TransForM – A New Regional Travel Demand Model Developed for Prince George's County

Project Final Report

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CHAPTERS

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Chapter 1 Introduction, Background, and Overview

This report documents the model components, model inputs, process and results of the new travel demand model that has been developed for the Prince George's County Planning Department of the Maryland-National Capital Park and Planning Commission (M-NCPPC). The model has been implemented in TransCAD 4.8 and embodies many enhancements to prior models and the MWCOG TPB TP+ Travel Forecasting Model.

The overall objective of this project has been to provide a forecasting tool that will be more suitable for modeling land use impacts and transportation improvements in Prince George's County. The new model adds considerable network and traffic analysis zone detail in Prince George's County, has calibration updated to the year 2000 using the most recent data available, employs some improved modeling procedures, and more closely matches validation data than previous models.

Apart from greater geographic detail and the use of a more recent base year, there were many other model development considerations. One included retaining a similar model structure to make it easier to accommodate future MWCOG updates. A second was the desire to make use of more user-friendly, Windows and GIS-based modeling software as embodied in TransCAD. A third consideration was to employ better algorithms for transit pathfinding, trip distribution, and traffic assignment and to achieve higher convergence and closer calibration of the model to observed data. Lastly, there was an attempt to consider TRB review criticisms of the MWCOG model and address them to the extent possible.

The new Prince George's County Transportation Forecasting Model (TransForM) is a regional model that has the same geographic modeling scope as the MWCOG regional model. The MWCOG model was developed in TP+ and encompasses a 6,800-square-mile study area. The MWCOG modeled area is currently comprised of 2,191 Traffic Analysis Zones or TAZs and encompasses 22 of the region's major jurisdictions spanning the District of Columbia, Northern Virginia, suburban Maryland and one county in West Virginia.

The other important precursor was a SYSTEM 2 model for Prince George's County that was implemented in 1992 and last updated in 1995. This model had greater geographic detail for Prince George's County than the MWCOG regional model.

The original concept for this project was to convert the regional model from TP+ to TransCAD and add further detail from the System II model and closer calibration in Prince George's County. In the first phase of the project, the original TP+ components were transferred to TransCAD. TransCAD was then run and successfully replicated the 1994 model results fairly closely. During this conversion process, a new interface was implemented and most of the TP+ and FORTRAN programs were converted to TransCAD scripts.

The second phase of the model development effort focused on examining and revising the data and model components used by each of the model steps. Geographically accurate road and transit networks were developed and substituted for the networks used in the MWCOG model. This was a major effort that was performed by Caliper without using project funds so it could be distributed to others. The road network was conflated and re-aligned so that it closely matches aerial photography for the region and replicates the actual shape of roadway links. Also, major roads were coded with two one-way links and interchanges and access road details were added. The key attributes of the network that affect model computations such as link functional classes, number of lanes and directionality were thoroughly revised and corrected as needed.

A new base year transit network was also developed that is more geographically accurate and is consistent with the new road network. GPS data from WMATA was utilized to obtain the correct route alignments for bus routes. The regional rail network was also created using GIS files.

The model is based on a 2,523-zone system of which 2,476 zones are internal and 47 are external. There are 885 zones in PGC instead of the 381 original zones in Prince George's County from the MWCOG model.

The model uses the latest demographics from MWCOG. Demographics for the more detailed PGC TAZs were further disaggregated using US Census 2000 data for the region.

The centroid connectors for the entire network were regenerated for the expanded zone system and more geographically accurate road network. These were reviewed in light of network loadings and comparisons with validation data.

A major effort was undertaken to collect and integrate traffic count data in the model network. Traffic counts from many sources were brought in and transferred to the highway network using special GIS tools. Electronic copies of traffic counts were obtained via M-NCPPC staff from the Maryland State Highway Administration, the District of Columbia Department of Transportation, the Virginia Department of Transportation, and the Prince George's County Department of Public Works and Transportation.

The model uses a comprehensive new transit route system that combines both the peak and the offpeak networks in one database, thereby eliminating the need to maintain several versions of the route systems and highway databases. The rail routes were also merged into the same system. Further, the route system is based on the same highway database that is used to run the travel demand models. As a result, improved representations of transit access, transfers, and egress were introduced.

Each component of the four-step model was revised and modified. Some model steps were redeveloped from scratch whereas others were modified to a lesser extent. A complete description of each of the model components is provided in subsequent chapters of this report. A major difference that is prevalent across all model steps is the elimination of various adjustments factors used by the COG model.

Significantly more computation is performed, resulting in more highly converged model steps for trip distribution and trip assignment. In addition, the model employs a convergent feedback loop procedure.

The model makes extensive use of a Year 2000 wave of a panel survey conducted by the MWCOG. Despite the relatively small sample size, we found the data to be of high quality and sufficient to build and calibrate the trip generation and trip distribution models that were developed.

The third phase of the project involved calibration and refinement of the model based upon comparisons with external data that was used for validation. The new model matches validation targets much more closely than the MWCOG model throughout the region and matches ground counts especially well in Prince George's County and Montgomery County.

A user-friendly interface was developed to make it easy to perform model runs. The interface provides a push-button means of selecting scenarios and launching model runs. It also makes it extremely easy to produce informative graphics illustrating model results.

The remainder of this report provides a detailed description of the data preparation, model estimation, model application, and validation. A companion User's Guide explains how to use the model software.

Chapter 2 TAZ Geography and Highway and Transit Network Development

This chapter describes the development of the key databases used in the PGC TransForM model. These include the TAZ database and the highway and transit networks.

The TAZ database was developed by the Maryland-Capital Planning Park and Planning Commission and is an expanded version of the MWCOG TAZ database with a much larger number of zones in Prince George's County. While for consistency, the TransForM model uses the latest round of demographics from the MWCOG, these data needed to be disaggregated for the smaller zones in PGC.

This chapter also describes the development of the highway and transit networks that are used in the PGC TransForM model. New networks using a variety of GIS data and other sources were developed. The networks have much greater geographic accuracy than those used in prior modeling efforts and considerable effort was also expended to correct attribute information as well. This work was done by Caliper outside of the contracted effort so that the road network could be made available to other TransCAD users.

A key aspect of the road network development effort was the addition of considerable additional detail in Prince George's County. The resulting network has all of the links that were in the earlier System II network for Prince George's County and all of the links elsewhere in the region that are in the MWCOG model. In addition, to improving the road geography, divided highways are explicitly represented and ramps were corrected and added as appropriate.

The new regional network was aligned over aerial photography throughout the entire region. This results in a very accurate network for planning and also served as the basis for the development of a new transit network. Bus routes in the transit network sit directly on the roads in the highway network. When necessary, links were added to the road network to make this possible. Rail links were also added to represent WMATA rail and commuter rail services. Further, a single comprehensive transit network consisting of both the peak and the off-peak routes was developed. The following sections describe the methods and procedures used to develop these databases.

TAZ Database Preparation

The model uses a TAZ database consisting of 2,523 zones out of which 47 are external stations. This database was developed from the MWCOG model in which the zones in Prince George's County were expanded. The number of zones in Prince George's county was increased from 381 in the MWCOG model to 885 in the new database. The updated zone geography for Prince George's County was provided by the Maryland-Capital Park and Planning Commission. The zone geography in the new model is the same as the previous system for all zones outside Prince Georges' County.

Figure 2.1 shows the TAZ geography for the region.

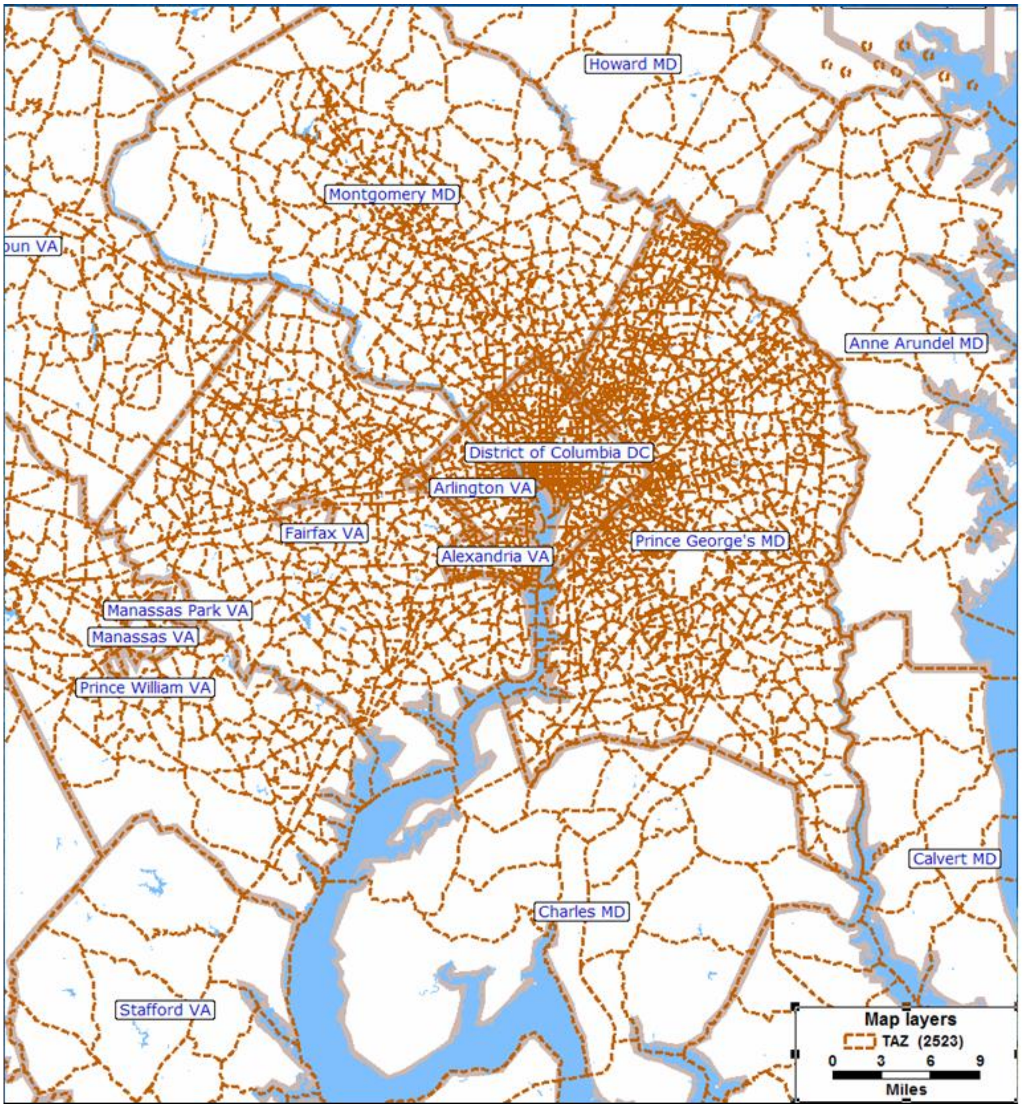

Figure 2.1 TAZ Geography

TAZ Demographics

The TAZ demographics consist of households, population and employment estimates by industry. These were generated from the 2000 COG 7.0 Cooperative Forecasts. However, since the COG 2000 Forecasts were based on the MWCOG zonal system, the demographics had to be disaggregated for zones in Prince George's County. In order to disaggregate the demographics, we first generated the demographics for the newer zones in Prince George's County using Census 2000 data. For a large zone in the MWCOG model, the COG 7.0 forecasts were disaggregated to the newer zones using the ratios of these Census 2000 demographics estimates.

Highway Network Preparation

The model uses a conflated and realigned highway network that incorporates all of the links that were present in the previous model. The work was done in close conjunction with the Maryland Park and Planning Commissions (MNCPPC). There were several tasks performed in highway network preparation.

First, aerial photography and GIS datasets were assembled from various sources. Next, the SYSTEM II network from Prince Georges' County and the MWCOG network were imported into TransCAD. The imported networks were merged by a process that deleted the PGC links from the MWCOG network and replaced them with those from SYSTEM II. The resulting network was then virtually completely redone as it was then conflated and realigned to sit directly on top of the aerial imagery.

Conflation is a process in which links in the network line layer are replaced by links that have more accurate geography. Typically, this means they have many more "shape" and also more accurately place shape points. However, it also involves correcting the beginning and ending locations of the nodes for links. Links may also be realigned or reshaped directly on top of high resolution aerial photography. This may entail a similar process of adding or correcting the location of beginning and ending nodes as well as shape points. Conflation and realignment can be used together to achieve the best results. The conflation and realignment effort resulted in network links that closely match the correct geographic shape of the roads included in the network. During this process, new links were also added such as freeway ramps that did not previously exist in the network. Particular attention was paid to the freeway and freeway/ramp interchanges, "dualizing" link segments and identifying HOV facilities. During the network development procedure, links with incorrect attributes were also identified and the attributes were corrected. PGC staff assisted Caliper in thoroughly reviewing and correcting key attributes in the network such as the link functional class, the link direction flag, number of lanes and link limit codes used to identify HOV facilities and used to designate link prohibitions.

A visual comparison of the MWCOG and new networks illustrates the types of changes that were made and the resultant improvements. Figure 2.2 shows a close-up of the new network at the north-east corner of the beltway and Figure 2.3 shows the same close-up in the MWCOG network. As can be visually seen, the new network is re-aligned and represents actual road geometry. Further, the new network has more local roads than the MWCOG network.

A close-up of the I-295 and I-495 interchange (in both the networks) at the Greenbelt region is shown in Figure 2.4.

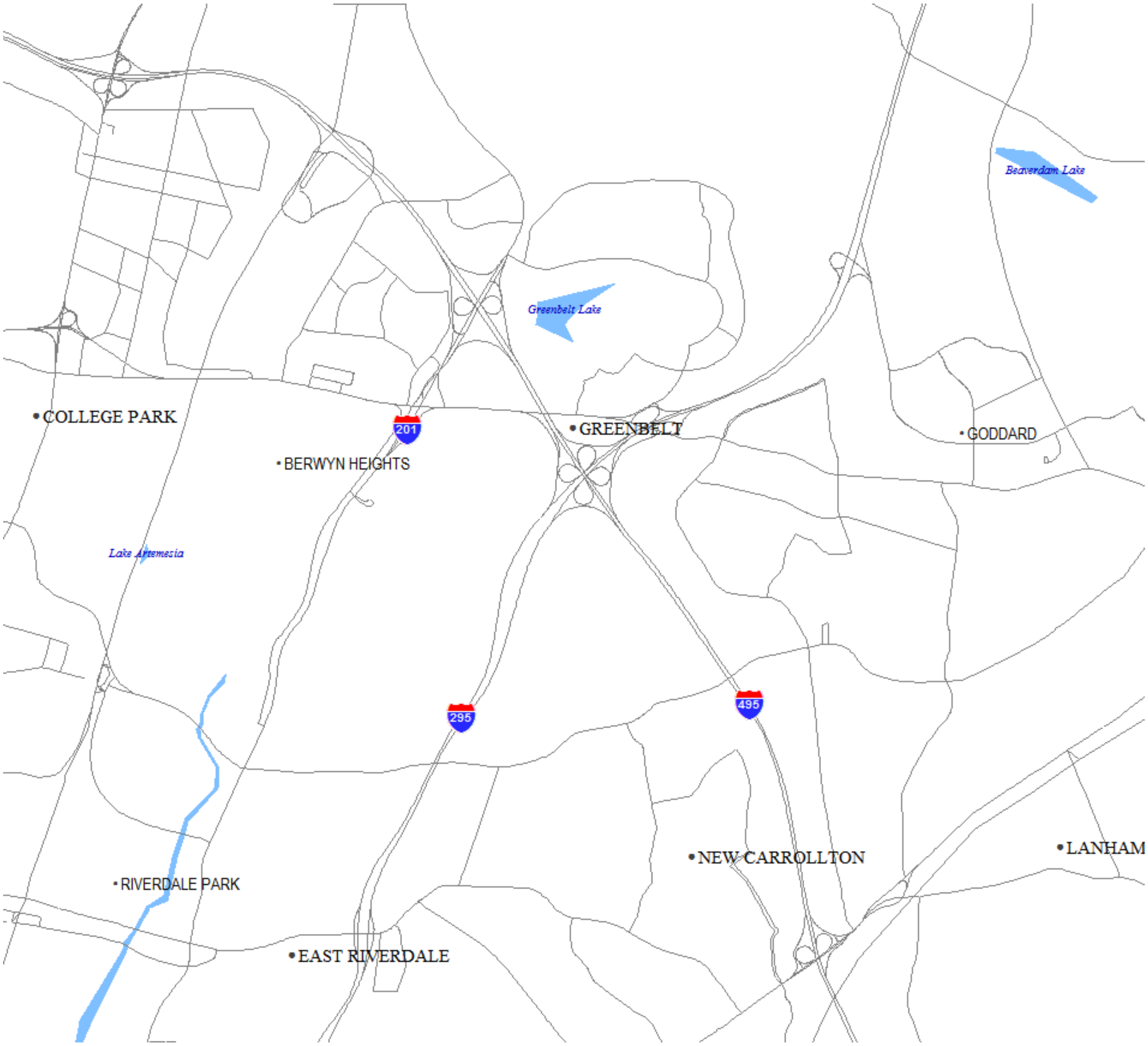

Figure 2.2 A close-up view of the TransForM Model Network

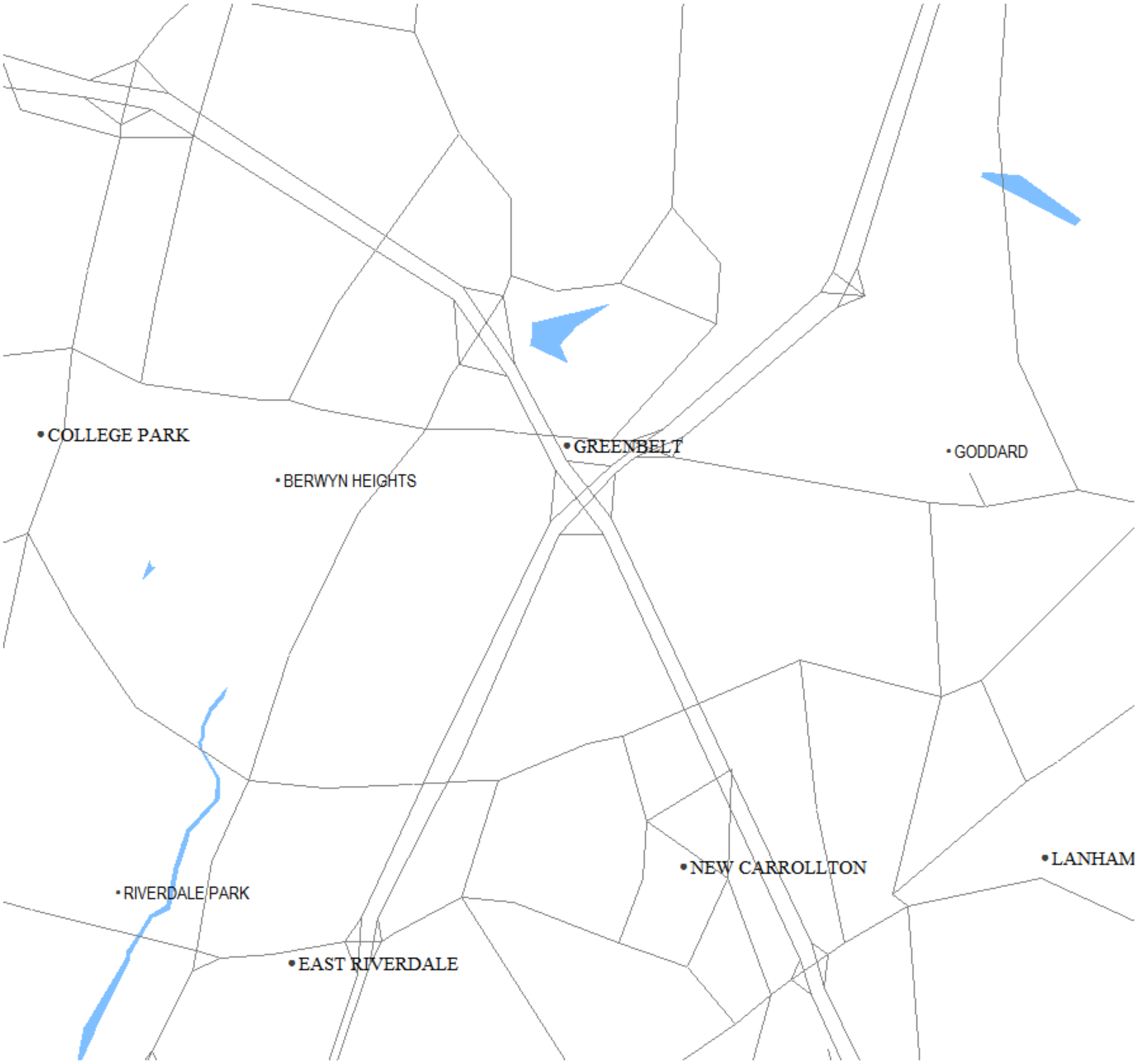

Figure 2.3 A close-up view of the MWCOG Network at the same location

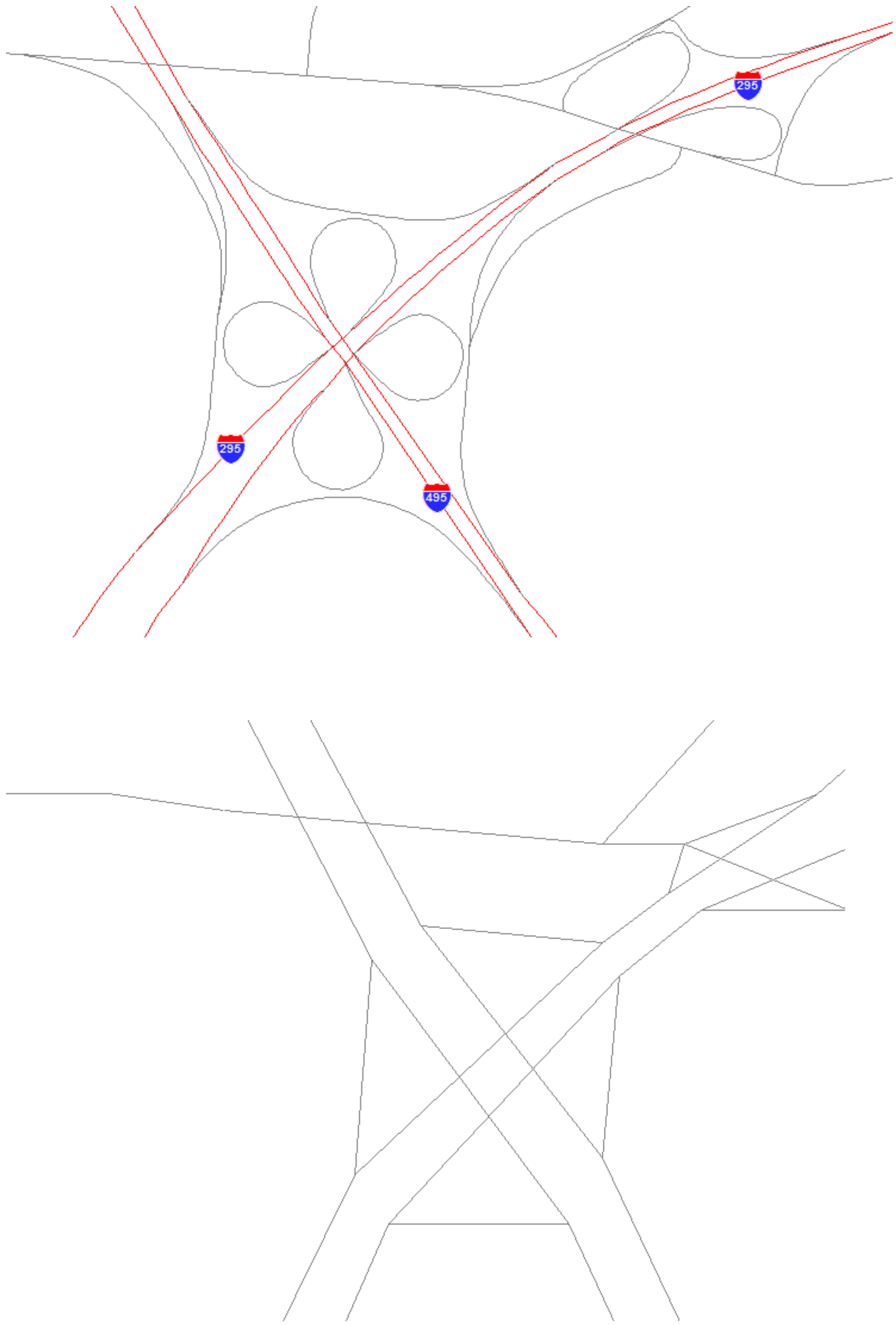

Figure 2.4 Comparison of the two networks at the I-495 and I-295 interchange

The benefits are not merely visual however. More accurate measures of network distances and travel times result.

Centroid Connectors

Before the network could be used, it was necessary to generate new centroid connectors. These were generated using an automated tool that is part of TransCAD. The tool makes it possible to specify rules for generating centroid connectors.

During the first pass with the tool, up to six connectors were permitted for each internal centroid. In this pass, the connectors were prevented from connecting to freeways, expressways, major arterials and ramps and were constrained to lie within the zonal boundaries. The rationale for having multiple connectors is to properly represent travel in all directions between zones.

The connectors generated were reviewed and in some cases additional connectors were added if there were two few that met the criteria specified. Some connectors were also removed if they were redundant. Aerial photography was used in judging the need for additional connectors. Preliminary traffic assignments were also used to judge if the network was being loaded properly.

The connectors for the external zones were initially the same as the ones used in the MWCOG TP+ model. However, in certain areas such as the near Baltimore, the external connectors were modified.

Integration of Traffic Counts

Traffic counts were obtained from many sources and were transferred to the network.

The traffic counts utilized are those listed below:

- Beltway counts for the DC region
- Virginia Traffic Counts
- Maryland Traffic Counts
- Counts from MNCPPC
- Counts from the ICC study

The raw traffic count information from each of these sources was first converted to a point database. All the counts that pertained to the spring months of 2000 and 2001 were employed. These raw counts were aggregated based on the time period to generate AM. PM and off-peak counts. The counts were then transferred to appropriate links in the network using specialized procedures written in TransCAD for this purpose. Finally, the counts were compared against capacities and any links where the counts were far greater than the capacities were identified and checked.

Transit Network Preparation

The TransForM model employs a comprehensive route system that incorporates both peak and off-peak transit routes. The appropriate subset is used in building the peak and off-peak transit networks.

There were five major datasets used in the development of the transit networks. The first of these was the highway network described above. The second was a geographically accurate GPS point tracking database that, for every bus route for every minute, tracks the route location. The database was provided by the Washington Metropolitan Area Transit Authority (WMATA). For rail routes, we used Caliper's 1:200,000 scale railroad network. We also utilized the TIGER/LINE Street Network and the MWCOG TP+ peak and offpeak transit networks.

The procedure to develop the transit network had five major steps which are described below.

Step 1 – Creating Bus Transit Routes from GPS Database for WMATA Area

In the first step, an automated procedure was written to convert the ordered GPS route points from the WMATA tracking database into a TransCAD route system. The route system was based on the TransForM Highway Planning Network. During the conversion, we found that many of the GPS points went over streets that were not in the TransForM network. A procedure was written to automatically identify these streets, using the TIGER/LINE street network, and then add them to the PGC highway network. The route creation procedure was run again and the result was a geographically accurate transit network for the WMATA area. The routes and stops were then checked one-by-one manually to ensure the fidelity and accuracy of the conversion process. Streets were edited and routes were manually realigned as necessary.

Step 2 – Creating Bus Transit Routes Outside of the WMATA Area from TP+ Transit Networks

Unfortunately, the GPS data points did not encompass the entire study area of the PGC model; thus routes had to be generated outside of the WMATA area using an alternate methodology. The transit routes defined in the MWCOG TP+ model did encompass the entire study area so a procedure was written to convert these TP+ routes into TransCAD route system format. For bus routes wholly inside of the WMATA area, the GPS points were used since the geographic accuracy of this dataset was vastly superior to that of the TP+ routes. The TP+ routes were only used to define transit routes either wholly outside of the WMATA area or crossing into the WMATA area. In the original TP+ dataset, peak and offpeak routes were coded as separate datasets. During the TransCAD conversion, peak and offpeak routes were combined into a single dataset. After the routes were converted into TransCAD format, each route was checked one-by-one manually to ensure accuracy. Sometimes bad route paths were the result of highway network errors which lead to improvements in the underlying planning network. Due to the crude geography of the original TP+ transit networks, much more extensive route checking and manual editing was necessary.

Step 3 – Assigning Bus Transit Route Attributes

In this step, we assigned transit route model attributes such as peak and offpeak headways, and peak and offpeak running times. For the TP+ transit routes outside of the WMATA area that were converted, the original TP+ model route attributes were used. For the GPS-converted routes inside the WMATA area, no route attributes existed in the GPS dataset. In order to assign attribute data, each GPS route was manually matched with a corresponding TP+ route based on the similarity of their route names and similarity of route alignment. Then, after matching, the appropriate TP+ route attributes were transferred.

Step 4 – Creating Fixed Rail (Subway and Commuter Rail) Routes

Since fixed rail routes do not generally go over the street network, a separate fixed rail line database had to be developed. The geography for this line database came from Caliper's 1:200,000 scale nationwide rail network. First, the regional study area portion of this rail network was extracted. Second, unnecessary links such as siding links and track links that were not used by fixed rail roads were taken out. Third, using the TP+ coded fixed rail routes as a guide, fixed rail routes and stops were manually coded in on top of the fixed rail network, and the TP+ route attributes were transferred over. Fourth, the fixed rail routes and fixed rail links were merged into the bus routes and highway planning network. Lastly, connector links were created to provide connectivity between the highway network and the rail network.

Step 5 – Creation of Transit Networks from Transit Route System

In this step, a TransCAD transit network were created from the converted route system so that the PGC model could create transit skim matrices to feed into the mode split model, and so that the PGC model can perform a transit assignment to estimate transit ridership. First, we adjusted the In-Vehicle Travel Times (IVTT) for the bus routes to match the run times from WMATA. Second, the walk access links were identified in the highway network and filled with a walking time based on speeds of 3 miles per hour. Drive access links were then identified and peak and off peak drive times were computed using the model congested highway times. It should be noted that the walk and drive connectors in the TP+ networks are not used, since the transit networks in the TransForM model use the local streets as access links. For skimming methodology, we used TransCAD's Pathfinder method since it has the highest flexibility in terms of network settings and consistently produces the most reasonable paths compared to alternate methods such as those in TP+ or TRANPLAN.

Figure 2.5 illustrates some of the transit routes

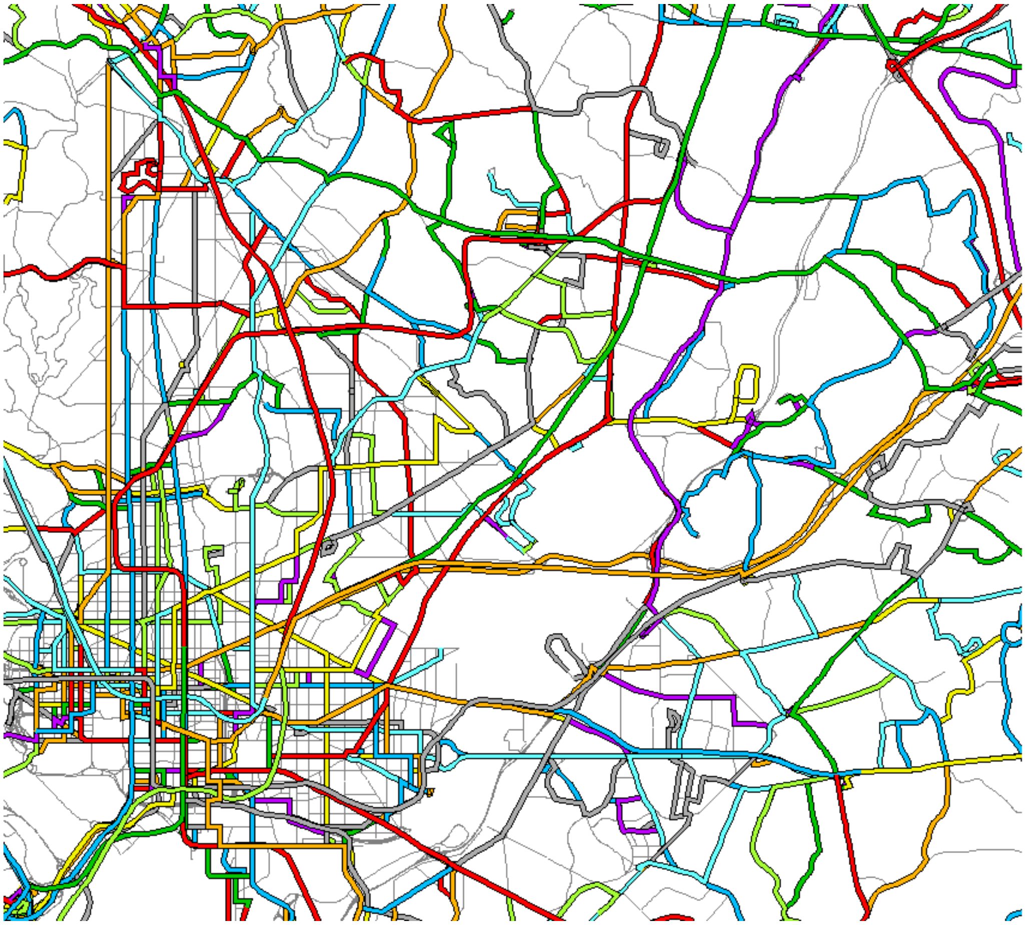

Figure 2.5 Sample Routes in the DC and Prince George's County Region

Chapter 3 Trip Generation

This Chapter describes the development of the trip generation models that were implemented. Because of the goal of creating a model with a Year 2000 base, the trip generation model was developed utilizing data collected in the COG Panel Survey. We began with an approach that was similar to the MWCOG Version #2.1D trip generation model but ultimately modified it for trip production modeling while retaining the trip attraction models. For most purposes, trips are balanced to productions as the last part of the trip generation model. This chapter provides background information on the MWCOG trip generation model, discusses the reasons for developing a new trip production model, and describes the PGC TransForM trip generation model development and application processes.

The MWCOG Trip Generation Model

The trip purposes used in the MWCOG model are:

- Home Based Work Trips (HBW)
- Home Based Shop Trips (HBS)
- Home Based Other Trips (HBO)
- Non Home Based Trips (NHB)
- Medium Truck Trips (single unit, 2 Axles, 6 or more tires)
- Heavy Truck Trips (all combination vehicles)
- Internal External Trips (IX)
- External Internal Trips (XI)

The trip production in the MWCOG model is performed based on the three dimensions of Income (with 4 categories approximating income quarterlies), Household Size (with 1, 2, 3 and 4 and over persons per household) and the number of vehicles in the household (with 0, 1, 2 and 3+ vehicles). The trip rates were determined from the COG/TPB 1994 Household Travel Survey and applied to the entire region. However, these trips were first adjusted by a global factor to account for underreporting of trips in the survey data and were then subsequently adjusted at the jurisdiction level using jurisdiction factors that varied by trip purpose.

The trip attraction models were regression equations derived from the 1994 survey and primarily used employment data. The computed attractions were then multiplied by global factors by purpose to account for underreporting of trips. Subsequently, the attractions were multiplied by factors that varied by district.
The truck trips were obtained using regression equations derived from the 1996 Truck Internal and External Survey.

For the HBW trip purpose, the non-motorized trip productions were subtracted out using walking percentages based on area types. The non motorized attractions were determined using a regression equation and subtracted out.

The productions obtained by the cross-classification also included Internal External (IX) and External Internal (XI) trips. These were subtracted from the productions. The share of Internal External (IX) productions were computed using a model as below:
IXP = 0.079 * Exp(-0.088 * DNE), where IXP denotes the percentage of IX productions for the zone and DNE denotes the distance to the nearest zone.

Further details of the MWCOG trip generation process are provided in the COG/TPB Travel Forecasting Model, Version 2.1D Draft #50 Calibration report.

Trip Generation Analysis

The basic approach taken was to attempt to use the Year 2000 Wave 3 of the COG 1998-2002 Washington Region Longitudinal Household Travel Surveys as the source for the trip generation models. The panel survey had a sample size of approximately 2400 households. Despite the rather small sample size, we felt that the more recent data might provide a superior model and that this might avoid the use of a large number of correction factors.

The 2000 Panel survey data were imported into TransCAD and were processed to yield a file of the number of trips by trip purpose for each survey respondent. To do this, the trips were first classified into the trip purpose categories. Then the number of trips in each category was tabulated. Lastly, the household and individual characteristics were appended to the person level trip file. This resulted in an aggregated file that contained one record for every person and contained the number of trips (of each trip purpose) made by the person in addition to the characteristics of the person and the household. These data were used to determine trip generation determinants and rates.

Statistical analysis of trip rates tabulated from the survey was the primary basis for developing the market segmentation that was used. A wide variety of different explanatory factors were investigated. Early on in the analysis, we decided to model person trip rates rather than household trip rates. This has several advantages an important one being that it increases the sample size considerably. It also appears to increase the variation in travel behavior to be explained. In other words, aggregating to the household level lessens the variation in trip rates. Lastly, on theoretical grounds it provides a richer theory for how households share certain trip making responsibilities. For example, in households with two adults and only one worker, the non-worker tends to make a greater number of shopping trips.

Another element of the trip generation analysis was an attempt to distinguish trip rates by tripmakers' geographic location within the region. This was done by tabulating separate trip generation rates for the District of Columbia and each jurisdiction covered in the survey in Maryland and Virginia. The jurisdictions in Maryland were the counties of Prince Georges, Montgomery, Calvert, Charles, and Carroll and Frederick Counties combined. The jurisdictions in Virginia were the independent cities of Arlington, Alexandria, the combination of Falls Church County, Fairfax County and Fairfax City, Loudon County, Manassas and Prince William Counties, and Spotsylvania and Stafford

Counties. For other areas in the model for which trip rates could not be determined from the survey either due to unavailable records or sample size issues, we used the trip rates from adjacent areas.

The statistical tools utilized were multiple regression and binary logit analysis. Preliminary regressions established that there was significant variation in trip rates by geography and that different market segment categories might work better than using the same exact dimensions used in the MWCOG model. Because for many people, only zero or one trip were reported for a particular trip purpose, we switched to logit analysis to identify the key classifications that we would use.

In order to determine the variables that affect the trip making patterns for the HBW, HBS, HBO and NHB trip purpose, binary logit models were estimated for each trip purpose. The binary logit model was used to determine the factors that were associated with a person making a trip. Thus, records in the survey database were flagged to identify whether the person made a trip of for each particular trip purpose. The binary field that represents whether a person made a trip (of a particular purpose) was used as the dependent choice variable for the binary logit estimation procedure.

Based on the household and person characteristics, several variables were generated (such as a dummy variable representing whether the household in which the person has access to a car or not, whether the person is a worker or not etc). For each trip purpose, several binary logit models were estimated for each county as well as for the entire region. A broader set of key variables were examined during the process including household size, auto availability, worker status, household income, number of children in the household, the age and the sex of the person. Some of these variables such as the last three were not significant when other factors were taken into account. After several tests, the best model was determined for each trip purpose and the trip production classification was identified. Based upon the analysis, we picked the dimensions of worker status, the number of persons 16 and over in the household, and vehicle ownership. These dimensions worked well across trip purposes and were used to tabulate the survey responses for the geographical segmentation described above. Due to the limited sample, we restricted the number of variables and classification levels to a modest number. It should be noted that with a larger sample, a more refined set of models could be developed. Also, more elaborate models could be constructed including models of tour generation.

An example of the analysis performed follows. Shown below are the estimation results for the best model for the probability of a person making a home-based shopping (HBS) trip purpose.

Parameter	Estimate	Std. Error	T Test
CONSTANT	-1.853497	0.089261	-20.764883
HHSize1GE16	0.496484	0.104321	4.759212
HHSize2GE16	0.244135	0.076157	3.205703
AUTOAVAIL	1.053245	0.091283	11.538193
WORKER	-0.612797	0.075291	-8.139072

Maximum likelihood reached after 10 iterations.

Source	Df	SS	Mean SS	F Ratio
Model	4	432.50043	108.12511	633.97608
Error	5428	925.74957	0.17055	
Total	5432	1358.25000		

R Squared = 0.318425, Adjusted R Squared = 0.317922
LL(0) = -3765.87, LL(c) = -2925.54
LL(Bhat) = -2835.36

-2[LL(0) - LL(Bhat)] = 1861.02
-2[LL(c) - LL(Bhat)] = 180.374
Rho Squared = 0.247091, Adjusted Rho Squared = 0.245763
Root Mean Square Error = 0.412978

The above model results illustrate that for the HBS trip purpose, the probability of making a trip depends significantly upon 3 variables, the household size (whether the household has 1 person over the age of 16 , the auto availability of the household and whether the person is a worker or not. Note that workers are less likely to make shopping trips than non-workers. In particular, the sign of the parameters is consistent with expectations and the t test results indicate that these variables are significant.

It was found that the above sparse set of variables were significant for the other trip purposes as well. The estimation was also performed on subsets of the survey data by county of residence for each survey respondent. In this analysis, it was found that while the same variables were significant, the coefficients of the estimates varied significantly by location. This was also later seen from the computation of the trip rates for each county based on the above classification.

TransForM Trip Production Rates

The aggregated trip survey file was used to determine trip rates by county of residence Region wide trip rates based on the county of residence were generated from the survey for the above classification. If the trip rates of two or more counties were very similar, they were grouped into one classification. Whenever accurate estimates of trip rates for a particular county and classification could not be generated due to sample size restrictions, the region average or an alternative county's rates were used.

For the HBW trip purpose, any person who is not a worker is deemed to make no HBW trips. The trip rates are listed for the following jurisdictions.

- District of Columbia
- Calvert County, Maryland
- Charles County, Maryland
- Carroll and Frederick Counties, Maryland
- Montgomery County, Maryland
- Prince Georges County, Maryland
- Arlington, Virginia
- Alexandria, Virginia
- Falls Church County, Fairfax County and Fairfax City, Virginia
- Loudoun County, Virginia
- Manassas and Prince William Counties, Virginia
- Spotsylvania and Stafford Counties, Virginia

The following table highlights the trip production rates for each of the 4 basic purposes:

County	Auto Avail	Worker	Persons 16+	HBWRate	HBSRate	HBORate	NHBRate
DC	0	0	1	0.00	0.63	0.91	0.42
DC	0	0	2	0.00	0.30	0.70	0.23
DC	0	0	3	0.00	0.30	0.87	0.40
DC	0	1	1	1.28	0.29	0.31	0.87
DC	0	1	2	1.24	0.26	0.47	0.60
DC	0	1	3	1.35	0.22	0.48	0.37
DC	1	0	1	0.00	1.13	1.96	0.45
DC	1	0	2	0.00	0.60	1.64	0.51
DC	1	0	3	0.00	0.34	1.29	0.54
DC	1	1	1	1.35	0.39	0.93	1.05
DC	1	1	2	1.22	0.28	1.11	1.04
DC	1	1	3	1.14	0.47	1.25	1.04
CALVERT_MD	0	0	1	0.00	0.18	1.06	1.02
CALVERT_MD	0	0	2	0.00	0.18	1.06	1.02
CALVERT_MD	0	0	3	0.00	0.18	1.06	1.02
CALVERT_MD	0	1	1	1.19	0.18	1.06	1.02
CALVERT_MD	0	1	2	1.19	0.18	1.06	1.02
CALVERT_MD	0	1	3	1.19	0.18	1.06	1.02
CALVERT_MD	1	0	1	0.00	0.18	1.06	1.02
CALVERT_MD	1	0	2	0.00	0.26	1.06	1.02
CALVERT_MD	1	0	3	0.00	0.18	1.06	1.02
CALVERT_MD	1	1	1	1.19	0.18	1.06	1.02
CALVERT_MD	1	1	2	1.15	0.10	1.42	1.38
CALVERT_MD	1	1	3	1.43	0.18	1.06	0.36

CHARLES_MD	0	0	1	0.00	0.24	1.11	0.99
CHARLES_MD	0	0	2	0.00	0.24	1.11	0.99
CHARLES_MD	0	0	3	0.00	0.24	1.11	0.99
CHARLES_MD	0	1	1	1.14	0.24	1.11	0.99
CHARLES_MD	0	1	2	1.14	0.24	1.11	0.99
CHARLES_MD	0	1	3	1.14	0.24	1.11	0.99
CHARLES_MD	1	0	1	0.00	0.24	1.11	0.99
CHARLES_MD	1	0	2	0.00	0.60	1.11	0.99
CHARLES_MD	1	0	3	0.00	0.37	1.11	0.99
CHARLES_MD	1	1	1	1.00	0.24	1.11	0.99
CHARLES_MD	1	1	2	1.07	0.20	1.09	1.09
CHARLES_MD	1	1	3	1.22	0.22	1.29	1.00
CARR_FRED_MD	0	0	1	0.00	0.35	0.94	0.99
CARR_FRED_MD	0	0	2	0.00	0.35	0.94	0.99
CARR_FRED_MD	0	0	3	0.00	0.35	0.94	0.99
CARR_FRED_MD	0	1	1	1.23	0.35	0.94	0.99
CARR_FRED_MD	0	1	2	1.23	0.35	0.94	0.99
CARR_FRED_MD	0	1	3	1.23	0.35	0.94	0.99
CARR_FRED_MD	1	0	1	0.00	0.35	0.94	0.99
CARR_FRED_MD	1	0	2	0.00	0.90	1.64	0.90
CARR_FRED_MD	1	0	3	0.00	0.44	1.17	0.86
CARR_FRED_MD	1	1	1	1.23	0.35	0.94	0.99
CARR_FRED_MD	1	1	2	1.34	0.42	0.78	0.99
CARR_FRED_MD	1	1	3	1.10	0.25	1.14	0.85
MONTG_MD	0	0	1	0.00	0.41	1.14	0.85
MONTG_MD	0	0	2	0.00	0.41	1.14	0.86
MONTG_MD	0	0	3	0.00	0.41	1.09	0.86
MONTG_MD	0	1	1	1.25	0.41	1.14	0.85
MONTG_MD	0	1	2	1.25	0.41	1.14	0.85
MONTG_MD	0	1	3	1.25	0.41	1.14	0.86
MONTG_MD	1	0	1	0.00	0.41	1.83	0.86
MONTG_MD	1	0	2	0.00	1.03	1.90	0.68
MONTG_MD	1	0	3	0.00	0.68	1.19	0.57
MONTG_MD	1	1	1	1.31	0.59	1.06	1.06
MONTG_MD	1	1	2	1.22	0.44	1.22	0.93
MONTG_MD	1	1	3	1.31	0.32	1.10	0.82
PRINCEG_MD	0	0	1	0.00	0.33	0.88	0.89
PRINCEG_MD	0	0	2	0.00	0.42	0.67	0.21
PRINCEG_MD	0	0	3	0.00	0.21	1.03	0.27
PRINCEG_MD	0	1	1	1.24	0.33	0.88	0.89
PRINCEG_MD	0	1	2	1.24	0.33	0.88	0.89
PRINCEG_MD	0	1	3	1.54	0.15	0.54	0.31
PRINCEG_MD	1	0	1	0.00	0.74	1.97	0.94
PRINCEG_MD	1	0	2	0.00	0.73	1.68	0.93
PRINCEG_MD	1	0	3	0.00	0.47	1.40	0.30
PRINCEG_MD	1	1	1	1.26	0.39	0.86	1.27
PRINCEG_MD	1	1	2	1.13	0.36	1.10	1.08
PRINCEG_MD	1	1	3	1.31	0.30	0.74	0.76
ARL_VA	0	0	1	0.00	0.36	0.97	0.87
ARL_VA	0	0	2	0.00	0.36	0.97	0.87

ARL_VA	0	0	3	0.00	0.36	0.97	0.87
ARL_VA	0	1	1	1.22	0.36	0.97	0.87
ARL_VA	0	1	2	1.22	0.36	0.97	0.87
ARL_VA	0	1	3	1.22	0.36	0.97	0.87
ARL_VA	1	0	1	0.00	1.29	1.82	0.87
ARL_VA	1	0	2	0.00	0.69	2.31	0.67
ARL_VA	1	0	3	0.00	0.36	0.97	0.87
ARL_VA	1	1	1	1.15	0.46	1.05	1.18
ARL_VA	1	1	2	1.14	0.37	0.90	0.92
ARL_VA	1	1	3	1.44	0.28	1.30	0.72
ALEX_VA	0	0	1	0.00	0.36	1.04	0.81
ALEX_VA	0	0	2	0.00	0.36	1.04	0.81
ALEX_VA	0	0	3	0.00	0.36	1.04	0.81
ALEX_VA	0	1	1	1.24	0.36	1.04	0.81
ALEX_VA	0	1	2	1.24	0.36	1.04	0.81
ALEX_VA	0	1	3	1.24	0.36	1.04	0.81
ALEX_VA	1	0	1	0.00	0.57	1.67	0.81
ALEX_VA	1	0	2	0.00	0.57	1.62	0.67
ALEX_VA	1	0	3	0.00	0.36	1.04	0.81
ALEX_VA	1	1	1	1.13	0.37	0.97	1.08
ALEX_VA	1	1	2	1.25	0.35	1.17	0.82
ALEX_VA	1	1	3	1.43	0.48	0.88	0.63
FALLS_FAIR_VA	0	0	1	0.00	0.34	1.00	0.93
FALLS_FAIR_VA	0	0	2	0.00	0.34	1.00	0.93
FALLS_FAIR_VA	0	0	3	0.00	0.34	1.00	0.93
FALLS_FAIR_VA	0	1	1	1.21	0.34	1.00	0.93
FALLS_FAIR_VA	0	1	2	1.21	0.34	1.00	0.93
FALLS_FAIR_VA	0	1	3	1.21	0.34	1.00	0.93
FALLS_FAIR_VA	1	0	1	0.00	1.08	1.84	0.87
FALLS_FAIR_VA	1	0	2	0.00	0.80	1.99	0.61
FALLS_FAIR_VA	1	0	3	0.00	0.74	2.09	0.66
FALLS_FAIR_VA	1	1	1	1.27	0.22	1.20	1.10
FALLS_FAIR_VA	1	1	2	1.18	0.32	0.89	0.82
FALLS_FAIR_VA	1	1	3	1.22	0.40	1.19	1.26
LOUDOUN_VA	0	0	1	0.00	0.34	1.05	1.08
LOUDOUN_VA	0	0	2	0.00	0.34	1.05	1.08
LOUDOUN_VA	0	0	3	0.00	0.34	1.05	1.08
LOUDOUN_VA	0	1	1	1.12	0.34	1.05	1.08
LOUDOUN_VA	0	1	2	1.12	0.34	1.05	1.08
LOUDOUN_VA	0	1	3	1.12	0.34	1.05	1.08
LOUDOUN_VA	1	0	1	0.00	0.34	1.05	1.08
LOUDOUN_VA	1	0	2	0.00	0.57	2.06	0.57
LOUDOUN_VA	1	0	3	0.00	0.26	1.32	0.42
LOUDOUN_VA	1	1	1	1.11	0.23	0.45	1.08
LOUDOUN_VA	1	1	2	1.11	0.24	1.05	1.21
LOUDOUN_VA	1	1	3	1.06	0.58	1.36	0.91
MANAS_PRINCEW _VA	0	0	1	0.00	0.31	1.01	1.01
MANAS_PRINCEW _VA	0	0	2	0.00	0.31	1.01	1.01

MANAS_PRINCEW_VA	0	0	3	0.00	0.31	1.01	1.01
MANAS_PRINCEW_VA	0	1	1	1.21	0.31	1.01	1.01
MANAS_PRINCEW_VA	0	1	2	1.21	0.31	1.01	1.01
MANAS_PRINCEW_VA	0	1	3	1.21	0.31	1.01	1.01
MANAS_PRINCEW_VA	1	0	1	0.00	0.31	1.01	1.01
MANAS_PRINCEW_VA	1	0	2	0.00	0.56	1.90	0.58
MANAS_PRINCEW_VA	1	0	3	0.00	1.01	2.31	0.53
MANAS_PRINCEW_VA	1	1	1	1.22	0.31	1.01	1.01
MANAS_PRINCEW_VA	1	1	2	1.21	0.33	0.94	0.85
MANAS_PRINCEW_VA	1	1	3	1.22	0.30	1.20	1.26
SPOT_STAF_VA	0	0	1	0.00	0.25	0.69	0.85
SPOT_STAF_VA	0	0	2	0.00	0.25	0.69	0.85
SPOT_STAF_VA	0	0	3	0.00	0.25	0.69	0.85
SPOT_STAF_VA	0	1	1	1.33	0.25	0.69	0.85
SPOT_STAF_VA	0	1	2	1.33	0.25	0.69	0.85
SPOT_STAF_VA	0	1	3	1.33	0.25	0.69	0.85
SPOT_STAF_VA	1	0	1	0.00	0.25	0.69	0.85
SPOT_STAF_VA	1	0	2	0.00	0.75	0.69	0.85
SPOT_STAF_VA	1	0	3	0.00	0.25	0.69	0.85
SPOT_STAF_VA	1	1	1	1.33	0.25	0.69	0.85
SPOT_STAF_VA	1	1	2	1.31	0.23	0.33	0.78
SPOT_STAF_VA	1	1	3	1.27	0.32	1.14	1.09

Table 3.1: Trip Production Rates by County

Application of Production Trip Rates: Population Synthesis

In order to apply the trip generation model, it is necessary to have estimates of the number of individuals in each of the cross-classified categories for which the trip production rates were developed. Normally, trip production rates are applied with zonal data. However, data on individuals within households of various types is not provided on a zonal basis by the Census and surveys have samples that are too small to provide these small area estimates so an alternative method was needed. This method uses a technique known as population synthesis to create the data for all of the zones in the MWCOG region.

1. In population synthesis, disaggregate data is expanded to match known marginal totals or aggregates at the small area level. There is population synthesis tool in TransCAD used to generate a person level and household

level database for a given region. This is done with individual data records with sample weights. These are usually available from a survey. These sample records contain rich household and person information but may have little or no information household location. The Public Use Microdata Sample PUMS database from the U.S Census Bureau is often used in population synthesis and was used in the project.

2. A zonal file that contains aggregate marginal household statistics. Typical examples are the block and the block group geographic files with these marginals. These data provide geographic specificity but only for totals and subtotals.

The population synthesis procedure expands the sample files to generate the entire population or household database such that certain household and person statistics match on a zonal basis. Thus the resulting file is rich in household, individual, and geographic information. Trip rates can easily be applied to the synthesized population either on a household or persons by person basis or basis on new crosstabs at the zonal level.

For the PG County TransForM model, a special population synthesis procedure was used to match selected household and population demographics at both the block group and the block level.

The household and person demographic variables chosen for matching marginals at the block and block group level are listed below.

Block Group:

- Household Income: Six categories of HH Income were considered:
    1. Income < 20K
    2. Income between 20K and 35K
    3. Income Between 35K and 45K
    4. Income between 45K and 60K
    5. Income between 60K and 100K
    6. Income > 100K
- Number of Vehicles in the household: Four categories were considered. Households with 0, 1, 2 and 3+ vehicles
- Number of Workers in the household: Five categories were considered. Households with 0, 1, 2, 3 and 4+ workers

Block:

- Household Size: Five categories were employed. Households with a size of 1, 2, 3, 4 and 5+
- Household Tenure: Owner/Rental
- Age of Person: Four categories were used. Age 15-34, 35-54, 55-64, 65+
- Race: White, Black, Asian, Other

- Hispanic, Non-Hispanic
- Number of children

The resulting household file and the population file contain as many records as the number of households in the region and the population of the region respectively. Each record has a corresponding block and block group ID, so that the aggregated demographics by block and block group match the marginals at the block and block group level for the above variables.

The trip production rates in Table 1 are then applied to produce productions for the HBW, HBS, HBO and NHB trip purposes by zone.

The HBW trips were further split into four categories based on income grouping. This is required for the income-stratified trip distribution model for the HBW purpose. The factors to split the HBW trips into the income categories were generated based on the earlier MWCOG TP+ model and used as inputs.

The specific software for computing trip productions was a GISDK script that performs the functions of the MWCOG FORTRAN model. This included the trip attraction models which are described below.

Trip Attraction Rates

The trip attractions rates used in the model are those recommended by COG in the Version 2.1 #50 Draft Calibration Report. It was found that the COG 2000 survey data was inadequate to perform regression models at the zonal level and the attraction models developed based on Area Type and various types of employment developed by COG were used. The trip rates for the basic trip purposes are listed in Table 3.2.

The HBW trip rates include both motorized as well as non-motorized attractions, whereas the trip rates for the other purposes constitute only motorized trips. The NHB trip rates represent one half of the total trip ends.

Trip Purpose	Area Type	Independent Variables			
		Total Employment	Retail Employment	Non-Retail Employment	Household Population
HBW	All (1-7)	1.11			
HBS	1		0.29		
	2		2.44		
	3-7		3.35		
HBO	All (1-7)		1.30	0.30	0.77
NHB	1			0.42	
	2-7		2.77	0.49	0.28

Table 3.2: Trip Attraction Rates by Trip Purpose and Area Type

Computing Trip Attractions

The demographics of the zones are used in conjunction with the above rates to generate the trip attractions for the basic purposes. As in the case of HBW productions, the HBW trip purpose attractions are further split into the 4 income groups based on the factors developed by COG and used as inputs.

Truck Trip Rates

Since a separate truck survey was unavailable, the truck trip rates in the model are identical to the ones developed by COG. These rates are listed in Table 3.3. They are based on fixed area types and land activity variables.

Vehicle Type	Location Type	Land Use Variables				
		Office	Retail	Industrial	Other	HH
Medium Trucks (Single Unit 6+ Tires)	1-Regional Core	0.01	0.17	0.09	0.04	0.04
	2-DC Non-Core	0.01	0.17	0.19	0.04	0.04
	3-VA 10 mi-sq	0.01	0.17	0.14	0.04	0.04
	4-Other	0.01	0.17	0.11	0.04	0.04
Heavy Trucks (All Combination Vehicles)	1-Regional Core	-	0.04	0.03	0.03	-
	2-DC Non-Core	-	0.04	0.13	0.03	-
	3-VA 10 mi-sq	-	0.04	0.04	0.03	-
	4-Other	-	0.04	0.11	0.03	-

Table 3.3: Truck Trip Rates

The truck trips above represent internal trips. The truck internal productions are set to the truck internal attractions.

Computing Motorized HBW Productions and Attractions

The HBW productions and attractions include motorized as well as non-motorized trips. To account for this, the non-motorized percentages have to be subtracted out. The COG 2000 Panel Survey was used to determine the walk and the bike percentages based upon area types. These percentages were similar to the ones used in the COG model and are shown in Table 3.4.

Area Type	Non-Motorized Trip Percentage
1 (Dense Urban Areas)	40.21
2	7.52
3	2.61
4-7 (Rural Areas)	1.21

Table 3.4: Non-Motorized HBW Percentages

These factors were used to subtract out the non-motorized productions for the HBW internal trips.

The non-motorized trip attractions were determined using COG's approach, whereby the non-motorized attractions are set to 0.89 times the non-motorized productions.

Computing Internal-External and External-Internal Trips

The productions and attractions for the basic trip purposed also include Internal-External (IX) trips as well as External Internal (XI) trips. In order to determine the fraction of IX and XI trips from each zone, the entire region was divided into several counties. The CTPP Part 3 journey to work estimates was observed and the percentage of work flows from a particular county to outside the region was examined.

It was found that for most of the region, the percent of IX journey to work flows was 1.2 percent. However, for counties in the outlying region (both in Virginia and Maryland), the percent of IX trips was much greater. This is because of the presence of large urban areas (such as Baltimore City) lying outside the study region that attract work trips from the outlying counties. Based on the study, the percentage of IX trips for the HBW purpose (and assumed for the other purposes) is provide in Table 3.5

County	IX Percentage
Carroll, MD	0.285
Clarke, VA	0.271
Howard, MD	0.193
Jefferson, WVA Frederick, MD Loudoun, VA	0.150
Anne Arundel, MD	0.144
King George, VA	0.019
Fauquier, VA	0.015
Rest of the region	0.012

Table 3.5: Internal-External and External-Internal Trip Percentages

The above percentages are used on the production ends to determine IX productions and are used on the attraction ends to determine XI attractions.

The IX attractions and the XI productions are determined from 2000 ground counts at locations near the external stations and are provided as External Attractions and External Productions respectively.

Trip Balancing

Trip balancing is required for the HBW, HBS, HBO and the NHB trip purposes. For the Internal-Internal trips for all these trip purposes, attractions were balanced to match production totals. For the IX component of the above purposes, productions were balanced to external attractions whereas for the XI component, attractions were balanced to productions. Table 3.6 shows the final production and attractions

Purpose	Internal Ps and As	IX and XI Ps and As	Total Ps and As
HBW	3,434,394	321,331	3,755,725
HBS	2,467,887	124,457	2,592,344
HBO	6,684,305	399,859	7,084,164
NHB	4,323,063	201,346	4,524,409
MedTRK	287,977	-	287,977
HvyTRK	113,362	-	113,362
All Purposes	**17,310,988**	**1,046,993**	**18,357,981**

Table 3.6: Final Productions and Attractions by Trip Purpose

Table 3.7 below compares the trip generation results from the PGC TransForM model with the MWCOG model for the year 2000.

Purpose	MWCOG Trips	PGC TransForM Trips
HBW	4,150,703	3,755,725
HBS	3,123,513	2,592,344
HBO	9,532,335	7,084,164
NHB	6,978,853	4,524,409
MedTRK	304,826	287,977
HvyTRK	159,340	113,362
All Purposes	**24,249,570**	**18,357,981**

Table 3.7: Comparison of MWCOG and PGC TransForM model results

As seen in the above table, the PGC model computes fewer productions and attractions for all the trip purposes. The PGC model uses person trip rates while the MWCOG model uses household trip rates and it is likely that using household trip rates overestimates the number of trips. Further, in the MWCOG model, the HBO and NHB trips from the cross classification process were factored by 1.25 and 1.5.

Tables 3.8 and 3.9 show the total productions and total attractions by major jurisdiction

Jurisdiction	**HBW Prods**	**HBS Prods**	**HBO Prods**	**NHB Prods**	**Truck Prods**	**Total Prods**
DC	274,351	212,266	574,608	525,853	54,517	1,641,595
Montgomery	558,463	458,281	1,049,369	660,087	50,432	2,776,632
Prince Georges	492,291	320,304	886,148	575,882	50,118	2,324,743
Arlington	136,040	75,215	216,327	194,942	12,338	634,863
Alexandria	92,197	51,077	137,679	123,867	10,149	414,969
Fairfax	638,569	528,235	1,492,926	779,185	54,729	3,493,643
Loudoun	98,284	64,808	216,912	136,646	12,997	529,647
Prince William	206,127	191,414	523,540	211,217	19,094	1,151,393
Frederick	118,105	77,254	211,759	142,727	13,110	562,956
Howard	170,530	129,055	296,102	186,387	19,661	801,736
Anne Arundel	313,568	197,414	539,703	348,383	37,072	1,436,141
Charles	70,918	36,353	139,635	93,779	7,564	348,249
Carroll	89,379	59,674	164,807	90,828	8,682	413,370
Calvert	49,457	12,755	81,839	48,512	4,001	196,564
St. Mary’s	54,815	14,494	92,571	65,359	5,522	232,762
King George	10,282	5,147	12,680	12,029	774	40,912
Fredericksburg	11,623	5,377	12,210	33,117	2,488	64,816
Stafford	60,091	27,468	72,943	70,777	5,750	237,028
Spotsylvania	49,496	25,198	59,831	55,534	4,903	194,961
Fauquier	30,112	21,226	71,319	36,129	3,114	161,900
Clarke	6,964	4,722	15,862	9,034	939	37,521
Jefferson	22,834	16,209	54,439	27,383	2,503	123,368
Total	**3,554,496**	**2,533,946**	**6,923,208**	**4,427,656**	**380,459**	**17,819,766**

Table 3.8: Total Productions by Trip Purpose and Jurisdiction

Jurisdiction	HBW Attrs	HBS Attrs	HBO Attrs	NHB Attrs	Truck Attrs	Total Attrs
DC	795,189	162,119	822,763	525,752	54,517	2,360,340
Montgomery	500,914	356,836	1,023,510	659,908	50,432	2,591,600
Prince Georges	363,345	397,714	917,487	575,740	50,118	2,304,405
Arlington	193,445	90,097	255,852	194,898	12,338	746,631
Alexandria	95,200	76,747	166,549	123,839	10,149	472,483
Fairfax	625,186	428,440	1,194,706	778,937	54,729	3,081,998
Loudoun	96,758	96,726	204,600	136,610	12,997	547,690
Prince William	118,162	141,750	359,771	211,140	19,094	849,917
Frederick	107,524	86,676	224,993	142,680	13,110	574,983
Howard	144,593	105,347	284,801	185,569	19,661	739,972
Anne Arundel	271,157	191,412	549,359	347,488	37,072	1,396,488
Charles	53,394	76,435	141,741	93,746	7,564	372,879
Carroll	59,022	43,806	156,617	89,973	8,682	358,100
Calvert	27,469	32,516	82,500	48,495	4,001	194,981
St. Mary’s	49,845	41,384	100,208	65,339	5,522	262,298
King George	11,955	4,417	19,492	12,023	774	48,660
Fredericksburg	23,977	36,826	31,803	33,113	2,488	128,208
Stafford	26,706	69,614	106,476	70,754	5,750	279,299
Spotsylvania	28,914	45,834	87,384	55,520	4,898	222,550
Fauquier	22,415	22,742	61,234	36,115	3,114	145,620
Clarke	6,374	5,254	13,983	8,972	939	35,523
Jefferson	17,091	16,764	45,654	27,299	2,503	109,311
Total	**3,638,636**	**2,529,453**	**6,851,484**	**4,423,909**	**380,454**	**17,823,937**

Table 3.9: Total Attractions by Trip Purpose and jurisdiction

Figure 3.1 shows a pie chart for the production and attractions for the entire region, while Figure 3.2 depicts the productions and attractions for PG County.

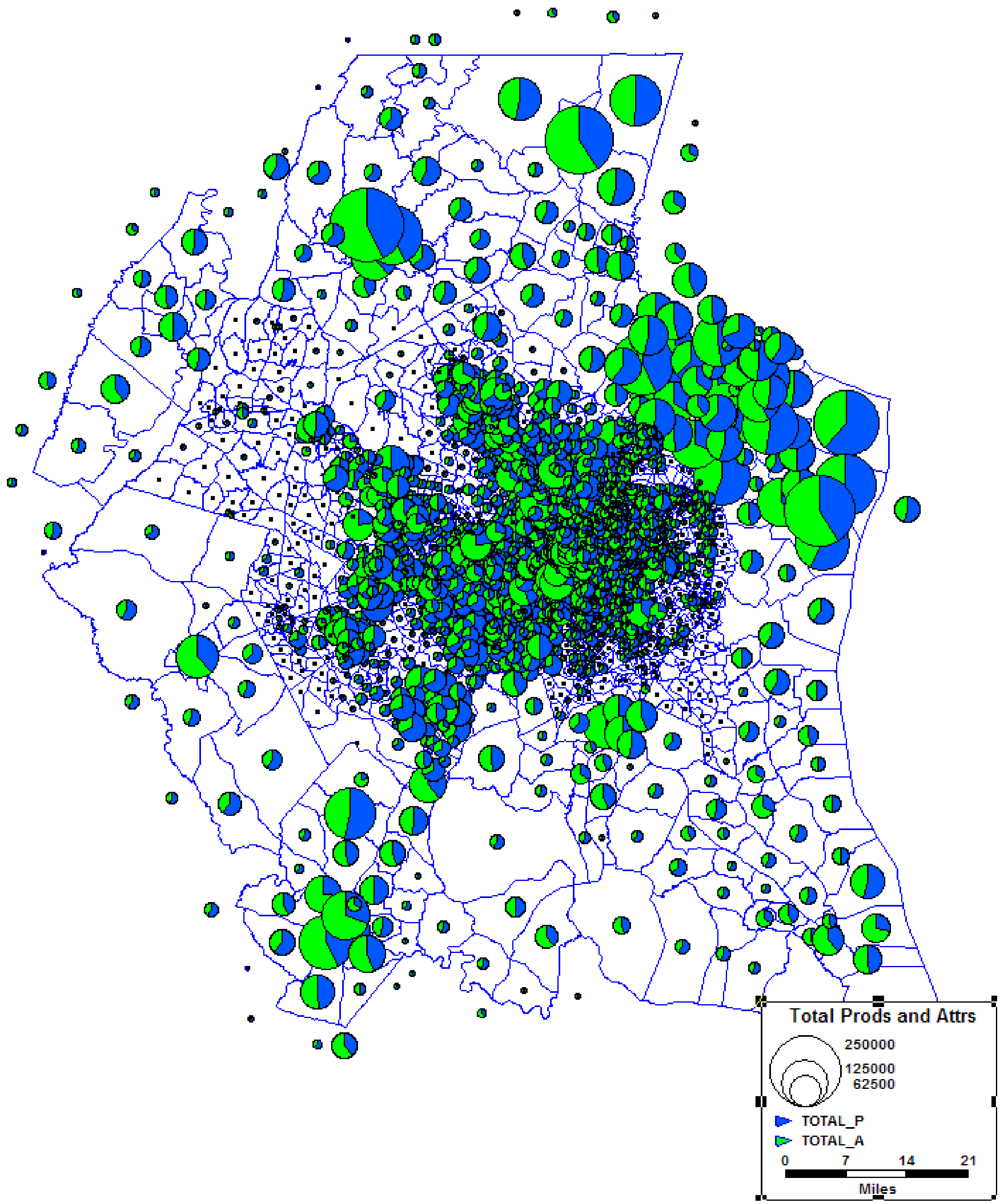

Figure 3.1: Productions and Attractions for the entire region

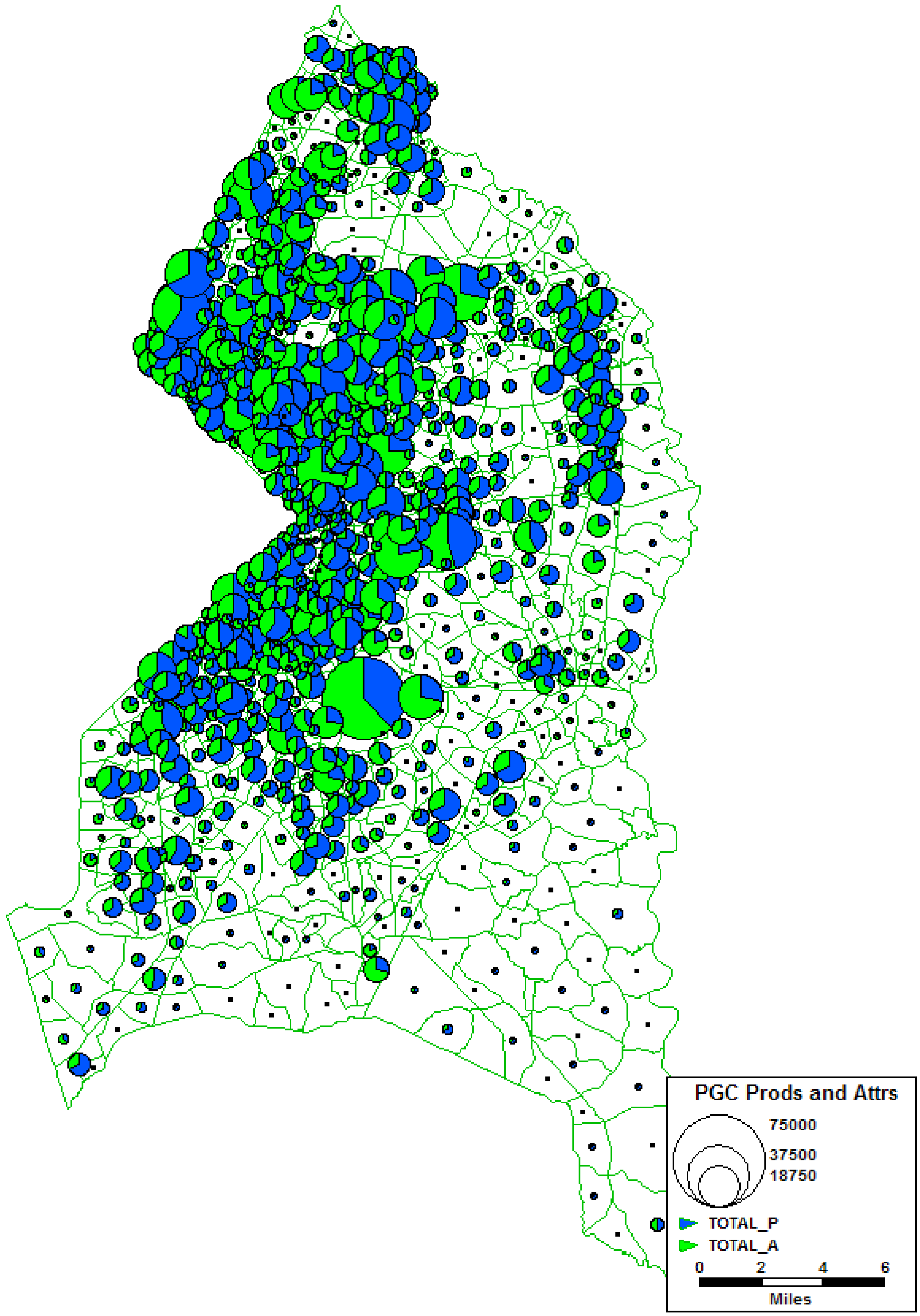

Figure 3.2: Total Production and Attractions for Prince George's County

Figures 3.3 and 3.4 show the productions and attractions of work trips (HBW trips) for the entire region and for PGCounty respectively.

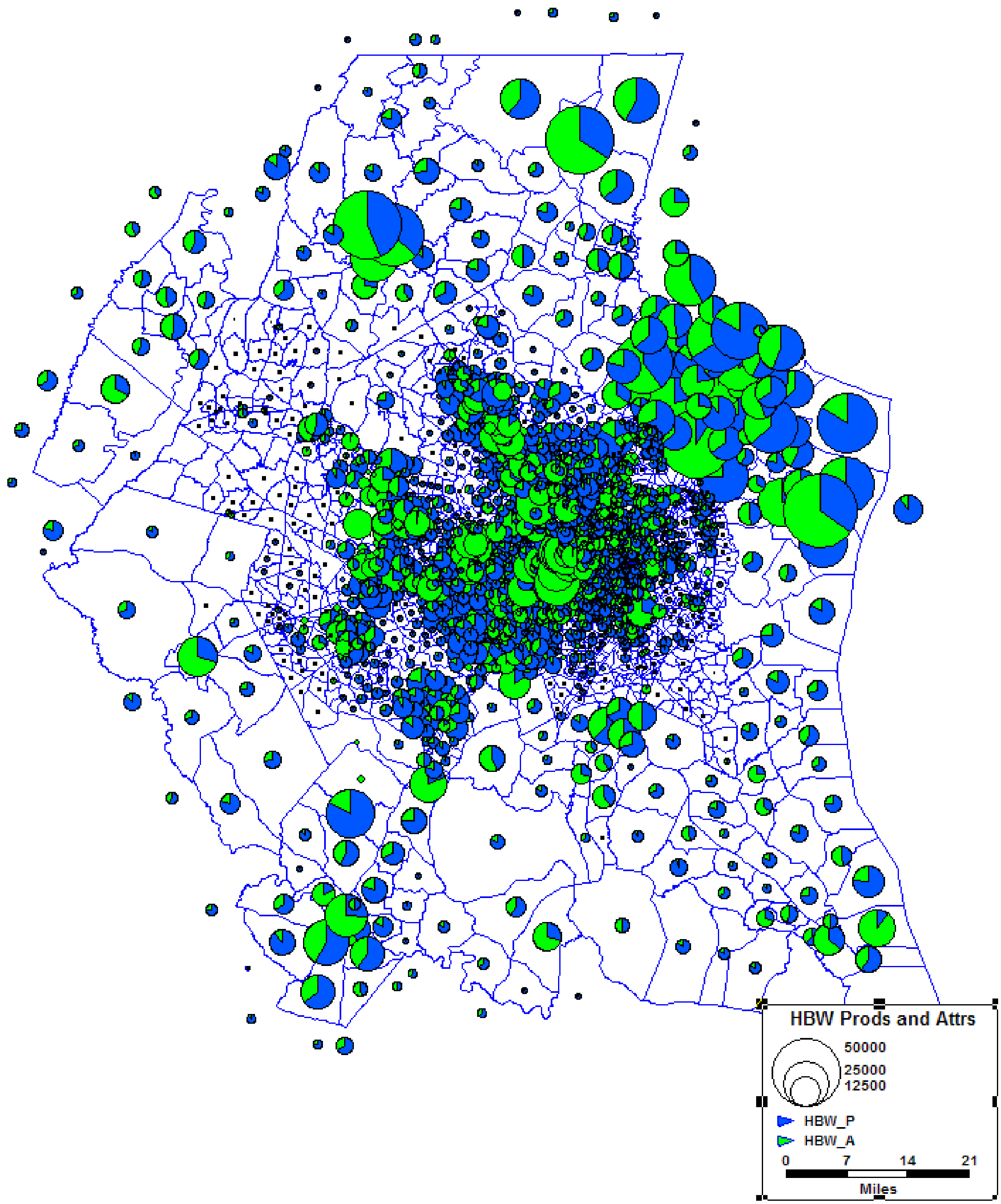

Figure 3.3: HBW Productions and Attractions for the entire region

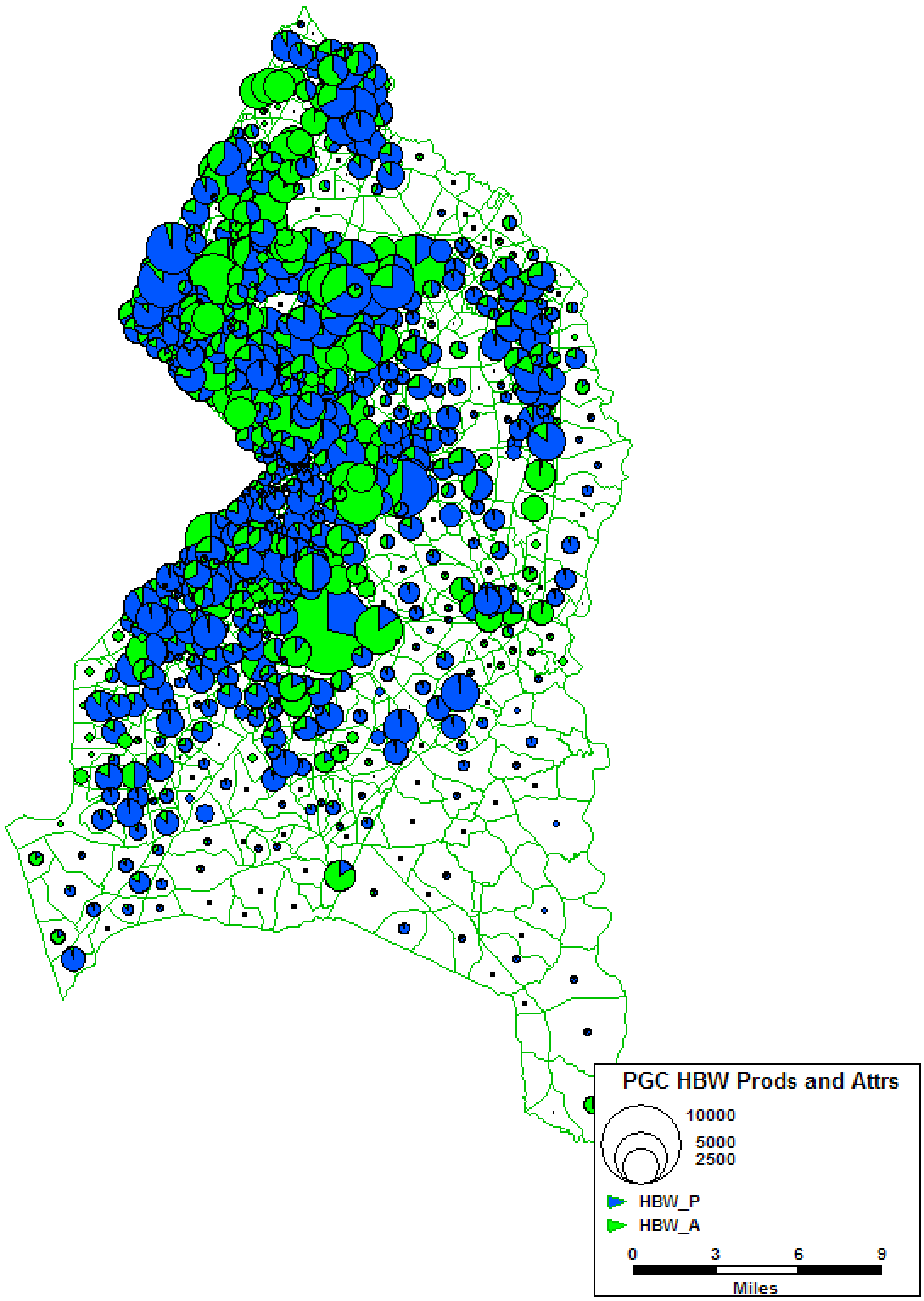

Figure 3.4: HBW Productions and Attractions for Prince George's County

Chapter 4 Trip Distribution

This chapter describes the development of the trip distribution models that were implemented in the TransForM model. The chapter describes the MWCOG Trip Distribution model and then focuses on the changes implemented for the TransForM model.

The MWCOG Trip Distribution Model

The MWCOG Trip Distribution model employs a TP+ gravity procedure and a composite (highway and transit) travel time impedance measure.

The internal productions and attractions are obtained for each of the four income categories from the trip generation procedure for inputs into the trip distribution process for the HBW, HBS and the HBO purposes. The internal productions and attractions are not split into the income categories for the NHB, Medium Truck and the Heavy Truck purposes. In addition, productions and attractions for the IX and XI trips are computed from the trip generation process.

The friction factors curves for the HBW, HBO, HBS and NHB trips were developed by COG using the COG 1994 Panel Survey. Four sets of friction factors corresponding to trips made by households in each income classification were developed for the HBW, HBS,and HBO purposes. The truck survey was used to develop friction factor curves for the truck purposes. For the IX and XI trips, friction factor curves were developed for trips that travel to external stations using interstates and for trips that travel to external stations using arterials.

The friction factors are smoothed using a gamma function. There are further adjustments that were used iteratively to approximate the trip length distributions observed in the 1994 survey by purpose.

The highway skims are combined with the transit skims to provide a composite skim for use for the HBW, HBS, HBO and NHB purposes. Further details on this procedure are provided later in this Chapter.

In the MWCOG model, the trip distribution method employs a set of K-Factors to adjust jurisdiction to jurisdiction flows. The initial set of K-Factors was developed in 1994 and was subsequently modified in the MWCOG model as described in the Version 2.1D Draft #50 calibration report dated September 17, 2004.

The TP+ procedure balances rows (productions) and then factors the calculated attractions so that they are normalized to match the input attractions. However, in this process, the external attractions are held fixed. Therefore, this procedure applies the gravity equation (employing the friction factors) only to the productions and not to the attractions.

Early in the project, we performed several experiments to study the behavior of the MWCOG TP+ gravity model and the TransFORM model. The TP+ method is similar to the method used in UTPS and TRANPLAN and approximates a doubly-constrained model by balancing origins and using a normalization loop on attractions. While TransCAD supports this type of gravity model, the doubly-constrained model in TransCAD was thought to be more efficient and to give more accurate answers.

The MWCOG trip distribution model is run with a maximum of 7 iterations and uses a default convergence criterion of a root mean square error (RSME) of 10 percent. We examined the output from the distribution models run in the second pass of the model (after the first pump-prime feedback loop) and discovered that most of the models were not converged. In fact, the RMSEs were rather high for most of the trip purposes, suggesting that quite a bit more computing would be indicated. We thus resolved to use the TransCAD doubly constrained gravity model and to use a much higher convergence value in the TransForM model.

Highway and Transit Skimming

The first step before the trip distribution analysis was the generation of highway and transit skim matrices based on the updated network and route system. The peak and off-peak highway skim matrices were generated from the latest network using the peak and the off-peak congested travel times computed from the calibration runs. The skims were generated for SOV, HOV2 and HOV3+ modes and were performed for the peak and the off peak period to generate six sets of skims. The link prohibitions for the SOV vehicles and HOV2 vehicles were taken into account in building the appropriate network file to be used for the skimming process.

The congested times that are input to the skimming procedure are the result of several full model runs using the feedback procedure with the Method of Successive Averages (MSA). During each loop of the feedback process, the congested times are fed into the trip distribution procedure. After the traffic assignment stage, the output flows are averaged and updated link travel times are computed. The resulting times are fed back into the skimming procedure and the above process is repeated until some degree of convergence is achieved which implies that the travel times input to the skimming procedure are similar to the ones that are produced by the traffic assignment step. Further details of this process are provided in Chapter 7, Traffic Assignment.

The peak period skims are the average of the AM and PM skims, which is believed to be more accurate than just using the AM values.

The intra-zonal travel times are computed by using one-half of the average distance to the two neighboring zones. The intra-zonal travel times are computed after the highway skimming process during each calibration loop.

The terminal times are then added after computing the intra-zonal times. The terminal time for each zone is specified in the zone database and is based on the employment density as follows:

Employment Density	Terminal Time (min)
< 4,600	1.0
>= 4,600 and < 6,600	2.0
>= 6,600 and < 11,500	3.0
>- 11,500 and < 33,000	4.0
>= 33,000	5.0

Table 4.1 Zone Terminal Times based on Employment Density

The terminal times are based on the same classifications as in the MWCOG model, however the values of the terminal times used are smaller. The MWCOG model employed as high as 8 minutes of terminal times for the zones with the highest employment density.

For the transit skims, the TransCAD Pathfinder method developed by Caliper was employed on the latest route system to generate the peak and the off-peak transit skims. Pathfinder takes account of the reduced first wait for overlapping services and calculates the travel time components and number of transfers for the best paths between origins and destinations. The Pathfinder method also takes the fare into account in finding the best transit path which is another difference from the MWCOG model. A default value of time of $12 per hour is used although this could be fine-tuned further by income category if desired.

To obtain composite times, the skim matrices were combined using the composite impedance equation as per the MWCOG model for the HBW trip purpose
$1.0/CT_i = 1.0/HT + P_i/TT$, where
CT_i = composite time for income group I
HT = highway time
TT = transit time
P_i = Regional transit share of income group

The percentage of transit trips for household under each income type (for the HBW purpose) was obtained from the COG Panel survey and the numbers were similar to the percentages used in the MWCOG model. The transit percentage by income group for the HBW purpose is shown in the table below:

Income Category	Percentage Transit
1	25.7
2	14.8
3	13.7
4	14.0

Table 4.2 Transit Percentages by Income Group

However, unlike MWCOG model, the income stratification based trip distribution model was applied only for the HBW purpose. This is in keeping with the general notion that income does not greatly affect the distribution of non-work purposes. It was also warranted by the relatively small sample size of the panel survey. For the other purposes the off peak skims were directly used in evaluating the distribution model equations.

Friction Factor Curves and Calibration

The MWCOG model used gamma curves for the friction factors, and the same functional form was used in the TransForM model. The friction factors were adjusted for the Year 2000 using the panel survey.

In order to calibrate the friction factors, the origin and the destination TAZ of each trip in the survey database were identified using TransCAD's geocoding tools. Thus, the travel time for each trip could be computed from the skim matrices. The average travel times were then extracted from the survey for each of the purposes. For the HBW purpose, additional average travel times were obtained for each of the four household income classifications. The average times for the internal trips for each of the purposes from the survey are listed in Table 4.3.

The MWCOG friction factor curves for each of the trip purposes were then adjusted to yield the above estimates of average trip lengths. In particular it was observed that the trip lengths from the MWCOG model were longer than desired and hence the curves were shifted to the left to yield lower trip lengths.

Trip Purpose	Avg Trip Length (min)
HBW – Income 1	19.0
HBW – Income 2	21.7
HBW – Income 3	25.5
HBW – Income 4	26.0
HBW – All Incomes	24.3
HBS	11.9
HBO	15.5
NHB	13.8

Table 4.3 Observed Trip Lengths from the 2000 COG Panel Survey

It must be emphasized that in order to calibrate the above friction factor curves, several model runs had to be performed since the friction factors depend on the peak and off-peak congested travel times, which in turn depend on the traffic assignment results. These congested travel times were thus constantly updated during the calibration process and hence the friction factors were also adjusted on a regular basis. The final congested times after several model runs were used to calibrate the final friction factor curves. The friction factor curves for the four purposes are shown in the figures below.

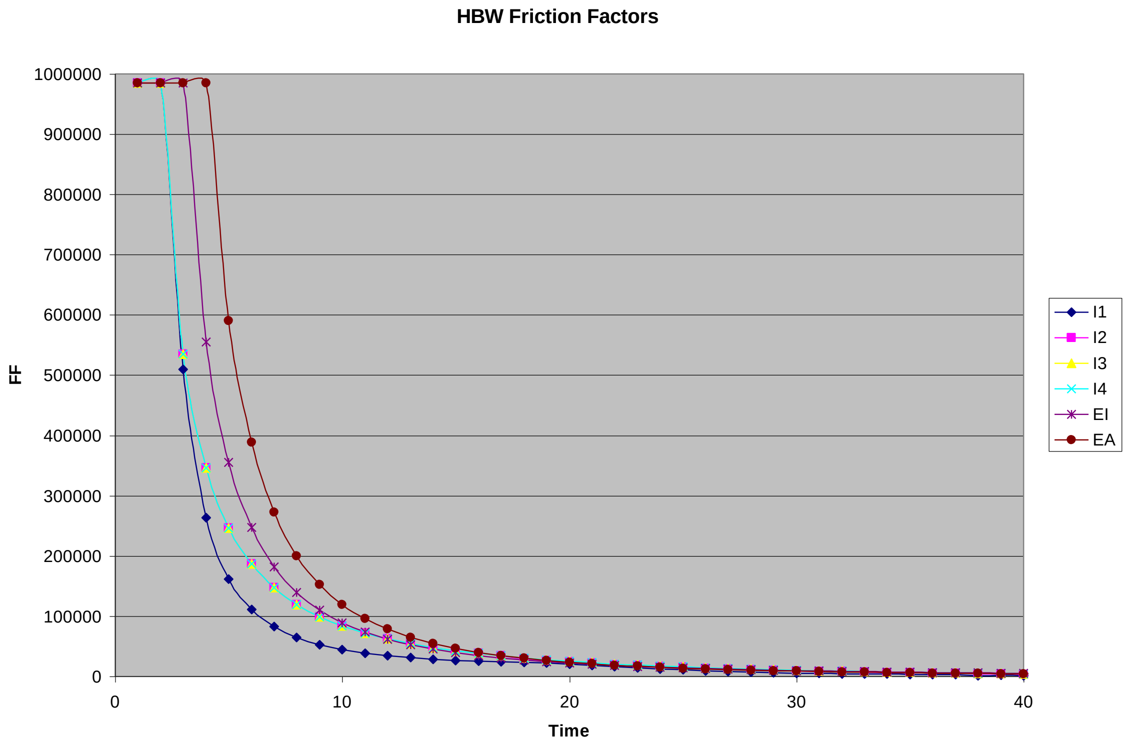

Figure 4.1 HBW Friction Factors

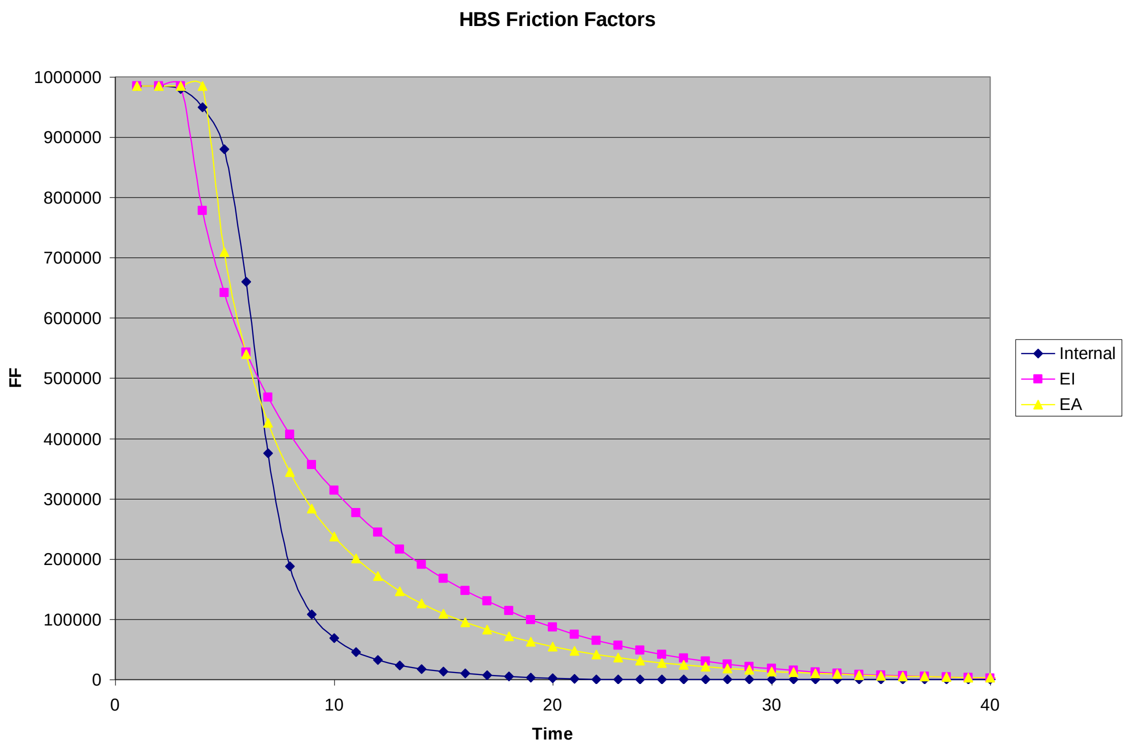

Figure 4.2 HBS Friction Factors

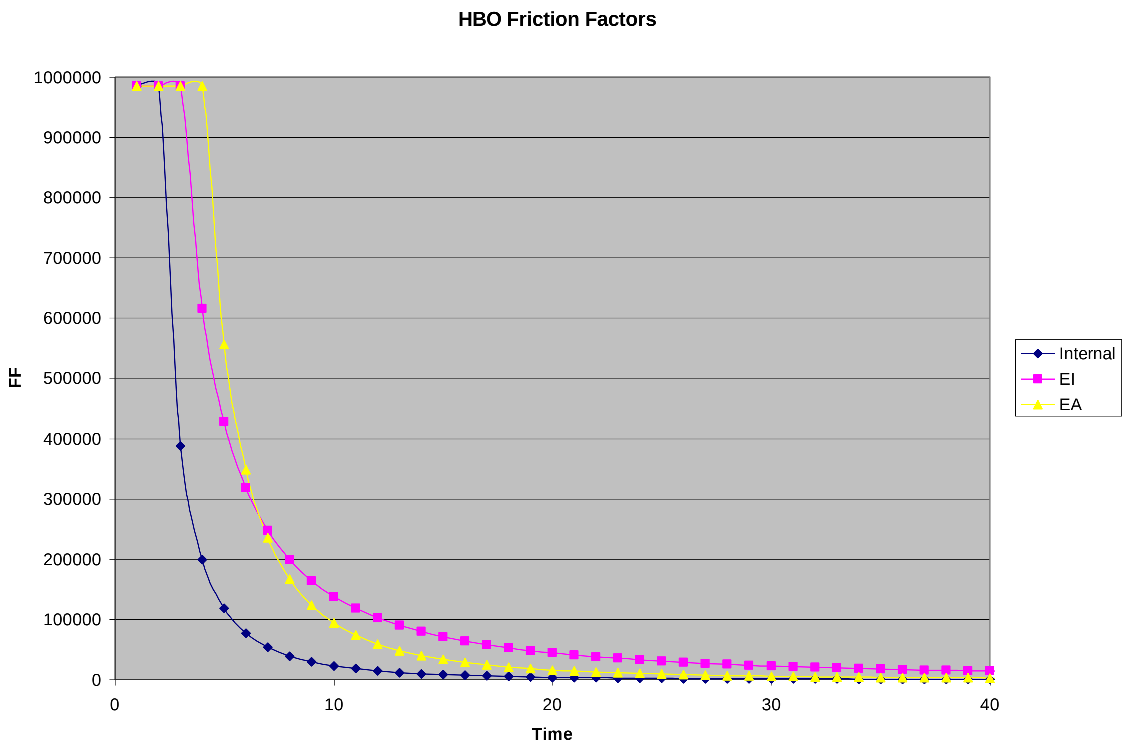

Figure 4.3 HBO Friction Factors

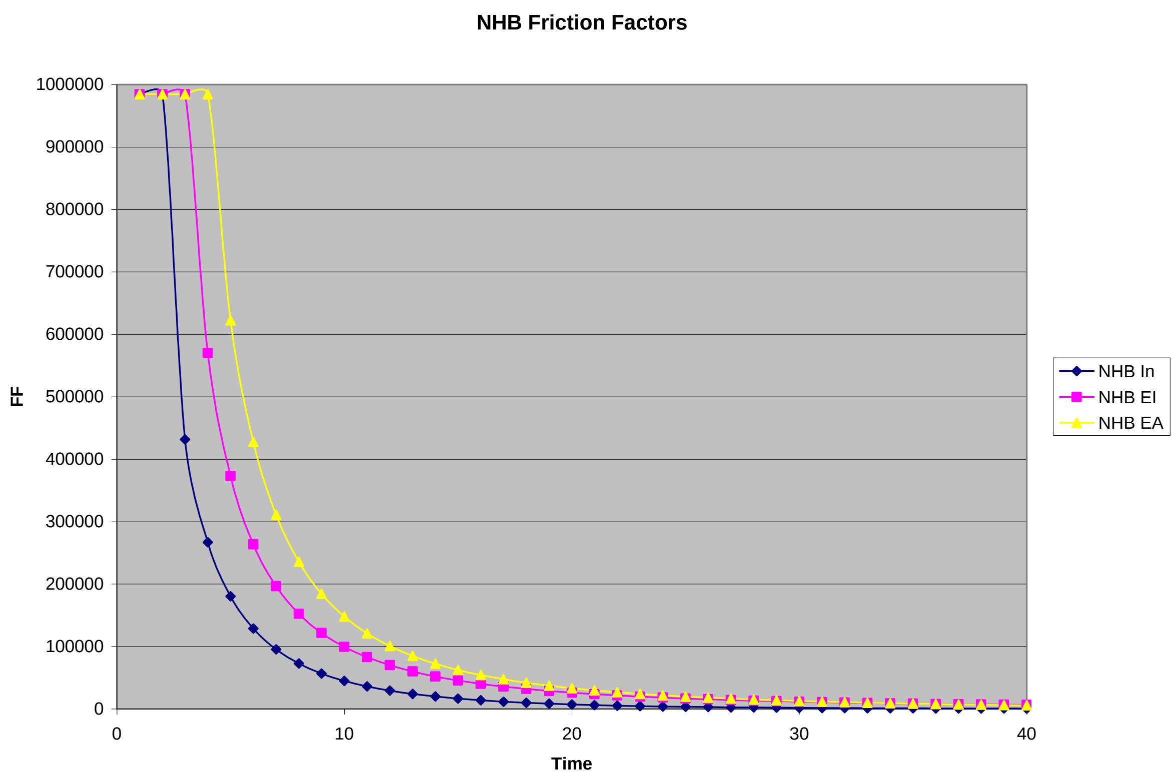

Figure 4.4 NHB Friction Factors

Trip Distribution for the HBW, HBS, HBO and NHB purposes

The doubly constrained gravity procedure was applied to all the Production and Attraction vectors with the appropriate friction factor curves. The composite impedance matrices were used for the HBW purpose, whereas the off peak impedance matrices were used for the other purposes. The procedure was run until convergence with a tolerance of 0.001.

The TransForM Trip Distribution model does not employ K Factors for the 4 basic trip purposes. This is an advantage of this model since the extensive usage of K Factors is generally not recommended.

Truck Trip Distribution

Since no information was available regarding the truck trips, the friction factors and the K Factors for the trucks as in the MWCOG model were employed. The only difference is that the truck trip distribution uses the latest impedance matrix.

IX and XI Trip Distribution

The IX and XI trips for all the purposes are split into two main categories: Trips through interstates known as EI trips and trips through arterials known as EA trips. The friction factor curves are different for the above categories and in general the EA friction factor curve falls more steeply than the EI friction factor curve (as seen in the figures above). Further, each external station in the model is categorized to one of these two types. External stations that are connected to the network by major arterials fall under the EA category, while external stations connected to the network by interstates fall under the EI category. The gravity model is applied twice to the IXXI trips, once with the EI friction factor curve and once with the EA friction factor curve to produce the EA and the EI gravity matrix for each purpose. The impedance matrices applied during the process are modified so that Internal-Internal (II) and External-External (XX) trips have a high impedance to prevent any allocation of trips to these regions. Then depending on the category of each external station, either the EA or the EI matrix for that particular station (row and column) is zeroed out.

Finally, after the procedure is completed, the resulting matrix is not subject to the bucket rounding method as in the MWCOG model.

Trip Distribution Results

Survey versus Model Trip Percentages

Figures 4.5 to 4.8 show the percentage of trips in each time interval by purpose obtained from the survey and those obtained from the model after the trip distribution procedure (using the output matrix and the skims). Each point in the figures below represents the percent of trips that have the corresponding travel time on the X-axis (within a 1 minute interval).

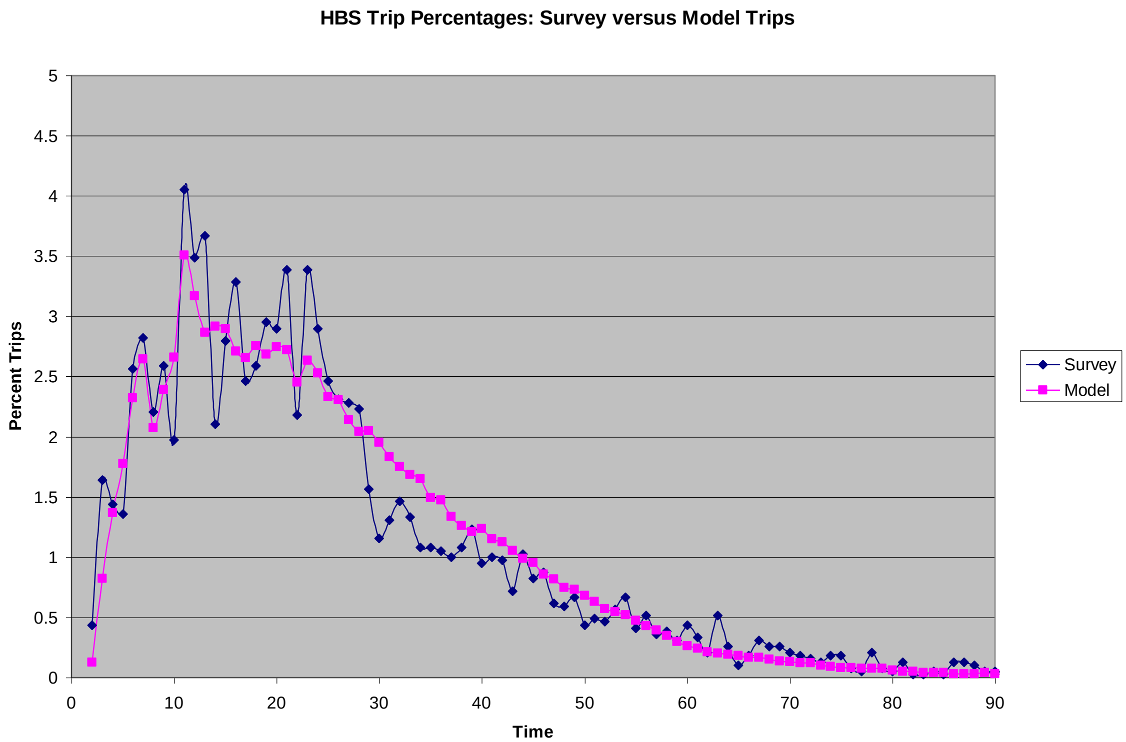

Figure 4.5 HBW Trips: Survey versus Model Trip Frequencies

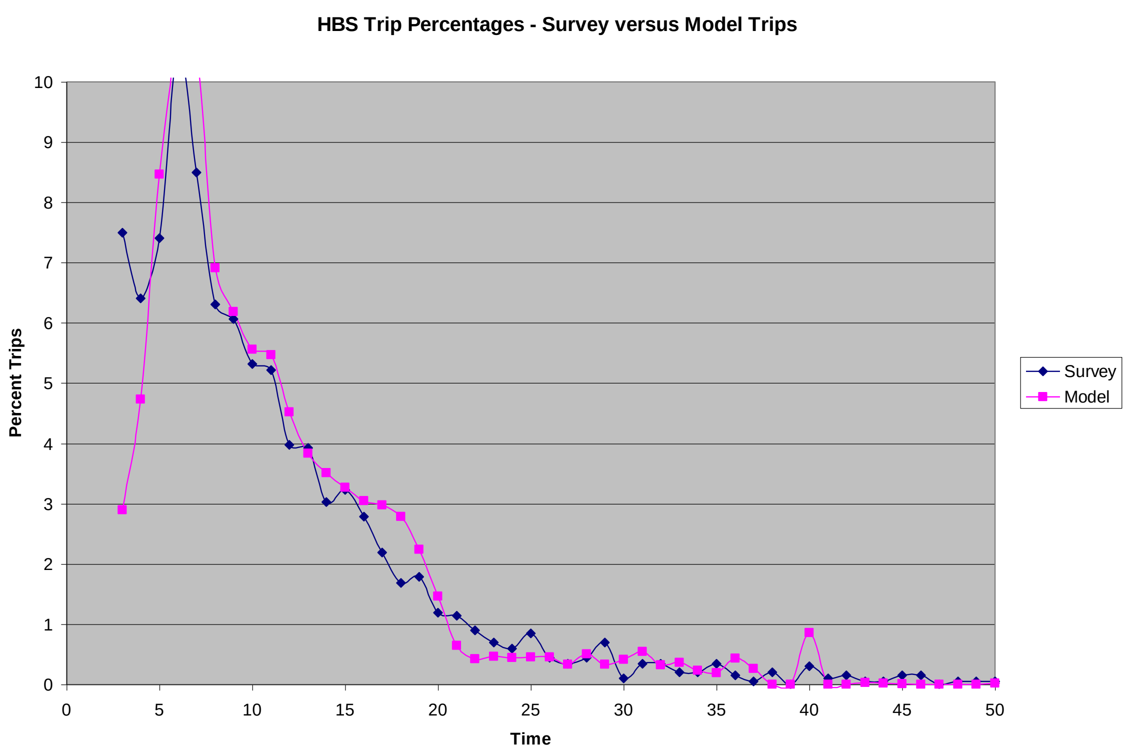

Figure 4.6 HBS Trips: Survey versus Model Trip Frequencies

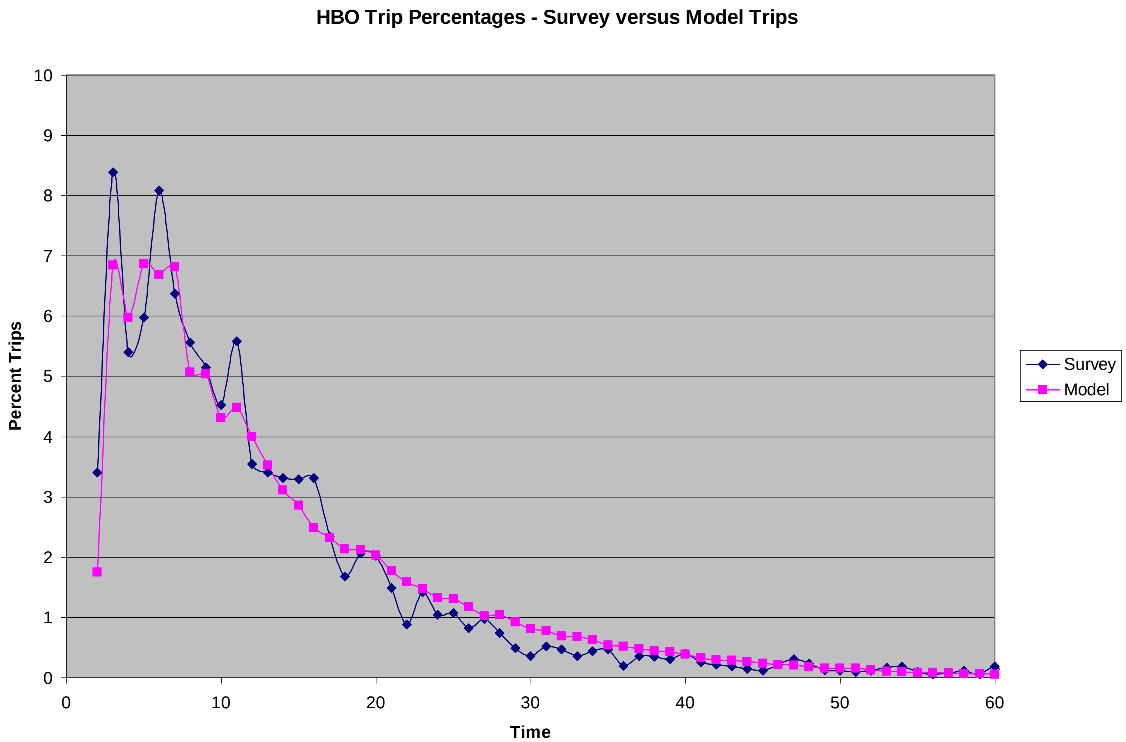

Figure 4.7 HBO Trips: Survey versus Model Trip Frequencies

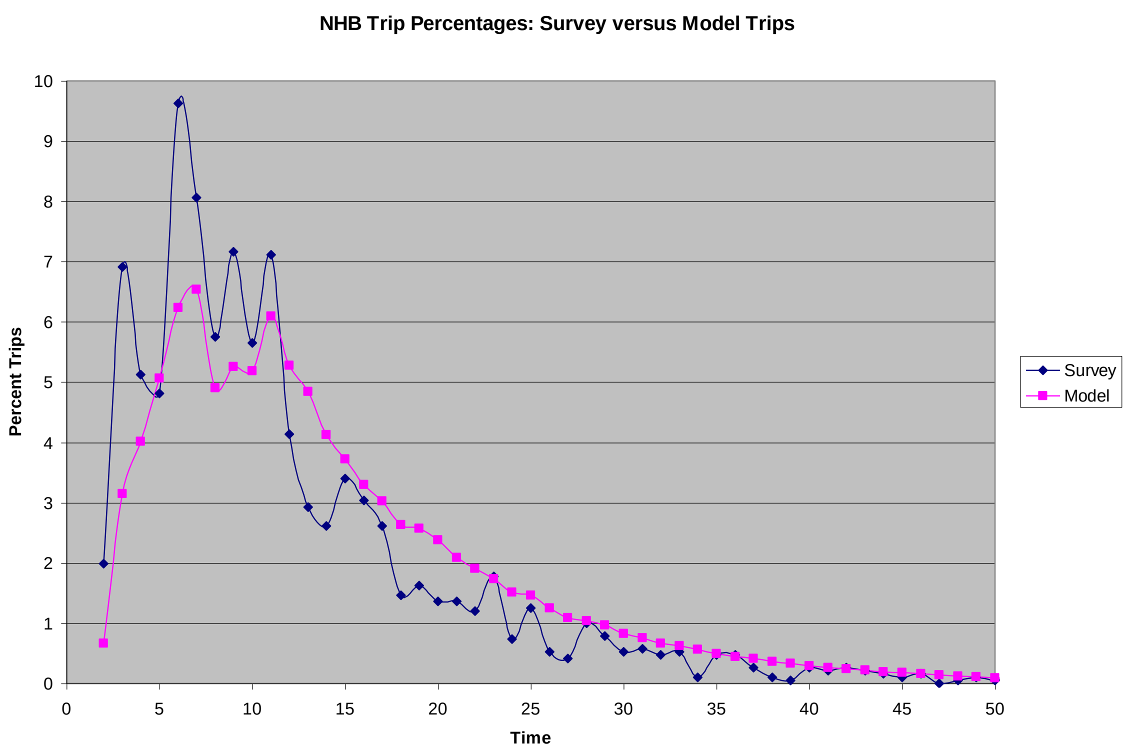

Figure 4.8 NHB Trips: Survey versus Model Trip Frequencies

Table 4.4 shows the number of trips for each purpose along with the number of intra-zonal trips, the intra-zonal trip percentage, the average trip length in miles and the average trip duration in minutes.

Trip Purpose	Number Trips	Number IZ Trips	Pct IZ Trips	Avg Trip Duration	Avg Trip Dur. (Survey)
HBW - Inc 1	548,113	34,103	6.2	18.9	19.0
HBW - Inc 2	861,414	54,349	6.3	22.0	21.7
HBW - Inc 3	724,651	38,024	5.2	25.0	25.5
HBW - Inc 4	1,300,217	48,873	3.8	26.9	26.0
HBW - Total (with EI and EA trips)	**3,755,725**	**175,349**	**4.7**	**26.0**	**24.3**
HBS – Total	**2,592,345**	**346,946**	**13.4**	**14.1**	**11.9**
HBO – Total	**7,084,164**	**1,309,202**	**19.6**	**14.7**	**15.5**
NHB – Total	**4,525,409**	**704,762**	**15.6**	**15.0**	**13.8**
MedTrk – Total	**287,977**	**13,281**	**4.6**	**27.3**	**-**
HvyTrk – Total	**113,365**	**3,600**	**3.2**	**30.4**	**-**

Table 4.4 Trip Distribution Results

The estimated trip distribution between and within jurisdictions for the HBW purpose is shown in Figure 4.9. Tables 4.3 to 4.9 indicate the estimated number of trips between various jurisdictions for each of the purposes.

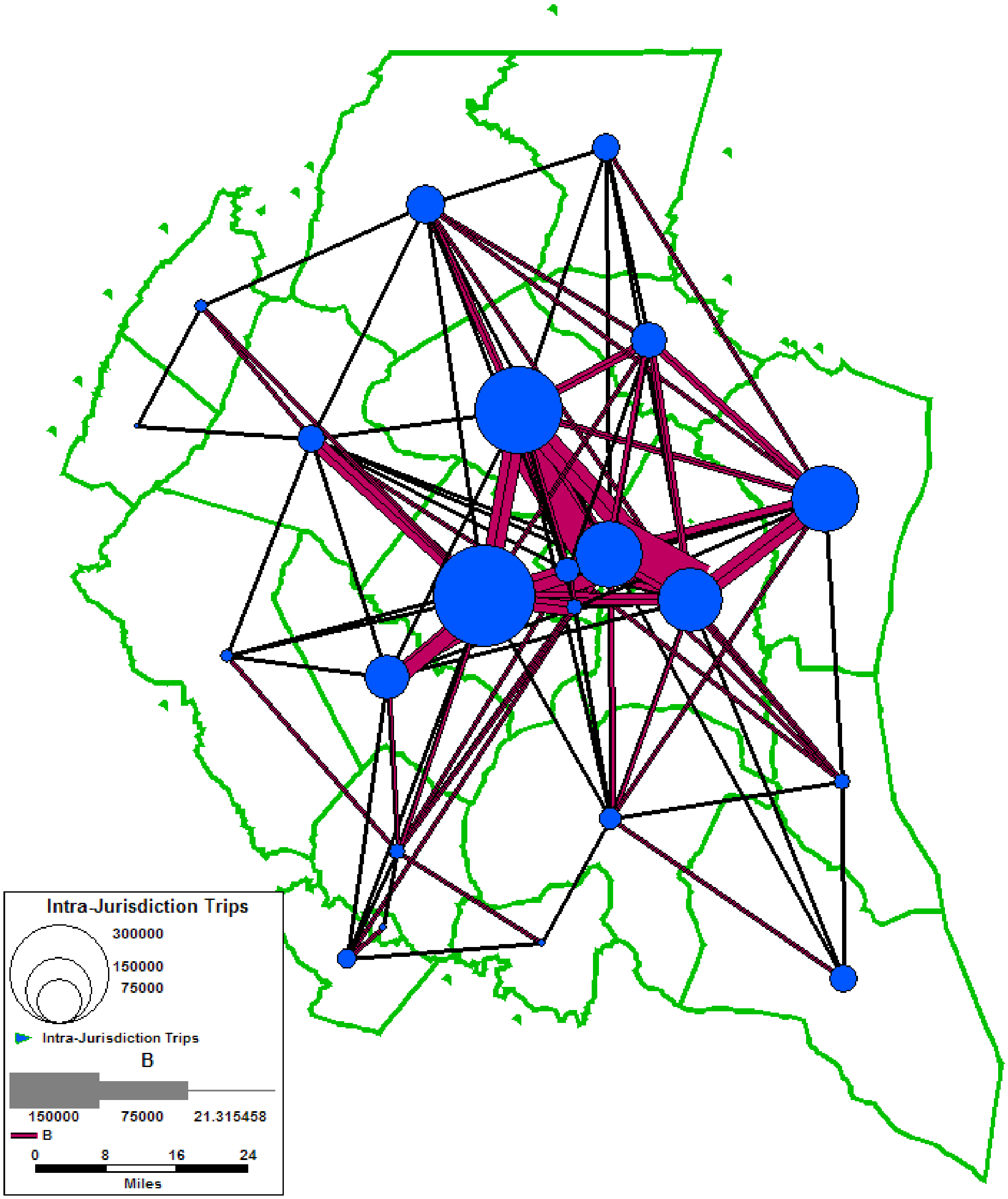

Figure 4.9 HBW Trip Patterns

	DC	MTG	PGC	ARL	ALX	FFAX	LDN	PW/MN	FRD	HWD	ANNE	CHL	CAR	CAL	STM	KGRG	FBURG	STF	SPT	FQR	CLK	JF	EXT
DC	165,984	33,421	29,089	18,904	5,049	15,632	267	50	47	808	1,241	622	2	51	5	0	0	0	18	3	0	0	3,028
MTG	142,854	279,207	46,160	18,599	4,286	32,156	1,320	99	11,642	10,469	5,176	134	379	29	2	0	0	0	9	6	4	43	5,776
PGC	184,100	46,899	164,541	22,600	7,918	18,171	269	86	91	8,380	22,192	9,904	9	1,552	416	7	0	1	18	3	0	0	4,900
ARL	44,432	9,352	4,216	32,703	8,448	34,030	1,019	163	17	56	71	42	0	3	1	0	0	0	22	7	0	1	1,455
ALX	24,728	3,720	3,730	16,298	16,062	25,766	308	389	6	25	54	100	0	5	1	0	0	1	26	3	0	0	978
FFAX	96,407	31,554	14,173	54,818	36,981	351,876	31,940	11,674	270	303	422	572	2	30	7	1	9	44	173	697	25	35	6,727
LDN	5,298	3,578	454	2,493	758	34,948	43,232	1,471	3,120	61	18	6	9	0	0	0	0	1	5	552	442	820	1,114
PW/MN	15,535	3,555	2,057	9,195	7,636	69,274	7,368	80,051	88	26	43	74	0	3	1	40	791	3,773	460	4,095	31	17	1,999
FRD	6,146	25,557	1,401	893	168	2,943	2,935	60	70,726	2,980	472	2	1,738	1	0	0	0	0	0	14	70	770	1,256
HWD	20,547	25,632	19,955	2,106	482	2,062	73	5	2,710	51,293	16,134	42	986	11	1	0	0	0	2	0	1	13	27,605
ANNE	37,925	12,426	44,933	3,963	1,072	2,248	29	7	122	16,587	158,994	732	28	2,411	35	1	0	0	9	0	0	1	31,875
CHL	17,409	1,339	11,712	2,421	1,292	1,931	16	9	1	91	655	30,002	0	1,148	1,934	217	2	1	19	0	0	0	704
CAR	2,688	11,785	1,913	301	57	521	162	3	13,155	7,363	1,186	3	28,253	1	0	0	0	0	0	1	3	45	23,008
CAL	7,247	848	7,817	918	316	482	5	2	2	92	3,152	1,907	0	19,200	6,951	6	0	0	6	0	0	0	499
STM	2,537	151	2,887	303	152	183	3	1	1	14	219	5,960	0	2,430	39,310	93	1	1	23	0	0	0	547
KGRG	599	34	363	83	55	113	1	139	0	2	14	1,611	0	35	151	6,147	287	269	194	22	0	0	158
FBURG	99	14	15	63	61	321	5	693	0	0	0	42	0	1	4	792	5,989	1,348	1,911	152	0	0	114
STF	3,090	460	408	1,808	1,667	9,051	189	11,823	3	3	7	296	0	6	25	2,285	6,582	15,104	4,293	2,425	3	1	573
SPT	1,112	183	202	680	652	3,026	57	3,864	5	21	76	387	6	41	152	2,016	9,711	5,122	21,211	557	2	2	422
FQR	732	350	70	495	252	6,983	1,734	5,197	36	2	2	3	0	0	0	18	218	606	80	12,820	92	36	376
CLK	42	60	3	23	10	617	1,252	179	117	3	0	0	0	0	0	0	0	0	1	445	1,957	630	1,690
JF	187	832	33	56	16	991	2,670	49	3,221	54	6	0	11	0	0	0	0	0	0	62	919	11,541	2,285
EXT	15,135	9,791	6,982	3,762	1,868	12,323	2,028	2,165	2,152	44,799	60,733	1,004	28,585	524	924	333	391	444	447	562	2,932	3,349	0

Table 4.5 HBW Jurisdiction to Jurisdictions Trips

	DC	MTG	PGC	ARL	ALX	FFAX	LDN	PW/MN	FRD	HWD	ANNE	CHL	CAR	CAL	STM	KGRG	FBURG	STF	SPT	FQR	CLK	JF	EXT
DC	122,786	7,622	66,315	4,685	438	267	0	0	0	1	15	5,807	0	152	1,759	1	248	123	339	0	0	0	1,611
MTG	28,366	341,042	60,124	1,036	64	5,463	169	0	4,879	621	216	96	57	603	6,797	4	1,536	839	2,676	0	0	0	3,684
PGC	9,192	3,772	249,495	53	14	3	0	0	0	507	4,585	38,615	0	8,580	2,854	0	20	12	22	0	0	0	2,475
ARL	543	6	65	52,927	8,291	12,493	0	3	0	0	0	2	0	4	84	0	49	24	119	0	0	0	598
ALX	44	0	254	10,866	32,773	6,378	0	18	0	0	0	76	0	2	91	0	41	53	71	0	0	0	411
FFAX	122	14	1,610	19,487	34,235	396,162	31,383	19,273	0	0	0	414	0	40	1,386	2	6,796	5,021	7,775	266	0	0	4,224
LDN	0	0	0	0	0	1,225	62,203	16	130	0	0	0	0	0	3	0	62	47	83	24	221	272	523
PW/MN	0	0	0	0	2	901	910	120,477	0	0	0	0	0	1	29	1	10,178	42,898	7,043	7,511	0	0	1,488
FRD	0	45	0	0	0	0	624	0	75,138	2	0	0	47	3	21	0	27	17	39	0	0	668	648
HWD	2	2,255	12,961	0	0	0	0	0	1,756	88,106	4,519	19	454	142	1,875	1	106	58	61	0	0	0	17,150
ANNE	1	12	4,611	0	0	0	0	0	0	1,167	165,196	16	0	8,841	1,827	0	3	1	16	0	0	0	15,504
CHL	0	0	32	0	0	0	0	0	0	0	0	30,761	0	1,013	4,246	8	0	0	1	0	0	0	287
CAR	0	60	0	0	0	0	0	0	4,714	941	0	129	34,283	863	5,261	2	772	443	774	0	0	0	11,429
CAL	0	0	0	0	0	0	0	0	0	0	0	0	0	12,097	555	0	0	0	0	0	0	0	102
STM	0	0	0	0	0	0	0	0	0	0	0	3	0	9	14,365	0	0	0	0	0	0	0	116
KGRG	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	4,288	353	325	100	0	0	0	67
FBURG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,637	105	605	0	0	0	30
STF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	10,483	13,590	3,245	0	0	0	146
SPT	131	95	145	219	198	840	108	289	1	15	47	131	2	78	103	14	694	235	21,732	5	6	5	106
FQR	0	0	0	0	0	0	143	25	0	0	0	0	0	0	0	0	458	5,115	693	14,577	1	0	223
CLK	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	15	10	19	0	3,803	6	860
JF	0	0	0	0	0	0	11	0	1	0	0	0	0	0	0	0	1	0	1	0	231	14,755	1,209
EXT	1,188	2,937	3,134	503	422	2,482	642	918	719	14,472	17,591	488	9,077	188	234	45	193	371	246	235	1,041	1,271	0

Table 4.6 HBS Jurisdiction to Jurisdictions Trips

	DC	MTG	PGC	ARL	ALX	FFAX	LDN	PW/MN	FRD	HWD	ANNE	CHL	CAR	CAL	STM	KGRG	FBURG	STF	SPT	FQR	CLK	JF	EXT
DC	384,549	54,132	103,252	10,289	2,828	4,707	33	50	143	1,842	4,134	1,462	25	356	90	37	19	32	346	2	0	1	6,036
MTG	93,498	798,466	80,769	5,030	1,037	8,297	349	35	14,655	24,187	7,457	206	2,548	142	167	112	62	104	531	8	1	13	11,067
PGC	135,240	53,371	598,889	4,155	2,769	3,924	17	53	126	13,943	41,437	16,800	66	3,672	1,048	267	38	65	484	4	0	1	9,305
ARL	51,155	9,689	9,554	90,418	18,744	32,711	150	233	60	173	437	273	11	47	40	25	14	64	203	5	0	0	2,267
ALX	21,651	2,796	7,950	25,796	51,120	25,216	50	330	14	64	284	558	7	58	35	18	16	101	148	2	0	0	1,426
FFAX	109,868	59,360	48,253	108,089	80,700	990,466	39,184	23,508	941	954	1,874	3,334	193	472	766	491	673	3,485	2,453	1,690	31	37	15,889
LDN	2,034	4,582	585	1,538	429	36,089	152,955	1,714	9,410	148	210	95	142	92	210	208	115	196	577	837	935	1,398	2,516
PW/MN	10,350	3,174	4,621	8,031	7,314	80,780	5,709	326,949	255	164	449	395	158	203	629	778	7,536	38,342	11,678	10,357	59	18	5,454
FRD	211	10,317	160	28	6	94	1,023	6	184,157	3,262	118	26	9,262	26	29	34	29	52	113	4	13	386	2,240
HWD	1,922	14,531	14,149	55	13	71	5	2	2,758	186,571	17,754	22	3,791	23	48	32	18	30	275	2	0	1	50,823
ANNE	3,305	2,909	27,858	102	50	81	3	4	38	13,280	426,203	404	52	4,312	124	58	32	54	510	3	0	1	60,130
CHL	1,759	136	10,924	97	141	176	1	3	10	23	426	113,046	9	1,841	5,454	3,797	39	69	188	2	0	0	1,456
CAR	37	1,384	95	5	2	10	4	2	5,227	3,201	105	11	110,102	10	10	10	3	12	88	2	0	1	48,084
CAL	361	76	2,585	14	13	17	1	1	6	18	3,269	792	5	68,012	5,645	30	8	14	89	1	0	0	857
STM	29	11	288	2	2	5	1	1	4	5	22	2,933	2	2,442	84,863	836	12	20	111	1	0	0	962
KGRG	1	1	3	0	0	0	0	0	0	0	1	112	0	1	31	10,910	308	590	502	0	0	0	211
FBURG	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	77	8,154	1,139	2,709	1	0	0	128
STF	7	4	5	5	6	34	0	257	2	2	5	4	2	2	8	1,005	8,615	50,834	11,249	135	0	0	746
SPT	300	164	251	130	105	566	32	224	4	107	263	96	60	46	82	201	3,783	1,818	51,023	15	4	4	604
FQR	176	170	128	158	51	2,516	1,086	3,761	72	59	152	70	55	71	144	245	2,035	8,600	3,202	47,265	278	34	1,034
CLK	27	35	33	6	3	59	823	42	162	15	40	17	15	10	6	41	22	38	111	291	9,092	905	4,707
JF	64	296	77	14	7	65	1,624	10	5,260	63	96	33	67	18	6	56	53	89	256	26	1,019	39,520	6,738
EXT	6,094	7,590	6,821	1,883	1,210	8,890	1,695	2,560	1,647	35,124	44,631	1,029	31,376	607	717	219	218	733	583	599	2,884	3,843	0

Table 4.7 HBO Jurisdiction to Jurisdictions Trips

	DC	MTG	PGC	ARL	ALX	FFAX	LDN	PW/MN	FRD	HWD	ANNE	CHL	CAR	CAL	STM	KGRG	FBURG	STF	SPT	FQR	CLK	JF	EXT
DC	312,234	59,542	84,065	29,919	9,252	20,875	257	615	114	1,494	3,174	1,316	6	233	11	0	0	0	38	0	0	0	2,609
MTG	58,468	495,376	47,858	6,824	1,783	19,801	897	98	8,235	11,057	3,575	74	1,114	38	0	0	0	0	19	0	0	22	4,675
PGC	83,036	49,019	370,015	6,190	4,747	9,513	32	258	74	12,109	25,655	9,048	35	1,963	294	11	0	0	34	0	0	0	3,752
ARL	31,251	6,674	6,405	80,330	22,055	44,934	440	1,139	14	75	225	166	0	18	0	0	0	8	57	4	0	0	1,135
ALX	9,944	1,769	4,669	22,643	44,305	37,831	154	1,296	1	14	109	317	0	23	1	0	0	23	51	1	0	0	714
FFAX	21,001	17,380	9,545	45,726	38,964	581,099	30,886	25,497	119	128	154	522	2	28	1	0	2	274	343	1,059	17	13	6,499
LDN	293	844	33	488	171	30,212	97,631	2,562	1,558	4	0	0	6	0	0	0	0	0	9	599	461	800	1,078
PW/MN	712	189	331	1,177	1,370	25,883	1,944	170,948	3	0	0	7	0	0	0	5	128	3,202	293	3,067	17	2	1,929
FRD	79	7,982	41	10	0	122	1,686	5	125,490	1,484	11	0	3,607	0	0	0	0	0	0	1	29	896	1,285
HWD	1,558	11,450	12,502	64	10	122	3	0	1,373	121,084	14,166	2	1,678	4	0	0	0	0	3	0	0	1	21,921
ANNE	2,978	3,720	25,189	168	83	112	0	0	13	14,814	274,701	253	35	1,832	5	0	0	0	10	0	0	0	24,870
CHL	1,280	84	8,994	157	304	448	0	2	0	3	271	77,658	0	964	2,136	564	2	4	52	0	0	0	865
CAR	4	1,091	40	0	0	1	6	0	3,573	1,736	33	0	60,971	0	0	0	0	0	10	0	0	2	23,234
CAL	231	43	1,992	14	21	20	0	0	0	5	1,805	942	0	40,544	2,422	2	0	0	13	0	0	0	462
STM	12	0	286	0	0	0	0	0	0	0	5	2,090	0	2,409	59,899	113	0	0	37	0	0	0	514
KGRG	0	0	10	0	0	0	0	5	0	0	0	481	0	2	97	10,197	241	546	283	2	0	0	168
FBURG	0	0	0	0	0	4	0	135	0	0	0	1	0	0	0	206	20,800	5,784	6,030	55	0	0	103
STF	1	0	0	9	26	285	0	3,193	0	0	0	4	0	0	0	500	5,701	54,952	4,704	843	0	0	567
SPT	37	19	35	53	50	337	8	315	0	2	11	53	7	13	39	271	6,103	4,603	43,104	56	1	0	437
FQR	0	1	0	12	3	1,094	446	3,184	1	0	0	0	0	0	0	2	59	858	64	29,920	93	9	386
CLK	0	0	0	0	0	18	460	26	25	0	0	0	0	0	0	0	0	0	1	128	6,033	676	1,765
JF	0	22	0	0	0	10	813	2	845	1	0	0	2	0	0	0	0	0	1	13	713	22,666	2,530
EXT	2,513	4,494	3,619	1,098	692	6,279	1,045	1,863	1,231	21,125	23,960	832	22,336	447	493	160	97	540	415	371	1,706	2,434	0

Table 4.8 NHB Jurisdiction to Jurisdictions Trips

	DC	MTG	PGC	ARL	ALX	FFAX	LDN	PW/MN	FRD	HWD	ANNE	CHL	CAR	CAL	STM	KGRG	FBURG	STF	SPT	FQR	CLK	JF	EXT
DC	22,167	4,577	4,938	1,583	876	2,675	333	524	175	611	436	326	154	202	132	25	29	112	48	72	12	39	169
MTG	5,482	19,462	4,023	929	513	2,916	605	493	252	1,540	1,042	174	675	155	69	12	19	89	25	98	31	149	325
PGC	5,899	4,057	18,520	766	611	1,906	236	391	158	1,205	1,862	568	187	403	227	37	22	88	34	53	8	33	234
ARL	986	1,139	988	2,722	839	2,202	218	365	59	255	194	91	48	54	37	8	17	69	31	45	8	17	58
ALX	544	623	762	838	2,332	1,866	134	328	34	155	136	101	27	49	39	8	15	65	27	31	5	10	39
FFAX	1,556	3,325	2,314	2,163	1,873	23,827	2,183	2,569	235	717	466	299	157	153	113	27	82	344	143	384	67	123	229
LDN	189	672	276	211	132	2,095	3,953	560	216	170	74	31	83	14	8	2	12	52	20	173	93	190	80
PW/MN	304	588	480	359	329	2,576	510	7,048	58	148	107	72	24	37	23	24	104	481	169	390	34	41	91
FRD	212	173	154	53	31	222	208	59	7,306	208	77	8	402	5	3	1	1	3	2	22	25	144	150
HWD	729	1,505	1,196	258	159	765	180	158	182	6,767	898	45	352	45	18	3	1	6	2	9	6	32	185
ANNE	518	1,068	1,885	151	110	390	64	87	74	972	19,367	122	131	218	77	10	2	12	4	7	1	11	334
CHL	396	181	583	74	83	246	27	59	9	47	126	3,469	7	139	209	48	18	34	30	7	0	1	33
CAR	187	674	198	40	23	139	74	19	382	371	131	7	3,372	6	5	1	1	4	3	5	9	49	344
CAL	243	161	412	43	40	127	12	29	7	46	219	137	6	1,027	456	16	7	12	11	2	0	1	42
STM	161	75	232	30	32	92	7	18	3	19	78	207	5	458	2,552	44	18	30	29	3	1	2	57
KGRG	29	13	38	7	7	24	1	24	0	3	10	47	1	17	44	128	46	81	71	10	0	0	18
FBURG	37	24	25	15	14	76	11	100	1	1	3	17	1	7	18	44	485	471	543	40	2	1	33
STF	142	101	99	61	60	317	44	453	4	7	16	34	3	13	30	81	467	1,678	625	153	6	4	78
SPT	66	36	42	27	26	134	17	164	2	2	4	30	3	11	30	71	545	610	1,582	66	3	1	118
FQR	102	107	63	46	32	368	147	381	19	12	10	9	4	3	3	10	41	153	68	640	31	29	56
CLK	17	32	9	7	5	62	86	37	23	7	1	0	10	0	1	0	2	7	3	34	169	106	37
JF	47	154	31	15	9	111	180	44	140	37	12	1	51	1	2	0	1	5	1	33	108	803	52
EXT	199	327	239	51	35	211	72	89	135	197	333	34	339	42	57	18	37	77	124	57	37	52	0

Table 4.9 Medium Truck Jurisdiction to Jurisdictions Trips

	DC	MTG	PGC	ARL	ALX	FFAX	LDN	PW/MN	FRD	HWD	ANNE	CHL	CAR	CAL	STM	KGRG	FBURG	STF	SPT	FQR	CLK	JF	EXT
DC	7,270	1,667	1,665	287	225	690	99	164	63	225	378	93	38	57	63	7	10	41	31	27	6	18	1,691
MTG	1,794	1,844	1,366	195	145	820	198	215	326	614	487	488	116	68	40	4	10	55	20	44	12	41	2,559
PGC	1,905	1,458	4,641	151	167	496	85	146	64	480	837	116	43	104	83	8	8	40	22	26	4	17	1,976
ARL	167	238	179	311	146	336	37	64	13	51	46	29	8	10	12	1	2	10	8	7	2	4	289
ALX	122	178	191	147	331	458	33	84	12	48	47	48	8	12	16	2	3	13	9	7	2	4	296
FFAX	355	938	556	332	460	5,187	628	758	75	237	194	148	41	49	49	7	15	73	47	71	12	28	1,636
LDN	49	215	89	35	32	603	1,555	193	64	80	58	32	19	8	3	1	5	20	12	33	13	29	640
PW/MN	83	236	156	65	86	782	184	2,196	36	111	91	59	10	20	12	6	18	112	43	99	7	14	874
FRD	68	326	61	12	12	71	61	37	1,755	68	50	6	54	3	0	0	0	1	1	9	4	27	851
HWD	252	628	472	56	54	274	94	136	65	1,643	528	22	60	23	12	1	0	3	2	7	3	12	1,450
ANNE	423	516	835	39	41	177	54	85	49	575	5,715	52	39	77	53	4	0	8	4	6	1	9	2,391
CHL	176	102	341	21	34	109	25	47	11	32	74	399	3	47	69	8	5	16	14	6	0	0	286
CAR	42	118	43	7	7	37	17	8	54	62	39	2	232	1	0	0	0	0	1	1	2	6	1,201
CAL	65	71	106	9	11	46	8	18	5	23	79	34	1	255	105	3	3	6	6	1	0	0	182
STM	71	47	84	10	14	44	3	9	1	13	54	50	0	105	764	6	5	11	12	0	0	0	241
KGRG	7	5	7	1	2	7	1	6	0	1	4	6	0	2	5	10	4	10	8	2	0	0	47
FBURG	10	12	9	2	2	13	4	17	0	0	1	3	0	2	4	4	42	59	64	4	0	0	161
STF	41	54	36	9	11	64	16	103	2	4	12	10	0	6	10	10	56	305	85	21	2	1	354
SPT	34	29	25	7	8	43	11	42	1	2	5	9	1	5	12	8	65	87	223	10	1	1	452
FQR	29	44	26	6	7	69	29	98	8	9	9	5	1	1	1	2	4	22	10	130	3	5	212
CLK	7	12	4	1	2	11	12	8	4	3	1	0	2	0	0	0	0	2	1	3	21	12	108
JF	20	42	15	4	4	26	28	15	28	12	8	0	7	0	0	0	0	1	1	5	12	104	226
EXT	1,921	2,677	1,964	260	268	1,507	597	825	849	1,509	2,406	190	1,201	180	235	46	160	336	445	214	109	227	0

Table 4.10 Heavy Truck Jurisdiction to Jurisdictions Trips

Chapter 5 Mode Choice

This chapter discusses the mode choice component of the TransForM model and includes a discussion of both model calibration and validation. The mode choice model is based upon the MWCOG mode choice model which is briefly described below. In the TransForM model, we use the same mode choice equations as in Version 2.1 D of the MWCOG model, but with different constants. In some exploratory estimation, we found that similar model coefficients would be obtained with the panel survey data. Unlike the MWCOG model, the models applied are pure logit models without adjustments except for the constants. Also, the mode choice models are run in each loop of the overall model run. This also produces greater consistency in the model.

The MWCOG Mode Choice Model

When began the project, the mode choice component in the MWCOG model was not executed during every loop of the model although this has subsequently been changed.

Currently, the mode choice is performed by a FORTRAN program (COGMC.EXE) that is run once for each trip purpose (HBW, HBS, HBO and NHB). There are 3 main steps to the mode choice procedure: (1) Logit models to obtain probabilities, (2) Adjustment of logit probabilities to match district-to-district shares, and (3) application of resulting probabilities to input trips to obtain trips by each mode.

The logit model has 3 alternatives: transit, drive alone and carpool, and is applied to 21 market segments defined by:

- Transit Access
  - Short walk *at origin* – Short walk *at destination*
  - Short walk – Long walk
  - Long walk – Short walk
  - Long walk – Long walk
  - Drive – Short walk
  - Drive – Long walk
  - No transit access
- Auto Ownership
  - 0-auto household
  - 1-auto household
  - 2+-auto household

The resulting mode choice probabilities are then adjusted to match district totals.

After the mode choice model is run, there is an auto occupancy routine that separates SOV auto drivers into the number of 1-occupancy auto, 2-occupancy auto, and 3 or more-occupancy auto trips for each origin-destination (OD) pair. This is performed via linear equations that are a function of auto occupancy as follows:

$$\text{1\_Person\_Auto} = \text{SOV\_Auto\_Drivers} * (\alpha_1 + \beta_1 * \text{Auto\_Occupancy})$$

$$2\_Person\_Auto = SOV\_Auto\_Drivers * (\alpha_2 + \beta_2 * Auto\_Occupancy) + HOV\text{-}A\ (2)\ Drivers\ (for\ HBW\ only)$$

$$3+\_Person\_Auto = SOV\_Auto\_Drivers * (\alpha_3 + \beta_3 * Auto\_Occupancy) + HOV\text{-}B\ (3+)\ Drivers\ (for\ HBW\ only)$$

where α_i and β_i vary based on purpose and on whether or not the auto occupancy is above or below 1.12.

An issue with the MWCOG model is with the manner in which adjustments are made to the choice probabilities. These adjustments are introduced in order to obtain target district-to-district mode shares and also to introduce some distance-based adjustments (e.g., if the highway distance is short, households with higher auto availability are more likely to drive than the logit model predicts). Calibrating a mode choice model to target aggregate shares is a common and accepted practice. However, the MWCOG model makes linear adjustments directly to the transit and carpool probabilities, and then manipulation is performed to assure that all probabilities are between 0 and 1, and that they sum to 1. This method of calibration applies linear adjustments to a non-linear model (the probabilities), and therefore the resulting probabilities are no longer logit. This means that all of the beneficial properties of logit (such as being consistent with behavioral theory and having known mathematical properties) are lost. The preferable method of calibrating to district-to-district shares is to apply the adjustments as constants directly in the utility equations. These additional constants can be calibrated such that district-to-district shares are achieved, and the resulting probabilities are logit probabilities.

Mode Choice Analysis

Ideally, the best approach would be to estimate and employ a nested logit model (with a nest for the carpool alternative). It would also be desirable to predict utilization of the various transit modes instead of overall transit use. However, consistency with the MWCOG model and the small size of the panel survey necessitated the continued use of a two-stage Multinomial Logit model. The first set of models predicts the shares for the Drive Alone, Carpool and Transit modes. The second set of models predicts the shares of HOV2, HOV3 and HOV4+ drivers among the carpool trips.

The mode choice model is applied to 3 market segments only, which are based on vehicle ownership (0 vehicle, 1 vehicle and 2+ vehicle households). In order to facilitate this, the output matrix from the trip distribution had to be split into the above market segments. This was achieved by using zone factors based on the number of 0 vehicle, 1 vehicle and 2+ vehicle households for each zone.

The equations for the mode choice model and model coefficients were obtained from the MWCOG Travel Forecasting Model 2000 Calibration report. Some of the variables used to influence the shares are the peak and off-peak highway and transit skims, fares, operating costs, parking costs etc.

A second distinction in the TransForM model is that the choice of walk access to transit versus drive access to transit is predetermined based on the values of the walk and the drive access skim for each OD pair. If the generalized cost of the drive skim is less than the generalized cost of the walk skim for a particular OD pair, then drive access is preferred for that OD pair and the values of the drive access skims are used as the transit skim variable in the transit utility component. Likewise, the values of the walk access skims are used if the generalized cost of the walk access skim is less that that of the drive access skims. For OD pairs where walk or drive access to transit was infeasible, the transit choice was made unavailable.

Third, for the market segments with 0 vehicle households, the drive alone choice was made unavailable (unlike in the MWCOG model, which predicted shares for the drive alone alternative for 0 vehicle households).

Finally, the procedure of adjusting the shares to match observed shares and district to district totals was dispensed with. Instead, a calibration routine was developed at Caliper that adjusts the alternate specific coefficients of the individual utility components to match mode choice shares. This calibration routine was based on incremental logit coupled with a binary search algorithm to obtain the alternate specific constants. It must be noted that the calibration of the alternate specific constants was performed at regular intervals throughout the calibration effort, since the inputs to the mode choice (the congested highway travel times) were often updated during the calibration process.
In order to match certain district to district shares, dummy variables were used in the utility equation and the coefficients of these dummy variables were adjusted to yield appropriate district to district shares. For instance, a dummy variable for transit was used in the DC sub-region and a positive co-efficient was calibrated to achieve the correct share of transit users in DC.

The outputs of the mode choice model consists of drive alone, HOV2 and HOV3+ trips for each of the purposes. The person trips obtained after applying the MNL models are converted to auto trips using auto occupancy rates derived from the COG 2000 panel survey. The auto occupancy rates for the 4+ carpool trips derived from the COG survey are 4.55, 4.36, 4.36 and 4.38 for the HBW, HBS, HBO and NHB purposes respectively.

Mode Choice Utility Specifications

The mode choice utilities for each of the purposes are shown in tables 5.1 and 5.2. Note that unless a distinction is made, the coefficients in the table below are the same for the three market segments. A description of the variables is then provided.

Variable	Description	HBW	HBS	HBO	NHB
ASC_DA 1 Veh HH	Alternate Specific Constant for the Drive Alone mode for the 1 Veh HH market segment	-0.178	3.389	1.387	1.907
ASC_DA 2+ Veh HH	Alternate Specific Constant for the Drive Alone mode for the 2+ Veh HH	0.924	6.023	1.634	2.146

	market segment				
ASC_CP 0 Veh HH	Alternate Specific Constant for the Carpool mode for the 0 Veh HH market segment	-4.403	0.613	-0.050	0.229
ASC_CP 1 Veh HH	Alternate Specific Constant for the Carpool mode for the 1 Veh HH market segment	-2.218	1.232	-0.009	0.053
ASC_CP 2+ Veh HH	Alternate Specific Constant for the Carpool mode for the 2+ Veh HH market segment	-1.838	4.329	0.711	0.289
LUMI|Orig for DA	Land Use Mix Index at the origin zone for the Drive Alone mode only	--	2.267e-5	2.585e-5	1.369e-5
LUMI|Dest for DA	Land Use Mix Index at the destination zone for the Drive Alone mode only	-2.518e-5	2.438e-5	2.171e-5	1.3e-5
LUMI|Orig for Transit	Land Use Mix Index at the origin zone for the Transit mode only	4.49e-5	--	5.194e-5	--
LUMI|Dest for Transit	Land Use Mix Index at the destination zone for the Transit mode only	--	4.869e-5	2.307e-5	1.659e-5
Hwy IVTT	The Highway In-Vehicle Travel Time for the Drive Alone and the Carpool Modes	-0.03	-0.00912	-0.01902	-0.03242
Hwy Terminal Time	The Highway Terminal time for the Drive Alone and the Carpool Modes	-0.03	-0.00912	-0.01902	-0.03242
Hwy Oper Cost	The Highway Operating Cost based on 9.1 cents per mile for the Drive Alone and the Carpool Modes	-0.00425	-0.00416	--	--
Ln Hwy Oper Cost	The natural logarithm of the Highway Operating Cost for the Drive Alone and Carpool Modes	--	--	-0.78384	-0.86043
Hwy Park Cost	The Parking cost for the Drive Alone and the carpool modes	-0.00425	-0.00416	--	--
Hwy Toll	The Highway Toll for the Drive Alone and the carpool modes	-0.00425	-0.00416	--	--
Transit Walk Time	The Walk Access Time to transit for the walk to transit OD pairs (transit mode only)	-0.075	-0.02432	-0.04991	-0.0286
Transit Init Wait	The Initial Waiting Time for the transit mode	-0.075	-0.02432	-0.04991	-0.06695
Transit XFer Wait	The Transfer Waiting time for the transit mode	-0.075	-0.02432	-0.04991	-0.06695
Transit IVTT	The Transit In Vehicle Travel Time	-0.03	-0.00912	-0.01902	-0.06695
Transit Drive Access Time	The Transit Access Drive Time for the drive to transit OD pairs	-0.03	-0.00912	-0.01902	-0.03242
Transit Fare	The transit fare	-0.00425	-0.00912	--	--
Ln Transit Fare	The natural logarithm of the transit fare	--	--	-0.78384	-0.86043
Drive Bias for	The Drive Bias Dummy variable for the	-2.0499	-2.9	-2.9	-1.4

Transit 0 Veh HH	transit mode only for the 0 Veh HH market segment				
Drive Bias for Transit 1 Veh HH	The Drive Bias Dummy variable for the transit mode only for the 1 Veh HH market segment	-0.5876	0.0	-1.1	0.0
Drive Bias for Transit 2+ Veh HH	The Drive Bias Dummy variable for the transit mode only for the 2+ Veh HH market segment	-0.3571	2.0	-0.65	0.0
Short Walk Dummy	The Short Walk Dummy Variable for the transit mode only. Applies if walk to transit is the best option and if the walk time is less than 5 minutes	--	--	0.41346	0.76998
Metrorail Bias Dummy	The Metrorail Bias Dummy for the transit mode only. Applies if Metrorail IVTT is more than 25% of Total IVTT	--	0.84404	0.69708	1.47447
Carpool Hwy Time Savings	The Highway Time Savings by using Carpool (for the Carpool mode only)	0.03611	--	--	--
Counties Dummy for DC	The transit dummy variable for households in the DC sub-region (transit mode only)	1.35	--	--	--
Counties Dummy for Inner Ring VA	The transit dummy variable for households in the Inner Ring VA subregion (transit mode only)	-1.9	--	--	--

Table 5.1 Utility Specification for the Basic Mode Choice MNL Model

Table 5.2 shows the utility specification for the MNL model that splits carpool trips into 2 occupancy, 3 occupancy and 4+ occupancy trips. As in the previous specification, unless mentioned the coefficients apply to all the three market segments.

Variable	Description	HBW	HBS	HBO	NHB
ASC_3 Persons 0 Veh HH	Alternate Specific Constant for the 3 Persons alternative for the 1 Veh HH market segment	0	0	0	-0.92477
ASC_3 Persons 1 Veh HH	Alternate Specific Constant for the 3 Persons alternative for the 2+ Veh HH market segment	-1.47162	-0.92201	-0.31756	0
ASC_3 Persons 2+ Veh HH	Alternate Specific Constant for the 3 Persons alternative for the 0 Veh HH market segment	-1.88085	-0.48966	-0.15151	0
ASC_4+ Persons 0 Veh HH	Alternate Specific Constant for the 4+ Persons alternative for the 1 Veh HH market segment	0	0	0	-1.41003
ASC_4+ Persons 1 Veh HH	Alternate Specific Constant for the 4+ Persons alternative for the 2+ Veh HH market segment	-3.04973	-1.51854	0	0
ASC_4+ Persons 2+ Veh HH	Alternate Specific Constant for the 4+ Persons alternative for the 0 Veh HH market segment	-2.54494	-0.84071	0.21854	0
HOV2 Oper Cost	The HOV2 highway operating cost only for the 2 Person Alternative	-0.01124	--	--	--

HOV2 Toll	The HOV2 highway toll only for the 2 Person Alternative	-0.05077	--	--	--
HOV2 Time	The HOV2 highway time only for the 2 Person Alternative	--	-0.45633	-0.6853	-0.00709
HOV2 Distance	The HOV2 highway distance only for the 2 Person Alternative	--	--	--	-0.00187
HOV3+ Oper Cost	The HOV3+ highway operating cost only for the 3 and 4+ Persons Alternatives	-0.01124	--	--	--
HOV3+ Toll	The HOV3+ highway toll only for the 3 and 4+ Persons Alternatives	-0.05077	--	--	--
HOV3+ Time	The HOV3+ highway time only for the 3 and 4+ Persons Alternatives	--	-0.45633	-0.6853	-0.00709
HOV3+ Distance	The HOV3+ highway distance only for the 3 and 4+ Persons Alternatives	--	--	--	-0.00187

Table 5.2 Utility Specification for the Carpool MNL Model

In the above tables, it must be noted that the peak highway skims are used for the HBW trip purpose, whereas the off peak skims are used for all the other modes. The HOV skims are used in the second MNL model that splits the carpool trips into 2, 3 and 4+ occupancy trips. The skim values for the highway modes are expressed in tenths of miles and minutes in the above equations.

For the transit trips, depending on whether walk or drive is likely (based on the total generalized cost), the walk skim times or the drive skim times are used.

The Land Use Mix Index is a variable used in the above specification and is defined as LUMI = (HH_POPD * N_EMPD)/(HH_POPD + N_EMPD), where

HH_POPD = Household population density and
N_EMPD = Normalized employment density

Further, the utility specification for the main MNL model includes sub-region dummy matrices for the transit alternative in the HBW purpose (for the DC and the Inner Ring VA sub-regions). This variable was introduced to capture the relatively higher use of transit in the DC sub-region for the work purpose.

Mode Choice Results

The mode choice results for each of the purposes are shown in Tables 5.3 to 5.6. The percentages of the individual modes are indicated in brackets.

Market Segment	Drive Alone	Carpool	Transit	2_Person CP	3_Person CP	4+_Person CP
0 Veh HH	0 (0.0%)	90,986 (31.7%)	196,339 (68.3%)	30,377	30,304	30,304
1 Veh HH	758,120 (67.4%)	106,418 (9.5%)	260,298 (23.1%)	83,400	19,081	3,937
2+Veh HH	2,029,059 (86.6%)	138,359 (5.9%)	176,141 (7.5%)	112,445	17,107	8,806
All Segments	**2,787,180 (74.2%)**	**335,765 (8.9%)**	**632,779 (16.8%)**	**226,223**	**66,493**	**43,048**

Table 5.3 HBW Mode Choice Shares

Market Segment	Drive Alone	Carpool	Transit	2_Person CP	3_Person CP	4+_Person CP
0 Veh HH	0 (0.0%)	193,171 (91.4%)	18,121 (8.6%)	64,389	64,390	64,390
1 Veh HH	704,523 (89.4%)	73,460 (9.3%)	10,042 (1.3%)	45,436	18,071	9,952
2+Veh HH	1,353,583 (85.0%)	233,925 (14.7%)	5,516 (0.3%)	114,427	70,130	49,368
All Segments	**2,058,106 (79.4%)**	**500,557 (19.3%)**	**33,680 (1.3%)**	**224,253**	**152,592**	**123,711**

Table 5.4 HBS Mode Choice Shares

Market Segment	Drive Alone	Carpool	Transit	2_Person CP	3_Person CP	4+_Person CP
0 Veh HH	0 (0.0%)	519,124 (91.2%)	50,378 (8.8%)	173,027	173,048	173,048
1 Veh HH	1,701,007 (79.5%)	390,967 (18.3%)	48,664 (2.3%)	143,282	104,342	143,342
2+Veh HH	3,138,855 (71.8%)	1,181,756 (27.0%)	53,409 (1.2%)	380,605	327,293	473,857
All Segments	**4,839,863 (68.3%)**	**2,091,848 (29.5%)**	**152,452 (2.2%)**	**696,915**	**604,684**	**790,248**

Table 5.5 HBO Mode Choice Shares

Market Segment	Drive Alone	Carpool	Transit	2_Person CP	3_Person CP	4+_Person CP
0 Veh HH	0 (0.0%)	397,169 (90.4%)	42,403 (9.6%)	237,490	94,194	65,484
1 Veh HH	1,263,876 (85.0%)	185,346 (12.5%)	37,046 (2.5%)	59,190	59,190	66,965
2+Veh HH	2,230,173 (85.8%)	335,741 (12.9%)	33,652 (1.3%)	106,243	106,242	123,254
All Segments	**3,494,049 (77.2%)**	**918,256 (20.3%)**	**113,102 (2.5%)**	**402,924**	**259,627**	**255,704**

Table 5.6 NHB Mode Choice Shares

Table 5.7 shows the estimated versus the observed mode choice shares. The observed mode choice shares are from the COG 2000, Version 2.1D Draft #50 report. In the table below, the auto occupancy factor is defined as the ratio of the share of the non-transit trips (that is the sum of shares of drive alone and carpool trips) to the share of drive alone trips.

Purpose	Observed Transit Pct	Estimated Transit Pct	Observed Auto-Occ Factor	Estimated Auto-Occ Factor
HBW	16.9	16.8	1.12	1.12
HBS	1.2	1.3	1.23	1.24
HBO	2.1	2.2	1.44	1.43
NHB	2.5	2.5	1.25	1.26

Table 5.7 Estimated versus Observed Mode Choice Shares

HBW Mode Choice Analysis

Since a significant percent of the HBW trips are transit trips, the HBW shares are analyzed in greater detail below.

The mode choice results for the HBW purpose are listed by jurisdiction in Table 5.8 and 5.9. Table 5.8 shows the shares of trips originating from the jurisdiction, whereas table 5.9 shows the shares of trips destined to the jurisdiction.

Jurisdiction	Drive Alone Pct	Transit Pct	Carpool Pct
District of Columbia DC	25.9	68.9	5.2
Montgomery MD	65.8	26.8	7.4
Prince George's MD	64.4	27.1	8.5
Arlington VA	54.9	37.0	8.1
Alexandria VA	59.2	31.9	8.9
Fairfax and Falls Church VA	84.4	5.8	9.8
Loudoun VA	89.6	0.6	9.8
Manassas & PrinceWilliam VA	84.1	6.3	9.6
Frederick MD	88.0	0.0	12.0
Howard MD	83.5	6.8	9.7
Anne Arundel MD	86.0	2.0	12.0
Charles MD	87.0	1.4	11.6
Carroll MD	88.9	0.0	11.1
Calvert MD	87.8	1.8	10.4
St. Mary's MD	87.6	0.0	12.4
King George VA	88.2	0.0	11.8
Fredericksburg VA	79.2	0.0	20.8
Stafford VA	90.3	0.4	9.3
Spotsylvania VA	89.7	0.0	10.3
Fauquier VA	88.7	0.0	11.3
Clarke VA	87.1	0.0	12.9
Jefferson WV	86.2	0.0	13.8

Table 5.8 HBW Mode Choice Shares by Jurisdiction (Origin)

Jurisdiction	Drive Alone Pct	Transit Pct	Carpool Pct
District of Columbia DC	48.8	45.5	5.7
Montgomery MD	70.5	21.7	7.9
Prince George's MD	75.2	15.1	9.7
Arlington VA	66.7	23.6	9.7
Alexandria VA	73.1	17.9	9.0
Fairfax and Falls Church VA	85.1	4.6	10.2
Loudoun VA	89.4	0.2	10.4
Manassas & PrinceWilliam VA	87.4	3.1	9.6
Frederick MD	87.9	0.0	12.1
Howard MD	87.7	2.7	9.6
Anne Arundel MD	88.4	0.2	11.5
Charles MD	87.3	0.3	12.4
Carroll MD	91.0	0.0	9.0
Calvert MD	89.0	0.0	11.0
St. Mary's MD	87.7	0.0	12.3
King George VA	88.5	0.0	11.5
Fredericksburg VA	87.1	0.0	12.9
Stafford VA	89.7	0.0	10.3
Spotsylvania VA	89.1	0.0	10.9
Fauquier VA	89.2	0.0	10.8
Clarke VA	90.1	0.0	9.9
Jefferson WV	87.9	0.0	12.1

Table 5.9 HBW Mode Choice Shares by Jurisdiction (Destination)

In addition to the above shares, the sub-region to sub-region transit trips were observed. To facilitate this, the entire region is divided into 6 sub-regions as shown in Figure 6.1. The six sub-regions for study are:

1. DC
2. Montgomery, MD
3. Prince Georges County, MD
4. Inner Ring VA Counties (Fairfax, Fairfax City, Arlington, Alexandria)
5. Outer Ring VA Counties
6. Outer Ring MD Counties

The sub-regions are based on the density of transit routes in the region. For example, the transit coverage is the greatest in the DC sub-region and transit coverage in the outer ring counties is not as high.

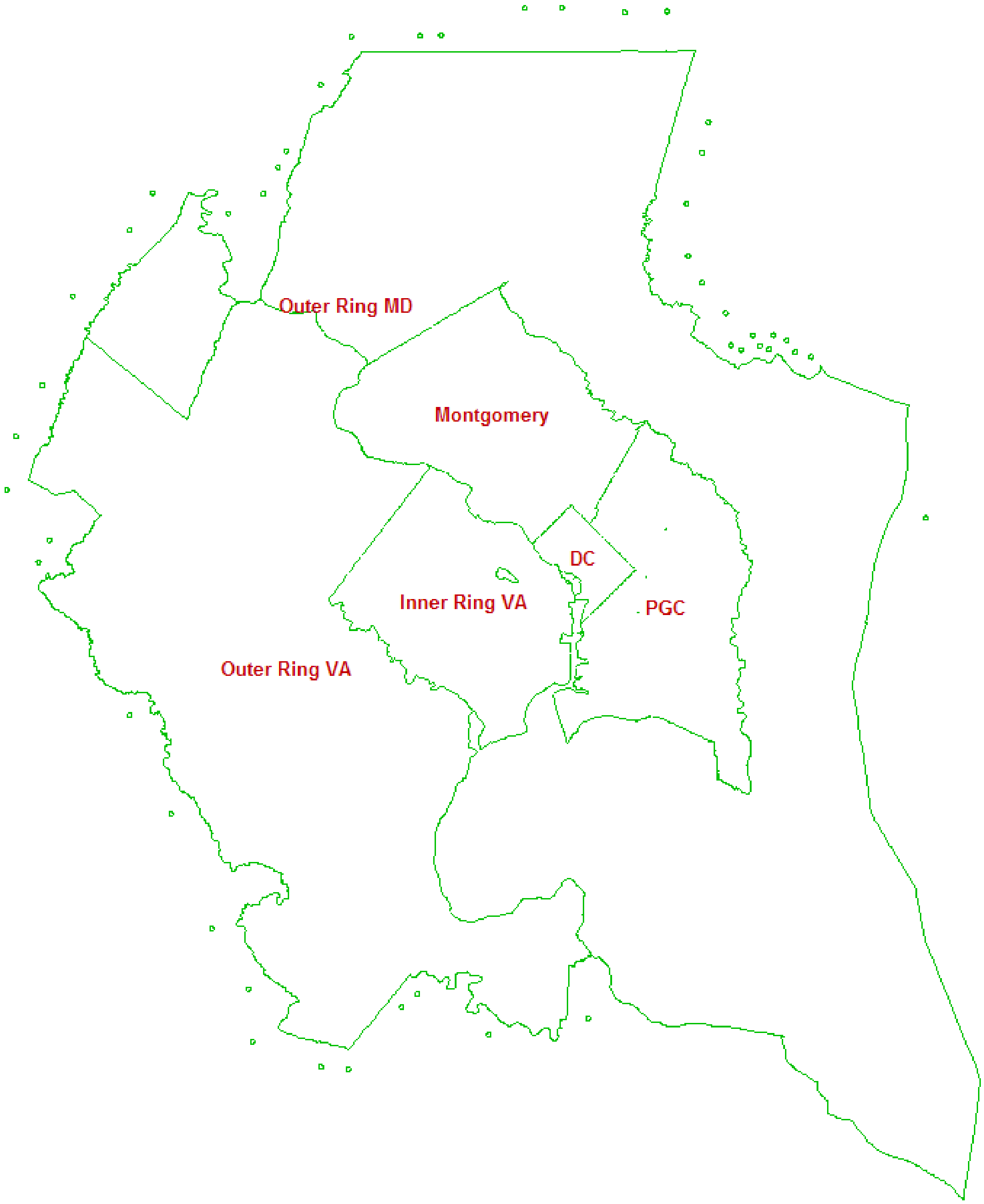

Figure 5.1 Sub-regions for Mode Choice Analysis

The CTPP Part 3 data from the 2000 census was used to determine the percentage of transit flows from sub-region to sub-region using the above classification. The model was then calibrated (with the help of dummy variables to capture transit flows in DC and Inner Ring VA) to approximate the trend of transit flow trips depicted by CTPP Part 3 data.

Tables 5.10 to 5.12 show the regional matrices depicting the percentages of auto and transit trips (for the HBW purpose). Note that the sum of the three matrices yields 100 percent in all the cells.

	DC	**Montgo-mery**	**PGC**	**Inner Ring VA**	**Outer Ring VA**	**Outer Ring MD**
DC	21.8	25.0	32.7	34.7	43.6	48.3
Montgomery	45.6	69.9	74.6	78.3	82.8	85.2
PGC	46.7	66.1	75.0	73.3	76.9	83.3
Inner Ring VA	58.2	77.6	79.8	81.4	87.2	84.3
Outer Ring VA	69.3	85.8	86.8	87.2	88.5	90.7
Outer Ring MD	79.3	86.8	86.9	87.0	88.1	88.7

Table 5.10 HBW Drive Alone Sub-region to Sub-region Shares

	DC	**Montgo-mery**	**PGC**	**Inner Ring VA**	**Outer Ring VA**	**Outer Ring MD**
DC	75.0	71.2	58.6	57.4	32.8	22.8
Montgomery	49.9	22.8	16.8	11.2	6.5	2.6
PGC	48.1	25.7	15.3	15.0	9.8	3.4
Inner Ring VA	34.9	13.1	9.2	8.6	2.5	3.2
Outer Ring VA	22.0	5.3	4.1	3.0	1.2	0.3
Outer Ring MD	11.3	3.1	2.8	2.4	0.1	0.3

Table 5.11 HBW Transit Sub-region to Sub-region Shares

	DC	Montgo-mery	PGC	Inner Ring VA	Outer Ring VA	Outer Ring MD
DC	3.2	3.8	8.7	7.9	23.6	28.9
Montgomery	4.5	7.3	8.6	10.5	10.7	12.2
PGC	5.2	8.2	9.7	11.7	13.3	13.3
Inner Ring VA	6.9	9.3	11.0	10.0	10.3	12.5
Outer Ring VA	8.7	8.9	9.1	9.81	10.3	9.0
Outer Ring MD	9.4	10.1	10.3	10.6	11.8	11.0

Table 5.12 HBW Carpool Sub-region to Sub-region Shares

The above three matrices illustrate a few points. For instance, the transit share is higher in the DC sub-region (both flows into DC and out of DC). This is according to expectations, since the transit coverage is most dense around this sub-region. The outer ring counties have fewer transit trips.

Figure 5.2 shows a pie-chart depicting the mode choice shares of trips originating in each sub-region. Figure 5.3 shows a pie-chart depicting the mode choice shares of trips terminating in each sub-region. Again, these graphs show a higher transit percentage for the DC sub-region.

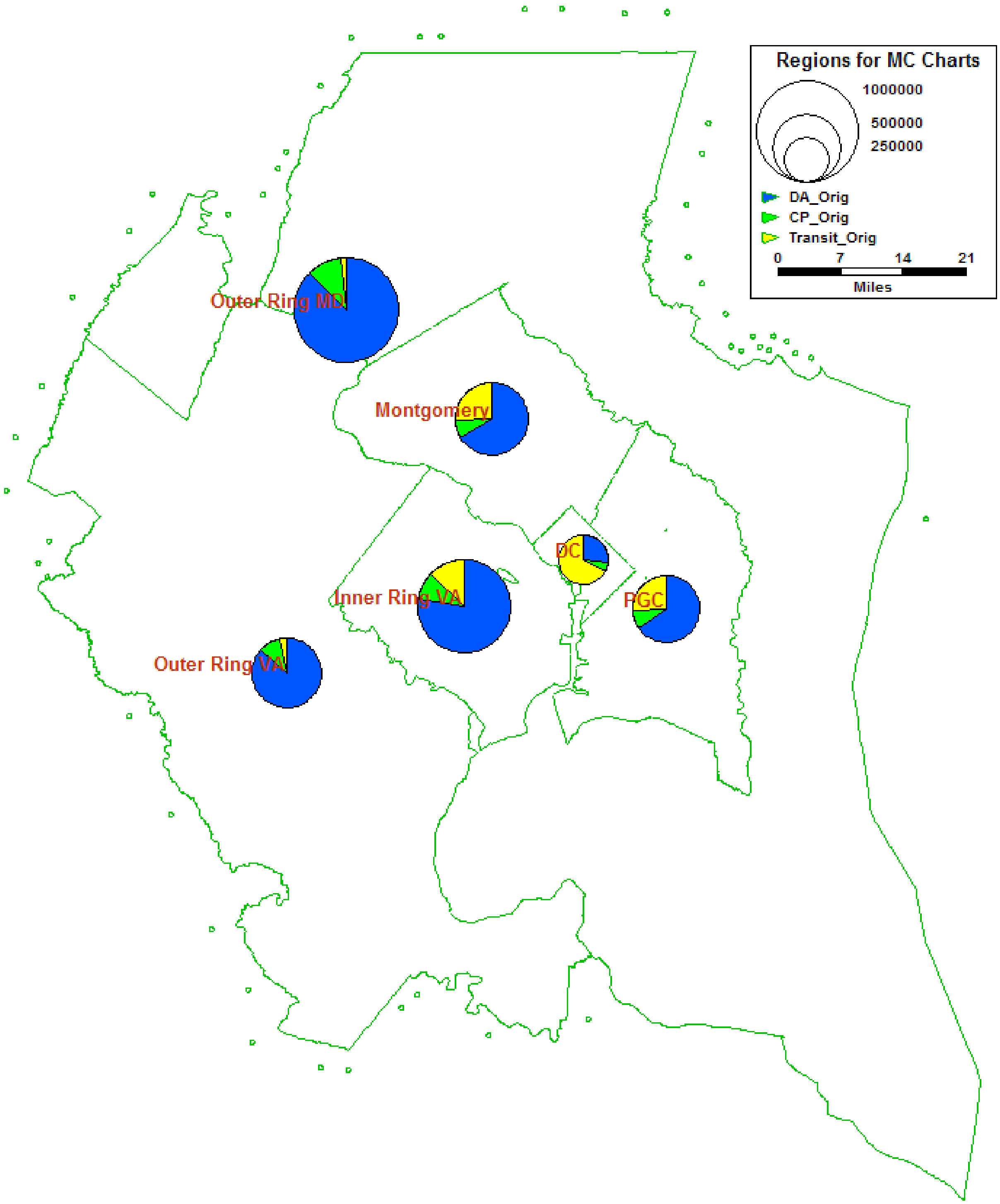

Figure 5.2 Mode Shares of HBW Trips – Origin

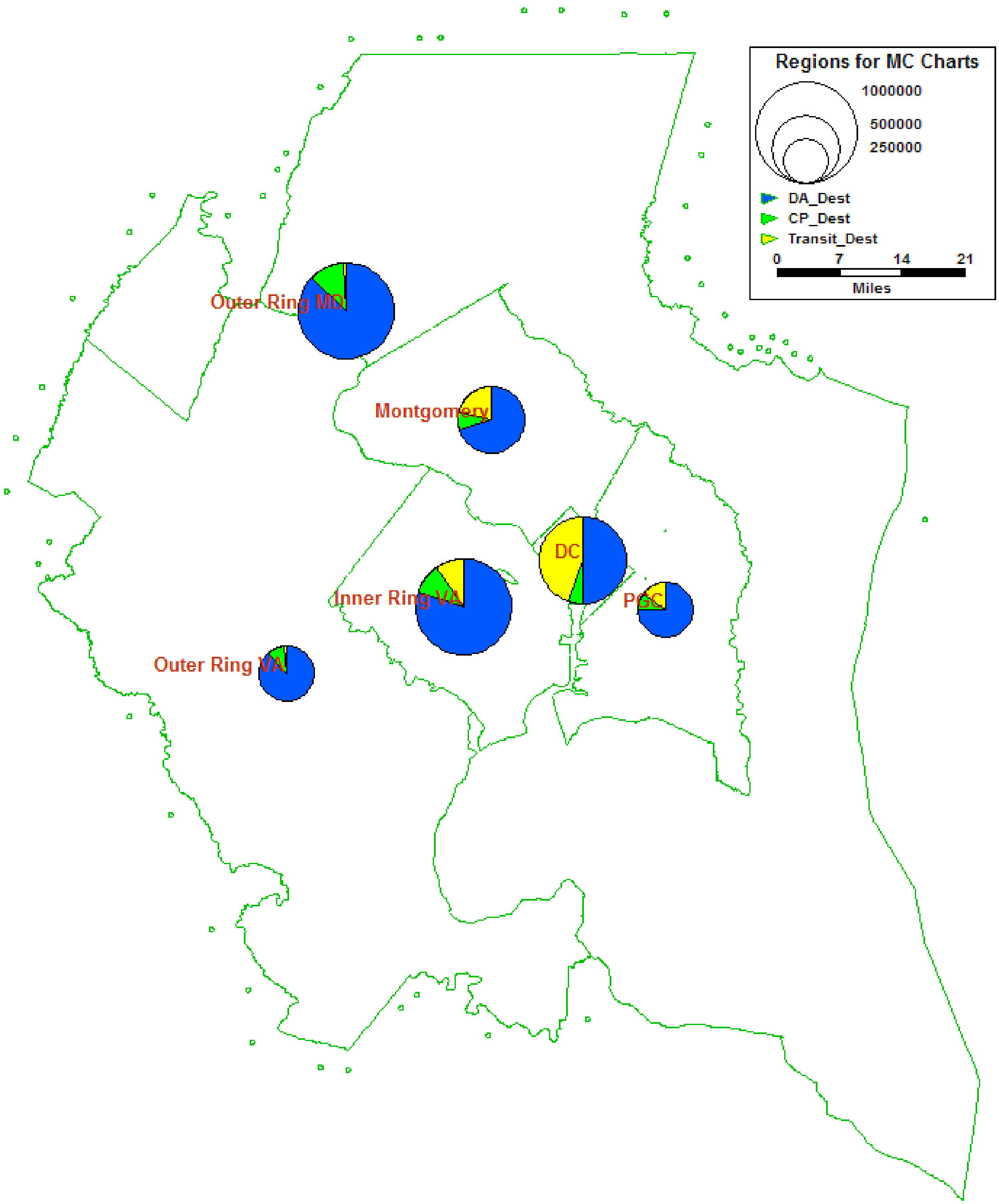

Figure 5.3 Mode Shares of HBW Trips – Destination

Table 5.13 shows the final auto trips for each purpose for the LOV, HOV2, HOV3+ modes and also shows the final transit person trips.

Purpose	LOV Trips	HOV2 Trips	HOV3+ Trips	Transit Trips (Person)
HBW	2,787,180	113,112	31,626	632,779
HBS	2,058,106	112,127	79,238	33,680
HBO	4,839,863	348,458	382,811	152,452
NHB	3,494,049	201,462	144,923	113,102

Table 5.13 Final Trips by Mode

Chapter 6 Time of Day Trip Allocation

This chapter describes the procedure used to allocate trips by time of day. The time of day routine generates AM, PM and Off-peak trip matrices from the output mode choice matrices. The procedure is performed in two parts-- first for miscellaneous trips (trips that are not modeled but are input to the model) and second for modeled trips. The procedure closely follows the MWCOG model, except that the time of day percentages for modeled trips were computed from the COG 2000 Panel Survey.

After the time of day factors are applied to obtain OD matrices by time period, the modeled trip matrices for each purpose are summed up by mode (SOV, HOV2, HOV3+) in preparation for traffic assignment. (In the TransForM model formulation, these modes are given as LOV, AUTO2 and AUTO3.)

Miscellaneous Trips Time of Day

The miscellaneous trips consist of additional matrices that are not modeled explicitly but are inputs to the TransForM model. The trips come from the following trip classes:

- External to External Auto Trips
- External to External Truck Trips
- Taxi Trips
- Visitor Trips
- School Trips
- Airport Trips

An input matrix with the above vehicle trips was used along with a time of day lookup table to generate miscellaneous trips for the three periods. The lookup table for the miscellaneous trips contains the percentage of trips for each of the above classes for each of the time periods. Additionally, the lookup table also consists of the factors to split the medium and heavy truck trips (that are modeled) into the three periods. The factors are shown in Table 6.1. These factors are from the MWCOG model.

Classification	AM Percent	PM Percent	OP Percent
Medium Truck Trips	19.5	15.2	63.3
Heavy Truck Trips	15.4	13.0	71.6
External Auto Trips	18.0	22.0	60.0
External Truck Trips	23.0	11.0	66.0
Taxi Trips	9.0	27.0	64.0
Visitor Trips	33.0	33.0	34.0
School Trips	33.0	33.0	34.0
Airport Trips	10.0	10.0	80.0

Table 6.1 Miscellaneous Time of Day Factors

For the external to external auto trips, the trips were further split into SOV, HOV2 and HOV3+ trips using the percentage splits of 50.21, 34.26 and 11.53 percent respectively.

Time of Day Allocation of Modeled Trips

This component of the time of day procedure splits the HBW, HBS, HBO and NHB trips by time period using departure and return percentages. The departure and return percentages were computed from the COG 2000 Panel Survey.

It was observed from the survey data (from Figure 6.1 below) that the time periods that appropriately classify the AM, PM and Off-peak periods were:

- AM – 6 AM to 9 AM
- PM – 4 PM to 6:30 PM
- Off-peak – Remaining hours

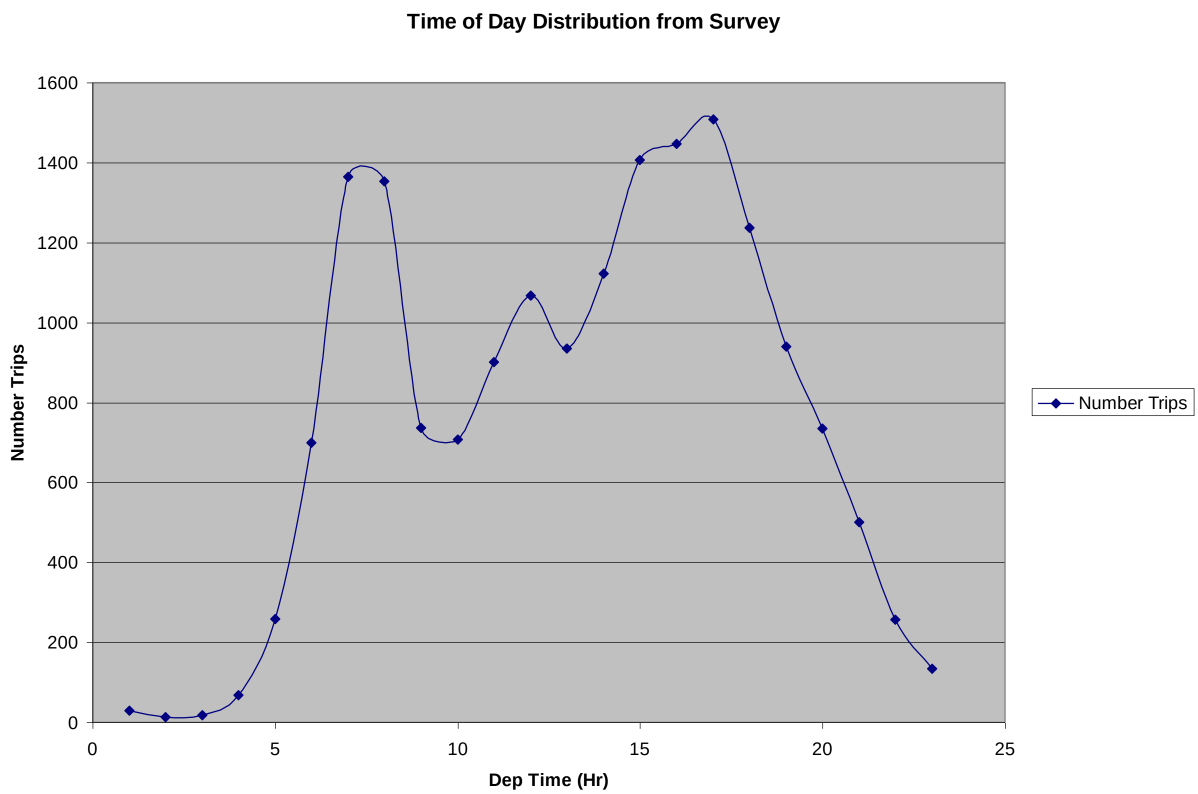

Figure 6.1 Time of Day Distribution from the COG 2000 Panel Survey

During the calibration process, several other configurations were examined to classify the periods. For instance, we tried MWCOG's recommendation that the PM peak be from 4 PM to 7PM. However, based on excessive flows in the PM period, we reduced the PM peak by 30 minutes (as is evident from the above graph).

The time of day factors are shown in Table 6.2. Note that each column constitutes 50 percent of the total trips for that purpose.

Period	HBW Dep	HBW Return	HBS Dep	HBS Return	HBO Dep	HBO Return	NHB Dep	NHB Return
AM	33.3	1.0	4.8	1.2	11.1	3.3	2.9	2.9
PM	1.3	28.5	37.8	34.0	30.6	35.8	39.1	39.1
OP	15.4	20.5	7.4	14.8	8.3	10.9	8.0	8.0

Table 6.2 Time of Day Departure and Return Percentages

The time of day procedure takes as input the SOV, HOV2 and HOV3+ trips for each purpose (from the mode choice results). The procedure then split the trips for each purpose using the above factors into the three time periods to produce departure and return trips for each purpose and mode. The return trips matrices are then transposed. Finally the AM, PM and OP trips by mode (SOV, HOV2 and HOV3+) are generated by summing the appropriate matrices. For example:

HBW AM SOV Trips = 0.333*(HBW SOV Trips) + 0.01*(Transposed HBW SOV Trips)

Finally, the modeled trips are combined with the miscellaneous trips to yield the final trip matrices (by time period and mode) for the assignment process.

Time of Day Results

Table 6.3 shows the final trip totals (both modeled and miscellaneous trips) from the Time of Day Analysis.

Mode/Period	AM	PM	OP	Total
SOV	2,182,533	2,977,341	8,650,250	13,810,123
HOV2	261,265	356,997	811,548	1,429,810
HOV3+	79,785	124,519	438,987	643,291
Truck	81,147	62,113	285,075	428,335
Airport	2,566	2,566	20,528	25,660
Total	**2,607,295**	**3,523,535**	**10,206,388**	**16,337,218**

Table 6.3 Time of Day Results

Chapter 7 Traffic Assignment

This chapter discusses the highway traffic assignment procedure and presents the assignment results. The major differences in the assignment methodology from that used in the MWCOG model are noted throughout the discussion. The model results are then described in detail. The results presented are the result of feedback loops run with the full model.

Traffic Assignment Inputs and Volume Delay Functions

In TransForM, the TransCAD Multi-Modal, Multi-class (MMA)User Equilibrium highway assignment procedure is run for each of the three time periods (AM, PM and OP). The primary inputs used in the assignment procedure are:

- Link travel times and capacities (from the appropriate peak or off-peak network).
- Link volume-delay function (VDF) parameters.
- Trip tables matrices for each time period by highway user class.

The AM and the PM assignments use the peak network whereas the OP assignment uses the off-peak network. The link free flow travel times and link capacities are obtained from the appropriate network file.

Five classes of traffic are assigned simultaneously. These are single occupant vehicles, HOV-2, HOV-3, trucks, and airport vehicle trips. The trip matrices are obtained after the time of day procedure and consist of 5 classes for each time period.

In addition to the above inputs, traffic assignment routines require the use of a delay function that computes congested link travel times depending on the flow of traffic on the link.

In the MWCOG model, which employs TP+, the volume-delay functions are specified as piecewise linear functions. Furthermore, an upper bound or ceiling is applied to the resulting congested travel times. If a volume-to-capacity ratio (v/c) exceeds the highest value specified in the volume delay function, the travel time no longer increases. In the Version 2.1 C of the MWCOG model that we initially reviewed and seemingly in Version 2.1 Draft #50, this cutoff in travel time occurs at a v/c ratio of 1.5. This practice is inconsistent with traffic assignment theory and also impairs the convergence of the MWCOG traffic assignment model.

In the TransForM model, we sought an improved approach, and we chose to use the BPR volume delay functions that are recommended for planning applications in the 2000 Highway Capacity Manual. Other choices would certainly be possible, but would require additional data that was not available. The form of the BPR functions is shown below:

$$t = t_f \left[1 + \alpha \left(\frac{v}{c} \right)^{\beta} \right]$$

where t is the congested travel time
t_f is the free flow travel time
α is the BPR alpha parameter
β is the BPR beta parameter
v is the volume on the link
c is the link capacity

The values of the link VDF parameters are defined based on the functional class of the link and are shown in Table 7.1. The corresponding delay curves are shown in Figure 7.1 below. The initial parameter values (α and β) were obtained from recommendations in the Highway Capacity Manual. Subsequently, some of the parameters were altered during the calibration process. The adjustment was based on the percent difference between the flows and the counts by functional class. These values along with the speeds and lane capacities are obtained from speed and capacity lookup tables input to the model.

Functional Class	BPR Alpha	BPR Beta
Freeways	0.25	9.0
Expressways	0.75	9.0
Major Arterials	1.25	6.0
Minor Arterials	1.00	5.0
Collectors	1.00	5.0
Ramps	1.00	6.0
Centroid Connectors	0.15	4.0

Table 7.1 BPR Link Delay Parameters

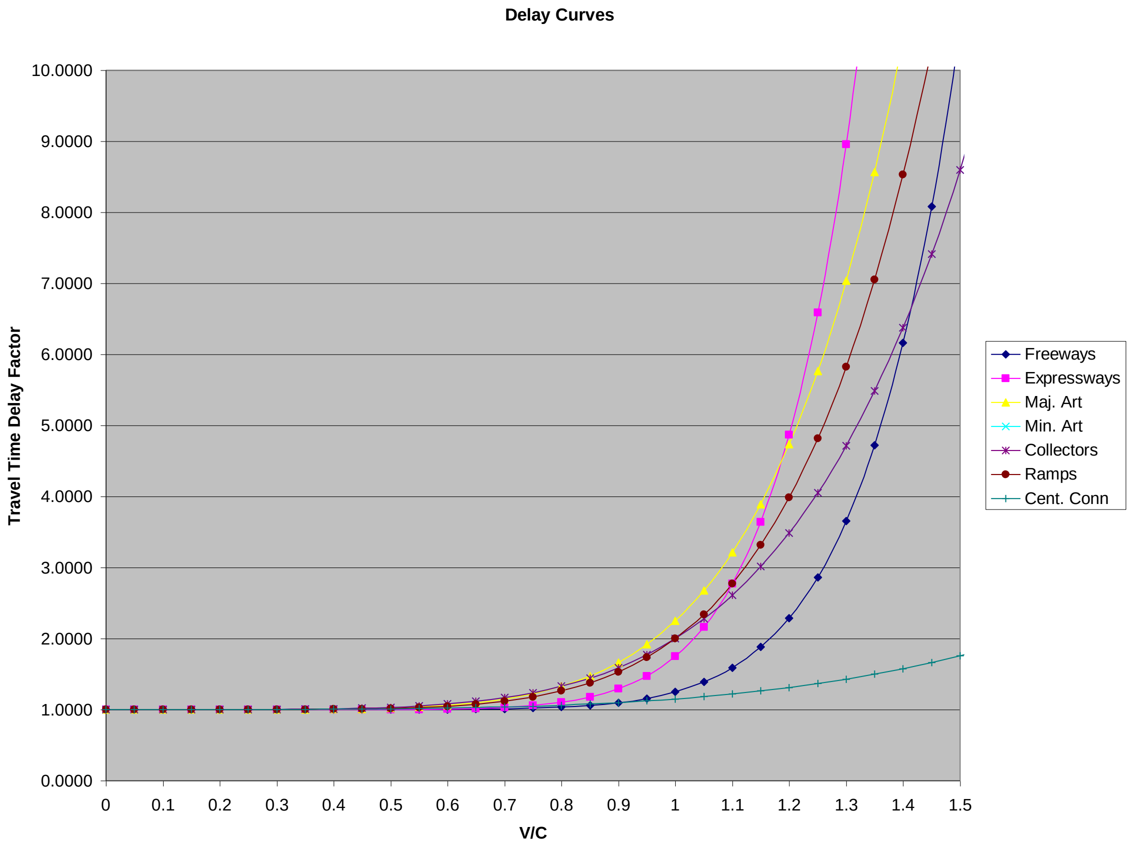

Figure 7.1 Volume Delay Functions based on Functional Class

Traffic Assignment Procedure

A multi-modal, multi-class assignment (MMA) is performed to assign the 5 classes. Three assignment routines are executed with one for each time period. The assignment employs exclusion sets for the vehicle classes to exclude the facilities that are prohibited for each vehicle class. This is achieved in TransCAD by disabling link segments by direction depending on the vehicle class. In addition, reversible lanes in the AM and the PM periods are incorporated using TransCAD's network update functions.

During the calibration process, the assignment procedures were run until convergence with a relative gap of 0.001. This is a much lower value than is typically encountered in U.S. modeling practice. It was observed that the number of iterations required to achieve this tolerance was somewhere between 80 to160 depending upon the time period and the level of congestion. The number of feedback loops varied depending upon the changes that were made in calibration.

The "relative gap" in TransCAD is a metric that has been shown in the literature to be one of the more useful and rigorous measures of convergence to user equilibrium. It is the same measure that is used in EMME/2. However, it is a very different and significantly more stringent measure than the measure that is named the "gap" in TP+.

The gap measure in TP+ is a measure of the difference between successive iterations of the assignment and is calculated as (VHT_i- VHT_{i-1})/ VHT_i. This is a very poor measure of convergence which overstates the actual convergence and gives improper signals to modelers to use too fewer iterations. Limiting the v/c ratio further reduces the gap although it does so artificially. This exacerbates the problem of premature termination of the traffic assignment.

While 0 .001 was used in calibration, we also set about determining the appropriate level of convergence to be used in model application. This is useful, because the selection of the gap and the feedback convergence criteria have a dominant impact upon model run times. We determined that for most purposes, a true relative gap of 0.01 in the traffic assignment would be sufficient. In the model, it takes 24-26 iterations to converge to below this value for the AM peak period, 18-21 iterations for the Off-peak period, and 46-50 iterations for the PM peak.

Assignment Procedure with Feedback

The TransForM model is run sequentially with feedback loops to get a more consistent estimate of traffic flows and transit utilization. In the first loop, all model steps are executed, and in subsequent loops, all steps except those prior to skimming and trip distribution are run again. One loop of the feedback consists of the highway skimming procedure (with the latest estimate of the congested times), trip distribution, mode choice procedure, time of day and traffic assignment procedures. During each feedback loop and after the assignment stage, TransCAD uses the Method of Successive Averages (MSA) to generate new estimates of the MSA link flows and the corresponding travel times for each of the three assignments (AM, PM and OP). These estimates are internally stored in the peak and Off-Peak network files. The MSA flows and times for the AM and the PM assignments are stored in the peak network file, whereas the MSA flows and times for the OP period are stored in the Off-Peak network.

After each run of the feedback loop, these MSA flow and time vectors are extracted from the respective network files. A weighted average of the AM and PM MSA times (using the AM and PM MSA flows as weights) is constructed to represent the peak congested link travel times, which are input into the skimming stage of the next feedback loop. Similarly, the off peak congested times are simply the OP MSA times extracted from the offpeak network.

Four loops of the model are typically executed. At the end of the feedback procedure, the final congested link flows and times are written out. With the current version of the model, a high degree of feedback convergence was also obtained. In particular, the differences between the final input skim matrix and the one that is consistent with the final solution has a root-mean-square error of less than one percent.

Another refinement in the calculation of the model to feedback convergence is the use of congested times for the initial skims. These were derived from prior model runs generated during the calibration effort and lead to a more highly converged, consistent, and fast running model.

The model with feedback takes approximately 6 hours to run on 2.1 GHz Core Duo Dell laptop. One loop of the model takes 1.5 hours on that machine. The model takes 1hour per loop and a total of 4 hours to run on a HP 2.2 GHz Dual Opteron 275 with two cores per chip. These relatively fast times are due in some measure to the multi-threaded traffic assignment in TransCAD. Further speed improvements are achievable with distributed processing and through several other optimizations that we have yet to apply.

Traffic Assignment Results

The results of the traffic assignment are presented in this section. Traffic flow maps for the entire region and for Prince George's County are provided to give an overview of regional traffic levels and their geographic distribution. A comparison of the model outputs with traffic counts is then provided using the root mean square error (RMSE) as a measure of how well the model fits ground counts. These RMSE values are provided for each time period and are for each county and functional class combination. The annual estimated Year 2000 VMT values from the model are presented by county and compared to the estimates from HPMS. Screenline analyses are also presented. Potential improvements to the model are suggested, wherever appropriate.

In viewing the results, it should be kept in mind that a principal focus was on achieving a closer calibration for the more detailed Prince Georges County network. This has been achieved, while at the same time the model fits well for other jurisdictions and the region as a whole. Undoubtedly, the model and the model calibration could be further improved by a similar focusing of attention on other counties and the District of Columbia. This would include adding links to the road network as well as revising centroid connectors. Also, we suspect that the development and application of some adjustment factors for county to county flows, survey underreporting, and data problems with traffic counts would result in a superior model. It is, however, encouraging that the model has relatively high goodness of fit without such adjustments.

In judging the comparisons with traffic counts and HPMS data, we suggest that a measure of caution is warranted. In our experience and in that of the MWCOG, there are many errors in published traffic counts, and these errors are a major impediment to the development of improved regional and local models. Our understanding is that MWCOG will attempt to remedy this situation in the future.

In the remainder of this chapter, we present the results of the traffic assignments after the full feedback process. Figure 7.2 shows the flow pattern of the daily flows for the entire region. Figures 7.3 to 7.5 show the flow patterns of the daily, AM and PM flows for the for an area containing the Beltway, the District of Columbia and the Prince George's County

In these figures, the width of the road segments depends on the modeled flow value, while the colors reflect the modeled volume to capacity (V/C) ratios. Links with a low V/C value (and hence less congested) are coded in green, whereas links with high V/C values are coded in red. Yellow and orange colors depict links within these extremes. The maps show that flow is generally higher into the DC region during the AM period and the reverse in the PM period. The PM peak period is generally more congested than the AM peak period.

The estimated Year 2000 regional vehicle miles of travel from the TransForM model is 154,409,000. This is comparable but somewhat higher than the corresponding estimate of 143,644,783 from the Version 2.1D, #50 forecast run of the MWCOG model.

Region	Daily VMT (in thousands)
TOTAL	154,409
DC	8,214
VA	57,412
MD	85,502

Table 7.2 Regional VMT Estimates

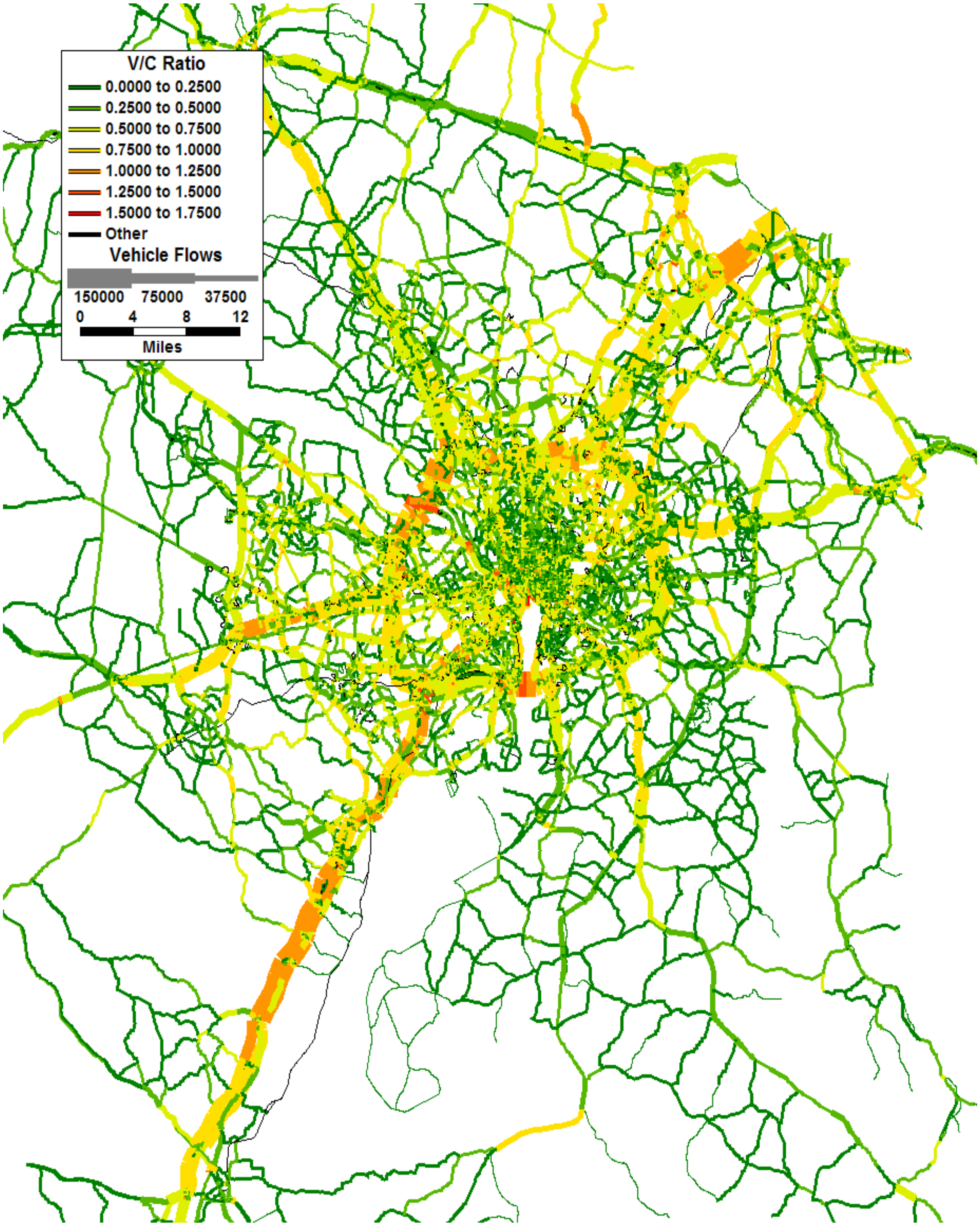

Figure 7.2 Daily Regional Traffic Flow Map

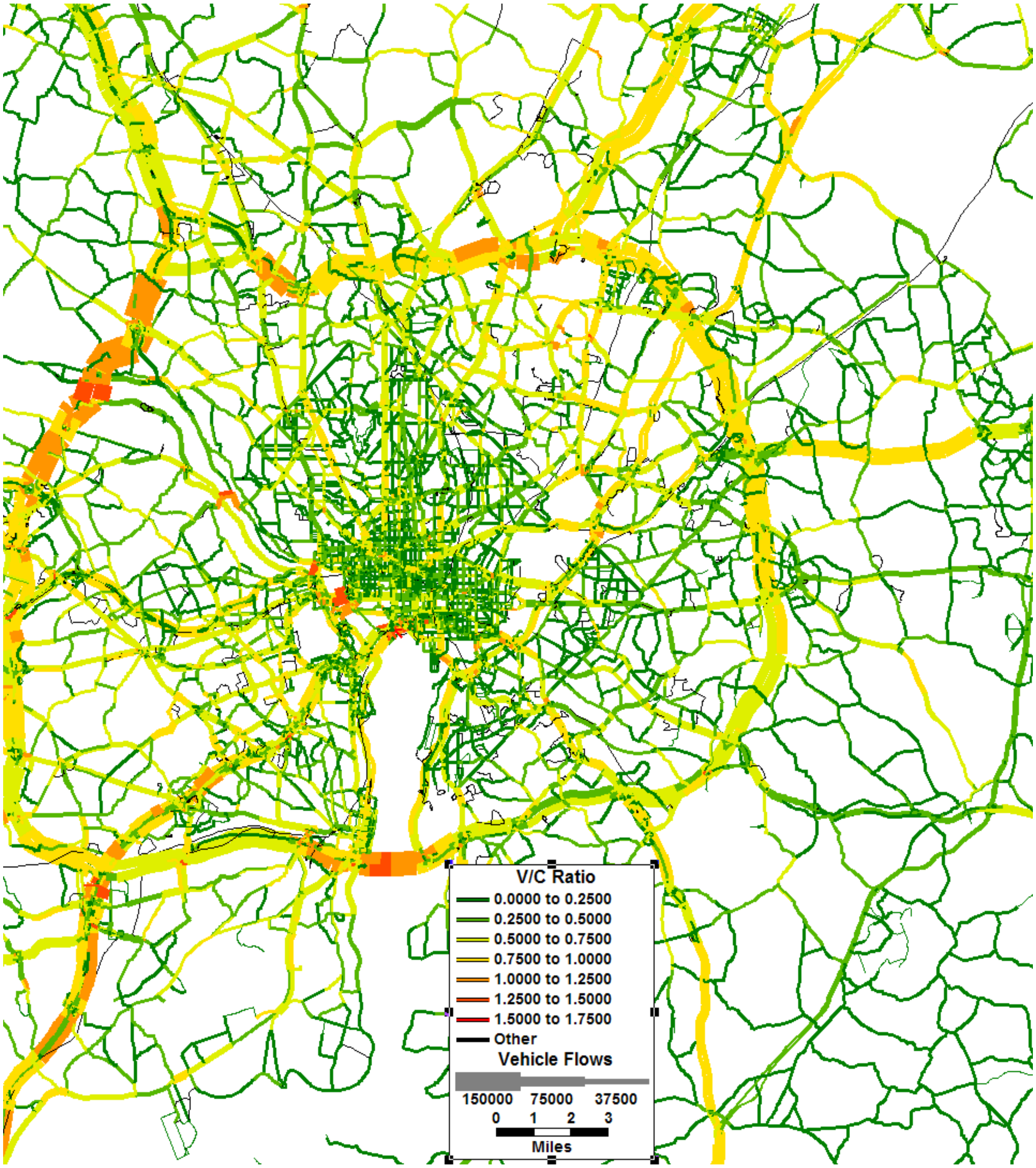

Figure 7.3 Daily Traffic Flows: Beltway, DC and Prince George's County

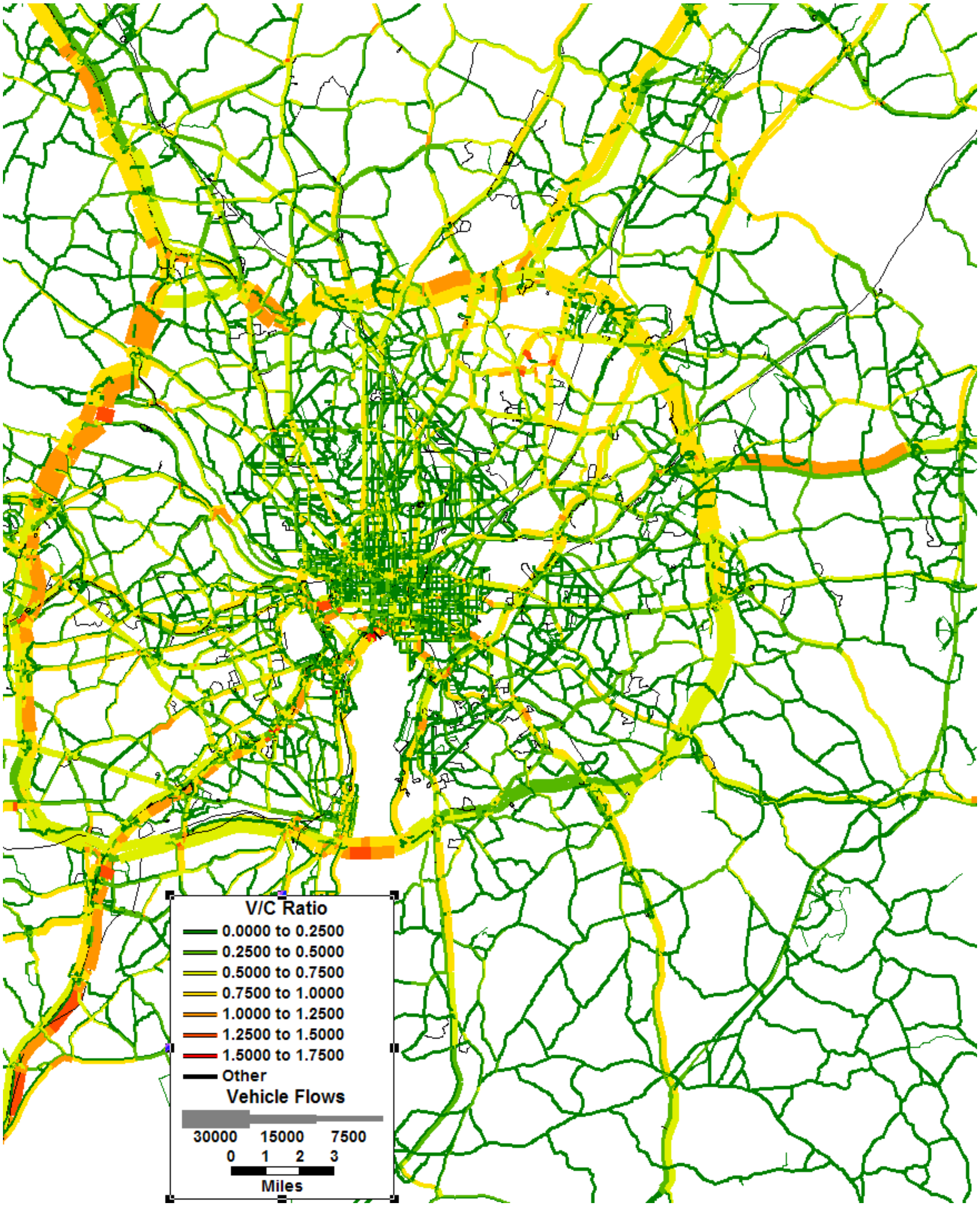

Figure 7.4 AM Traffic Flows: Beltway, DC and Prince George's County

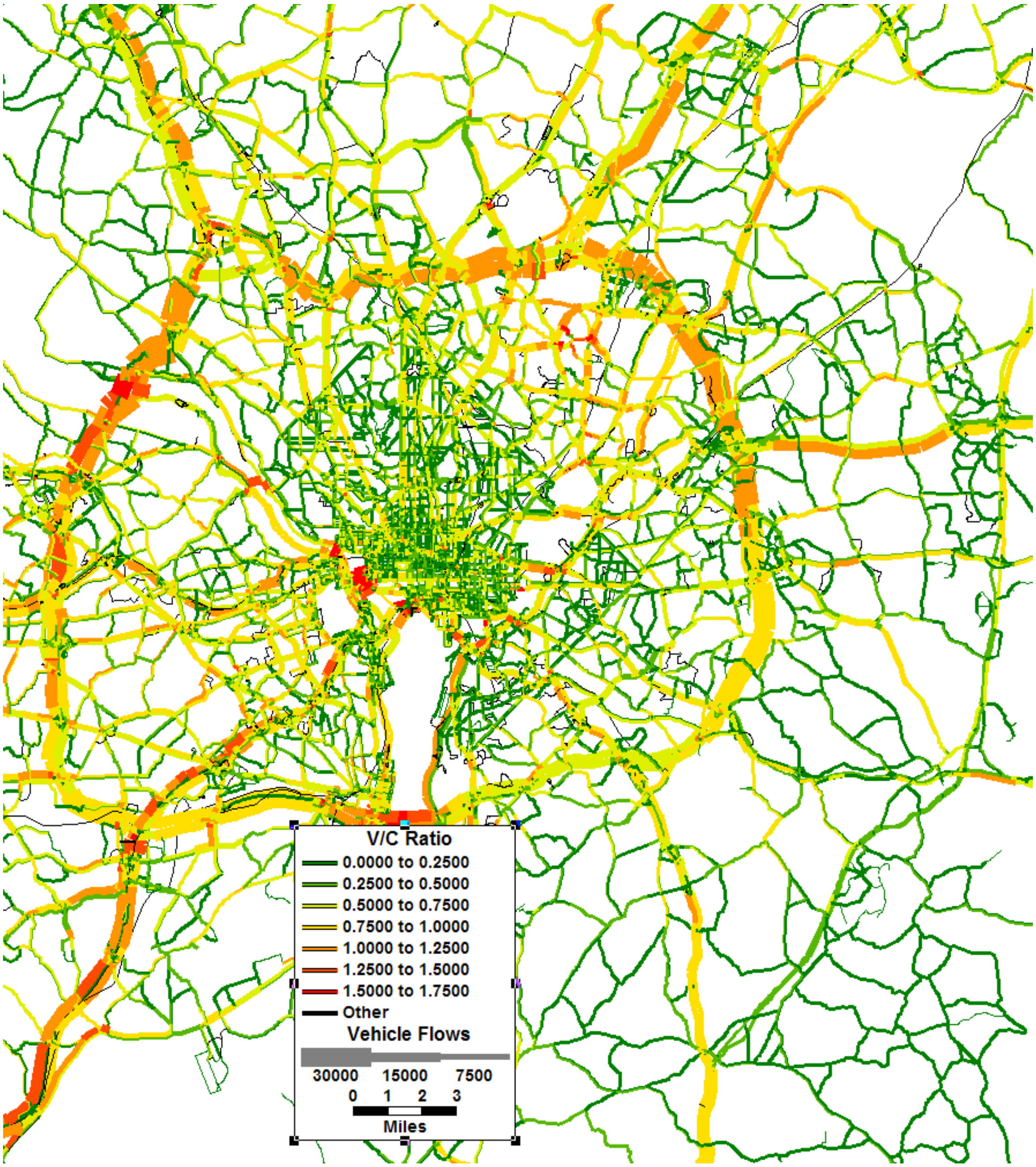

Figure 7.5 PM Traffic Flows: Beltway, DC and Prince George's County

Comparison of Model Output with Traffic Counts--RMSE Estimates

The model output was compared with available traffic counts. This is done using the root mean square statistic applied to the links for which counts are available.

The counts for comparison were obtained from the Prince George's County Planning Department, the Maryland and Virginia DOTs, and the District Department of Transportation. Counts by time period and direction were always sought, but not always available. The details of the count databases were discussed under the network building chapter (Chapter 2).

The Percent RMSE formula is given by:

$$\%RMSE = 100 * \sqrt{(\sum_i (Model_i - Count_i)^2 / (Numberofcounts - 1)} / (\sum_i (Count_i / NumberofCounts)$$

Table 8.3 shows the Daily RMSE statistics by county and functional class. In the tables below, it should be noted that RMSE statistics where the number of observations is 15 or below may not be meaningful and representative for that classification. Also, for the counties not listed, the count information was not available. Furthermore, it is obvious to us and also to MWCOG that not all published counts are correct.

The Daily Regional RMSE value for all the observations is 41.69 percent. The RMSE for freeways is 15.52 percent, which meets the acceptable standard of 20 percent or less. The results for Prince George's County were even better with an overall RSME of 35.74 and a value of 12.69 percent for freeways. The results for Montgomery County are also especially good with an overall RSME of 25.19 percent and 15.67 percent for freeways.

As regards other counties, it is to be noted that no additional calibration for these counties was performed. It is observed that the RMSE values for Montgomery County are acceptable and the model fits the counts well in Montgomery. However, for DC and Fairfax, the model warrants improvement as the RMSE's are higher than desired. In particular, it seems that the flows are higher in DC (by about 16 percent) and lower in Fairfax in comparison to the counts (by about 9 percent). A general observation from the flow maps is that this may be caused by a slightly high number of trips from Fairfax to DC (via the bridges). This could be due a variety of reasons that are not captured in the model currently but may be improved significantly with additional data. Nevertheless, the model fits the overall counts well, and the RMSE values on the major roads are well within the acceptable limits.

The RMSE values are provided by time period in Tables 7.4 to 7.6 that follow. Again, the RMSE for each time period for the overall network is acceptable and somewhat better for Prince George's County. Again, similar observations in the daily RMSE's can be made at the county level. In general, the RMSE values by time period tend to be higher than for daily values, as is reflected in the tables.

County	FClass	Pct RMSE	Num Obs	TotalFlow	TotalCount	Pct Diff
ALL Counties	**ALL Classes**	**41.33**	**2086**	**28,339,640**	**27,817,345**	**1.88**
ALL Counties	Freeways	15.42	105	7,334,492	7,508,328	-2.32
ALL Counties	Major Arterials	43.59	718	12,071,226	11,011,901	9.62
ALL Counties	Minor Arterials	53.30	671	4,484,348	4,324,570	3.69
ALL Counties	Collectors	89.49	411	1,015,660	1,407,578	-27.84
ALL Counties	Expressways	26.52	125	3,230,283	3,256,646	-0.81
ALL Counties	Ramps	60.47	36	199,584	227,187	-12.15
PG County	**ALL Classes**	**35.45**	**992**	**12,577,597**	**12,423,373**	**1.24**
PG County	Freeways	12.67	46	3,431,988	3,497,144	-1.86
PG County	Major Arterials	37.46	238	3,397,700	3,153,986	7.73
PG County	Minor Arterials	52.37	468	2,945,139	2,761,817	6.64
PG County	Collectors	72.03	118	232,675	336,000	-30.75
PG County	Expressways	25.69	97	2,429,552	2,506,410	-3.07
PG County	Ramps	36.23	17	136,495	135,566	0.69
Montgomery	**ALL Classes**	**23.83**	**80**	**2,725,916**	**2,814,693**	**-3.15**
Montgomery	Freeways	15.20	20	1,737,983	1,846,695	-5.89
Montgomery	Major Arterials	28.50	32	734,499	708,744	3.63
Montgomery	Minor Arterials	39.80	2	15,325	12,600	21.63
Montgomery	Collectors	54.67	2	7,134	11,598	-38.49
Montgomery	Expressways	23.79	5	167,883	143,435	17.04
Montgomery	Ramps	94.81	19	63,089	91,621	-31.14
DC	**ALL Classes**	**57.06**	**626**	**7,280,654**	**6,389,192**	**13.95**
DC	Freeways	16.46	4	164,143	185,300	-11.42
DC	Major Arterials	51.17	297	5,421,992	4,307,091	25.89
DC	Minor Arterials	57.40	121	905,259	907,321	-0.23
DC	Collectors	93.84	195	501,548	665,182	-24.60
DC	Expressways	22.25	9	287,710	324,298	-11.28
Fairfax	**ALL Classes**	**40.95**	**198**	**2,195,798**	**2,418,869**	**-9.22**
Fairfax	Freeways	16.54	8	578,959	557,809	3.79
Fairfax	Major Arterials	29.63	47	856,564	936,068	-8.49
Fairfax	Minor Arterials	42.86	56	476,054	519,270	-8.32
Fairfax	Collectors	95.59	72	223,956	306,925	-27.03
Fairfax	Expressways	44.89	3	60,263	50,112	20.26
Anne Arundel	**ALL Classes**	**37.82**	**33**	**624,763**	**673,250**	**-7.20**
Anne Arundel	Freeways	18.32	4	140,993	122,837	14.78
Anne Arundel	Major Arterials	40.64	20	356,720	435,325	-18.06
Anne Arundel	Collectors	96.04	4	2,329	9,500	-75.48
Anne Arundel	Expressways	32.88	3	114,722	104,888	9.38
Howard	**ALL Classes**	**25.79**	**25**	**962,657**	**1,028,012**	**-6.36**
Howard	Freeways	17.39	7	583,149	604,936	-3.60
Howard	Major Arterials	35.00	15	281,884	354,976	-20.59
Howard	Expressways	60.97	3	97,624	68,100	43.35
St. Mary's	**ALL Classes**	40.98	15	140,373	125,551	11.81
St. Mary's	Major Arterials	38.41	12	137,074	116,266	17.90
St. Mary's	Minor Arterials	80.44	3	3,298	9,285	-64.47

Table 7.3 Daily RMSE Statistics

County	Fclass	Pct RMSE	Num Obs	TotalFlow	TotalCount	Pct Diff
ALL Counties	**ALL Classes**	**47.49**	**843**	**3,745,524**	**3,888,632**	**-3.68**
ALL Counties	Freeways	23.74	113	1,636,587	1,617,642	1.17
ALL Counties	Major Arterials	61.14	326	1,201,246	1,262,583	-4.86
ALL Counties	Minor Arterials	73.20	135	193,020	203,433	-5.12
ALL Counties	Collectors	121.41	110	64,042	98,961	-35.29
ALL Counties	Expressways	41.58	124	618,086	657,161	-5.95
ALL Counties	Ramps	86.40	35	32,542	40,993	-20.62
PG County	**ALL Classes**	**38.48**	**332**	**1,758,609**	**1,757,420**	**0.07**
PG County	Freeways	21.25	49	745,415	730,482	2.04
PG County	Major Arterials	53.01	122	433,928	419,206	3.51
PG County	Minor Arterials	59.63	40	62,281	59,316	5.00
PG County	Collectors	122.57	9	757	3,293	-77.01
PG County	Expressways	39.84	96	493,036	523,538	-5.83
PG County	Ramps	59.33	16	23,190	21,585	7.44
Montgomery	**ALL Classes**	**25.70**	**100**	**712,029**	**704,921**	**1.01**
Montgomery	Freeways	12.99	26	474,737	475,984	-0.26
Montgomery	Major Arterials	40.88	37	191,864	179,430	6.93
Montgomery	Minor Arterials	59.83	8	6,300	7,952	-20.77
Montgomery	Collectors	126.92	4	4,422	3,243	36.37
Montgomery	Expressways	47.71	6	25,351	18,904	34.11
Montgomery	Ramps	115.86	19	9,352	19,408	-51.81
Fairfax	**ALL Classes**	79.57	204	515,914	550,121	-6.22
Fairfax	Freeways	46.46	12	154,134	143,159	7.67
Fairfax	Major Arterials	67.69	52	207,991	210,887	-1.37
Fairfax	Minor Arterials	77.51	62	99,412	109,226	-8.98
Fairfax	Collectors	120.70	75	43,228	70,114	-38.34
Fairfax	Expressways	50.24	3	11,146	8,876	25.58
Anne Arundel	**ALL Classes**	**57.72**	**41**	**168,816**	**255,960**	**-34.05**
Anne Arundel	Freeways	45.99	6	43,199	60,730	-28.87
Anne Arundel	Major Arterials	65.61	22	76,461	126,052	-39.34
Anne Arundel	Collectors	139.40	2	63	850	-92.58
Anne Arundel	Expressways	49.40	9	47,252	68,228	-30.74
Howard	**ALL Classes**	**32.89**	**32**	**220,004**	**232,157**	**-5.23**
Howard	Freeways	22.70	7	119,546	110,728	7.96
Howard	Major Arterials	44.82	18	68,051	89,705	-24.14
Howard	Collectors	44.54	2	3,162	3,900	-18.91
Howard	Expressways	33.16	5	29244	27824	5.10
St. Mary's	**ALL Classes**	**36.33**	**15**	**15570**	**19095**	**-18.46**
St. Mary's	Major Arterials	33.29	12	15117	17593	-14.07
St. Mary's	Minor Arterials	86.41	3	452	1502	-69.85

Table 7.4 AM RMSE Statistics

County	FClass	Pct RMSE	Num Obs	TotalFlow	TotalCount	Pct Diff
ALL Counties	**ALL Classes**	**39.03**	**782**	**3,667,168**	**3,669,254**	**-0.06**
ALL Counties	Freeways	20.80	91	1,354,067	1,356,892	-0.21
ALL Counties	Major Arterials	45.48	308	1,313,773	1,310,055	0.28
ALL Counties	Minor Arterials	59.43	135	252,800	243,517	3.81
ALL Counties	Collectors	102.97	104	78,850	108,989	-27.65
ALL Counties	Expressways	30.66	108	626,710	592,130	5.84
ALL Counties	Ramps	70.77	36	40,966	45,471	-9.91
PG County	**ALL Classes**	**29.34**	**314**	**1,761,158**	**1,687,670**	**4.35**
PG County	Freeways	14.21	41	657,477	667,116	-1.44
PG County	Major Arterials	40.95	120	498,003	452,312	10.10
PG County	Minor Arterials	48.81	40	81,620	68,182	19.71
PG County	Collectors	104.06	9	1,820	4,662	-60.95
PG County	Expressways	31.05	87	495,687	471,130	5.21
PG County	Ramps	51.38	17	26,549	24,268	9.40
Montgomery	**ALL Classes**	**29.24**	**89**	**614,647**	**596,844**	**2.98**
Montgomery	Freeways	18.10	20	349,546	342,700	2.00
Montgomery	Major Arterials	36.69	32	187,257	173,585	7.88
Montgomery	Minor Arterials	64.83	8	10,525	8,487	24.02
Montgomery	Collectors	147.02	4	6,224	3,582	73.76
Montgomery	Expressways	12.52	6	46,677	47,287	-1.29
Montgomery	Ramps	92.93	19	14,417	21,203	-32.00
Fairfax	**ALL Classes**	**55.36**	**195**	**500,386**	**569,683**	**-12.16**
Fairfax	Freeways	23.90	5	80,049	77,406	3.41
Fairfax	Major Arterials	45.66	51	221,986	242,809	-8.58
Fairfax	Minor Arterials	59.05	62	124,847	135,029	-7.54
Fairfax	Collectors	103.17	73	56,642	82,108	-31.01
Fairfax	Expressways	49.56	4	16,860	20,131	-16.25
Anne Arundel	**ALL Classes**	**58.60**	**37**	**187,000**	**186,729**	**0.15**
Anne Arundel	Freeways	71.48	7	51,591	58,457	-11.74
Anne Arundel	Major Arterials	45.53	23	105,644	102,846	2.72
Anne Arundel	Collectors	92.22	2	1,491	1,250	19.33
Anne Arundel	Expressways	24.13	3	26,116	23,951	9.04
Howard	**ALL Classes**	**27.25**	**26**	**215,754**	**237,947**	**-9.33**
Howard	Freeways	16.76	7	119,092	122,706	-2.94
Howard	Major Arterials	40.06	16	76,115	99,641	-23.61
Howard	Expressways	43.73	3	20,546	15,600	31.71
St. Mary's	**ALL Classes**	**49.20**	**16**	**39,554**	**35,211**	**12.34**
St. Mary's	Major Arterials	45.99	12	38303	31511	21.56
St. Mary's	Minor Arterials	77.42	4	1250	3700	-66.20

Table 7.5 PM RMSE Statistics

County	FClass	Pct RMSE	Num Obs	TotalFlow	TotalCount	Pct Diff
ALL Counties	**ALL Classes**	**37.14**	**786**	**10,226,905**	**10,950,521**	**-6.61**
ALL Counties	Freeways	22.40	104	4,540,086	4,785,669	-5.13
ALL Counties	Major Arterials	39.61	300	3,072,514	3,338,657	-7.97
ALL Counties	Minor Arterials	55.15	115	523,931	515,536	1.63
ALL Counties	Collectors	88.99	116	214,985	314,523	-31.65
ALL Counties	Expressways	30.34	116	1,772,918	1,852,274	-4.28
ALL Counties	Ramps	72.91	35	102,468	115,236	-11.08
PG County	**ALL Classes**	**25.92**	**296**	**4,740,900**	**4,899,784**	**-3.24**
PG County	Freeways	13.94	45	2,104,317	2,207,070	-4.66
PG County	Major Arterials	35.19	109	1,093,250	1,077,031	1.51
PG County	Minor Arterials	60.49	28	133,223	104,875	27.03
PG County	Collectors	87.14	8	2,790	8,575	-67.46
PG County	Expressways	28.61	90	1,344,169	1,438,007	-6.53
PG County	Ramps	51.19	16	63,148	64,226	-1.68
Montgomery	**ALL Classes**	**25.39**	**81**	**1,882,096**	**2,006,790**	**-6.21**
Montgomery	Freeways	17.76	25	1,295,620	1,423,749	-9.00
Montgomery	Major Arterials	27.48	30	437,805	441,675	-0.88
Montgomery	Minor Arterials	97.11	2	8,730	6,550	33.29
Montgomery	Expressways	28.88	5	100,619	83,806	20.06
Montgomery	Ramps	101.10	19	39,320	51,010	-22.92
Fairfax	**ALL Classes**	**68.38**	**205**	**1,356,013**	**1,523,007**	**-10.96**
Fairfax	Freeways	57.82	9	381,730	330,781	15.40
Fairfax	Major Arterials	31.98	51	502,859	583,834	-13.87
Fairfax	Minor Arterials	45.47	58	283,825	314,727	-9.82
Fairfax	Collectors	95.28	84	151,169	236,126	-35.98
Fairfax	Expressways	46.77	3	36,427	28,913	25.99
Anne Arundel	**ALL Classes**	**43.85**	**44**	**583,636**	**710,833**	**-17.89**
Anne Arundel	Freeways	50.97	7	140,346	179,964	-22.01
Anne Arundel	Major Arterials	42.39	24	253,742	314,702	-19.37
Anne Arundel	Collectors	102.53	2	692	2,400	-71.16
Anne Arundel	Expressways	29.82	9	182,851	213,392	-14.31
Howard	**ALL Classes**	**27.21**	**29**	**615,427**	**661,047**	**-6.90**
Howard	Freeways	18.78	7	344,510	371,502	-7.27
Howard	Major Arterials	29.75	16	192,355	226,570	-15.10
Howard	Collectors	10.82	2	9,669	10,400	-7.03
Howard	Expressways	64.31	4	68,892	52,575	31.04
St. Mary's	**ALL Classes**	**48.33**	**16**	**85690**	**73054**	**17.30**
St. Mary's	Major Arterials	44.75	12	83653	67162	24.55
St. Mary's	Minor Arterials	78.82	4	2037	5892	-65.43

Table 7.6 Off-Peak RMSE Statistics

It is significant that the comparisons between the model estimates and the counts are also fairly good by time period of the day. This supports the validity of the model in a way that a comparison with daily counts does not.

VMT Comparisons with Traffic Counts and HPMS

The estimated VMT from the model is compared below with that from the links on which there were traffic counts. The fit is good region wide, and especially so in Prince George's County. Additional calibration would be needed to improve the results for Virginia and the District of Columbia.

Region	**Model Daily VMT (thousands)**	**Count Daily VMT (thousands)**	**Ratio (Mod/Count)**
Overall	15,784	15,031	1.05
DC	1,342	1,212	1.11
VA	2,279	2,512	0.91
MD (including PGC)	11,894	11,072	1.07
Prince George's County, MD	5,816	5,776	1.01

Table 7.7 VMT comparison on links that have counts

The total estimated VMT for Prince George's County and the breakdown by functional class from the TransForM model is shown in Table 8.8 below. Two measures of annual VMT are shown. The Annual VMT (365) is obtained by multiplying the daily VMT by 365, whereas the Annual VMT (300) is obtained by multiplying the daily VMT by 300 to account for weekends, when the traffic flows are lower.

Table 7.8 compares the VMT summaries for Prince George's County (by functional class) with the VMT estimates from the HPMS database. It can be seem that the predicted VMT is fairly close to the HPMS estimates. In particular, the total HPMS VMT lies between the two annual VMT estimates calculated. Of course, the HPMS data come from a fairly small sample and may not be accurate.

Table 7.9 compares the VMT totals for all other counties for which the HPMS numbers were available. Again the model numbers were close to the HPMS statistics.

County	**Functional Class**	**Total Daily VMT (Veh-Mi)**	**Annual VMT(365) (Millions of Veh-Mi)**	**Annual VMT (300) (Millions of Veh-Mi)**	**HPMS Annual VMT (Millions of Veh-Mi)**
PGC	Freeway	6,668,396	2,433	2,000	2,665
PGC	Expressway	4,489,666	1,638	1,346	1,229
PGC	Maj. Art	5,932,370	2,165	1,779	1,917
PGC	Min. Art	3,524,828	1,286	1,057	930
PGC	Collector	663,904	242	199	552
PGC	Ramp	827,047	301	248	NA
PGC	Connector	1,635,873	597	490	431
PGC	**TOTAL**	**23,742,087**	**8,662**	**7,119**	**7,724**

Table 7.8 VMT Comparison for Prince George's County

County	Total Daily VMT (Veh-Mi)	Annual VMT(365) (Millions of Veh-Mi)	Annual VMT (300) (Millions of Veh-Mi)	HPMS Annual VMT (Millions of Veh-Mi)
Anne Arundel MD	12,813,310	4,674	3,840	5,130
Calvert MD	1,730,566	629	517	631
Carroll MD	4,419,591	1,610	1,323	1,156
Charles MD	3,145,026	1,145	941	1,098
Frederick MD	7,525,961	2,743	2,255	2,490
Howard MD	10,035,546	3,660	3,007	3,156
Montgomery MD	19,237,851	7,018	5,768	6,757
St. Mary's MD	2,248,703	818	673	722

Table 7.9 VMT Comparison for other Counties (All functional classes)

Here the same comments might apply. While the model estimates are fairly close to the HPMS numbers, it would be helpful if statistical analysis could provide some support for the HPMS measurements and their standard errors.

Screen Line Analysis

Several screen line analyses were performed as additional verifications of the validity of the model. This analysis was focused upon Prince George's County and was not performed for other jurisdictions.

A map highlighting the various screen lines employed in PG County is shown in Figure 7.6, which follows. Screen line comparisons are based on the aggregation of flows crossing the screen line boundary.

The screenlines examined are:

- Screenline 1A – SE DC/PGC Border- Southern Avenue Boundary
- Screenline 1B – NE DC/PGC Border – Eastern Avenue Boundary
- Screenline 2 – Inside I-95/I-495 Capital Beltway, concentric ring
- Screenline 3 – Mid-County Concentric ring outside the Capital Beltway
- Screenline 4 – Concentric ring along east side of US 301 and west of Patuxent river
- Screenline 5 – Southern Charles/PGC Border, east of MD 210
- Screenline 6 – East side of MD 210
- Screenline 7 – East side of MD 5, from Charles County to the Beltway
- Screenline 8 – South side of MD 4 from Anne Arundel County to the Beltway
- Screenline 9 – South side of MD 214 and MD 332 from DC Border to Anne Arundel County
- Screenline 10 – South side of US 50 from DC Border to Anne Arundel County
- Screenline 11 – East side of Baltimore-Washington Parkway from DC border to Anne Arundel County
- Screenline 12 – Montgomery/PGC border from Howard County to DC

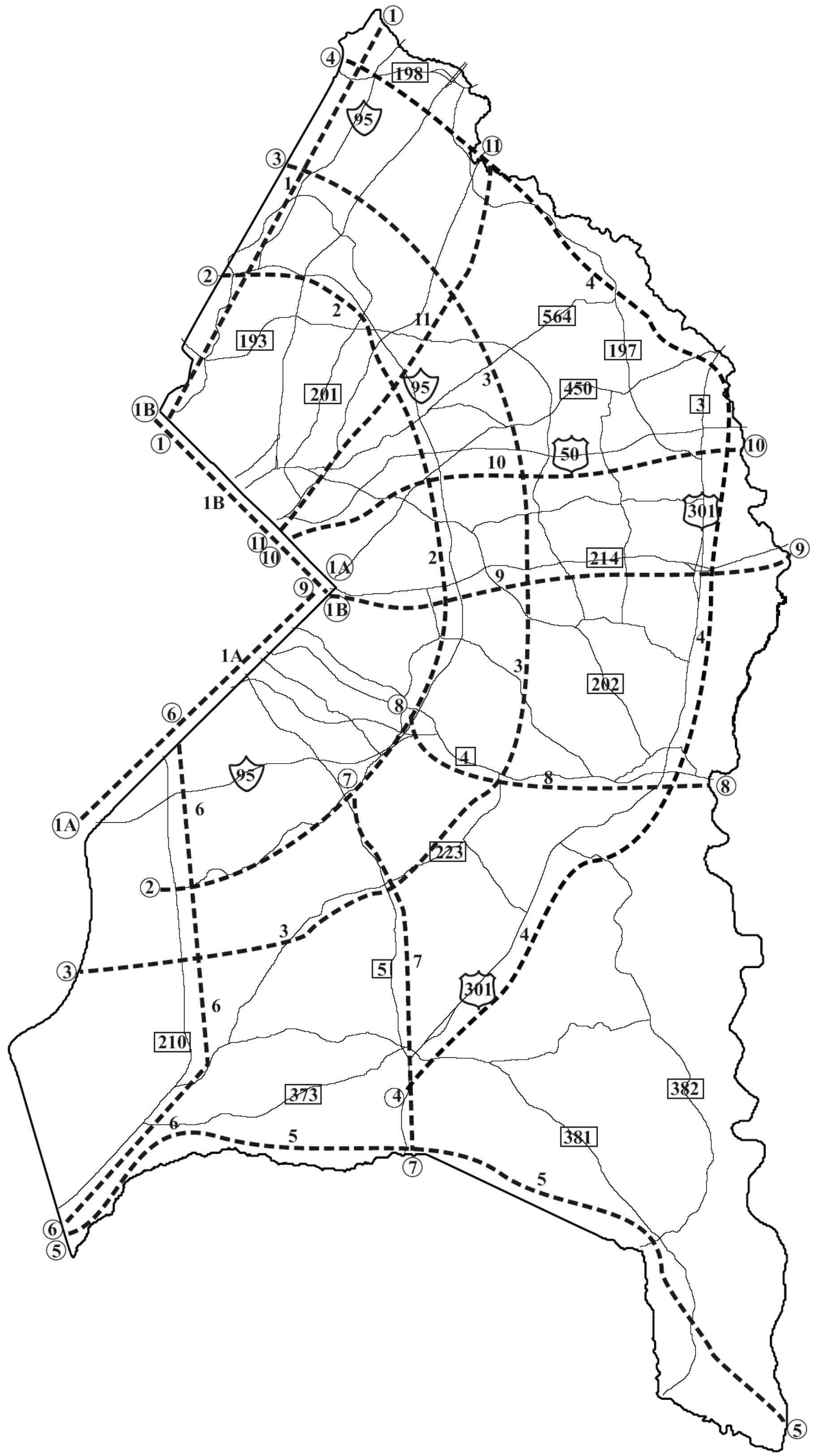

Figure 7.6 Prince George's County Screenlines

Screenline Results

1. ScreenLine 1A: SE DC/PGC Border- Southern Avenue Boundary

Name	AB_Flow	BA_Flow	AB_Count	BA_Count	Tot_Flow	Tot_Count
I-295	36,297		37,501		36,297	37,501
I-295	28,235		37,501		28,235	37,501
MD 210	25,588	26,070	20,100	13,300	51,658	33,400
Owens Rd	3,729	2,854	4,750	4,750	6,583	9,500
Wheeler Rd	6,893	8,044	10,250	10,250	14,937	20,500
23rd Pkwy	9,939	10,927	4,750	4,750	20,866	9,500
Suitland Pkwy	20,604	20,331	25,000	25,000	40,935	50,000
MD 637 (Naylor Rd)	10,003	9,884	10,250	10,250	19,887	20,500
MD 5	17,051	17,178	16,050	17,900	34,229	33,950
MD 218	4,250	3,543	5,000	5,000	7,793	10,000
MD 4	16,150	16,684	14,279	14,317	32,834	28,596
Alton St	4,245	4,009	2,850	2,850	8,254	5,700
Bowen Rd	2,818	2,972	6,400	7,200	5,790	13,600
Benning Rd	10,547	10,841	6,750	6,750	21,388	13,500
MD 332	7,476	6,753	5,000	5,000	14,229	10,000
MD 214	16,515	17,362	13,250	13,250	33,877	26,500
Total	**220,340**	**157,452**	**219,681**	**140,567**	**377,792**	**360,248**

Ratio of Flow versus count = 1.05
RMSE (30 observations) = 35.4

2. Screenline 1B – NE DC/PGC Border – Eastern Avenue Boundary

Name	AB_Flow	BA_Flow	AB_Count	BA_Count	Tot_Flow	Tot_Count
MD 704	15,043	14,872	13,000	13,000	29,915	26,000
Sheriff Rd	10,011	11,279	10,500	10,500	21,290	21,000
Addison Rd	6,011	4,827	8,500	8,500	10,838	17,000
MD 295	54,326		66,500		54,326	66,500
MD 295	55,580		66,500		55,580	66,500
U.S 50 - EB	35,324		31,975		35,324	31,975
U.S 50 - WB		38,194		31,850	38,194	31,850
Alt US 1	12,561	12,802	10,000	10,000	25,363	20,000
US 1	17,668	17,565	10,250	10,250	35,233	21,500
MD 5	17,051	17,178	16,050	17,900	34,229	33,950
Sargent Rd	9,077	9,069	6,000	6,000	18,146	12,000
MD 212	15,061	14,658	11,600	11,300	29,719	22,900
Chillum Rd	1,384	1,469	4,750	4,750	2,853	9,500
MD 650	25,730	26,884	19,000	20,000	52,614	39,000
Total	**274,827**	**168,797**	**274,625**	**144,050**	**443,624**	**419,675**

Ratio of Flow versus count = 1.06

RMSE (24 observations) = 29.9

3. Screenline 2 – Inside I-95/I-495 Capital Beltway, concentric ring

Name	ab_flow	ba_flow	ab_count	ba_count	tot_flow	tot_count
MD 650	39,873	40,064	36,500	36,500	79,937	73,000
MD 212	14,196	13,506	10,000	10,000	27,702	20,000
Cherry Hill Rd	10,624	10,899	11,500	11,500	21,523	23,000
US 1	23,999	23,297	27,600	29,200	47,296	56,800
Rhode Island Ave	7,484	6,968	8,500	8,500	14,452	17,000
Cherrywood Lane	6,787	6,312	6,250	6,250	13,099	12,500
MD 201 NB	22,700		25,700		22,700	25,700
MD 201 NB	22,705		27,200		22,705	27,200
MD 193	25,114	24,310	25,000	25,000	49,424	50,000
BW Pkwy NB	27,425		47,500		27,425	47,500
BW Pkwy NB		29,699		47,500	29,699	47,500
Good Luck Rd	6,444	6,720	8,750	8,750	13,164	17,500
MD 450	19,934	18,482	22,250	22,250	38,416	45,000
MD 950 (Garden City)	142		3,000		142	3,000
US 50 EB	36,955		48,000		36,955	48,000
US 50 EB		38,460		39,200	38,460	39,200
MD 704	18,459	17,657	15,000	15,000	36,116	30,000
Ardwick Ardmore Rd	3,551	2,652	4,750	4,750	6,203	9,500
MD 202	30,256	26,855	30,000	30,000	57,111	60,000
Arena Dr	3,678	3,331	4,500	4,500	7,009	9,000
MD 214	34,984	36,864	36,500	36,500	71,848	73,000
Ritchie-Marlboro Rd	8,303	7,604	6,500	6,500	15,907	13,000
Darcy Rd	1,510	777	2,750	2,750	2,287	5,500
MD 4	26,725	30,048	32,000	32,000	56,773	64,000
Suitland Pkwy EB	16,867		10,000		16,867	10,000
Suitland Pkwy EB	8,917		10,000		8,917	10,000
Forestville Rd	5,267	9,482	7,750	7,750	14,749	15,500
Suitland Rd	10,984	10,797	10,050	10,050	21,781	21,000
Auth Rd	3,101	1,673	2,125	2,125	4,774	4,250
MD 5	33,363	34,092	32,500	32,500	67,455	65,000
Temple Hill Rd	53,313		67,200		53,313	67,200
MD 414 NB		25,276		24,000	25,276	24,000
MD 414 NB	23,976		24,000		23,976	24,000
Livingston Rd	11,727	12,142	8,000	8,000	23,869	16,000
MD 210	21,038	21,075	12,500	12,500	42,113	25,000
I-295	28,235		37,501		28,235	37,501
I-295	36,297		37,501		36,297	37,501
Total	**644,933**	**459,042**	**698,877**	**473,575**	**1,103,975**	**1,173,852**

Ratio of Flow versus count = 0.94
RMSE (60 observations) = 26.8

4. Screenline 3 – Mid-County Concentric ring outside the Capital Beltway

Name	ab_flow	ba_flow	ab_count	ba_count	tot_flow	tot_count
Oxon Hill Rd	3,468	3,922	5,500	5,500	7,390	11,000
Livingston Rd W	3,572	1,924	6,500	6,500	5,496	13,000
SR 210	45,110	43,559	25,000	24,000	88,669	49,000
Allentown Rd	7,218	7,147	11,000	11,000	14,365	22,000
Temple Hill Rd	3,035	3,283	4,500	4,500	6,318	9,000
Old Branch Ave	7,937	8,058	8,500	8,500	15,995	17,000
MD 5	32,862	35,216	45,501	45,501	68,078	91,001
MD 223	4,629	4,885	10,250	10,250	9,514	20,500
Dangerfield Rd	1,604	1,563	3,500	3,500	3,167	7,000
Rosaryville Rd	8,740	9,450	9,250	9,250	18,190	18,500
S. Osborne Rd	6,917	7,629	5,500	5,500	14,546	11,000
MD 4 EB	16,095		24,000		16,095	24,000
MD 4 EB		16,863		25,779	16,863	25,779
Marlboro Pk	8,254	7,647	5,500	5,500	15,901	11,000
Old Marlboro Pk	987	1,075	2,500	2,500	2,062	5,000
Ritchie Marlboro Rd	5,184	4,815	3,250	3,250	9,999	6,500
Brown Station Rd	1,798	2,117	3,250	3,250	3,915	6,500
MD 202	15,860	16,587	13,326	13,326	32,447	26,652
Oak Grove Rd	5,285	4,780	2,250	2,250	10,065	4,500
MD 214	18,528	19,622	15,000	15,000	38,150	30,000
Woodmore Rd	4,442	3,727	5,000	5,000	8,169	10,000
US 50 EB	59,669		53,000		59,669	53,000
US 50 EB	60,873		53,000		60,873	53,000
MD 450	11,512	11,908	11,500	11,500	23,420	23,000
Daisy Ln	7,373	7,092	2,500	2,500	14,465	5,000
Prospect Hill Rd	2,656	2,096	3,500	3,500	4,752	7,000
MD 564	7,618	7,808	5,500	5,500	15,426	11,000
Good Luck Rd	24	108	1,750	1,750	132	3,500
Soil Conser. Rd	4,232	5,461	7,500	7,500	9,693	15,000
BW Parkway NB	31,289		43,400		31,289	43,400
BW Parkway NB		29,530		43,000	29,530	43,000
Odell Rd	1,123	1,108	2,500	2,500	2,231	5,000
Old Baltimore Rd	4,443	4,487	5,500	5,500	8,930	11,000
US 1	15,880	18,249	22,500	22,500	34,129	45,000
Virginia Manor Rd	7,900	7,384	4,000	4,000	15,284	8,000
I-95 NB	84,623		77,500		84,623	77,500
I-95 NB	85,047		77,500		85,047	77,500
Old Gunpowder Rd	10,613	9,507	4,500	4,500	20,120	9,000
Total	**596,400**	**308,607**	**584,727**	**324,106**	**905,007**	**908,832**

Ratio of Flow versus count = 1.00
RMSE (68 observations) = 43.0

5. Screenline 4 – Concentric ring along east side of US 301 and west of Patuxent river

Name	ab_flow	ba_flow	ab_count	ba_count	tot_flow	tot_count
I-95 NB	87,306		95,000		87,306	95,000
I-95 NB	86,598		94,000		86,598	94,000
MD 216	8,407	8,064	11,000	11,000	16,471	22,000
US 1 NB		18,517		17,500	18,517	17,500
US 1 NB	17,663		17,500		17,663	17,500
MD 198	18,660	18,188	20,000	20,000	36,848	40,000
Montpelier Dr	1,823	424	2,250	2,250	2,247	4,500
BW Parkway - NB	36,832		42,000		36,832	42,000
BW Parkway - NB	35,225		43,000		35,225	43,000
MD 3 - NB		32,048		37,500	32,048	37,500
MD 3 - NB	30,345		37,500		30,345	37,500
US 50	43,994		37,700		43,994	37,700
US 50	45,826		39,567		45,826	39,567
Governor Bridge Rd	44	39	2,500	2,500	83	5,000
MD 214	11,155	12,398	6,000	6,000	23,553	12,000
Marlboro Pk	2,585	1,300	4,000	4,000	3,885	8,000
MD 4 - EB		24,415		24,100	24,415	24,100
MD 4 - EB	28,359		23,700		28,359	23,700
Croom Station Rd	2,382	1,965	2,000	2,000	4,347	4,000
MD 382	5,284	4,648	1,750	1,750	9,932	3,500
Heathermore Blvd	3,911	3,966	4,500	4,500	7,877	9,000
Trumps Hill Rd	927	977	250	250	1,904	500
Fairhaven Ave	1,492	1,472	3,000	3,000	2,964	6,000
Rosaryville Rd	1,399	1,409	2,500	2,500	2,808	5,000
Frank Tippett Rd	151	491	500	500	642	1,000
Dyson Rd	720	584	1,250	1,250	1,304	2,500
Missouri Ave	58	67	1,250	1,250	125	2,500
MD 381	5,236	5,828	4,500	4,500	11,064	9,000
Cedarville Rd	2,180	2,172	2,000	2,000	4,352	4,000
Total	**478,562**	**138,972**	**499,217**	**148,350**	**617,534**	**647,567**

Ratio of Flow versus count = 0.95
RMSE (48 observations) = 24.9

6. Screenline 5 – Southern Charles/PGC Border, east of MD 210

Name	ab_flow	ba_flow	ab_count	ba_count	tot_flow	tot_count
MD 381	5,241	4,314	2,500	2,500	9,555	5,000
Doctor Bowen Rd	257	262	500	500	519	1,000
MD 382	361	323	500	500	684	1,000
US 301/MD 5 - NB		53,766		43,500	53,766	43,500
US 301/MD 5 - NB	52,970		43,500		52,970	43,500
MD 210	9,246	8,850	15,000	15,000	18,096	30,000
Total	**68,075**	**67,515**	**62,000**	**62,000**	**135,590**	**124,000**

Ratio of Flow versus count = 1.09
RMSE (10 observations) = 152.0

7. Screenline 6 - East side of MD 210

Name	AB_Flow	BA_Flow	AB_Count	BA_Count	Tot_Flow	Tot_Count
MD 228 (Berry Rd)	17,556	16,296	15,500	15,500	33,852	31,000
MD 373	1,343	1,613	4,750	4,750	2,956	9,500
Farmington Rd	2,844	2,878	1,750	1,750	5,722	3,500
Old Fort Rd S	2,128	2,135	3,000	3,000	4,263	6,000
Livington Rd S	8,018	7,785	4,250	4,250	15,803	8,500
Old Fort Rd N	9,388	9,798	6,500	6,500	19,186	13,000
Palmer Rd	4,277	5,150	7,000	7,000	9,427	14,000
Livington Rd N	10,813	11,145	4,250	4,250	21,958	8,500
MD 414	13,600	15,804	15,250	15,250	29,404	30,500
Ramp to I-95/I-495	17,546		19,500		17,546	19,500
I-95/I-495	59,771		72,000		59,771	72,000
I-95/I-495	56,608		66,400		56,608	66,400
Livington Rd	8,435	7,810	16,000	8,000	16,245	8,000
Southern Ave	11,257	10,242	14,000	7,000	21,499	7,000
Total	**223,584**	**90,656**	**250,150**	**77,250**	**314,240**	**297,400**

Ratio of Flow versus count = 1.06
RMSE (25 observations) = 38.6

8. Screenline 7 - East side of MD 5, from Charles County to the Beltway

Name	AB_Flow	BA_Flow	AB_Count	BA_Count	Tot_Flow	Tot_Count
US 301	14,646		15,500		14,646	15,500
US 301	14,779		15,500		14,779	15,500
MD 373	1,795	1,346	1,500	1,500	3,141	3,000
Brandywine Rd	5,266	5,084	4,900	4,100	10,350	9,000
Surratts Rd	6,414	6,293	6,000	6,000	12,707	12,000
MD 223	5,435	5,689	10,613	10,613	11,124	10,613
Malcolm Rd	3,177	3,145	3,750	3,750	6,322	7,500
Coventry Way	2,002	2,229	12,500	12,500	4,231	25,000
Old Alexandria Ferry Rd	7,494	8,119	1,500	8,500	15,613	10,000
MD 337	20,326	18,300	15,000	15,000	38,626	30,000
I-95/I-495	66,789		84,000		66,789	84,000
I-95/I-495	60,999		84,000		60,999	84,000
Total	**209,122**	**50,205**	**254,763**	**61,963**	**259,327**	**306,113**

Ratio of Flow versus count = 0.85
RMSE (20 observations) = 51.3

9. Screenline 8 - South side of MD 4 from Anne Arundel County to the Beltway

Name	AB_Flow	BA_Flow	AB_Count	BA_Count	Tot_Flow	Tot_Count
I-95/I-495	70,285		81,800		70,285	81,800
I-95/I-495	77,370		85,800		77,370	85,800
Old Marlboro Pk	2,651	3,079	6,500	6,500	5,730	13,000
MD 337	11,033	7,059	10,250	10,250	18,092	21,500
Dower House Rd	9,449	9,225	6,000	6,000	18,674	12,000
MD 223	11,729	11,971	8,995	8,995	23,700	17,990
Old Crain Hwy	6,502	2,345	6,500	2,500	8,847	9,000
U.S. 301	12,866		17,000		12,866	17,000
U.S. 301	12,371		16,300		12,371	16,300
Total	**214,256**	**33,679**	**239,145**	**34,245**	**247,935**	**274,390**

Ratio of Flow versus count = 0.90
RMSE (14 observations) = 25.0

10. ScreenLine 9: South side of MD 214 and MD 332 from DC Border to Anne Arundel County

Name	AB_Flow	BA_Flow	AB_Count	BA_Count	Tot_Flow	Tot_Count
Larchmont Ave	3,650	2,921	4,500	4,500	6,571	9,000
Suffolk Ave	2,025	2,094	2,500	2,500	4,119	5,000
Rollins Ave	169	199	1,500	1,500	368	3,000
Addison Rd	14,385	14,652	11,700	12,400	29,037	24,100
Shady Glen Dr	9,422	9,666	4,000	4,000	19,088	8,000
Ritchie Rd	12,018	13,969	13,250	14,850	25,987	28,100
Hampton Park Blvd	15,873	17,525	13,650	17,050	33,398	30,700
I-95/I-495	76,289		84,900		76,289	84,900
I-95/I-495	83,292		84,600		83,292	84,600
Harry S Truman Dr	8,841	9,071	9,000	9,000	17,912	18,000
MD 202	23,337	19,647	21,300	19,300	42,984	40,600
Campus Way	1,963	2,977	9,850	12,450	4,940	22,300
Kettering Dr	4,863	4,468	4,300	4,500	9,331	8,800
MD 193	8,643	9,530	6,600	6,600	18,173	13,200
Church Rd	6,120	6,004	2,000	2,000	12,124	4,000
Jennings Mill Dr	675	702	1,850	1,900	1,377	3,750
US 301	16,125		25,200		16,125	25,200
US 301	16,213		24,700		16,213	24,700
Total	**303,903**	**113,425**	**325,400**	**112,550**	**417,328**	**437,950**

Ratio of Flow versus count = 0.95
RMSE (32 observations) = 30.0

11. ScreenLine 10: South side of US 50 from DC Border to Anne Arundel County

Name	AB_Flow	BA_Flow	AB_Count	BA_Count	Tot_Flow	Tot_Count
MD 295	55,580		66,500		55,580	66,500
MD 295	54,326		66,500		54,326	66,500
Columbia Park Rd	13,175	13,561	9,450	7,900	26,736	17,350
MD 202	25,184	25,026	24,325	25,100	50,210	49,425
MD 410	10,065	7,040	9,700	11,500	17,105	21,200
I-95/I-495	92,440		96,000		92,440	96,000
I-95/I-495	99,906		92,000		99,906	92,000
Whitfield Chapel Rd	6,201	7,627	6,500	6,500	13,828	13,000
MD 704	14,097	11,073	14,000	14,000	25,170	28,000
Lottsford Vista Rd	3,622	3,256	4,500	4,500	6,878	9,000
MD 193	10,122	9,850	8,500	8,500	19,972	17,000
Church Rd	1,521	2,065	2,000	2,000	3,586	4,000
MD 197	11,622	11,953	23,500	23,500	23,575	47,000
US 301	22,731		32,000		22,731	32,000
US 301	23,761		29,600		23,761	29,600
Total	**444,353**	**91,451**	**485,075**	**103,500**	**535,804**	**588,575**

Ratio of Flow versus count = 0.91
RMSE (24 observations) = 24.4

12. Screenline 11 – East side of Baltimore Washington Parkway from DC border to Anne Arundel County

Name	AB_Flow	BA_Flow	AB_Count	BA_Count	Tot_Flow	Tot_Count
Eastern Ave	14,057	11,626	7,750	7,750	25,683	15,500
US 50	25,566		44,361		25,566	44,361
US 50	23,049		36,000		23,049	36,000
MD 202	33,211	26,413	24,054	21,200	59,624	45,254
MD 450	24,944	25,930	17,850	17,850	50,874	39,500
MD 410	23,872	24,103	16,000	16,000	47,975	32,000
Good Luck Rd	9,864	10,666	8,500	8,500	20,530	17,000
I-95/I-495	99,534		105,300		99,534	105,300
I-95/I-495	93,784		94,300		93,784	94,300
MD 193	28,128	26,531	18,000	18,400	54,659	36,400
Beaver Dam Rd	2,599	3,146	500	500	5,745	1,000
Powder Mill Rd	11,826	10,779	9,000	9,000	22,605	18,000
MD 197	17,626	17,843	18,500	18,500	35,469	37,000
Total	**408,060**	**157,037**	**400,115**	**117,700**	**565,097**	**521,615**

Ratio of Flow versus count = 1.08
RMSE (22 observations) = 31.4

13. Screenline 12 – Montgomery/PGC border from Howard County to DC

Name	AB_Flow	BA_Flow	AB_Count	BA_Count	Tot_Flow	Tot_Count
Eastern Ave	9,732	9,334	7,250	7,250	19,066	14,500
Sheridan Rd	1,059	1,319	2,925	2,975	2,378	5,900
Ray Rd	466	573	1,500	1,500	1,039	3,000
MD 410	16,540	16,371	12,000	12,000	32,911	24,000
MD 193	24,689	24,547	18,825	20,000	49,236	38,825
Merrimac Dr	2,021	2,025	2,225	2,225	4,046	4,500
Metzerott Rd	12,968	13,007	4,225	5,200	25,975	9,425
Adephi Rd	12,195	11,860	11,750	11,750	24,055	23,500
I-95/I-495	124,315		113,900		124,315	113,900
I-95/I-495	132,283		111,400		132,283	111,400
Powder Mill Rd	14,868	14,117	9,000	9,000	28,985	18,000
Cherry Hill Rd	12,000	12,838	14,000	14,000	24,838	28,000
Calverton Rd	11,556	10,039	7,750	7,750	21,595	15,500
Briggs Ch Rd	9,723	11,062	8,000	8,000	20,785	16,000
Greencastle Rd	8,349	8,891	2,500	2,500	17,240	5,000
MD 198	29,873		22,500		29,873	22,500
MD 198	29,887		22,500		29,887	22,500
Brooklyn Br Rd	1,454	704	2,500	1,500	2,158	4,000
Total	**453,978**	**136,687**	**374,750**	**105,650**	**590,665**	**480,450**

Ratio of Flow versus count = 1.23
RMSE (32 observations) = 39.3

Conclusion

The results presented in this chapter indicate that the model appears to achieve its principal objectives of generating traffic flows in Prince George's County that are close to those observed and also does a credible job of matching flows elsewhere in the region. Further calibration of the model is certainly possible and is warranted on an ongoing basis and especially when additional and higher quality traffic counts become available. Also, the calibration should be revisited when new survey data are obtained.