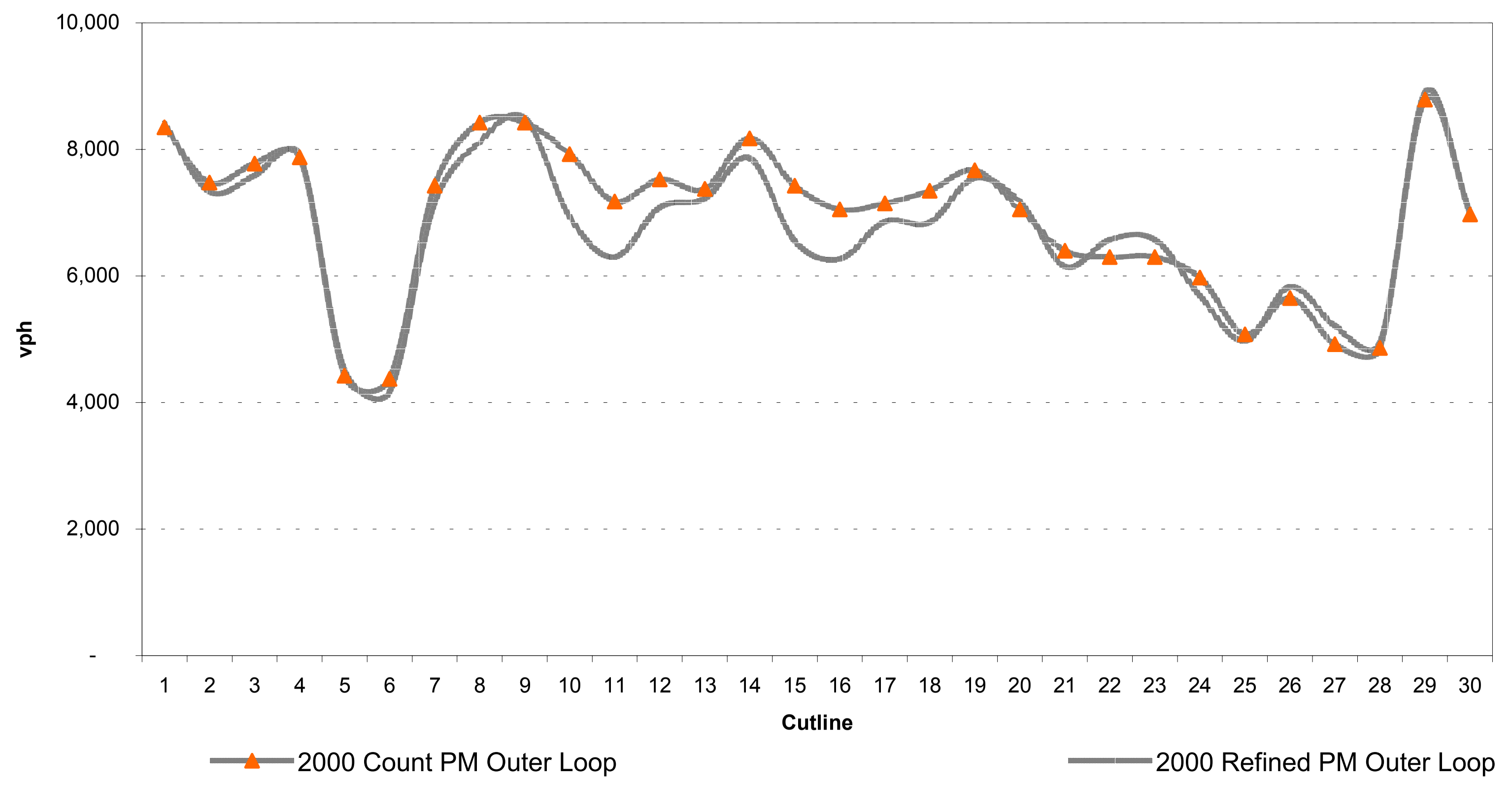


Figure 4-15: Pm Peak Hour Inner Loop Capital Beltway Mainline Peak Hour Volumes
10,000
8,000
6,000
4,000
2,000
-
vph
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Cutline
2000 Count PM Inner Loop
2000 Refined PM Inner Loop

Figure 4-16: Pm Peak Hour Outer Loop Capital Beltway Mainline Peak Hour Volumes



These graphs show the derived peak hour projections for the freeway segments between interchanges with the corresponding observed count volume. The general pattern between the count and projections is similar to that seen in the ADT evaluation. None of the data points are greater than a lane in the difference between the observed and the forecasted. There are some border line points where the observed count data is between lane capacities and the forecast falls just below the observed volume. The 2,000 vph lane capacity is only a rough estimate and could be plus or minus 200 vph.

There were three scatter plots done for the peak hour derivations. The scatter plots were done for the mainline links ramp volumes less than 1,500 vph and ramp volumes greater or equal to 1,500 vph. The ramp classification was based on the approximate capacity for a single lane ramp or loop. Ramps with greater than 1,500 vph represented major interchange movements, which were for the most part at the directional interchanges between the Capital Beltway and other bisecting freeway or parkway facilities. A trend line analysis was done for each of the scatter plots. Figure 4-17 shows the results for the mainline links during both the AM and PM peak hours. The trend line analysis resulted in a line with a slope equal to 1.029 and R^2 equal to 0.93. Figure 4-18 shows the scatter plot for ramps with less than 1,500 vph. The trend line analysis resulted in a line with a slope equal to 0.997 and R^2 equal to 0.95. Figure 4-19 shows the scatter plot for ramps with equal to or greater than 1,500 vph. The trend line analysis resulted in a line with a slope equal to 1.032 and R^2 equal to 0.92.

4.5 Time of Day Evaluation

In October 1997 the Travel Model Improvement Program published a report on time of day (TOD) modeling procedures. This report represented the state-of-the-practice and state-of-the-art. The report discussed the inadequacy of assigning daily trips and the need to develop peak period assignments for operational as well as environmental analyses. As part of this research project, a PM peak period assignment was performed using both an incremental capacity restraint assignment and an equilibrium assignment. The TOD method applied for this project was to factor the trip tables by purpose prior to the final highway assignment. The PM peak period was defined as a three-hour period between the hours of four and seven in the evening.

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

As in the previous evaluations, the percent root mean square error was the key measure applied for evaluating the results. For the TOD assignment and derived peak hour volumes for the Inner and Outer Loops were evaluated separately. The RMSE for the Inner Loop was 51.2 percent using the incremental capacity restraint (ICR) assignment and 48.5 percent for the Outer Loop. The RMSE using the equilibrium assignment was somewhat better. The Inner Loop RMSE with the equilibrium assignment was 20.9 percent and the Outer Loop was 24.5 percent. The equilibrium algorithm performed marginally better than the incremental capacity restraint algorithm when assigning a daily trip table, but it did substantially better with the peak period trip tables. This could be due to a variety of factors, but is most likely a function of the capacity and the supply versus the demand.

Figure 4-20 and Figure 4-21 show the link volumes by cutline for both assignment algorithms as well as the observed count data and the full refinement peak hour derivation. The RMSE showed that the incremental capacity restraint assignment over-simulated the traffic volumes for the corridor. For both assignments the pattern was still similar to the observed pattern, just different in magnitude. As with the daily assignments, both algorithms over-simulated at the river crossings.

Figure 4-22 and Figure 4-23 show the scatter plots for the Inner Loop and the Outer Loop, respectively. Both plots have data points representing the incremental capacity restraint and the equilibrium results. The data points on the scatter plots only represent the mainline link segments

Figure 4-17: Comparison of Count to Simulation Year 2000 Peak Hour Mainline

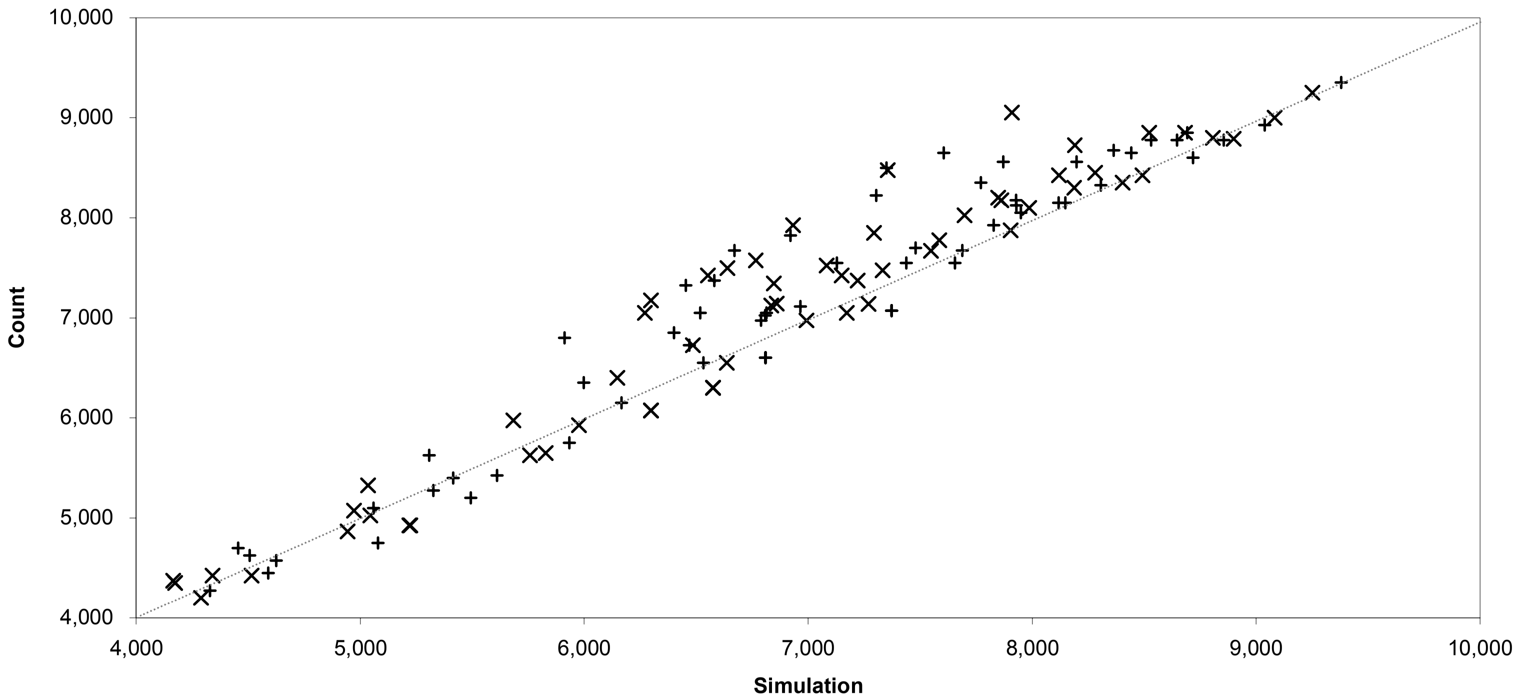


Figure 4-18: Comparison of Count to Simulation Year 2000 Peak Hour Ramp Volumes (< 1500 vph)

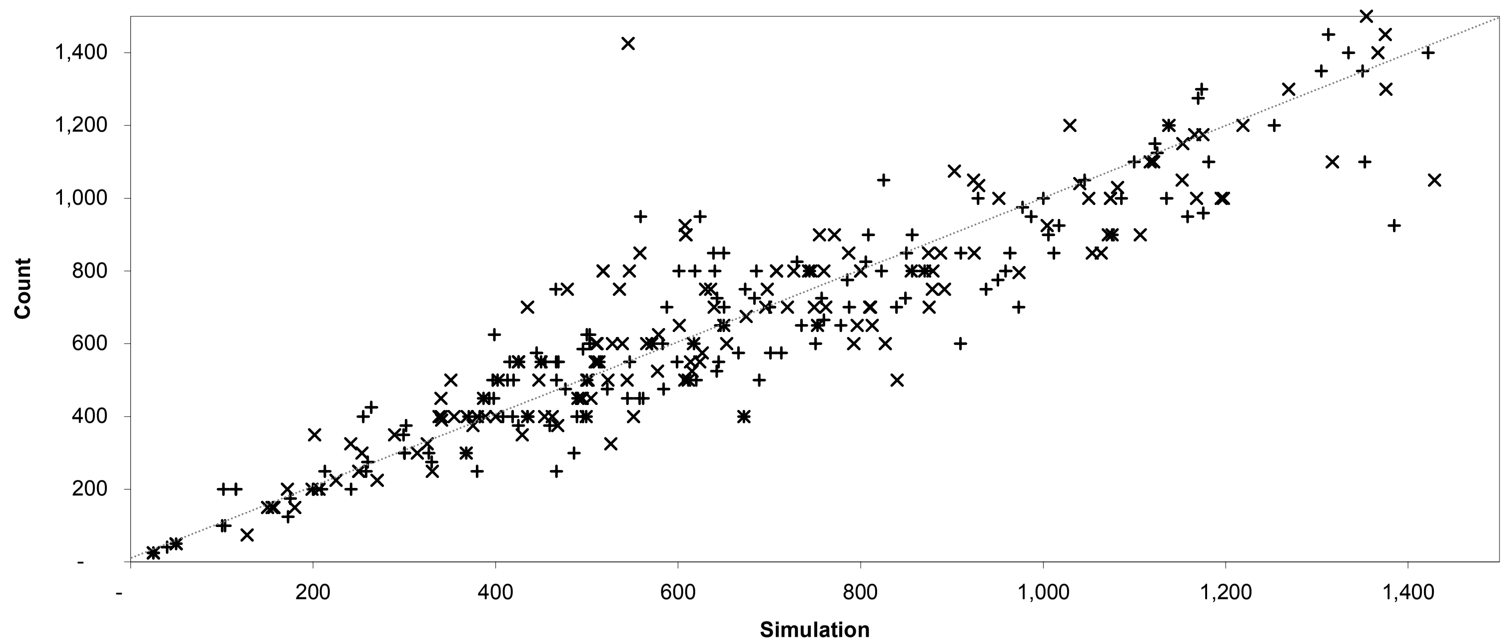


Figure 4-19: Comparison of Count to Simulation Year 2000 Peak Hour Ramp Volumes (> or = 1500 vph)

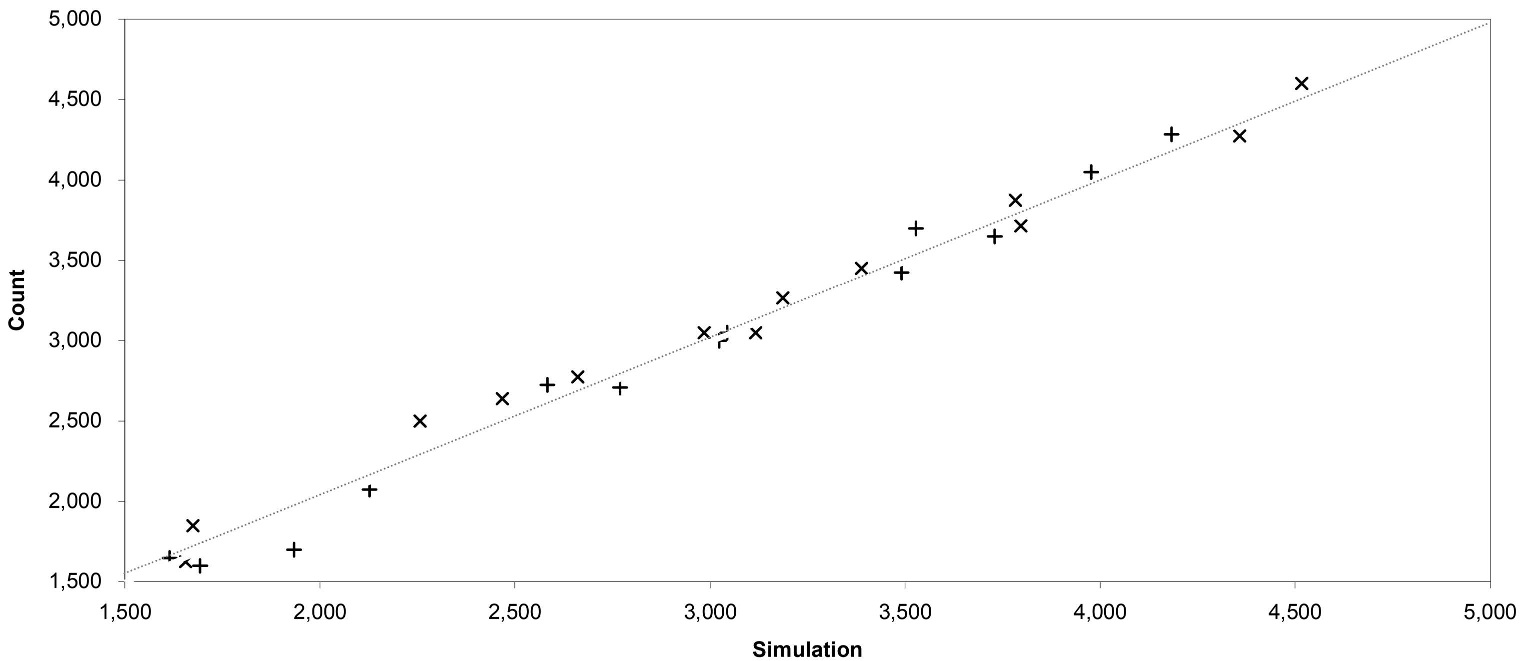


Figure 4-20: Peak Hour TOD Results Capital Beltway Mainline Peak Hour Volumes

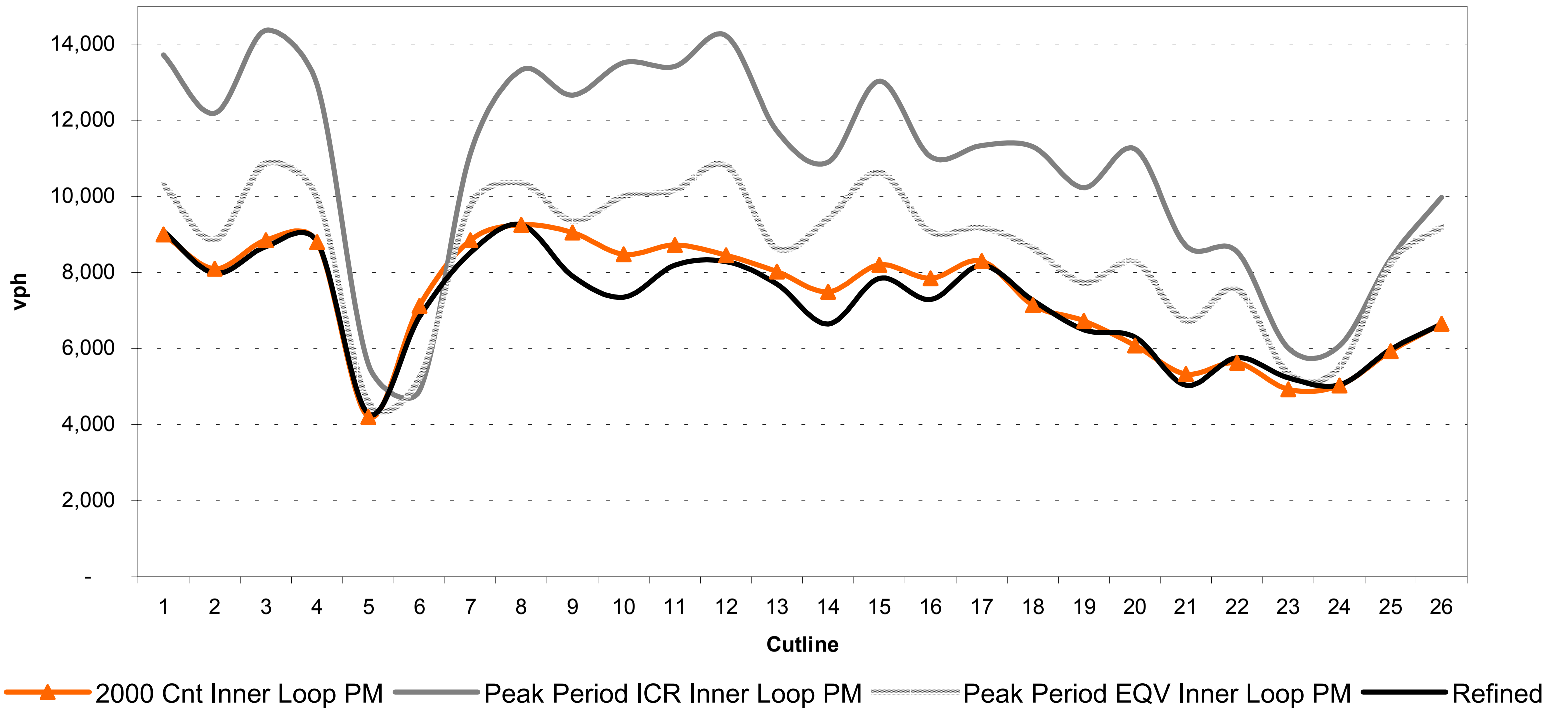


Figure 4-21: Peak Hour TOD Results Capital Beltway Mainline Peak Hour Volumes

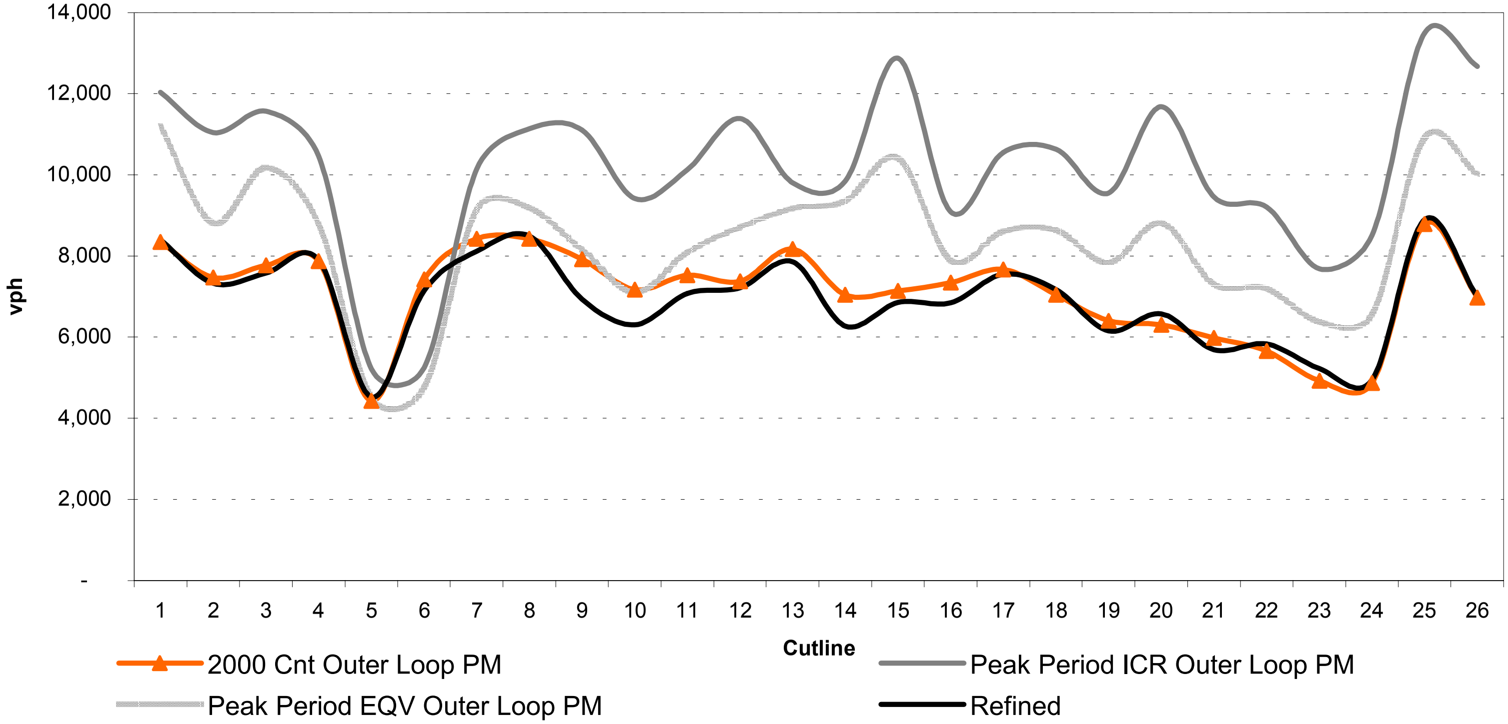
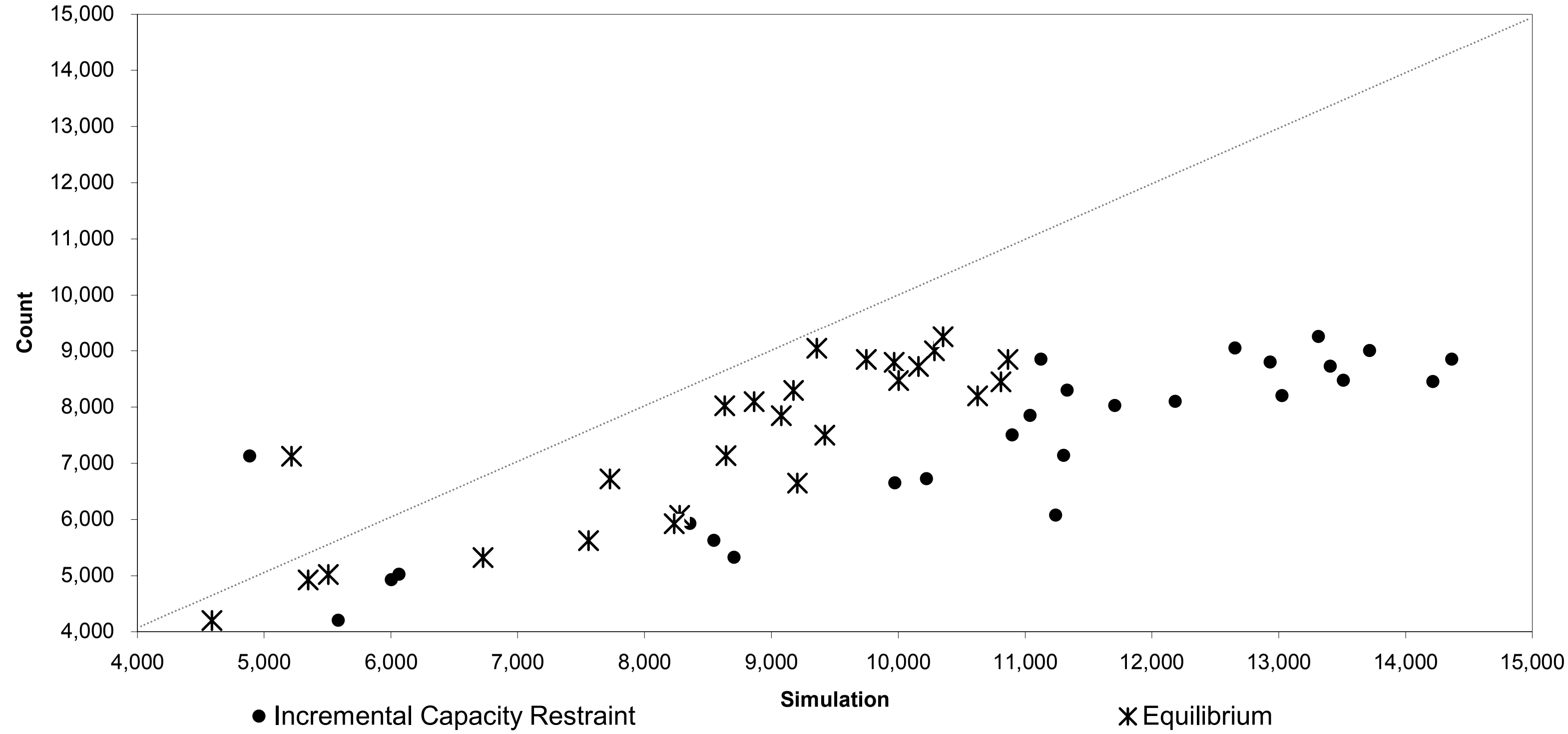


Figure 4-22: TOD Comparison of Count to Simulation Inner Loop PM Peak Hour Mainline Volumes



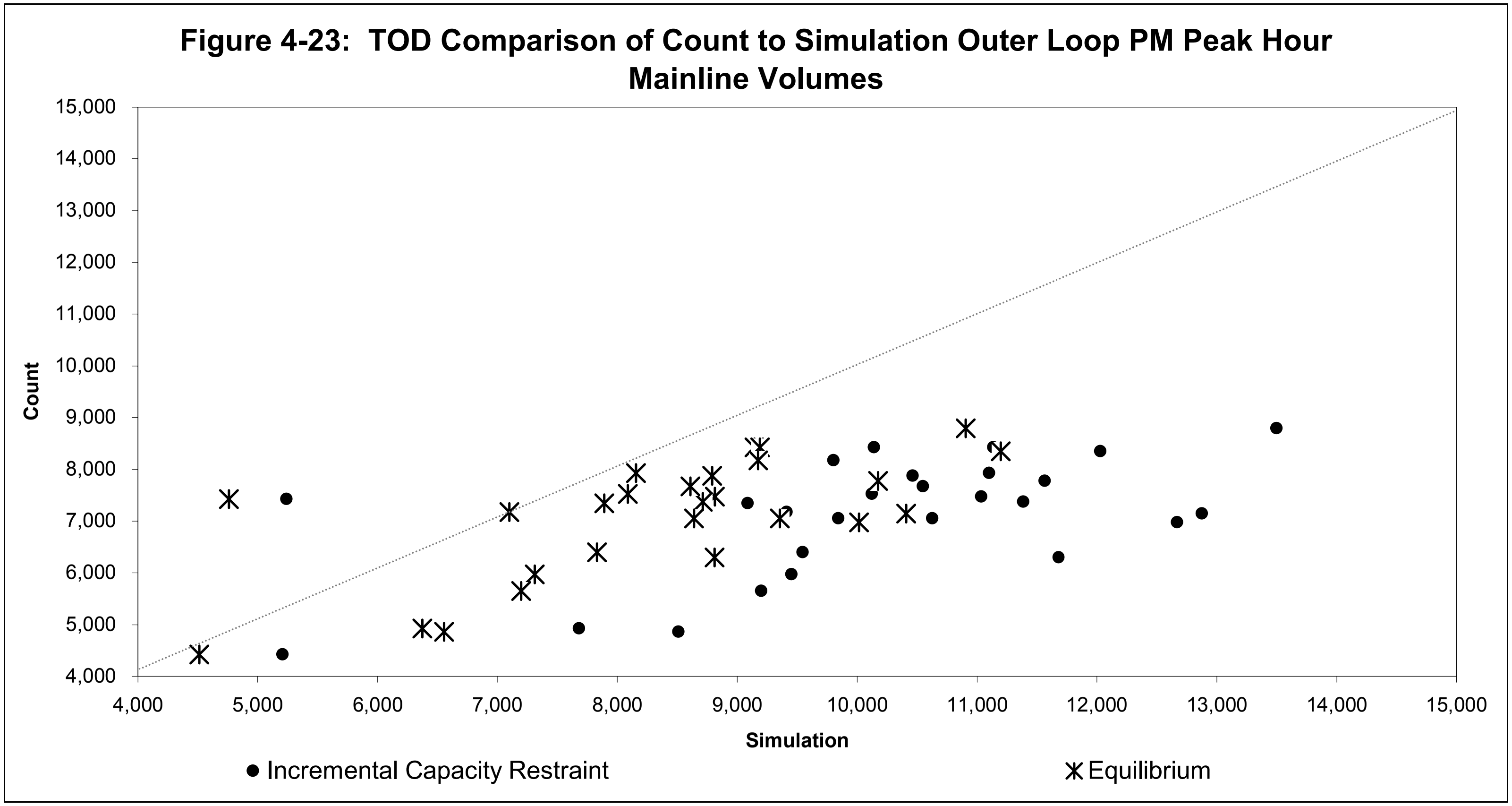


Figure 4-23: TOD Comparison of Count to Simulation Outer Loop PM Peak Hour Mainline Volumes
Count
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
13,000
14,000
15,000
Simulation
Incremental Capacity Restraint
Equilibrium

between interchanges. Turning movements were not part of this evaluation. The objective was to see if the TOD assignment resulted in better link forecasts than the post-process derived volumes.

4.6 Operational and Economic Impacts

Project Planning studies usually involve analysis of different alternatives. Alternative selection is based on the measures of effectiveness defined for a specific project. These measures are designed to evaluate the goals and objectives established by the stakeholders. Many of the common measures used to do alternative selection are reflective of operations or economic elements. The primary objective of this research project was to determine the benefit of applying post-processing procedures to "raw" model results. The resulting difference between the "raw" model output and the refined results has been quantitatively detailed in the previous sections. The measures used to evaluate the refined and "raw" results focused on statistical difference. For project planning, the measures are not so much statistical as they are related to real world impacts.

In an effort to better understand the impact resulting from the difference in the model output and the refined results, a capacity-based analysis was performed to determine level of service (LOS) on the freeway. LOS was only calculated for the Inner Loop during the PM peak hour. In addition to the LOS analysis, an economic analysis was done as part of this effort. The study section was the Inner Loop from the American Legion Bridge to the interchange of MD Route 414. The analysis did not address the area immediately adjacent to the Woodrow Wilson Bridge. The end point was determined prior to the river crossing due to the complexity of the interchange configurations in that area and the continuing construction around the bridge.

Level of service was calculated for the following scenarios:

- Year 2000 Observed Count
- Refined Peak Hour Derivation (full post-processed methodology)
- Time-of-Day Derived Peak Hour (ramp movements were based on count data)

The LOS analysis was for all elements of the freeway system including the mainline, ramp merges and diverges, ramp roadways, and weave areas. FRESYS software was used to perform the LOS and economic analysis. FRESYS software allows for a design or operations analysis. The operations analysis accounts for congestion and queues downstream. FRESYS is a deterministic model and does not include a micro-simulation component. The limitations of not using a micro-simulation model (e.g., CORSIM) were evident by the better than expected operations at some key choke points. The capacity analysis only focused on the freeway system and not the impacts of congestion on approach streets or adjoining freeways. For the Inner Loop analysis, the LOS analysis failed to show the effects of the I-270 diverge west of MD Route 190. Queues routinely build along I-270 and back onto the Capital Beltway. The capacity analysis was unable to incorporate the ramp queues back onto the freeway mainline. Although FRESYS is a better tool than the common HCS tool, CORSIM would have provided a more detailed operational evaluation of the freeway. Using CORSIM was not part of the scope of this project and would have required additional resources that were not available.

Figure 4-24 shows an operational summary for the observed count data. Figure 4-25 shows an operational summary for the post-processed results. Figure 4-26 shows an operational summary for the TOD results. Table 4-3 summaries the LOS by link and freeway system component for all three scenarios. The post-processed results are very similar to the observed count results. The TOD results show lower levels of service. If the post-processed results were used for a project planning study of this corridor the LOS analysis would yield the same conclusions as if the observed count was used. The same cannot be said for the TOD results.

Table 4-4 shows the results of the economic analysis. This analysis also looked at the environmental impacts of each scenario. There were three economic measures: user cost rate, total vehicle cost, and emissions cost. The environmental impacts were measured in fuel consumption, carbon monoxide (CO) emissions, hydrocarbon (HC) emissions, and nitrogen oxides (NOx) emissions. The table shows that the user cost rate, which is the user cost for travel time and delay per 1,000 vehicle miles traveled, is about the same for the observed data and the post-processed peak hour volumes. The peak hour forecast resulting from the TOD procedures

Figure 4-24: Traffic Operations Summary 2000 Observed Count Data (American Legion Bridge to I-95)

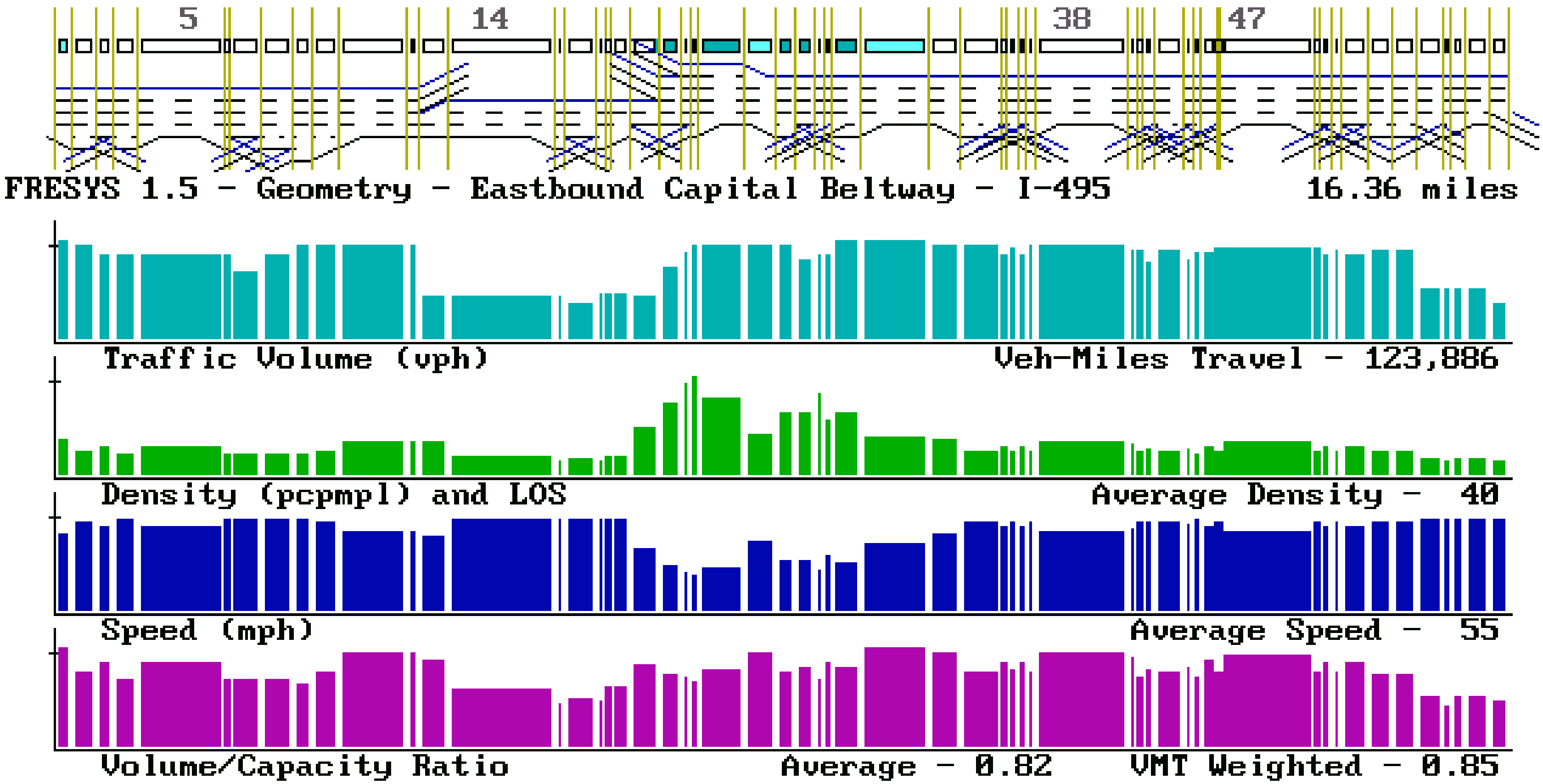


Figure 4-24: Traffic Operations Summary 2000 Observed Count Data (I-95 to MD 414)

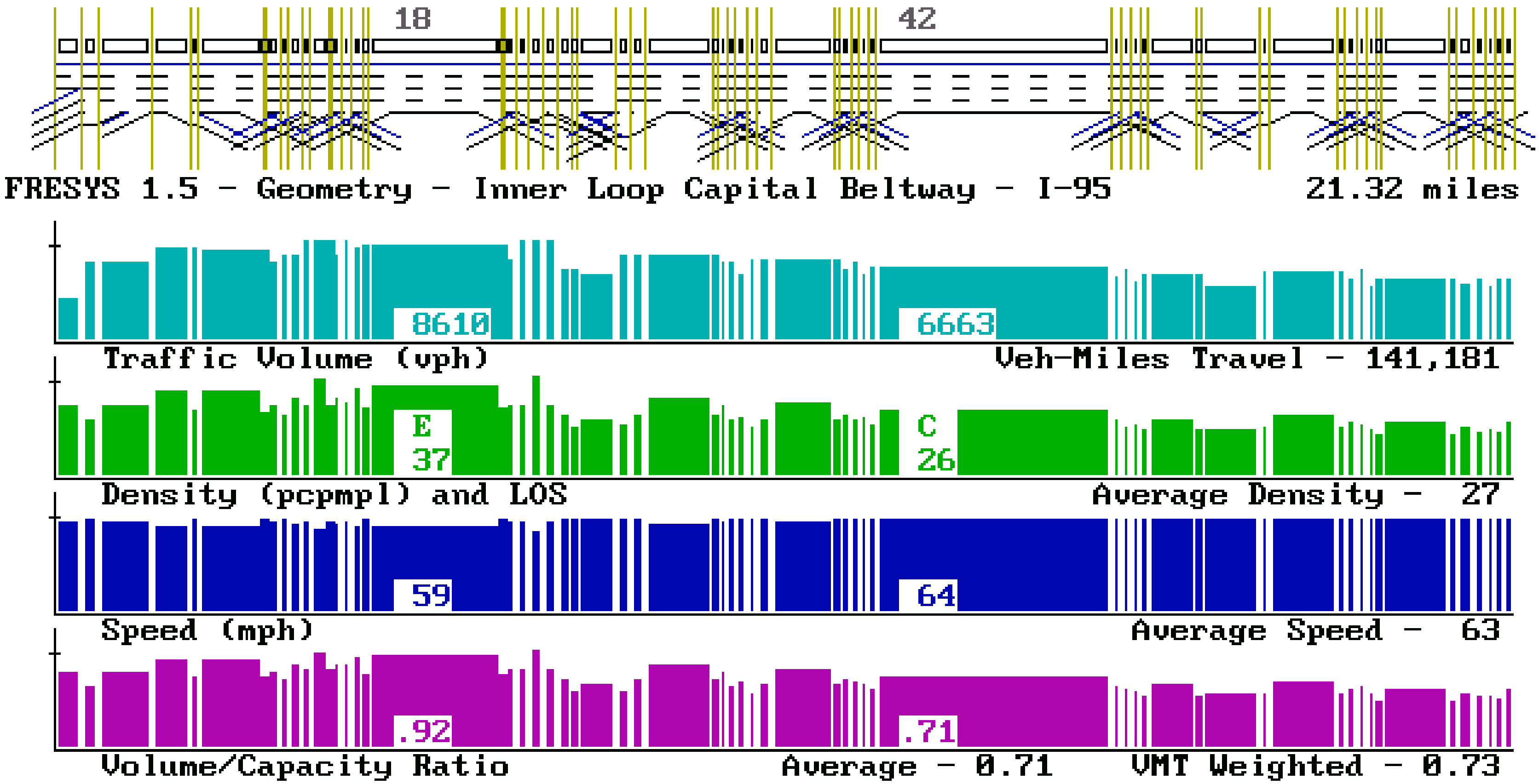


Figure 4-25: Traffic Operations Summary Post-Processed PM Peak Hour (American Legion Bridge to I-95)

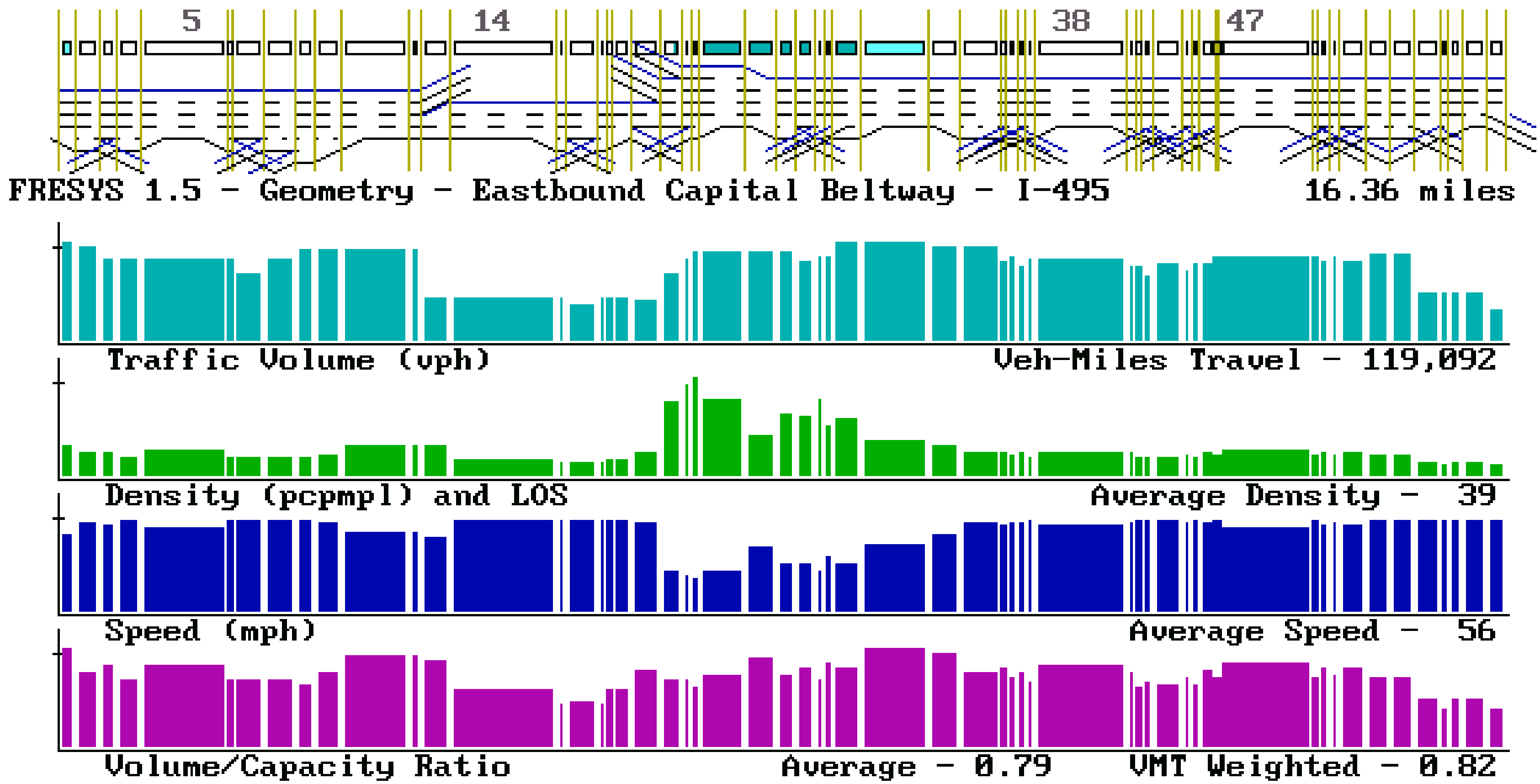


Figure 4-25: Traffic Operations Summary Post-Processed PM Peak Hour (I-95 to MD 414)

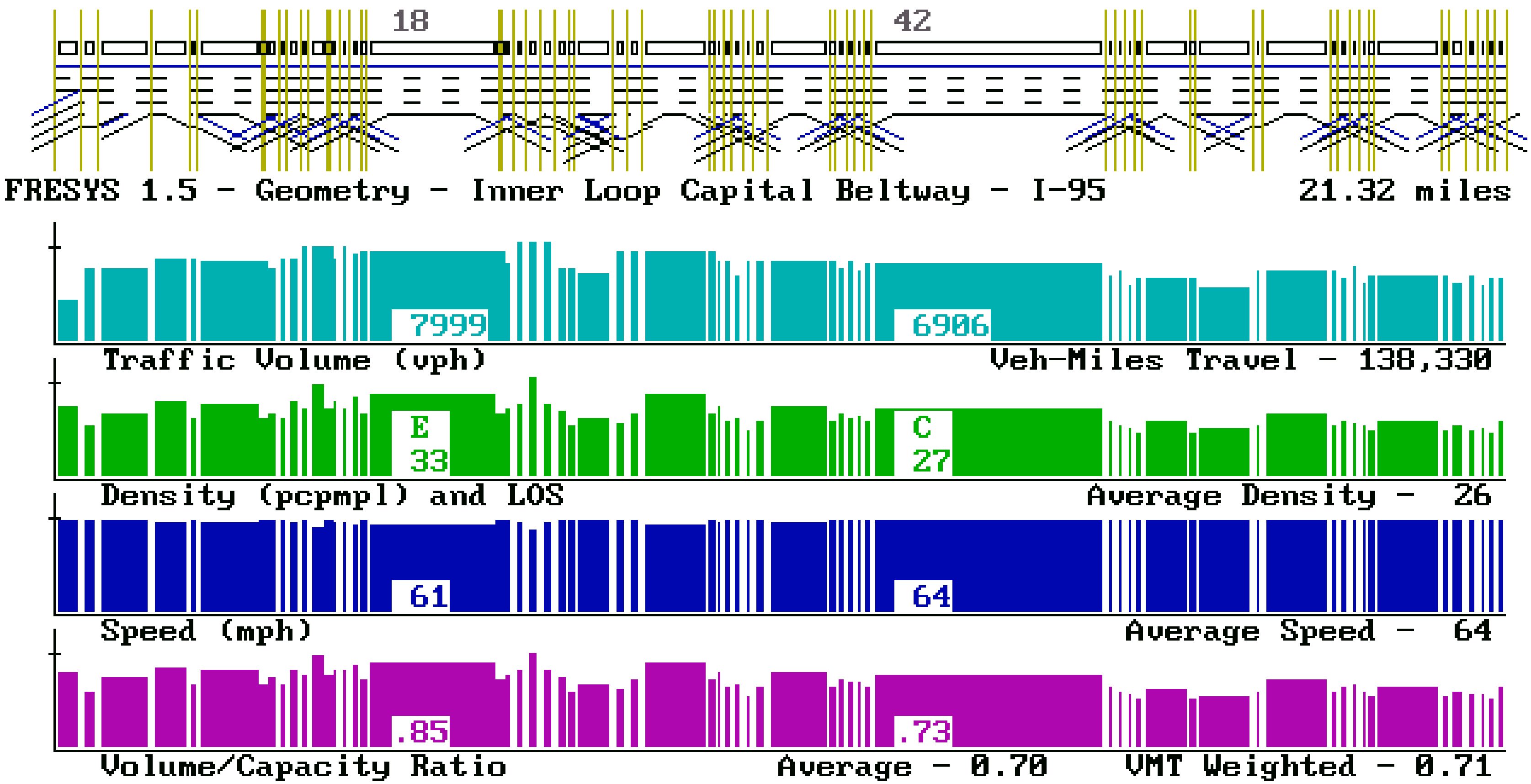


Figure 4-26: Traffic Operations Summary TOD PM Peak Hour Derivation (American Legion Bridge to I-95)

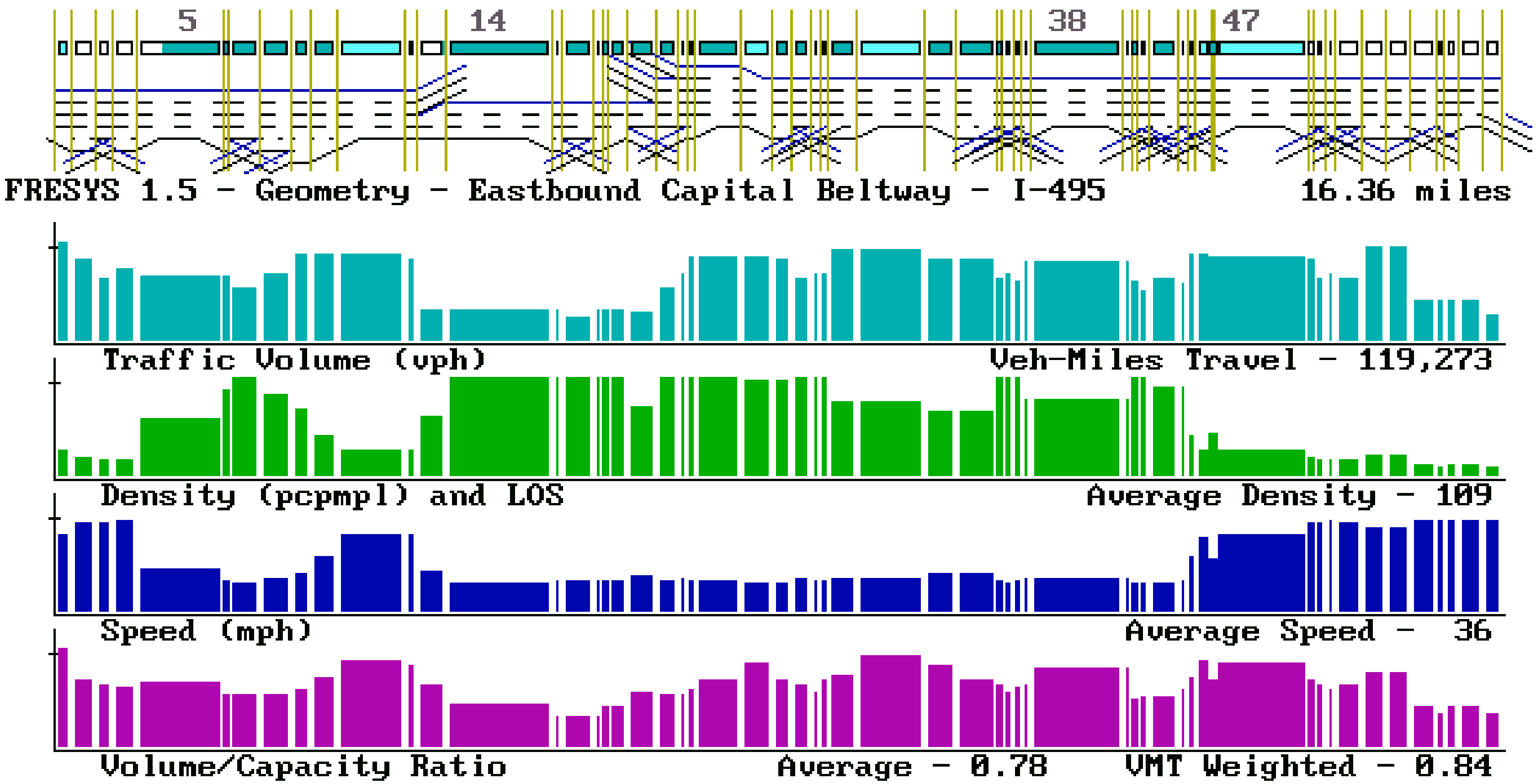


Figure 4-26: Traffic Operations Summary TOD PM Peak Hour Derivation (I-95 to MD 414)

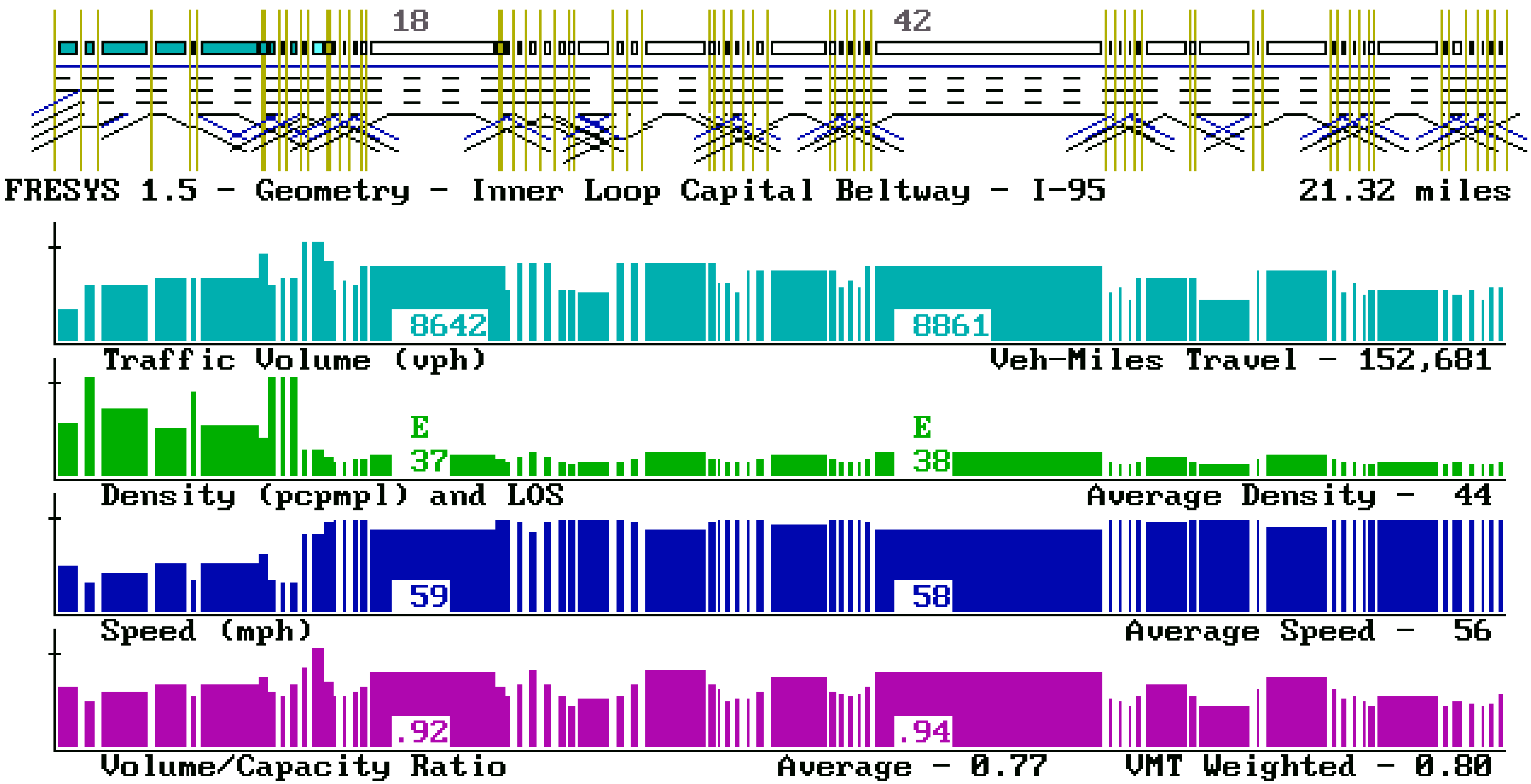


Table 4-3: Level of Service Summary PM Peak Hour Inner Loop

#	Segment	Basic Freeway			Weave			On Ramp Junction			On Ramp Roadway			Off Ramp Junction			Off Ramp Roadway		
		Cnt	Post	TOD	Cnt	Post	TOD	Cnt	Post	TOD	Cnt	Post	TOD	Cnt	Post	TOD	Cnt	Post	TOD
1	Legion Bridge Maryland State Line	F	F	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	Legion Bridge Marland State Line	D	D	D	-	-	-	-	-	-	-	-	-	B	C	E	C	C	F
3	Clara Barton Pkwy Off Ramp	E	E	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	Clara Barton Pkwy On Ramp	C	C	C	-	-	-	A	A	B	A	A	C	-	-	-	-	-	-
5	End Accel Lane	E	E	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	Begin Decel Lane	C	C	F	-	-	-	-	-	-	-	-	-	C	C	C	D	D	C
7	River Rd Off Ramp	D	D	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	River Rd EB On Ramp	C	C	F	-	-	-	C	C	C	D	D	D	-	-	-	-	-	-
9	River Rd WB On Ramp	C	C	F	-	-	-	B	B	E	B	B	F	-	-	-	-	-	-
10	Drop Accel Lane #2	D	D	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	Drop Accel Lane #1	F	F	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	Begin I-270 Spur Fork	E	E	E	-	-	-	-	-	-	-	-	-	F	F	F	F	F	F
13	I-270 Spur Left Off Ramp	E	E	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	Begin #3 Lane on Left	C	C	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	Begin Decel Lane	B	B	F	-	-	-	-	-	-	-	-	-	B	B	B	B	B	B
16	Old Georgetown Rd Off Ramp	C	C	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	Old Georgetown Rd On Ramp	B	B	F	-	-	-	B	B	B	B	B	B	-	-	-	-	-	-
18	End Decel Lane	C	C	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	Begin Auxiliary Lane	C	C	F	-	-	-	-	-	-	-	-	-	A	A	A	A	A	A
20	Wisconsin Ave Off Ramp	F	D	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	I-270 Left On Ramp	F	F	F	-	-	-	C	C	C	C	C	C	-	-	-	-	-	-
22	Wisconsin Ave Left On Ramp	F	F	F	-	-	-	C	C	C	C	C	C	-	-	-	-	-	-
23	Wisconsin Ave On Ramp	F	F	F	-	-	-	B	B	E	B	B	F	-	-	-	-	-	-
24	End Right Accel Lane	F	F	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	End Left Accel Lane	F	F	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	Begin Decel Lane	F	F	F	-	-	-	-	-	-	-	-	-	C	B	E	C	C	F
27	Connecticut Ave Off Ramp	F	F	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Segment	Basic Freeway			Weave			On Ramp Junction			On Ramp Roadway			Off Ramp Junction			Off Ramp Roadway		
	Cnt	Post	TOD	Cnt	Post	TOD	Cnt	Post	TOD	Cnt	Post	TOD	Cnt	Post	TOD	Cnt	Post	TOD
28 Connecticut Ave SB On Ramp	F	F	F	-	-	-	A	A	A	A	A	A	-	-	-	-	-	-
29 Drop Accel Lane	F	F	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30 Connecticut Ave NB On Ramp	F	F	F	-	-	-	C	C	F	C	C	F	-	-	-	-	-	-
31 Drop Accel Lane	F	F	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32 End 55 mph Curve	F	F	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
33 Begin Decel Lane	D	D	F	-	-	-	-	-	-	-	-	-	B	C	E	C	C	F
34 Georgia Ave SB Off Ramp	E	E	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
35 Georgia Ave SB On Ramp	D	C	F	F	F	F	B	A	A	B	A	A	A	B	A	A	B	B
36 Georgia Ave NB Off Ramp	E	D	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37 Georgia Ave NB On Ramp	D	C	F	-	-	-	B	A	E	B	A	F	-	-	-	-	-	-
38 End Accel Lane	E	D	F	-	-	-	-	-	-	-	-	-	F	F	F	A	A	A
39 Colesville Rd SB Off Ramp	E	D	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40 Begin Decel Lane	C	C	F	-	-	-	-	-	-	-	-	-	B	B	B	C	C	C
41 Colesville Rd NB Off Ramp	D	D	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
42 Colesville Rd NB On Ramp	D	C	F	E	D	D	C	C	C	C	C	C	B	A	A	B	A	A
43 University Blvd EB Off Ramp	E	D	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
44 University Blvd EB On Ramp	C	C	F	-	-	-	A	A	F	A	A	F	-	-	-	-	-	-
45 Drop Accel Lane	E	D	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46 University Blvd WB On Ramp	D	C	F	-	-	-	A	B	A	A	B	A	-	-	-	-	-	-
47 End Accel Lane	E	E	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48 Begin Decel Lane	D	C	D	-	-	-	-	-	-	-	-	-	B	A	F	B	B	F
49 New Hampshire Ave SB Off Ramp	E	E	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50 New Hampshire Ave SB On Ramp	D	C	C	F	F	F	A	A	A	A	B	B	A	A	A	A	A	A
51 New Hampshire Blvd NB Off Ramp	E	E	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
52 New Hampshire Ave NB On Ramp	C	C	E	-	-	-	A	A	F	A	B	F	-	-	-	-	-	-
53 Riggs Rd Overpass	C	C	E	-	-	-	-	-	-	-	-	-	E	F	F	E	E	F
54 I-95 NB Off Ramp	C	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Segment	Basic Freeway			Weave			On Ramp						Off Ramp					
							Junction			Roadway			Junction			Roadway		
	Cnt	*Post*	*TOD*	*Cnt*	*Post*	*TOD*	*Cnt*	*Post*	*TOD*	*Cnt*	*Post*	*TOD*	*Cnt*	*Post*	*TOD*	*Cnt*	*Post*	*TOD*
55 I-95 SB On Ramp	B	B	B	-	-	-	A	A	A	A	A	A	-	-	-	-	-	-
56 Drop Accel Lane	C	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
57 I-95 Overpass	B	B	B	-	-	-	-	-	-	-	-	-	B	B	B	B	B	B
58 US 1 CD Road Off Ramp	C	B	B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1 I-95 SB Ramp	D	D	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2 I-495 On Ramp	C	B	F	-	-	-	B	B	B	C	B	B	-	-	-	-	-	-
3 Drop #5 Lane	D	D	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4 US 1 CD Road On Ramp	D	D	F	-	-	-	F	D	D	C	B	B	-	-	-	-	-	-
5 Begin Decel Lane	C	C	F	-	-	-	-	-	-	-	-	-	A	A	A	A	A	A
6 Greenbelt P&R Off Ramp	E	D	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7 Begin Decel Lane	C	C	F	-	-	-	-	-	-	-	-	-	B	B	F	C	B	F
8 MD 201 Off Ramp	D	D	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9 MD 201 Loop On Ramp	C	C	F	-	-	-	B	B	B	B	B	B	-	-	-	-	-	-
10 MD 201 Loop Off Ramp	D	D	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11 MD 201 NB On Ramp	D	C	E	-	-	-	B	C	F	C	C	F	-	-	-	-	-	-
12 Drop Accel Lane	E	E	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13 Begin Decel Lane	D	C	D	-	-	-	-	-	-	-	-	-	B	B	F	C	C	F
14 BW Pkwy SB Off Ramp	D	D	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 BW Pkwy Loop On Ramp	D	C	C	F	F	F	C	B	B	C	C	C	A	A	A	B	B	A
16 BW Pkwy Loop Off Ramp	E	D	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17 BW Pkwy NB On Ramp	C	C	C	-	-	-	A	A	E	A	A	F	-	-	-	-	-	-
18 Drop Accel Lane	E	E	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19 Begin Decel Lane	C	C	C	-	-	-	-	-	-	-	-	-	C	B	F	C	C	F
20 MD 450 WB Off Ramp	D	D	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21 MD 450 Loop On Ramp	D	D	D	-	-	-	D	E	F	D	F	F	-	-	-	-	-	-
22 MD 450 Loop Off Ramp	E	E	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Segment	Basic Freeway			Weave			On Ramp Junction			On Ramp Roadway			Off Ramp Junction			Off Ramp Roadway		
	Cnt	Post	TOD	Cnt	Post	TOD	Cnt	Post	TOD	Cnt	Post	TOD	Cnt	Post	TOD	Cnt	Post	TOD
23 Begin Decel Lane	D	D	D	-	-	-	-	-	-	-	-	-	C	C	D	C	C	D
24 US 50 EB Off Ramp	D	D	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25 Begin Decel Lane	B	C	B	-	-	-	-	-	-	-	-	-	A	A	A	A	A	A
26 US 50 WB Off Ramp	C	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27 US 50 On Ramp	C	C	C	-	-	-	B	B	D	B	B	D	-	-	-	-	-	-
28 Drop #2 Aux Lane	D	D	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29 Drop #1 Aux Lane	D	E	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30 Begin Decel Lane	C	C	D	-	-	-	-	-	-	-	-	-	A	B	E	B	B	F
31 MD 202 WB Off Ramp	D	D	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32 Begin Decel Lane	C	C	C	-	-	-	-	-	-	-	-	-	B	B	B	C	C	C
33 MD 202 Loop Off Ramp	C	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
34 MD 202 On Ramp	B	B	C	-	-	-	A	A	C	B	A	C	-	-	-	-	-	-
35 Drop #2 Aux Lane	C	C	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
36 Drop #1 Aux Lane	D	D	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37 Begin Decel Lane	C	C	C	-	-	-	-	-	-	-	-	-	B	A	D	B	B	E
38 MD 214 WB Off Ramp	D	D	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39 MD 214 Loop On Ramp	C	C	C	F	F	F	B	B	B	B	B	B	B	B	B	C	B	B
40 MD 214 Loop Off Ramp	C	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41 MD 214 EB On Ramp	C	C	C	-	-	-	B	B	F	B	B	F	-	-	-	-	-	-
42 End Accel Lane	C	C	E	-	-	-	-	-	-	-	-	-	E	F	F	B	C	F
43 MD 4 NB Off Ramp	C	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
44 MD 4 Loop On Ramp	B	B	B	F	F	F	A	A	A	B	A	A	B	C	C	C	C	C
45 MD 4 Loop Off Ramp	C	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46 MD 4 SB On Ramp	B	B	C	-	-	-	B	A	F	B	B	F	-	-	-	-	-	-
47 Drop Accel Lane	C	C	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48 Begin Decel Lane	B	B	C	-	-	-	-	-	-	-	-	-	B	A	F	B	B	F
49 MD 337 Off Ramp	C	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50 MD 337 On Ramp	B	B	C	-	-	-	C	C	F	C	C	F	-	-	-	-	-	-

Segment		Basic Freeway			Weave			On Ramp						Off Ramp					
								Junction			Roadway			Junction			Roadway		
		Cnt	*Post*	*TOD*	*Cnt*	*Post*	*TOD*	*Cnt*	*Post*	*TOD*	*Cnt*	*Post*	*TOD*	*Cnt*	*Post*	*TOD*	*Cnt*	*Post*	*TOD*
51	Drop Accel Lane	C	D	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
52	Begin Decel Lane	B	B	C	-	-	-	-	-	-	-	-	-	A	A	F	B	A	F
53	MD NB Off Ramp	C	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
54	MD 5 Loop On Ramp	C	C	C	F	F	F	B	B	B	B	B	B	C	C	C	D	C	C
55	MD 5 Loop Off Ramp	C	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
56	MD 5 SB On Ramp	B	B	B	-	-	-	A	A	B	A	A	B	-	-	-	-	-	-
57	Drop Accel Lane	C	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
58	Begin Decel Lane	B	B	B	-	-	-	-	-	-	-	-	-	A	A	A	A	A	A
59	MD 414 NB Off Ramp	C	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60	MD 414 Loop On Ramp	B	B	B	E	E	E	A	A	A	A	A	A	B	B	B	B	B	B
61	MD 414 Loop Off Ramp	C	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
62	MD 414 SB On Ramp	B	B	B	-	-	-	B	A	C	B	B	C	-	-	-	-	-	-
63	end of study section	C	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

yield a 21.3 percent higher cost rate. For vehicle cost, the difference was not as great. For the emissions cost it was 6.2 percent higher than the observed cost, while the post-processed results were only 1.8 percent lower than observed cost.

For the environmental impacts, the fuel consumption was 7.7 percent higher for the TOD peak hour over the observed results. The post-processed results for fuel consumption were 2.1 percent lower than the observed results. For air pollution emissions the post-process results were about two percent lower than the observed results. The TOD peak hour results were about 12 percent higher for CO and HC, and about 23 percent higher for NOx. The TOD procedures over estimated the demand and resulted in higher impacts then would have actually materialized. The post-processed results were not exactly on the mark, but they better reflect the actual data impacts.

Table 4-4 Summary of Economic and Environmental Impacts

Scenario	User Cost Rate (USD/1000 VMT)	Vehicle Cost (USD)	Emissions Cost (USD)	Fuel Consumption (gallons)	CO Emissions (kg)	HC Emissions (kg)	NOx Emissions (kg)
Observed Data	$ 631.53	$ 59,394.70	$ 554.24	11,028	216.96	18.57	101.75
Post-Process Forecast	$ 633.17	$ 57,919.05	$ 543.99	10,791	211.84	18.15	102.16
TOD Forecast	$ 765.82	$ 61,140.86	$ 588.50	11,881	244.64	20.72	78.49

5.0 Conclusions

5.1 Summary of Findings

The purpose of this research project was to evaluate the techniques outlined in the *National Cooperative Highway Research Program Technical Report 255 Highway Traffic Data for Urbanized Area Project Planning and Design (NCHRP-255)*, published in 1982 by the Transportation Research Board. This evaluation was accomplished by using a regional travel demand forecast model calibrated and validated for the year 1990 and developing a highway forecast for the year 2000. The forecasted volumes along the Capital Beltway (I-495/I-95) portion located in the State of Maryland were compared to observed count data for that same year. A series of statistical measures were used to quantitatively evaluate the benefits of the techniques documented in NCHRP-255.

The primary research objectives were:

- To critically evaluate the ability of a regional travel demand forecast model to accurately forecast freeway corridor volumes by comparing link forecast volumes to the actual count data.
- To evaluate and determine the significance of post-processing techniques as outlined in NCHRP-255.

There were two levels of evaluation and analysis – average daily traffic (ADT) and peak hour. The ADT served as the primary level of analysis and the peak hour was supplementary. For the peak hour level of analysis a sublevel analysis was perform for the Capital Beltway's Inner Loop during the PM peak hour. This analysis focused on the same statistical measures as the primary analysis, as well as level of service (LOS), economic costs, and environmental impacts.

For the ADT level evaluations, the first step focused on the "raw" model results and the ability of different algorithms to better assign traffic. Since the development of this travel demand forecast model, the regional model has been improved by incorporating more recently developed state-of-practice elements in the modeling process. This has included the application of an equilibrium assignment algorithm. Other regional models have incorporated modifications to the impedance equations as part of their model improvement programs. Both of these improvements were evaluated as part of this research project. The most significant findings to come from this step in the evaluation were that:

- The equilibrium assignment more accurately forecasted the link volumes in the defined study corridor.
- Modifications to the calibrated impedance equation did not yield better results in the defined corridor.
- Even with the best assignment algorithm the percent root means square error was still greater than ten percent.

The second step for the ADT evaluation was to apply different techniques and methods to post-process the "raw" model output and compare it to the full refinement procedure outlined in NCHRP-255. The results from this step were also compared to the assignment algorithms evaluation. The most significant findings to come from this step in the evaluation were that:

- The procedures for link refinements outlined in NCHRP-255 produced the most accurate forecast for the study corridor. The percent root mean square error was less than six percent.
- Partial application of the NCHRP-255 method produced better results than the "raw" model output, but did not work as well as the full refinement procedure. This was especially true for links that were not over-saturated.
- Applying historical growth patterns and compounding the growth rate over a ten year period produced worse results than the "raw" assignment link outputs.

Since most project planning studies focus on measures of effectiveness related to peak hour operations versus average daily traffic, a process was employed to derive the peak hour volumes for the freeway corridor from the full refined average daily traffic link volumes. These results were compared with the observed peak hour counts. The peak hour projections were evaluated using statistical measures as well as operational and economic measures. The peak hour projections had less than a five percent root means square error for the links between interchanges. For turning movements and ramp volumes the percent root mean square error was approximately 15 percent. For the majority of basic freeway link segments, the operations analysis showed no difference with respect to the level of service between the forecast peak hour and the observed count. The same was true for the ramp merges and diverges as well as the weave areas.

The economic and environmental analysis showed very little difference between the peak hour forecast and the count data. The forecast user cost rate was within 0.3 percent of the observed user cost rate. For the other economic measures the forecast was approximately two percent different from the observed count. The same was true for the environmental emissions and fuel consumption.

Over the past decade travel model improvements have started to focus on the need for time-of-day assignments. For this research project a PM peak period assignment was performed post-mode choice. A set of factors taken from the most recent regional travel demand model for year 2000 were used to construct time-of-day trip tables by trip purpose. The assignment results from these trip tables were then factored to represent the PM peak hour. The time-of-day assignment did not yield better results than the full refined derive peak hour methodology. In general, the time-of-day procedures over-estimated the travel in the peak period. A factor of 0.34 was applied to calculate the PM peak hour volumes along the Capital Beltway. Even with the factor of 0.34 the percent root mean square error was around 23 percent. The time-of-day assignment represented a three hour peak period. Even if the demand for the peak period was distributed equally across the peak period it still would have over-simulated.

As with the full refinement derived peak hour volumes, an operational and economic analysis was performed and the results compared to the observed data. The time-of-day derived peak hour volumes resulted in many links having a lower level of service when compared to the observed count data. For the user cost rate, it was 21.3 percent greater than the observed data. The difference between the observed count data and the time-of-day forecast for the environmental emissions ranged from 11.6 percent to 22.9 percent. The time-of-day assignment did not result in a more accurate forecast for the study corridor.

From the peak hour evaluation and analysis the following conclusions can be made:

- For the Capital Beltway links time-of-day assignments did not yield better results than the post-processed forecast.
- Deriving peak hour projections from post-processed average daily traffic projections produced reasonable results for the Capital Beltway.
- An equilibrium algorithm performed much better for the time-of-day assignment than the base year incremental capacity restraint algorithm.

5.2 Lessons Learned

The most important lesson learned from this project is that although it was originally written in 1982, NCHRP-255 is still a very valuable resources for supplementing travel demand forecast model output. The "raw" model output is not reliable enough to be used directly for highway design, operational analysis, nor alternative or economic evaluations. The travel demand forecast model is a tool that is just part of the forecasting process. It is not a turn-key operation, and travel demand forecasts cannot be done without the application of engineering judgment.

An additional lesson learned is the importance of count data. The methods from NCHRP-255 and their application in any study relies on having good count data. Although the count data was supplied in the beginning of the project, it had to be reviewed multiple times and adjusted based on other sources, including permanent count stations, recent traffic counts from different sources for the same intersections, and field observations. Count data collection is often seen as a trivial task, when in fact it is a crucial step in the forecasting process.

The model processes used for this study projected average daily traffic. Many travel demand forecast models being applied today use some form of time-of-day procedure to assign peak period trips. Although this may be beneficial for air quality analysis, the benefit for developing vehicle forecasts may not be as pronounced. Average daily traffic is easier to post-process based on the simple fact that activities for the vast majority of people start and end in one day. Travelers' shifts in activities can be hard to measure with time-of-day applications. In a congested area such as Washington, D.C. discretionary trips will be shifted out of the peak period due to the high level of congestion. Capturing this shift with time-of-day models is complex. When focusing on a specific corridor, the application of peak to daily factors is easier to predict. In addition, it is easier to adjust these factors and determine the sensitivity or risk analysis associated with these factors on peak hour link volumes without having to deal with trip purposes and corresponding assignment issues.

The overall lessons learned and conclusion to be drawn from the research done for this project is that there is a need in the profession to develop tools that can better assist the practitioner in calculating reasonable travel forecasts for project planning needs. These tools do not have to rely on complex turn-key type computer programs, but rather should concentrate on developing the skill of the practitioner in the field. The practitioner needs tools that are easy to understand and apply. Complex computer programs and new models seem not to focus on the end product, but rather they concentrate on the complexity of algorithms and the available computer resources.

5.3 Recommend Further Research

Based on the results of this project and the current trends in the field of travel demand forecasting, there are three areas that given more resources and time, could have been investigated. These areas are:

- Corridor level micro-simulation and dynamic assignment
- Incorporating intersection delay calculations into the assignment models
- Improved network coding tools.

Corridor level micro-simulation and dynamic assignment would have been interesting to test. The idea would be to take the demand for a specific corridor and use a micro-simulation traffic model. An added benefit would be to see how a model with dynamic assignment would better reflect the corridor flows. Many times with twenty year forecasts, the peak hour volumes exceed the facility's capacity. Using micro-simulation models might help to determine how much traffic the facility could really accept. A dynamic assignment within the micro-simulation model would allow for route diversion to be better understood. In the future, it would seem that these will become valuable tools used in project planning studies. At this time, many departments of transportation do not see the benefit of such processes.

A lot of travel demand forecast modeling software being sold today try to incorporate intersection delay into the node characteristics. There is some question of worthiness to providing such details in an assignment process that is at a macro level, as well as the fact that there are other roadway characteristic not coded into the highway networks that also affect capacity and link travel time (e.g., parking, traffic calming, pedestrian crossing, etc.).

The final area of study not touched on in this project is the need for improvements in the way networks are coded and updated. Regional model networks can be rather large and cover wide geographical areas. Often times the least experienced engineer is given the task of network coding. The end result can be a network with many small errors that promulgate as the model process progresses. Many times a simple network coding issue can result in serious and hard to diagnose problems during model validation efforts.

Geographical information systems are becoming standard in network coding. More and more agencies and organizations are using them to apply turn-key coding procedures that update and code networks automatically. But, there is still a need to review of these networks visually and apply engineering judgment. Along with this, there is a corresponding need to develop guidelines and procedures for evaluating network coding. This research project did not deal with this issue, although it is a very important one.

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EDUCATION

B.S., Civil Engineering, University of Maryland College Park, 1996
B.A., Political Science, University of Florida, 1990

PREVIOUS POSITIONS

BMI, March 1999- present: Associate Engineer, project included major investment studies, traffic simulation studies, travel demand forecasting application and model development.

Wells and Associates LLP, September 1998 - February 1999: Senior Associate, projects included traffic impact studies, travel demand forecast modeling applications, and representing clients at public hearing for rezoning cases.

KHJE, Ltd., January 1998 - June 1998: Transportation Engineer, responsible for all travel demand model projects, and technical staff training.

ECDS/Uribitran Associates, November 1996 - December 1997: Transportation Engineer, responsible for travel demand model projects, traffic operational studies, and technical staff training.

COMSIS Corporation, February 1992 - October 1996: Associate, responsible for travel demand model studies, transit document publication, and survey analysis.

PUBLICATIONS

Goldfarb, Dan and Christopher Gay, *NCRHP-255 Alive & Well – Practical Applications of NCHRP-255 Procedures for Corridor Studies*, 9th TRB Conference on the Application of Transportation Planning Methods, April 2003.

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