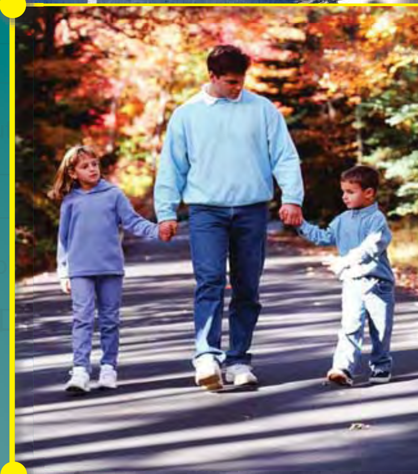

2000 AND 2005 VALIDATION OF THE DVRPC REGIONAL SIMULATION MODELS

Delaware Valley Regional Planning Commission

JULY 2008

2000 AND 2005 VALIDATION OF THE DVRPC REGIONAL SIMULATION MODELS

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Created in 1965, the Delaware Valley Regional Planning Commission (DVRPC) is an interstate, intercounty, and intercity agency which provides continuing, comprehensive, and coordinated planning to shape a vision for the future growth of the Delaware Valley region. The region includes Bucks, Chester, Delaware, and Montgomery counties as well as the City of Philadelphia, in Pennsylvania; and Burlington, Camden, Gloucester, and Mercer counties in New Jersey. DVRPC provides technical assistance and services, conducts high priority studies that respond to the request and demands of member state and local governments, fosters cooperation among various constituents to forge a consensus on diverse regional issues, determines and meets the needs of the private sector, and practices public outreach efforts to promote two-way communication and public awareness of regional issues and the commission.

Our logo is adapted from the official DVRPC seal, and is designed as a stylized image of the Delaware Valley. The outer ring symbolizes the region as a whole while the diagonal bar signifies the Delaware River. The two adjoining crescents represent the Commonwealth of Pennsylvania and the State of New Jersey.

DVRPC is funded by a variety of funding sources including federal grants from the U.S. Department of Transportation's Federal Highway Administration (FHWA) and Federal Transit Administration (FTA), the Pennsylvania and New Jersey departments of transportation, as well as by DVRPC's state and local member governments. This report was primarily funded by the Pennsylvania Department of Transportation and the Federal Highway Administration (FHWA). The authors, however, are solely responsible for its findings and conclusions, which may not represent the official views or policies of the funding agencies.

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EXECUTIVE SUMMARY

This report describes the current travel simulation models employed by the Delaware Valley Regional Planning Commission (DVRPC) and documents the validation of the models. The Delaware Valley Region consists of Bucks, Chester, Delaware, Montgomery, and Philadelphia counties in Pennsylvania and Burlington, Camden, Gloucester, and Mercer counties in New Jersey. Three municipalities in Berks County are also included in the travel simulation process.

Travel modeling is performed by DVRPC for a number of different purposes. The main purposes are the development of long and short-range plans and programs, highway traffic studies, air quality conformity demonstrations, Federal Transit Administration (FTA) New Starts programs, and member government transportation studies. The travel simulation models are guided by Federal Highway Administration (FHWA), Environmental Protection Agency (EPA), and FTA guidelines. The travel simulation models are mostly run by DVRPC staff. The models are also occasionally used by outside consultants with DVRPC assistance.

Travel demand modeling uses a mathematical representation of the transportation system, current and future data on population and economic activity, and the principles of supply and demand to estimate the travel behavior of people in the region. The DVRPC travel simulation process models person trips, truck trips, and taxi trips at the traffic analysis zone (TAZ) level. The region is divided into 1,912 TAZs. The four main models are trip generation, trip distribution, modal split, and assignment. Trip generation determines the number of trip attractions and productions (origins and destinations). This calculation is made by a combination of trip rates and socioeconomic variables. Attractions and productions are matched in trip distribution. This is done through the use of travel propensity functions and a gravity model, which assumes that travel is more likely between zones where travel is easy. The modal split model divides travelers between transit and auto modes. This is done by a logit model which divides trips between the two modes based on the relative ease of travel using either mode. Auto trips are assigned in highway assignment to specific paths in the highway network. This allows the determination of volumes on specific highway facility sections. Transit trips are assigned to specific transit routes and stations by the transit assignment model. Both the highway and transit assignment models assume that travelers pick the most desirable path from their origin to their destination considering time, cost, and other factors.

The trip distribution, modal split, and highway assignment models are run in an iterative fashion using the Evans algorithm to obtain an equilibrium solution. Dr. Susan Evans developed this algorithm which is used in the travel simulation process to more accurately model the choices that travelers make. This ensures that the travel times used in the trip distribution and modal split models are consistent with the levels of congestion determined in the highway assignment model. Each of the models is discussed in detail in this report.

The DVRPC travel simulation models were originally developed in the 1960s and have been updated several times in order to stay consistent with the state of the practice and all FHWA, FTA, and EPA regulatory requirements. Major changes that have occurred since the last model documentation (1997) include the use of three separate time periods, a non-motorized travel model, updated highway speed and capacity curves, and the use of the iterative Evans algorithm. Each of these model updates is discussed in detail in this report. The travel simulation models are run in slightly different ways for FTA alternatives analysis studies versus highway and conformity purposes due to differing regulatory requirements. These differences are also covered in this report.

Each model requires large amounts of data for validation and calibration. This includes demographic and employment data, mode choice data, trip length data, external vehicle counts, highway traffic counts, and transit station and line counts. Each data source is described in detail in this report. Also described is the areal system of traffic analysis zones used in the modeling process, and the highway and transit computer networks that are used to represent the real highway and transit systems in the Delaware Valley.

Air quality conformity demonstration is one of the primary uses of the DVRPC travel simulation model. The conformity process requires numerous post-processor calculations in order to calculate transportation related emissions. The post-processor performs an accurate calculation of highway speeds, among other things, that are then fed into the EPA MOBILE6.2 program in order to determine emissions. Travel simulation modeling for air quality conformity, including the use of the post-processor, is covered in this document.

The DVRPC travel simulation models are extensively validated to ensure that they produce reasonable results. The main data sources used to validate the travel simulation models are census data and highway and transit facility counts. An extensive comparison of counted and assigned volumes shows that the DVRPC model is well validated for regional simulation. Focused simulations, which are used when added accuracy is required for facility specific studies, are also reviewed and validated.

The validation results demonstrate that DVRPC's travel simulation models are able to accurately replicate observed travel patterns for both 2000 and 2005. The difference between the 2005 highway counts and simulated volumes for all screenlines is -3.2 percent. Similarly, the margin of error in the regional transit simulation is 4.4 percent. The regional simulation errors can be significantly reduced by using the DVRPC focused simulation process.

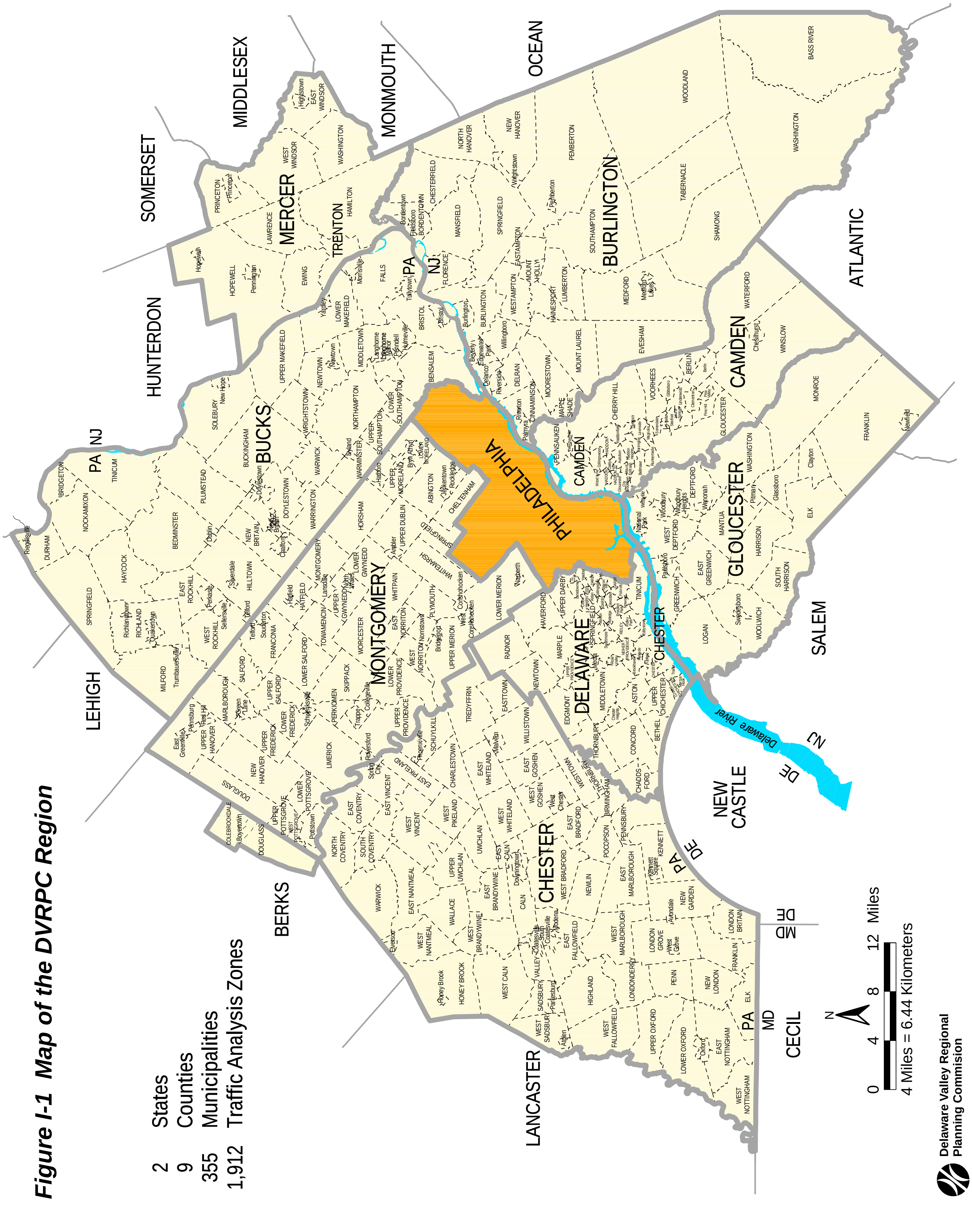
I. INTRODUCTION

This report describes the current travel simulation models employed by the Delaware Valley Regional Planning Commission (DVRPC) and documents the validation of the model. The Delaware Valley Region consists of Bucks, Chester, Delaware, Montgomery, and Philadelphia counties in Pennsylvania and Burlington, Camden, Gloucester, and Mercer counties in New Jersey. These nine counties together comprise over 3,800 square miles and are made up of 355 municipalities ***(Figure I-1)***. The region is home to 5.5 million residents and 2.8 million jobs. Land use varies from the dense urban core of Center City Philadelphia to the open rural areas of the New Jersey Pinelands.

This summary report is meant as a thorough introduction to the models for current and potential users, as well as a reference for new users. It is also meant as a guide for users of the results of the models in order to understand how results are derived. The travel demand model uses a mathematical representation of the transportation system, along with data on population and economic activity and the principles of supply and demand to estimate the travel behavior of people in the region. These models are also referred to as travel simulation models because they can be used to simulate the effect on traffic patterns (travel demand) of changes in the transportation system. The simulation process is based on the scientific method, which consists of the following major steps:

1. Development of an areal system – A system of zones for modeling is created at various levels - Traffic Analysis Zones (TAZ), Minor Civil Divisions (MCD), and County Planning Areas (CPA).
2. Preparation of TAZ data – Socioeconomic data, such as population and employment, are prepared for each TAZ for current and future years.
3. Network coding – A mathematical representation of the highway and transit networks are created in a link/node format suitable for modeling.
4. Data gathering – Important data on trip making behavior and system use is gathered from several sources including travel surveys and traffic counts. Afterwards the data are prepared and model parameters are estimated.
5. Estimation of trip generation – Based on the data gathered in the travel surveys, trip productions and attractions are estimated. These estimates are tied to zonal socioeconomic data using disaggregate methods. All types of trip ends, including both motorized and non-motorized trips, are estimated.
6. Estimation of trip patterns – Based on survey data the distribution of trip ends between zones is estimated.

Figure I-1 Map of the DVRPC Region



7. Estimation of modal split – Based on survey data, the choice that travelers make between auto and transit is modeled.

8. Estimation of auto occupancy – Auto occupancies are estimated based on surveys for those trips that use auto instead of transit. This converts person trips to auto or vehicle trips.

9. Estimation of highway traffic volumes and transit ridership – The volumes on individual highway facilities and transit ridership on specific routes is estimated by highway and transit assignment, respectively, based on the trip tables developed in previous steps and the coded transportation networks.

10. Estimation of evaluation measures – Various measures, such as VMT, mobile source emissions, energy consumption, number of accidents, and travel speeds are estimated by post-processing the highway and transit assignment results.

11. Validation – The results of the models are validated against existing traffic counts and survey data.

In this report each of the above elements is described in detail for the 2000 and 2005 models. In travel demand modeling several important criteria should be considered:

1. The input data should be accurate.

2. The models should be rational and up-to-date.

3. The output or results of the models should be reasonable and compare very well with actual data.

Because of these criteria, the errors in both the input data and models should be small since DVRPC uses this process for forecasting long-range travel for planning and designing transportation facilities. In order to lessen errors it is important that the model calibration be well validated and up-to-date. The DVRPC regional model has been calibrated and validated five times in the past 20 years – 1987, 1990, 1997, 2000, and 2005. Since much of the input data relies on the decennial census, the model calibrations and validations typically correspond with census years. In order to further minimize simulation errors, DVRPC uses focused travel simulations for corridor or area highway and transit studies. This DVRPC travel simulation process will be discussed in detail in this report.

Chapter II contains an overview of the DVRPC travel simulation models. A brief description of the current models is given. Important uses of the travel simulation models are discussed, along with regulatory requirements for each model. The evolution of the travel simulation models is then described and the history of the models is documented up to the current generation.

Chapters III, IV, V, and **VI** describe the input data used in the modeling process. In **Chapter III** the areal system for travel simulation is discussed. The system of dividing the DVRPC region into TAZs and classifying them with an area type is discussed. In **Chapter IV** the development of regional demographic and employment data is given. The various individual variables are described. Summary data is given and trends are analyzed. In **Chapter V** the highway and transit network representations are described. The basic information for coding both types of networks is given; special coding procedures are also discussed along with highway free-flow travel speeds and times. In **Chapter VI** travel surveys, such as traffic counts, transit ridership counts, roadside surveys, on-board surveys, and the household travel survey, are discussed.

Chapters VII-XII describes the various models used for travel forecasting. **Chapter VII** discusses the trip generation model. The methodologies used to generate both internal and external trips are discussed. Trip generation results for the 2000 model are given, as well as validation statistics. Operation of the trip generation model is also discussed. **Chapter VIII** discusses the trip distribution model. The theory of the gravity model, which is used to distribute trip ends, is discussed, as is input data. Trip distribution results for the 2000 model are given and compared to 1990 and 2005 results. Basic information on model calibration and operation is also discussed. **Chapter IX** describes the mode split model. Mode choice theory is discussed, including the former probit model used in 1990, the currently used logit model, and the transition from the probit to logit model. Model results for 2000 and 2005 are given and discussed. **Chapter X** describes the vehicle occupancy model, which is used to convert highway person trips to highway vehicle trips. **Chapter XI** discusses the highway assignment model, including the purpose and theory behind highway assignment. The integration of the various models into a combined equilibrium formulation solved by the Evans algorithm is also discussed. Validation statistics for the 2000 and 2005 models are given. Finally, **Chapter XII** discusses the transit assignment model. The purpose and results of the transit assignment model are discussed, as well as its integration into the Evans algorithm. Validation statistics for the 2000 and 2005 models are given.

Chapter XIII discusses the use of the model in air quality and conformity demonstration. This chapter describes the travel simulation models used to calibrate mobile source emissions, along with the planning assumptions, emission estimation procedures, MOBILE6.2 files, and emissions results. This chapter shows that the DVRPC transportation program and long-range plan conform with the Pennsylvania and New Jersey SIPs and their emissions budgets.

Chapter XIV discusses the validation of the 2000 and 2005 travel simulation models. The chapter begins with an exploration of the various sources of error present in travel simulation modeling. The methodology used to calibrate and validate the 2000 and 2005 models is discussed next. Following this, data demonstrating the validation of the 2000 and 2005 travel simulations models is presented, and then compared with data from earlier studies. Finally, recent model improvements and future steps are discussed.

Several sections of detailed information appear in this document after the main text. A list of references is given. There is also a glossary with a list of abbreviations. Following this are various appendices. Each appendix is associated with a particular chapter. **Appendix III-1** contains a table of TAZs and CPAs. **Appendix III-2** contains maps of each county showing both TAZs and MCD. **Appendices V-1 and V-2** contain detailed coding information for highway and transit networks respectively. **Appendices VI-1** contains 6 survey forms used by DVRPC to gather travel data for calibrating and validating the DVRPC simulation models and for various transportation studies. **Appendices VII-1-4** contain information related to travel with at least one trip end external to the DVRPC region as determined from surveys. **Appendix VII-1** lists external cordon station traffic counts for 2000 and 2005. **Appendix VII-2** lists through trips by cordon station. **Appendix VII-3** lists external transit trips by cordon station. **Appendix VII-4** lists time period factors for disaggregating external-internal highway trips.

Appendices VII-5 - VII-8 contain information related to trip generation. **Appendix VII-5** contains detailed information on each of the programs used for trip generation. **Appendix VII-6** contains descriptions of the various files, inputs, and parameters used in trip generation. **Appendix VII-7** contains a summary of 2000 and 2005 internal trip generation by CPA. **Appendix VII-8** contains trip generation summaries by trip purpose, county, and state. **Appendix IX-1** contains information about impedance needed for modal split. **Appendix IX-2** contains a summary of modal split results by CPA. **Appendix XI-1** contains descriptions of the focused simulation process as used for highway projects. **Appendix XII-1** gives an overview of the focused simulation process as applied to transit corridor and area studies. **Appendix XIV-1** discusses additional statistics related to the model validation

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II. OVERVIEW OF THE DVRPC TRAVEL SIMULATION MODELS

The purpose of this chapter is to summarize the DVRPC enhanced travel simulation models which are used in the four-step modeling process. The DVRPC travel simulation models follow the traditional steps of trip generation, trip distribution, modal split, and traffic assignment. However, an iterative feedback loop is employed from traffic assignment to the trip distribution step. The feedback loop ensures that the congestion levels and hence highway speeds used by the trip distribution and mode split models are equivalent to the highway speeds that result from the traffic assignment step. The iterative model structure also allows trip making patterns to change in response to changes in traffic patterns, congestion levels, and improvements to the transportation system. Additionally, travel throughout the day is modeled as three different time periods.

A. Description of the 2000 DVRPC Travel Simulation Models

Figure II-1 shows the major steps of the DVRPC travel demand forecasting process. The number of trip attractions and productions is determined in trip generation. Next, the initial highway minimum cost (both actual monetary travel costs and travel time are converted into a single measure of impedance) trees are found from the uncongested highway network; transit speeds are obtained from transit schedules. Attractions and productions are matched in trip distribution, while in modal split, travelers are split between transit and auto. Auto trips are assigned in highway assignment to specific facilities in the highway network. A new set of highway speeds is computed after highway assignment. The last three steps are integrated into an Evans algorithm, which solves each model iteratively until the highway speeds produced by assignment are consistent with the speeds used by the trip distribution and mode choice steps. After each iteration, the new highway speeds are used to rebuild the highway minimum costs trees, and the trip distribution, modal split, and highway assignment steps are repeated. Once convergence is reached, highway link volumes and trip tables from each iteration are weighted together. The weighted average transit trip table is then assigned to the transit network. Each of the four main steps, along with their integration into an Evans process and their allocation by time period, is now described.

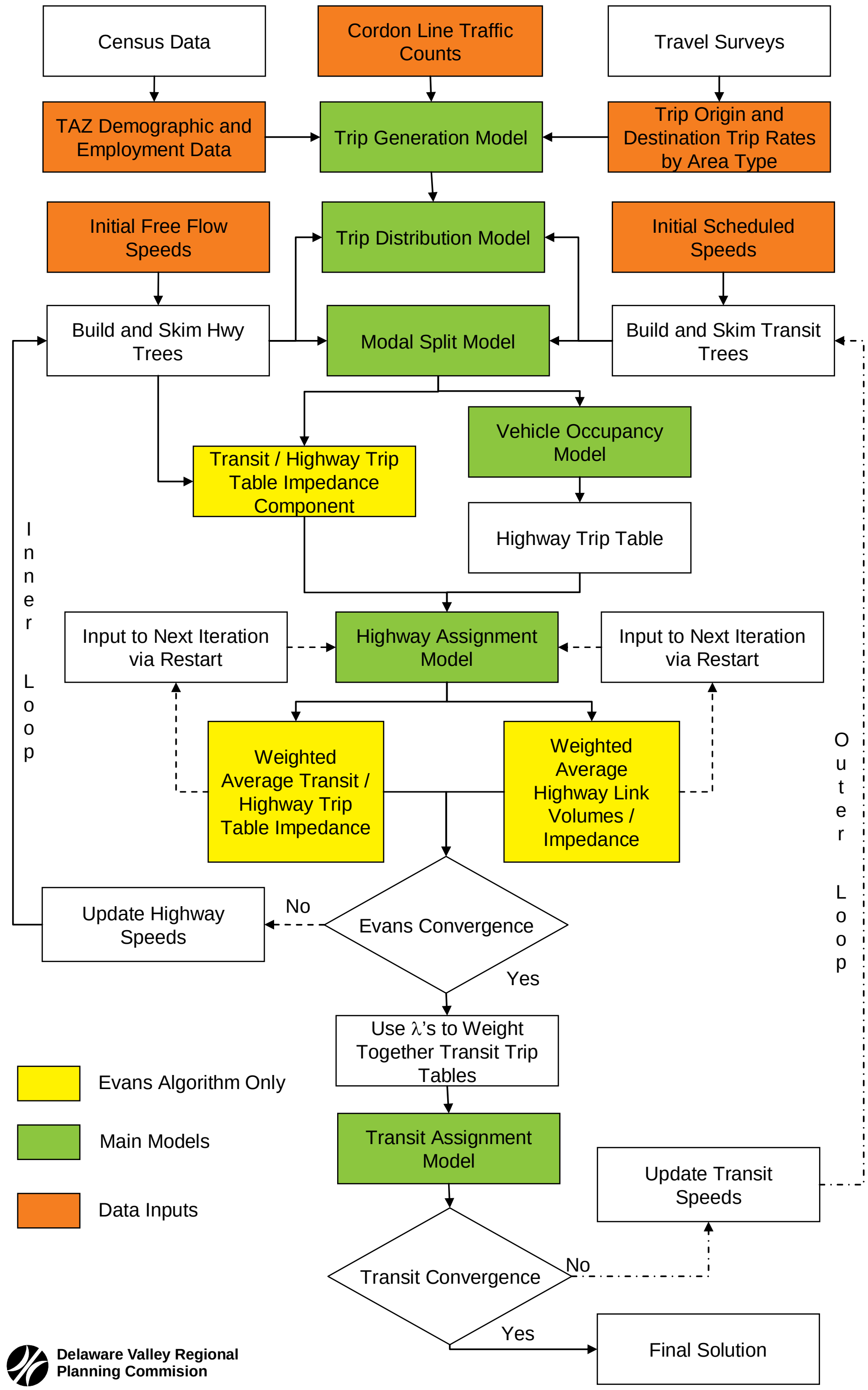


Figure II-1 2000 DVRPC Travel Simulation Process

1. Trip Generation Model

Both internal trips (those made within the DVRPC region) and external trips (those which cross the boundary of the region) must be considered in the simulation of regional travel. The region is divided into many small zones called traffic analysis zones (TAZs) in order to facilitate trip generation as well as other steps in the modeling process. For the simulation of travel demand, internal trip generation is based on zonal estimates of population and employment, whereas external trips are obtained from cordon line traffic counts and other sources. The latter also includes through trips which pass through the Delaware Valley region. Estimates of internal trip productions and attractions by zone are computed for each trip purpose on the basis of trip rates applied to the zonal estimates of demographic and employment data. Trip purposes include home-based work, home-based non-work, and non-work trips. Also included are light truck trips, heavy truck trips, and taxi trips. The rates are slightly adjusted to produce accurate traffic assignment volumes. Trip generation rates depend much more heavily on land use characteristics than on transportation system characteristics. As such, this part of the DVRPC model is not iterated on highway travel speeds. Rather, estimates of daily trip making by traffic zone are calculated and then disaggregated into peak, midday, and evening time periods.

- Home-to-Work Trips
- Home-to-Non-work Trips
- Non-home to Non-home Trips
- Truck Trips
- Taxi Trips
- External-Internal Trips
- Through Trips

2. Trip Distribution Model

Trip distribution is the process whereby the zonal trip ends established in the trip generation step are linked together to form origin-destination patterns in trip table format. Peak, midday, and evening trip ends are distributed separately. For each Evans Iteration, a series of ten gravity-type distribution models are applied at the zonal level. The ten trip types distributed by the current model are:

- Internal home-based work person trips.
- Internal home-based non-work person trips.
- Internal non-home-based person trips.
- External-internal auto driver trips, all purposes, Turnpike cordon stations.
- External-internal auto driver trips, all purposes, freeway cordon stations.
- External-internal auto driver trips, all purposes, arterial cordon stations.
- External-internal auto driver trips, all purposes, local cordon stations.
- All light truck trips (including external-internal).
- All heavy truck trips (including external-internal).
- All taxi trips.

These trips are generated by trip purpose and vehicle type stratifications as established in the trip generation. The trip distribution model will result in zone-to-zone trip matrices by trip purpose, trip type, and vehicle type.

3. Modal Split Model

The modal split model is also run separately for the peak, midday, and evening time periods. The modal split model calculates the fraction of each person-trip interchange in the trip table which should be allocated to transit and assigns the residual to the highway side.

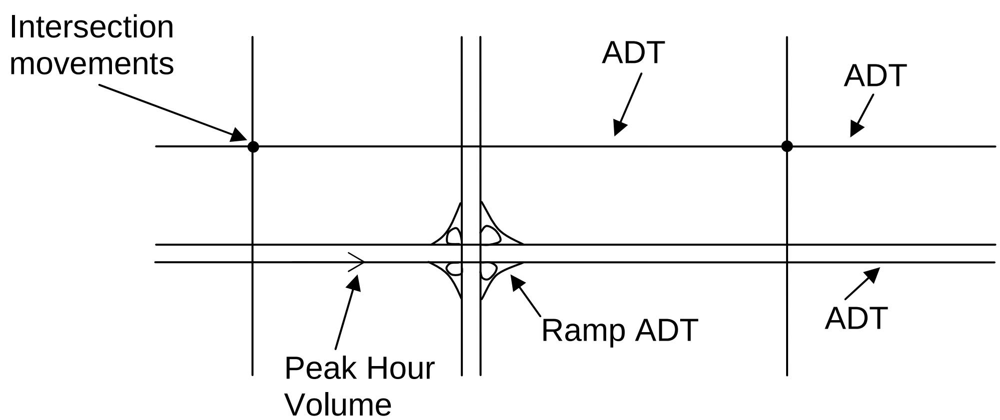
The choice between highway and transit usage is made on the basis of comparative cost, travel time, and frequency of service, with other aspects of mode choice being used to modify this basic relationship. Better transit service results in a higher fraction of trips assigned to transit, although trip purpose and auto ownership also affect the allocation. The model subdivides highway trips into auto drivers and passengers using vehicle occupancy data from field surveys. In this way auto person trips are transformed into auto vehicle trips. Auto vehicle trips are added to the truck, taxi, and external vehicle trips in preparation for assignment to the highway network.

4. Highway Traffic Assignment Model

For highway trips, the final step in the simulation process is the assignment of vehicle trips to the highway network. These highway vehicle trips are estimated from highway person trips by the vehicle occupancy values discussed above. For peak, midday, and evening travel, the assignment model produces traffic volumes for individual highway links that are required for various types of analyses.

Highway trips are assigned to the network by determining the best (minimum time) route through the highway network for each zonal interchange and then allocating the interzonal highway travel to the highway facilities along that route. This assignment model is "capacity restrained" in that congestion levels are considered when determining the best route. The impedance or disutility of travel on a given link is dependant on the ratio of the volume using that link to the capacity of the link. The equilibrium assignment method is used to implement the capacity constraint. When the assignment and associated trip table reach equilibrium, no path faster than the one actually assigned for each trip can be found through the network, given the capacity restrained travel times on each link.

The assignment model produces link volumes for the entire highway network. Various measures of system performance can be determined from link volumes, such as ADT (average daily traffic), peak hour flows, and intersection turning movements.

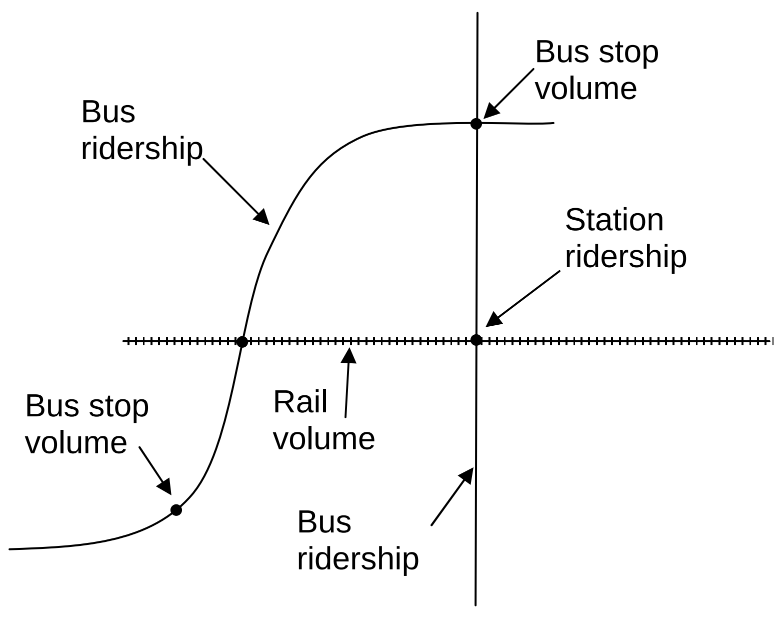


5. Evans Algorithm

The Evans algorithm involves iterating the trip distribution, mode split, and highway assignment models. After each iteration of highway assignment, the capacity constrained highway link speeds are recalculated, the minimum time paths through the network are rebuilt, and the minimum path interzonal travel times are reskimmed. For future simulations, bus transit times are also updated to reflect changes in highway congestion levels. The trip distribution, modal split, and highway assignment models are then executed in sequence given the new interzonal travel times. This cycle occurs for each iteration of the Evans algorithm. A weighting factor is assigned to each iteration. This weight is then used to prepare a convex combination of the link volumes and trip tables for the current iteration and a running weighted average of the previous iterations. For each time period, seven iterations of the Evans process are performed to ensure that convergence on travel times is reached. The entire process for running through the travel simulation models currently takes slightly more than two hours of computing time.

6. Transit Assignment Model

After highway speed equilibrium is achieved, the weighted average transit trip tables are assigned to the transit network to produce link, station, and route passenger volumes. The transit person trips produced by the modal split model are "linked." They include only the origin and destination of the trip, and do not include any transfers that occur either between transit trips or between auto approaches and transit lines. The transit assignment procedure accomplishes two major tasks. First, the transit trips are "unlinked" to include transfers, and second, the unlinked transit trips are associated with specific transit facilities to produce link, line, and station volumes. These tasks are accomplished simultaneously within the transit assignment model, which assigns the transit trip matrix to minimum impedance paths built through the transit network. There is no capacity restraining procedure in the transit assignment model.

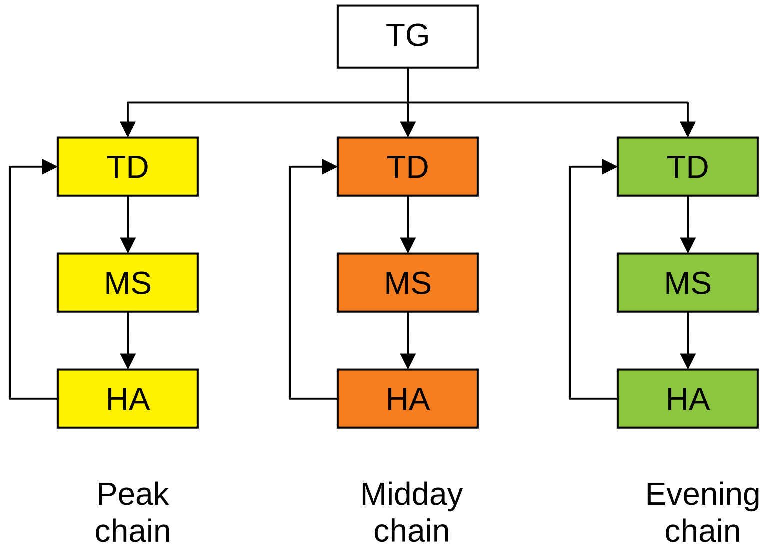


7. Time Period Disaggregation

The DVRPC travel simulation models are disaggregated into separate peak (combined AM and PM), midday (the period between the AM and PM peaks), and evening (the remainder of the day) time periods. The peak period is defined as 7:00 AM to 9:00 AM and 3:00 PM to 6:00 PM This disaggregation begins in trip generation where factors are used to separate daily trips into peak, midday, and evening travel. Peak period and midday travel are based on a series of factors which determine the percentage of daily trips that occur during those periods. Evening travel is then defined as the residual after peak and midday travel are removed from daily travel.

- AM Peak: 7:00 AM – 9:00 AM
- PM Peak: 3:00 PM – 6:00 PM
- Midday: 9:00 AM – 3:00 PM
- Evening: 6:00 PM – 7:00 AM

After trip generation the model is disaggregated into separate model chains for the peak, midday, and evening periods for the trip distribution, modal split, and travel assignment phases of the process. The enhanced process then utilizes completely separate model chains for peak, midday, and evening travel simulations. Time of day sensitive inputs to the models such as highway capacities and transit service levels are disaggregated to be reflective of time-period specific conditions. Capacity factors are used to allocate daily highway capacity to each time period. Separate transit networks are used to represent the difference in transit service over the course of a day. A schematic of the process can be seen on the next page.



TG = Trip Generation, TD = Trip Distribution,
MS = Modal Split, HA = Highway Assignment

Source: DVRPC July, 2008

External-internal productions at the nine-county cordon stations are also disaggregated into peak, midday, and evening components using percentages derived from the temporal distribution of traffic counts taken at each cordon station.

B. TRANPLAN Software

DVRPC uses the TRANPLAN software system for running its travel forecasting model. TRANPLAN is part of the Citilabs family of urban planning tools. This description of TRANPLAN is partly from the TRANPLAN 9.0 User Manual. TRANPLAN is based on the concepts and software developed by federally sponsored urban transportation planning efforts in the 1970s. These ideas are extended and added to the earlier urban planning software by TRANPLAN because of the limitations imposed by pervious generation computer and Geographic Information Systems (GIS). TRANPLAN, in conjunction with supplementary GIS interface software, enables users to generate and import data in database and GIS format, process it with TRANPLAN functions, and export results. TRANPLAN serves as a tool to assist the planner in testing land use and network alternatives. However, it is not a substitute for the experience and judgment of the planner.

At the most basic level, the typical TRANPLAN forecasting model is structured around the following four sequential steps that were discussed in the previous section:

- Trip Generation
- Trip Distribution
- Modal Choice
- Assignment

This four-step process is implemented within the larger context of the modeling framework comprising the steps of land use, analysis, and evaluation. These elements are briefly discussed below. Each of the entries in this modeling framework represents a general category of modeling procedures. Each category, in turn, includes one or more modeling tasks.

TRANPLAN is structured as a modular tool. There are more than 40 modules, referred to as "functions," each of which has specific capabilities. It is not possible to define a single, correct methodology which can be applied to all transportation planning models. Because of the comprehensive, modular structure and inherent flexibility of TRANPLAN, the planner must draw from her/his expertise when selecting the appropriate sequence of TRANPLAN functions and the appropriate options and parameters within each function for a particular model.

1. Land Use

Land use representation dictates the number and types of trips generated. Input data which must be provided by the transportation planner includes zonal land use data and trip generation rates. Land use data are the socio-economic characteristics of each zone, such as the number of households and employees. Trip generation rates are used to calculate the number and type of trips generated by each type of land use. Trip generation rates are influenced by the characteristics of the urban area being modeled, such as the density of population and employment. Transportation surveys such as the household travel survey have been conducted to determine trip generation rates in the Delaware Valley region.

Network representation dictates the available paths for getting from one point to another. Input data which must be provided by the planner includes a description of the network in terms of "nodes," "links," and transit "routes." Nodes define a given point or physical location within the study area. Each node must have a unique number, and if plotting or graphic display is desired, each node must be assigned an (x,y) coordinate pair. Links define a section of roadway or transit right-of-way between two nodes, and the attributes such as speed and capacity, that are to be associated with the link. Transit "route" or "line" data defines which series of links a transit vehicle traverses and at which nodes boarding/alighting is permitted.

2. Analysis

Analysis encompasses steps two through four of the four-step process (trip distribution, modal choice, and assignment), as well as several utilities for performing operations on matrices. Input data to be provided by the planner includes friction factors and vehicle occupancy rates. Studies have been conducted to determine these parameters, as is discussed in subsequent chapters.

3. Evaluation

Evaluation is actually performed at various steps throughout the modeling process in order to determine whether a particular procedure has yielded reasonable results. A network plot, for example, might be generated before assignment to confirm that the roadway system has been correctly coded.

This modeling framework is a simplification of what is typically involved in developing a transportation model for testing alternative land use scenarios and networks. In reality, each modeling task encompasses several procedures which might utilize one or more TRANPLAN modules.

4. Advantages of TRANPLAN for DVRPC

TRANPLAN hosts the DVRPC models in an efficient and flexible way. It is stable for the foreseeable future and compatible with Microsoft Vista. TRANPLAN is highly customized to the needs of the DVRPC models and no expensive customization is required at this time. It is computationally efficient and executes the DVRPC model in a fast timely manner on ordinary personal computers. TRANPLAN is compatible with related software such as the DVRPC Transportation Air Quality (TAQ) post-processor and the Federal Transit Administration (FTA) user benefits estimator (SUMMIT). Outside consultants are familiar with TRANPLAN and already have software licenses and operating experience. DVRPC has a TRANPLAN site license with source code rights. Software can be placed on as many machines as necessary and DVRPC staff can extend and modify TRANPLAN as required without the time and expense of preparing and executing contracts with outside consultants and vendors. All of the files and data sets from past DVRPC studies are compatible with TRANPLAN.

5. Disadvantages of TRANPLAN

Citilabs has not been aggressively supporting nor adding new capabilities to TRANPLAN. The existing software is lacking especially in the areas of public transit network maintenance and transit assignment analysis. Voyager is Citilabs current premier model package that gets most of the software development work, although, TRANPLAN software and data sets are supported in the VIPER GIS network analyzer and the new CUBE modeling package. Citilabs has not been pursuing new GIS highway and network integration capabilities with NAVTEC and other third party vendors; nor is Citilabs developing visualization capabilities for TRANPLAN outputs to enhance the communication of results with elected officials and the general public.

C. Uses of DVRPC Travel Simulation Models

Travel modeling is performed by DVRPC for a number of different purposes. The five main uses for DVPRC's travel simulation models are the development of long and short-range plans and programs, highway traffic studies, air quality conformity demonstration, Federal Transit Administration (FTA) New Starts programs, and member government transportation studies. Various regulations govern the structural form of the model depending on its use.

1. Development of short and long-range plans
2. Highway traffic studies
3. Air quality conformity demonstration
4. FTA New Starts evaluation
5. Member governments transportation studies

1. Development of Transportation Plans and Programs

DVRPC as the region's metropolitan planning organization (MPO) is required by federal law to develop a long-range plan and the Transportation Improvement Program (TIP) in order for the region to receive federal transportation funds. The most recent long-range DVRPC plan is **"*Destinations 2030,*"** a long-range transportation and land use plan up to 2030. The 2030 plan contains an analysis of future growth scenarios and a list of transportation projects to be funded. The TIP is a shorter term (4-5 years) plan that contains projects from the long-range plan. Both the long-range plan and the TIP require the use of transportation simulation models in order to assess the impacts of various transportation and land use changes. The transportation simulation models produce future estimates of VMT, travel time, transit usage, vehicle emissions, and other products of interest. These products are used in assessing the benefits of complete scenarios and individual transportation projects.

2. Highway Corridor Traffic Studies

Transportation simulation modeling for highway traffic studies is as described above in Section A. Typical products of interest for highway studies include average daily traffic forecasts, intersection turning movement forecasts, roadway Level-of-service (LOS) forecasts, and intersection LOS forecasts. Several enhancements are made to the travel simulation model for studies that are focused on a localized area versus the entire region. Traffic analysis zones in the area of study are split so that traffic from existing and proposed land use developments may be loaded more precisely onto the network. Local roads of interest that are not part of the regional model are added. DVRPC uses focused traffic assignment in conducting corridor or area highway traffic studies.

3. Transit Studies

The Federal Transit Administration's (FTA) discretionary New Starts program is the Federal government's primary financial resource for supporting locally-planned, implemented, and operated transit capital investments. To qualify for New Starts funding, candidate projects must have resulted from an alternatives analysis study which evaluates several modal and alignment options for addressing mobility needs in a given corridor. The alternatives analysis must include the benefits, costs, and impacts of alternative transportation investments. Because this is a competitive program, FTA requires all candidate projects to undergo the same evaluation methodology. To facilitate this, they have developed the SUMMIT program which works in conjunction with travel demand models to produce estimates of cost effectiveness and other measures of user benefits.

A separate and significant constraint forces all alternatives to use the same trip table. In practice this means that the build-alternatives must use the No-build trip table. Each alternative is forced to have identical travel patterns. Furthermore, the effects of reduced highway congestion on increasing transit speeds are not considered since highway link impedances are kept constant. These requirements are in contradiction to the criteria for travel demand models used in conformity demonstrations, where the trip table needs to be a function of the transportation network and its assigned travel impedances. Thus, DVRPC must develop and maintain different travel models for transportation conformity demonstration and transit New Starts evaluation.

Because of this constraint, an iterative procedure with feedback is used instead of the Evans algorithm procedure used for highway studies and conformity analysis. For the No-build alternative, the iterative portion of the forecasting process involves updating the highway and surface transit network restrained link travel speeds, rebuilding the minimum time paths through the networks, and skimming the inter-zonal travel time from the new congested minimum paths. Then the trip distribution, modal split, transit and highway assignment models are executed in sequence. This procedure is shown in ***Figure II-2***. Like highway corridor studies, DVRPC uses a focused travel simulation process for transit routes or corridors.

4. Transportation Conformity Analysis

The Clean Air Act (CAA), first enacted in 1963 and last amended in 1990, requires the US EPA to set national ambient air quality standards (NAAQS) for air pollutants that are considered harmful to public health and the environment. In compliance, US EPA has set NAAQS for several principal air pollutants, which are called "criteria" pollutants. These NAAQS criteria pollutants include ozone, carbon monoxide (CO), coarse and fine particulate matters (PM10 and PM2.5, respectively), sulfur dioxide (SO_2), and lead (Pb). The DVRPC region, or portions of it, has been designated as non-attainment areas for ozone and fine particulates. Areas in non-attainment must have a State Implementation Plan (SIP) for reaching attainment. One element of the SIP is a motor vehicle emissions budget (MVEB) which sets regional emission limits for motor vehicles. CAA regulations require that federally supported highway and transit projects be shown not to cause emissions in excess of the MVEB.

DVPRC's travel simulation models provide key inputs to the transportation conformity demonstration analysis process for air quality. The transportation conformity rule requires that conformity analyses be based on the latest motor vehicle emissions model approved by the Environmental Protection Agency (EPA), which is currently MOBILE6.2. The transportation simulation modeling process as described in Section A of this chapter is used in conformity analysis. The travel simulation models provide VMT inputs to the MOBILE6.2 model disaggregated by hour, facility type, and county. Disaggregated vehicle speeds are determined by post-processing travel simulation model outputs. Vehicle speeds and VMT are input to the MOBILE6.2 model. The MOBILE6.2 model produces estimates of emissions factors that are used to calculate total emissions. EPA regulations require that an iterative process be used so that highway travel times produced by highway

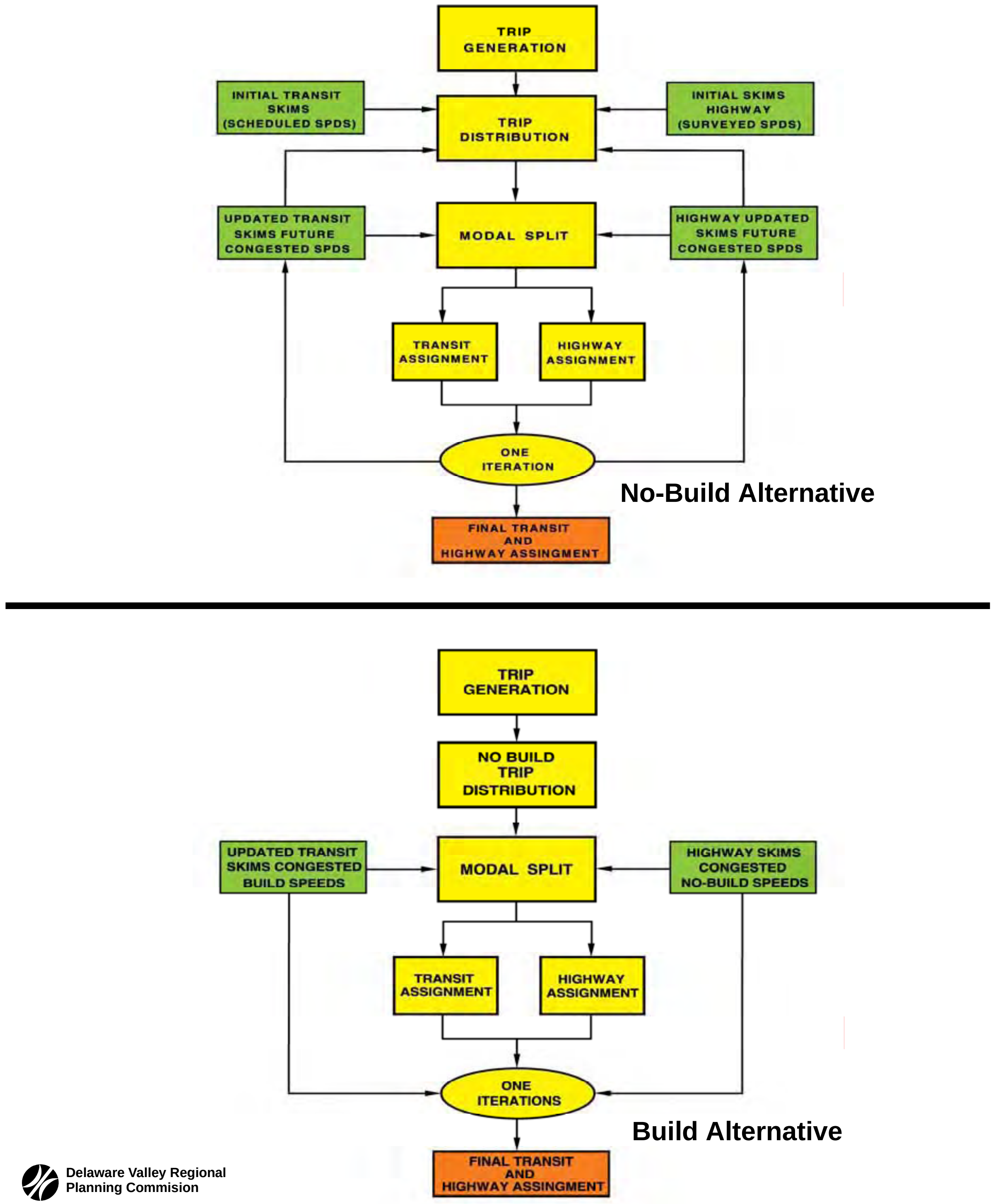


Figure II-2 FTA New Starts Compliant Model Structures for No-build and Build Alternatives

assignment are consistent with the travel time inputs to the trip distribution and modal split models. This requirement is met by the use of the Evans algorithm combined-equilibrium framework.

5. Member Government's Transportation Studies

DVRPC provides the transportation simulation models to its member governments for use in transportation studies. These models are often used by consultants under contract to member governments. Most consultants depend on DVRPC travel models to produce highway and transit travel forecasts for their studies. DVRPC sometimes provides consultants with data with which they use as inputs to their transportation models in order to produce travel forecasts. DVRPC also provides the model to non-profit organizations and citizens interested in transportation and clean air issues, such as the Clean Air Council.

D. Early DVRPC Models and 1990 Model Validation

The first Delaware Valley transportation models were created in the 1960s by the Penn-Jersey Transportation Study, DVRPC's predecessor agency. The Penn-Jersey Transportation Study covered the urbanized area, shown as the inner cordon in ***Figure XI-3*** (Page 234). The Penn-Jersey Transportation Study models were then extensively updated in the 1970s to adopt the now standard "four-step" modeling paradigm. At that time the DVRPC area was extended to cover the entire nine-county region. The model detail was also increased and the travel assignment model was improved in past transportation planning and travel simulation studies such as:

Penn-Jersey Transportation Study	1960s – 1970s
DVPRC Resimulation Study	1970s – 1980s
DVRPC Enhancement Study	1990s – 2005

In the 1980s the model was calibrated and validated based on 1980 data. Just prior to 1990, home interview travel surveys of 2,500 households were conducted in both New Jersey and Pennsylvania (1987 and 1988 respectively). Extensive vehicle surveys were performed on both internal screen lines and cordons to measure vehicles crossing the region's boundary (1988 – 1989). This was the first time that this type of data was available since the 1960s when the original models were created. These surveys, the 1990 Census Transportation Planning Package, and highway and transit ridership counts were used to update the travel demand model parameters that were initially estimated with 1960 survey data. Significant changes in the region's transportation networks also necessitated a major update to the model. The simulation models were also converted from UTPS software to the TRANPLAN model package. Modifications of the TRANPLAN package were needed in order to handle the large size of the DVRPC highway network. The process used to validate the 1990 model can be seen in ***Figure II-3***.

The steps in the process used for 1990 model validation are listed below:

1. Update networks and TAZs
2. Estimate socioeconomic inputs
3. Estimate employment inputs
4. Recalibrate external trip generation model
5. Recalibrate internal trip generation model
6. Recalibrate trip distribution model
7. Recalibrate modal split and auto occupancy models
8. Compare simulated highway results with screenline counts
9. Compare simulated transit results with ridership counts
10. Iterate steps 4-9 until sufficiently accurate results are achieved

In the first step the highway and transit networks were revised to reflect new facilities, service levels, and the updated traffic zones based on Census TIGER file geography. In the second step the socioeconomic inputs to the simulation model by traffic zone were extracted, examined, and adjusted from Census zonal data. Employment data by travel mode was extracted in the third step from census Journey-to-Work data.

In steps four through seven the models were recalibrated according to the inputs obtained in steps one through three. The external trip generation model was recalibrated in the fourth step based on the regional cordon line survey and the cordon station traffic counts. The internal trip generation model was recalibrated in the fifth step using the home interview survey, the Census zonal socioeconomic data, and the Census Journey to Work data. In the sixth step the modal split and auto occupancy models were recalibrated based on the home interview survey, the Census journey to work data, and the highway and transit networks.

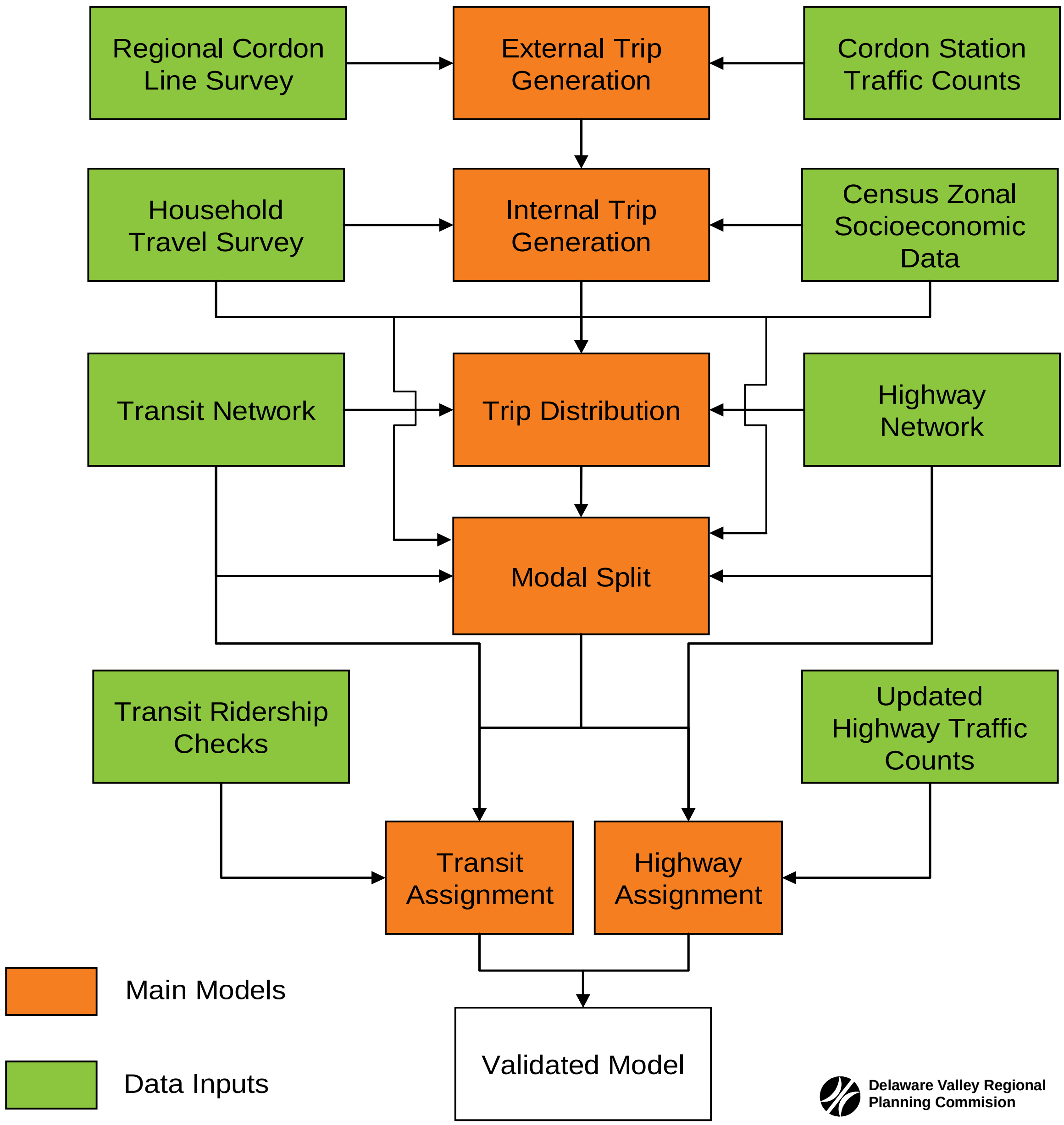


Figure II-3 1990 Model Validation Process

In steps eight and nine various model parameters were recalibrated so that simulated results for transit and highway respectively matched actual counts. The model was executed in the eighth step and the simulated transit results were compared to counts. Transit network coding and mode split parameters were adjusted as necessary. In the ninth step the model was executed and the highway simulated screenline results were compared with counts. Highway network coding, trip under-reporting rates, auto occupancies, speed lookup tables, and capacity lookup tables were adjusted as necessary. Step ten repeated steps four through nine until sufficient accuracy was reached.

The 1990 model update process modified the traffic zone structure to account for changes in Census geography. The number of traffic analysis zones was increased from 1,335 to 1,395, and the number of external stations was increased from 74 to 114. An additional County Planning Area (CPA) was created to include three Berks County municipalities that were added to the DVRPC study area for transportation planning and analysis purposes. These municipalities, Boyertown Borough and Colebrookdale and Douglass townships, were added so that the entire Pottstown urbanized area would be included in the DVRPC simulation model.

Numerous updates to the highway and transit network were necessitated by actual system changes that occurred in the 1980s and by the introduction of new TAZs. New highways added to the model include NJ 55 in Gloucester County and the US 422 expressway in Montgomery County. A total of 112 new directional freeway miles were added to the network. Many new links were added to the highway model due to new EPA regulations that required all roads with a 1990 Federal Functional Classification of Minor Arterial and greater to be included in the model. A complete review of functional classification was performed for the entire network. New links were also needed to provide adequate access and realistic loading for new TAZs created because of Census changes. Overall these updates increased the system mileage by about 2,100 one-way miles to 14,047, represented by 13,304 nodes and 39,767 links.

Similar to the highway network, the transit network was also updated to incorporate newly created TAZs. Fares and morning peak period headways were updated to spring 1990 levels. Several transit network changes were made due to the changes in transit service that occurred in the 1980s. The West Chester and Ivy Ridge Regional Rail lines were truncated due to service cutbacks. Abandoned SEPTA stations were also eliminated from the model. Changes also occurred in the New Jersey portion of the transit network. Alterations were made to the transit network because of the transition of Mercer Metro to New Jersey Transit (NJT) and the associated route restructuring. The network was also updated to reflect the initiation of NJT Atlantic City line service from Lindenwold to Atlantic City.

Changes were also made to the trip generation, trip distribution, mode split, and highway assignment models. Most of the changes were in calibration factors to reflect demographic and employment trends. Substantial changes occurred in the 1980s, the most significant being suburbanization. Occupied dwellings increased 8.7 percent, outstripping population growth. Zero and one automobile households decreased, while 2 and 3+ automobile households increased. Employment in the region grew 19 percent. New trip production rates were used for the trip generation model, although they were similar to the 1980 rates.

For trip distribution, gravity type models developed in earlier studies were recalibrated with the 1987/1988 home survey interview data. The external-internal attraction model was also recalibrated from the 1988-1989 cordon line origin – destination survey. Updated highway and transit impedance skims were used.

The binary probit mode split model was recalibrated. Transit sub-mode continued to be determined by the transit assignment procedure. Parameters for calculating Standard Transit Score for use in the probit modal split model were re-referenced to 1990 economic data. Recalibrated inter-area type coefficients were used to match the new data. The auto occupancy model, based on trip purpose and trip length, was recalibrated and adjusted according to the 1990 Census and 1987/1988 survey data. The major change in the highway assignment model was to significantly increase capacities for links in all functional classes. This was done to account for peak spreading that had occurred in the region during the 1980's. The link capacity restraint curves were also changed. These cost curves model the increase in travel time as traffic volumes and hence congestion increases. The curves were changed so that travel times increase more rapidly as traffic volumes increase. This was done in order to better model traffic flow conditions in the DVRPC region.

E. Enhancement of DVRPC Travel Simulation Models

DVRPC's travel simulation models were again updated in the late 1990s to simulate 1997 travel patterns. New data were used to update the models. Updated demographic and employment estimates were developed for the 1997 models. These reflected the continued suburbanization of the Delaware Valley. Urban areas continued to lose both employment and jobs, while suburban and rural areas gained both. DVRPC models were also updated to take into account the growth of vehicles in service and the growth in occupied housing that outstripped population growth in the 1990-1997 period. Area type classifications were also updated due to new population and employment figures. Changes were also made to the transit and highway networks to reflect the changes that had occurred in the 1990-1997 period. The 1997 models used the same TAZ system as the 1990 models.

DVRPC's models were also updated to reflect updated traffic and transit counts. Traffic cordon and external station counts were taken in 1995. Traffic and transit counts mirrored the demographic and employment changes that had taken place since the 1990 calibration.

The updated travel simulation models served as a starting point for a set of extensive model enhancements. These enhancements were occasioned by new federal requirements imposed by the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the Clean Air Act Amendment of 1990 (CAAA). In 1993, DVRPC hired consultants to review its existing models in light of these new requirements and recommend enhancements to the modeling process. Eleven specific recommendations were made:

1. Revise highway assignment speeds, capacities, and restraining curves.
2. Develop an iterative simulation model structure.
3. Develop a nested modal split model.
4. Separate transit assignment models by access mode.
5. Develop a transit highway network interface.
6. Separate travel simulation models into peak and off-peak time periods.
7. Revise the external-internal trip distribution model.
8. Develop a pedestrian/bicycle trip generation model.
9. Develop a vehicle ownership model.
10. Conduct a comprehensive travel time survey.
11. Review existing land use models.

Two separate model families were then created. The "existing" models were updated to consider the new demographic, employment, traffic count, and transit count data, but were identical in structure to the 1990 models. Separate "enhanced" models also used the updated calibration, but implemented a number of the model improvement recommendations. A comparison of the two models is shown in ***Figure II-4***.

The two most significant improvements in the enhanced model were the adoption of separate peak and off-peak modeling periods and the introduction of an iterative process. The later was done to ensure that the highway impedances used in the trip distribution model and mode split models were consistent with the assigned highway volumes. A combination of standard Frank-Wolfe and Evans algorithm procedures was used.

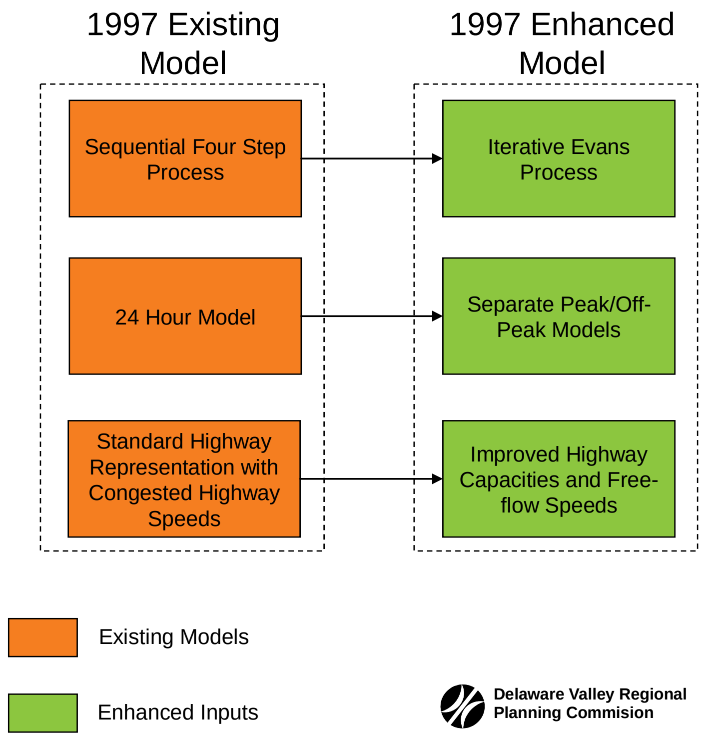


Figure II-4 1997 DVRPC Regional Model Comparison

Numerous improvements to the model were needed to accommodate the use of multiple time periods and the new iterative solution procedures. This required the development of new highway free-flow speeds and capacities. The representation of highway disutility was also improved. Additionally, the transportation network coding procedures were revised to expand the functional class system from 9 to 27 individual categories, model the effects of toll charges and queuing delays at bridge and turnpike toll booths, and reflect the difference in transit service between peak and off-peak time periods. The trip distribution, mode split, highway assignment, and transit assignment models were all updated to account for the two time periods and the iterative procedure.

F. Calibration and Validation of the Current DVRPC Models

The 2000 travel simulation models included calibration and structural changes from the 1997 models. In preparation for the 2000 calibration and validation, the number of traffic analysis zones in the region was also increased from 1,395 to 1,912 to reflect Census 2000 changes; the number of external cordon stations was increased from 114 to 156; and the Chester County Planning Area (CPA) boundaries were redrawn to match their school districts, bringing the number of CPAs to 74. In addition, more detail was added to the highway network, especially in simulating expressway interchanges. This increased the network coverage to 20,850 one-way miles, represented by 19,945 nodes and 54,328 links.

Various data sources were used for the 2000 calibration. The main data source was the 2000 Census and the Census Transportation Planning Package (CTPP). A home interview survey of 4,217 households was conducted to obtain detailed travel information from personal travel diaries. A cordon line survey was conducted in 2001 to obtain information about external trips. A highway travel time survey was conducted in the late 1990s. This was then augmented by a transit time survey conducted in 1997. A truck survey was conducted in 2001 via travel diaries. A small taxi survey was also conducted in 2001. Data from separate turnpike surveys conducted in the 1990's by PA and NJ were used. Highway screenline and cordon line traffic counts were obtained in 2000. Finally, transit ridership information was obtained from the National Transit Database program as provided by the transit operators in the DVRPC region

The structural model enhancement process that started with the 1997 travel simulation models continued with the 2000 travel simulation models. The 2000 models adopted the improvements from the enhanced 1997 model, such as the use of multiple time periods and an iterative model structure. The following structural modifications are briefly discussed:

1. Three and four time period modeling.
2. Improved coding procedure for transit facilities.
3. Logit modal split model.
4. Separate turnpike external-internal trip distribution model.
5. Separate freeway, arterial, and local external-internal trip distribution models.
6. Evans iterative solution process.
7. Emissions post-processor model.
8. Non-motorized travel model.

1. Multi-time Period Modeling

To increase model accuracy a three time period model was implemented by splitting off-peak travel into midday and evening/night. This improved the off-peak modal splits and transit results and also provided higher, more realistic highway travel speeds during the evening time period for transportation and air quality modeling.

This was especially important for the accurate representation of transit service, which has widely different levels of service in the evening than in the midday.

In some studies there is a need for separate AM and PM peak period highway assignments. Such studies include the simulation of some intelligent highway system (ITS) options, evaluation of CMAQ proposals, and the provision of travel forecasts for facilities that are highly peaked and/or operate only during peak periods. For these reasons, a four time period model was also developed which separates the peak period into AM peak and PM peak periods. The separation from total peak trips to separate AM and PM peak trips is done for highway trips only after the mode split step in the Evans framework.

2. Improved Coding of Transit Link Speeds

In-vehicle travel time on most bus lines and some light rail lines depends on the level of highway congestion. The coding procedure for the transit network was improved in order to capture the interaction between the highway and transit networks. The transit modes in the Delaware Valley region were segregated into 12 groups. Twelve different groups were needed to sufficiently reflect fundamental differences in speed characteristics between different transit sub-modes and to overcome certain software deficiencies. The speed on a given transit link can either be coded so that it is predetermined based on a general route or mode speed, or specific for the given link. The link can also be coded, however, so that its speed is determined by the prevailing level of highway congestion. In that case, the link speed is determined using a linear function of highway speeds.

3. Nested Logit Modal Split Model

In 2004 the structure of the modal split model was changed from binary probit to a logit formulation and a nested structure was implemented to be compatible with the Federal Transit Administration's (FTA) New Starts evaluation criteria. Similar to the binary probit approach, the logit model has 18 separate diversion curves for all permutations of:

- Trip purpose (3).
- Transit submode (3).
- Auto ownership (2).

In addition to the 18 separate diversion curves, the logit model is nested by transit access mode with separate branches for walk-access and auto-access. The FTA also requests that the modal split model be nested by mode of approach (walk/bus versus auto approach). This nesting is required to adequately model transit approach and provide required inputs into the SUMMIT model.

4. Turnpike Trip Distribution and Toll Booth Queuing Models

A new gravity model was developed in 2003 to distribute external-internal traffic from the cordon stations representing the Pennsylvania and New Jersey Turnpikes, which have a different trip length frequency distribution than other freeways in the region. The gravity model was calibrated from 1999 PA Turnpike and 1997 NJ Turnpike data for each of the three trip purposes, but on a daily basis as the data sets were too small to disaggregate by time of day. The calibration data showed that the NJ Turnpike's southern portal into the DVRPC region had trip characteristics similar to other freeways, and was therefore not included in the turnpike distribution model. A toll plaza queuing model was also adapted from the Florida Turnpike model included in TRANPLAN's EQUILB function to represent the disutility associated with decelerating, queuing, and accelerating at toll booths. This model was used for all toll booths in the region, including those on the turnpikes and bridges.

5. External-Internal Freeway, Arterial, and Local Trip Distribution Models

In relation to the turnpike trip distribution model, a separate freeway-only trip distribution model was retained to distribute external-internal trips from the non-toll freeways in the DVRPC region. The Arterial/Local external-internal trip distribution model was disaggregated into two separate models for the 2000 simulation. This was done because trips on these two different classes of facilities have significantly different trip lengths. This produced an arterial external-internal trip distribution model and a local external-internal trip distribution model.

6. Implementation of Iterative Evans Algorithm

As in the 1997 enhanced models described in this chapter, the 2000 model utilizes the Evans algorithm to iterate the model. Urban Systems Inc. was retained by DVRPC to prepare a special extended version of TRANPLAN that supports the

Evans algorithm procedures. This required creation of special computerized feedback and weighting mechanisms between the trip distribution, modal split and highway assignment programs. These special features have been incorporated into TRANPLAN Version 9.1.

7. Emissions Estimation and Conformity Demonstration

In 2002 the EPA released MOBILE6.2, an updated mobile emissions model. Conformity demonstration analyses are required to use the latest EPA mobile emissions model. The 1997 travel simulation models included a post-processor for use with MOBILE5. MOBILE5 provides emissions rates from link specific inputs of operating speed and VMT. MOBILE6.2, however, calculates emissions factors given distributions of travel by functional class, time of day, and speed. DVPRC's post-processor was rewritten in order to provide the correct data to MOBILE6.2 and to calculate total emissions given MOBILE6.2's different outputs. In addition to structural modifications in the MOBILE6.2 post-processor, the post-processor volume-speed curves were recalibrated using 1995/1996 speed data and 2000 traffic volume data.

8. Non-Motorized Travel Model

Previous versions of DVRPC's travel simulation model had only considered motorized travel (auto and transit). However, there is a growing recognition that non-motorized travel often serves as a substitute for motorized modes. This growing recognition, coupled with federal legislation aimed at reducing congestion and improving air quality, has stimulated interest in the analysis of non-motorized modes (walk and bike). A non-motorized travel model was incorporated into the DVRPC 2000 travel simulation model in order to quantify non-motorized trips and to measure the effectiveness of various policies in reducing motorized travel. Trip generation rates were developed to include both motorized and non-motorized travel based on the 2000 Household Travel Survey.

G. 2000 and 2005 Validation of the DVRPC Models

The enhanced models were validated with the 2000 and 2005 socioeconomic data, CTPP and survey data, traffic counts, and transit ridership estimates. Motorized and non-motorized travel models were used to estimate 2000 and 2005 travel demand. The travel simulation models used updated population and employment estimates. Regional employment grew 2.2 percent and regional population grew 2.4 percent in the 2000-2005 time period. The changes were larger on a county basis. For example, Chester County's population grew 9.3 percent in the same time period. These large and disproportionate changes required application of the models with the 2005 data. DVRPC's current travel demand models have been validated against observed conditions in both 2000 and 2005.

III. DEVELOPMENT OF AREAL SYSTEM FOR 2000 TRAVEL SIMULATION

Travel simulation models rely on Traffic Analysis Zones (TAZs) to estimate travel patterns. As part of the 2000 travel simulation, the DVRPC study area has been divided into 1,912 such zones. Population, employment, and other socioeconomic variables are assigned to these geographic units. The model determines trips between each pair of zones and assigns these to either the highway or transit networks. Each TAZ has a “middle” point called a centroid. All trips that originate or terminate in a particular TAZ are modeled as originating or terminating at the zone’s centroid. This chapter discusses how TAZs are determined and classified. A set of larger analysis zones called County Planning Areas (CPAs) is also discussed.

A. Criteria for Developing 2000 Traffic Analysis Zones

The 2000 US Census marked a departure from prior methods of defining TAZs. For the first time, the US Census agreed to provide Census data summarized by TAZ rather than Census tract, block groups, or blocks. A GIS program (TAZ-UP) was provided to assist DVRPC in defining TAZs. Because of continuity reasons DVRPC elected to respect census block geography, and in many cases block group geography, in designing the 2000 TAZs. The introduction of new GIS technology and an increase in computing capabilities allowed a significant expansion of the zonal system without a complementary increase in computation time. Theoretically, this leads to a better fit for the network as a whole and less work to enhance the network in corridors that are studied. In order to increase accuracy in general, and in areas that had experienced population and employment growth in particular, the number of TAZs was increased by splitting 1990 TAZs.

Four criteria were established for the TAZ splitting process. The first of these included changes to the Census geography. The second and third criteria were the population and employment of a TAZ. Where these exceeded a certain threshold, the TAZ was reviewed for possible subdivision. Finally, a zone with adequate population and employment could qualify for splitting based on the geography of the zone (for instance, a large township comprised of a single zone could be split). Respect for the current highway network was maintained in an attempt to add as few new facilities to the network as possible. Each of the four criteria is now discussed in detail.

- Census geography
- Zonal Population size
- Zonal Employment size
- Transportation access

Where the US Census identified a tract to be split, DVRPC split the corresponding TAZ exactly as the Census proposed. These identified tracts had in most cases surpassed the 10,000 population limit established by the Census. Changes to block groups, including boundaries and numbering, were not incorporated. Besides Center City and two municipalities in Delaware County, DVRPC had previously always used tract geography. As such, changes to block groups did not affect the process.

The population of a TAZ provided the second criteria for splitting a zone. The TAZs within each county were sorted by population in descending order. Target zone upper limits on population were established from the 1997 regional zone average population. The limits were set at 50 percent higher than the 1997 average (5,637) for suburban zones and 100 percent (7,516) higher than the 1997 average for Philadelphia zones. This resulted in a recommendation that a TAZ be split into 2, 3, etc. TAZs. Block group boundaries were posted for candidate zones on a set of maps specifically printed for this purpose. The 1990 block group population totals were used within a GIS program to gain a feel for how the population was distributed across the zone. In cases where the Census dictated the split, population was summarized for each of the subdivisions. Where the population criterion existed without also qualifying as a Census split, the block group boundaries generally dictated the subdivision of the zone. Exceptions to this rule were made when the highway network suggested a different split or when a block group was too large or geographically positioned to make following block group boundaries practical.

The procedure for splitting a zone based on employment was similar to that used for the population criteria. TAZs were sorted by employment. The upper limit was established as 100 percent greater than the 1997 average zonal employment (3,950) in suburban zones and 200 percent (5,925) higher in Philadelphia zones. Because the Census focus is on population and not employment, employment information was not available at the block group level. Therefore, local knowledge, county maps, and aerial photography were used to determine the distribution of employment in a targeted TAZ. Splits were attempted along block group boundaries, except in cases where a block group was too large or where the highway network suggested a better division.

The final criterion used in the review of TAZs for subdivision was the geography of an identified TAZ. Particularly at the extremities of the region, where population and employment densities are low, entire townships may be represented by a single TAZ. Previously, the model was not affected by this situation, as population and employment, and thus transportation improvement studies, were located closer to the center of the region. Two events have changed this situation. First, over time the region has decentralized, creating the need to perform transportation studies in many of these outlying areas. Second, ISTEA required that all highway facilities classified greater than "minor collectors" be included in the simulation's highway network. These were added in the mid 1990s; however, this resulted in many townships having facilities that were not loaded in the model - only four centroid connector links are allowed using TRANPLAN and a township TAZ may have nine or ten highway facilities. Thus, zone splitting may produce better loading and, thus, a better traffic assignment. County maps and aerial photographs were used in determining potential divisions for geographic reasons. Care was exercised to make sure that population and employment existed in each of the subdivisions and that the highway network was considered in the zone splitting process.

The 2000 travel simulation network contains 1,912 internal traffic analysis zones. This is an increase of 517 over the number in the 1990 validated network. The modeling software used by DVRPC, TRANPLAN, requires that TAZs be numbered in a consecutive, unbroken sequence beginning with the number "1." The TAZ centroid numbering sequence began with the 54 zones in the Philadelphia CBD, continued with the remainder in the City of Philadelphia, and proceeded with Delaware County and the remaining counties in a clockwise manner around Philadelphia. In order to maximize the correspondence between the 1980 zonal system and the traffic zones developed for the 1990 and 2000 Censuses, traffic zones were numbered in the same clockwise pattern beginning with 1336 in 1990 and 1396 in 2000.

Appendix III-1 shows the range of centroid numbers assigned to each area. It also lists the 74 CPAs established for the DVRPC region as well as the part of Berks County included in the travel simulation process. The maps in **Appendix III-2** show the TAZs for each county in the region beginning with Philadelphia County and proceeding clockwise around the region and ending with Gloucester County. The DVRPC models use the same areal system for the 2000 and 2005 travel simulations. The number of TAZs in the Delaware Valley region (1,912) is larger than the average number of TAZs in large metropolitan areas (1,739) in the United States (VHB, *"**Determination of the State of the Practice in Metropolitan Area Travel Forecasting**"*).

B. External Cordon Stations

Travel that crosses the outer boundary of the region must be represented in the travel simulation model. As mentioned above, ISTEA required that all highway facilities with a classification greater than minor collector be included in the simulation network. The entry/exit points in the transportation network model are called cordon stations. Thus, all of these facilities crossing the regional boundary were included as cordon stations. In addition, a number of local facilities that provide connectivity or fill gaps in the grain of the network were added.

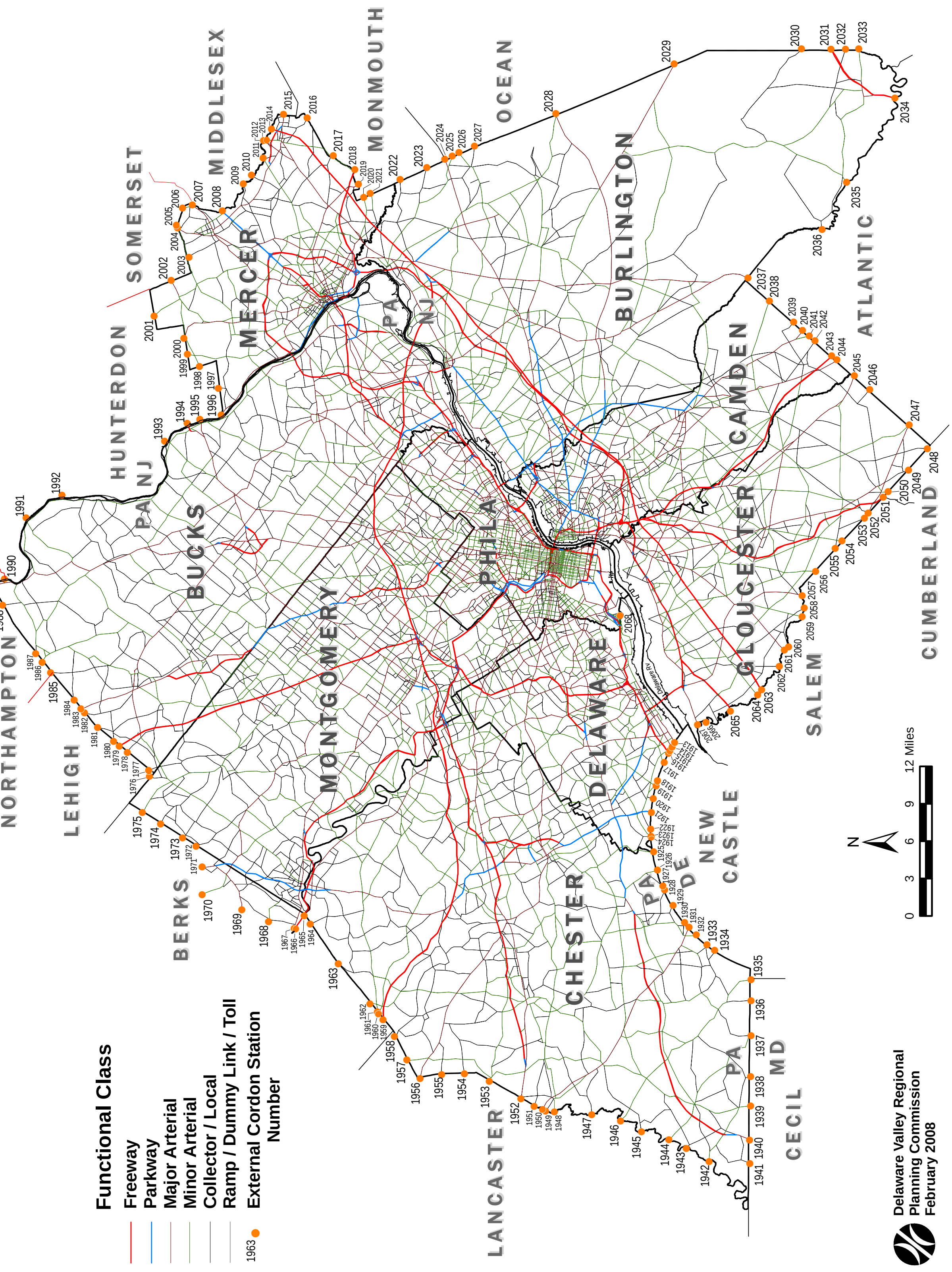
A systematic review of cordon crossings was performed in the preparation of the 2000 travel simulation. Additional cordon crossings were necessary due to two factors – the subdivision of traffic analysis zones near the regional boundary and the dispersion of population and employment toward the outer portions of the region. Each of these factors dictated a finer grain to the highway network in these areas. A total of 42 new locations, all local facilities, were added yielding 155 external cordon stations for the 2000 travel simulation. These stations were assigned centroid numbers, beginning with US 13 in Delaware County (number 1913) and continuing clockwise around the region through US 130 in Gloucester County (number 2067). The number of cordon stations in the DVRPC model (155) is much larger than the average number (46) in large metropolitan areas nationwide (VHB 2007). The volume of travel into and out of the region at Philadelphia International Airport necessitated adding a cordon station (number 2068) to facilitate loading as a special generator. The table in **Appendix III-1** also shows the range of external cordon station centroids assigned to each county. ***Figure III-1*** shows the 2000 external cordon stations.

C. County Planning Areas

Simulation results are tabulated on the basis of a system of analysis areas called "county planning areas (CPAs)." It is difficult to manage the various steps in the simulation process and to monitor the results unless TAZ level data is summarized at a higher level of aggregation. The use of analysis areas also simplifies the reporting of summary data.

Of the 74 CPAs in the DVRPC region, 73 were developed by the nine counties individually and represent those areas that are commonly used for county planning. An additional district was created to summarize information for the three Berks County municipalities added to the DVRPC region in 1990 for transportation planning and analysis purposes. This system makes the results of the simulation more usable by local planning agencies, as little or no conversion is required when data are passed to member governments for their use. For instance, the county planning areas for Chester County were redesigned in 2000 to match school districts as these are the subdivisions used for planning by the county planning commission.

Figure III-1 2000 External Cordon Stations and Highway Network



The 74 county planning areas are shown in ***Figure III-2***. **Appendix III-1** lists each county planning area by number, CPA name, and the county to which it belongs. The TAZs that comprise each CPA are also listed. The CPA names were provided by county planning staffs. Computer programs that are used in the modeling process to aggregate and summarize data make use of this equivalency table between zone number and the CPA number.

D. Area Type Classification

Common to all travel demand models is a system of area type categories that are used to classify the TAZs. Area type is an indicator of the intensity of travel activity occurring in a zone rather than zone size, land use, etc. This is a critical item of information in the models, as it affects all four steps of the travel forecasting process. It is used to select the coefficients in the trip generation analysis, set the terminal and intrazonal travel times for the distribution models, define the diversion curves that are to be used in the modal split analysis, and set the link parameters for the highway traffic assignment. The specific uses and effects of the area type categories will be explained in the relevant portions of this document. In addition, the area type code creates a useful means for interpreting summary data.

A measure of travel intensity is calculated for each TAZ as a starting point to grouping them into area type categories. This intensity of activity is estimated by computing the following factor for each zone:

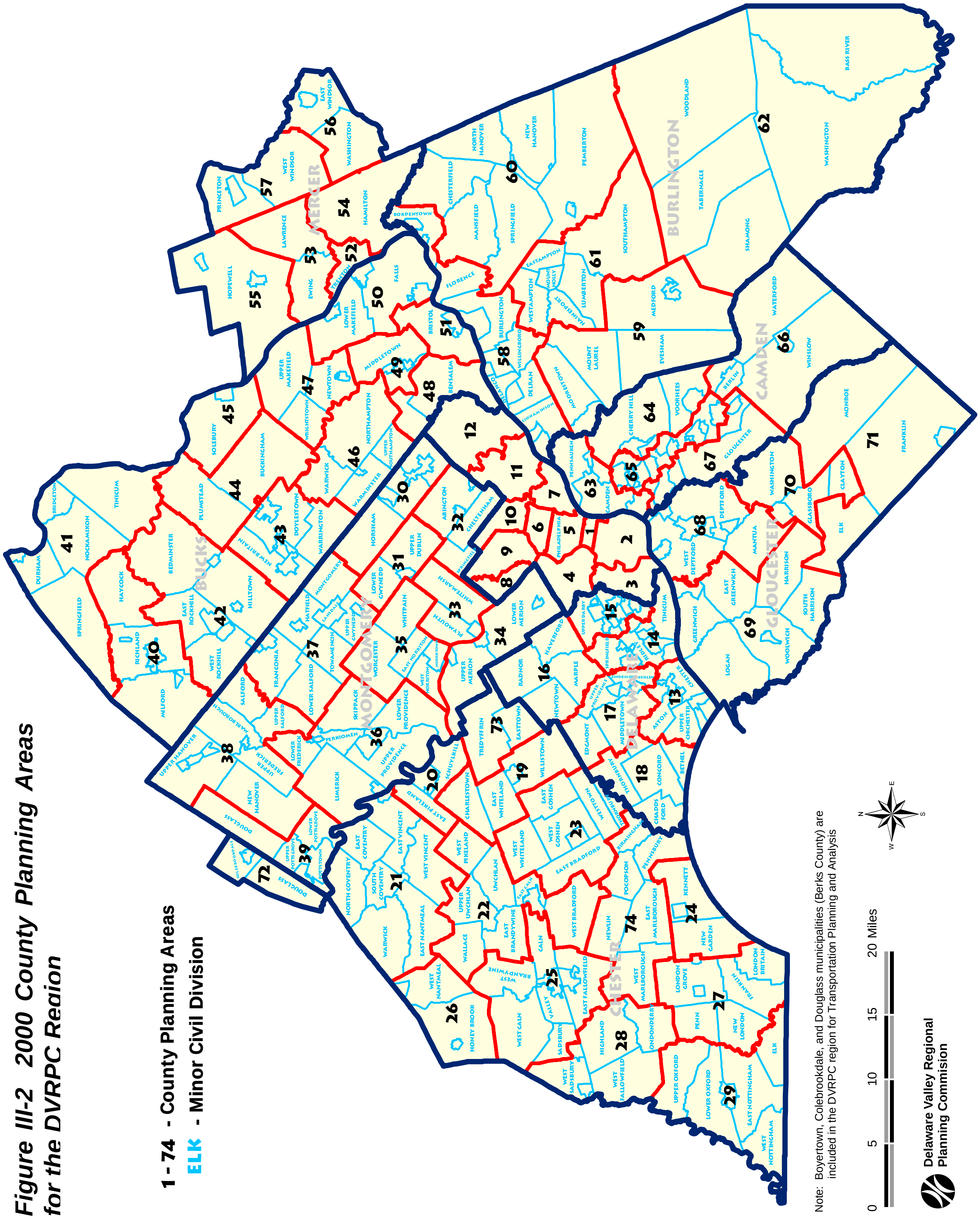
$$\text{Intensity Factor; } \alpha = \frac{(\text{Population}) + 2.37 \times (\text{Employment})}{(\text{Land Area, in Acres})}$$

The employment multiplier of 2.37 used in this equation is empirically derived, and was originally calculated in previous travel simulations by dividing the number of trips produced per resident (total population) by the number of trips generated per employee. This factor has demonstrated stability over time. The resulting value of this computed factor, falling within a specified range, establishes the initial area type for each zone. The six area types and the range of intensity factor values along with the frequency distribution of each category are shown in ***Table III-1***.

Figure III-2 2000 County Planning Areas for the DVRPC Region

1 - 74 - County Planning Areas

ELK - Minor Civil Division



Note: Boyertown, Colebrookdale, and Douglass municipalities (Berks County) are included in the DVRPC region for Transportation Planning and Analysis

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Table III-1 Area Type by Intensity Factor and Frequency

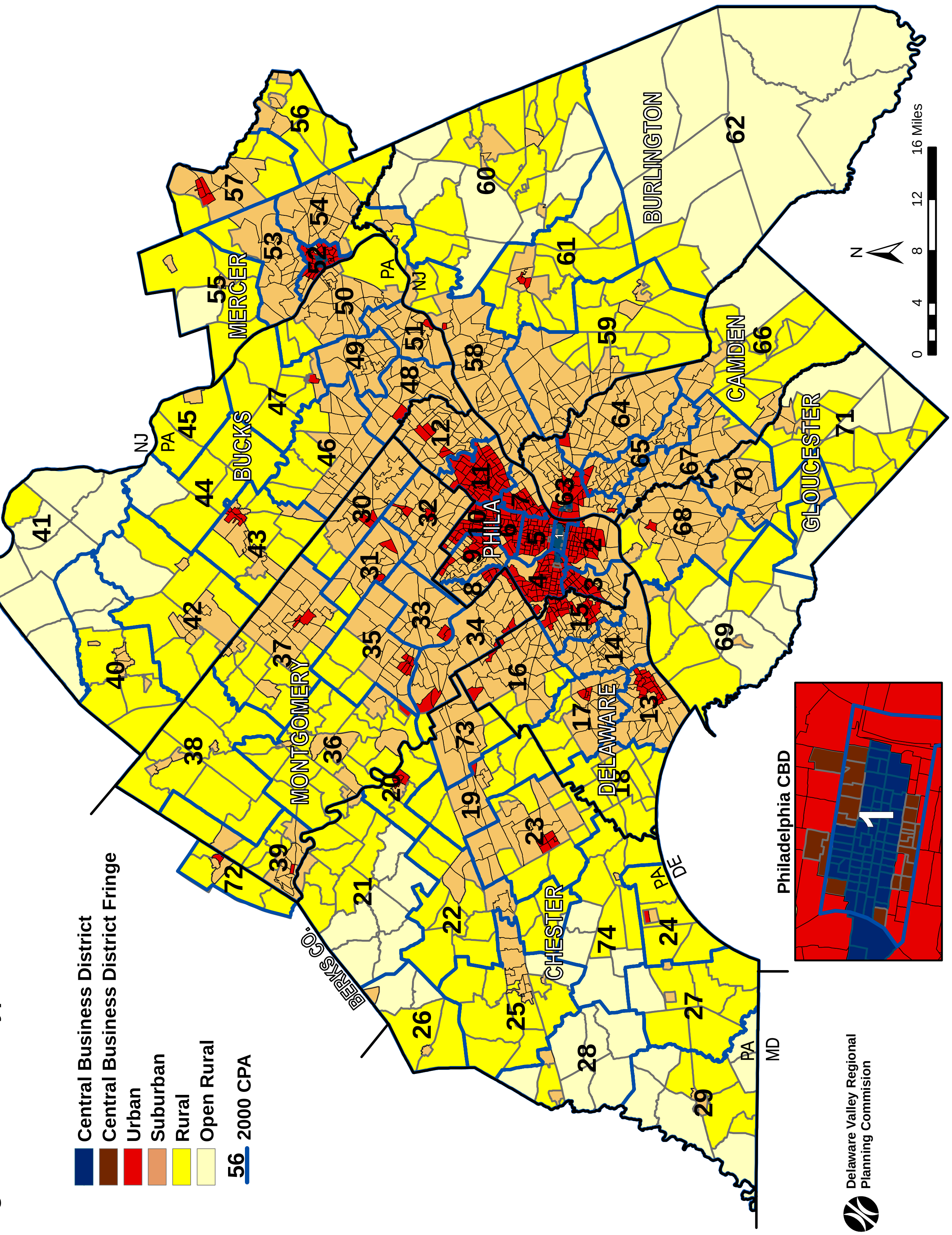
Code	Area Type	Factor Range	# of TAZs
1	Central Business District (CBD)	$200 < \alpha$	65
2	Fringe of CBD	$120 < \alpha < 200$	25
3	Urban	$25 < \alpha < 120$	483
4	Suburban	$4 < \alpha < 25$	976
5	Rural	$0.5 < \alpha < 4$	297
6	Open Rural	$0 < \alpha < 0.5$	66

Source: DVRPC July, 2008

The area types are then plotted on a zone map after an initial assignment of area type by intensity factor. The results are then reviewed manually. Manual adjustments provide continuity to the area types (for instance, providing that a traffic analysis zone in an urban area which includes a large park is not labeled "open rural" as a result of applying the above formula*).* ***Figure III-3*** displays the DVRPC zonal system showing the 2000 area type for each TAZ.

The zones corresponding to Census water tracts also require area type values. They were generally assigned area type codes equal to those of adjacent zones since the population and employment within these zones are zero. There is no net effect on the model of making these assumptions since water tracts neither produce nor attract trips. However, modelers reusing the water tracts to consider the effects of special generators or for other purposes need to be familiar with area type values and their effects on developing, distributing and assigning trips to and from the water tracts to be used.

Figure III-3 Area Types for Travel Simulation



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IV. SOCIOECONOMIC ZONAL DATA FOR TRAVEL SIMULATION

Demographic and employment data are the primary input into the DVRPC trip generation model. Variables such as population and employment are good indicators of trip making. The accurate estimation of these factors is important to the overall transportation modeling process. The accurate estimation of these factors is also data and time intensive. This chapter details how these various indicators were determined for both 2000 and 2005. Historical trends in the DVRPC region are analyzed. See the ***"2000 Data Bank for Transportation Planning"*** (DVRPC report # 04023) for a more extensive discussion.

A. 2000 Demographic and Employment Data

DVRPC uses demographic and employment data at the county, Minor Civil Division (MCD), and zonal (TAZ) levels for various planning activities. Zonal level data is required for modeling. The zonal data are drawn from the 2000 Census Transportation Planning Package (CTPP). The CTPP data were tabulated by the U.S. Bureau of the Census (CB) based on responses to the long-form questionnaire, which was distributed to about 17 percent of total households (1 in 6 households). Part 1 of the CTPP (worker and household characteristics by place of residence) includes demographic data. Part 2 (worker characteristics by place of work) has employment information. The zonal data are not fully consistent with Census Summary Files 1 and 3 (SF1, SF3) data because of sampling errors, rounding, and other considerations to maintain respondents' confidentiality. Census zonal socioeconomic raw data, such as population, households (occupied housing units), employed persons, and employment, have been adjusted slightly so that aggregated municipal and county totals equal their counterparts in SF1 or SF3. The employment data shown in this report are generally higher than those estimated by the CB in SF3 because they account for workers who did not commute during the census week and for those who had multiple jobs. The following are the major demographic and employment variables used in the DVRPC models:

- Population.
- Group quarters population.
- Households.
- Vehicle availability.
- Employed persons.
- Employment by sector.

Census Bureau definitions of the socioeconomic data included in this chapter are provided in the following sections:

1. Population

Population includes all people, male and female, child and adult, living in a given geographic area, or the total number of inhabitants in an area without regard to race, gender or any other social and economic variables. As mentioned above, the 2000 CTPP zonal population data have been adjusted slightly by DVRPC to minimize the sampling and non-sampling errors in the 2000 zonal data.

2. Group Quarters Population

DVRPC estimated the number of trips made by those in group quarters for the first time for the 2000 simulation. All people not living in housing units are classified by the Census Bureau as living in group quarters. There are two general categories of people in group quarters: (1) institutionalized population and (2) non-institutionalized population. The institutionalized population includes people under formally authorized supervised care or custody in institutions at the time of the census enumeration. Such people are classified as "patients or inmates" of an institution regardless of the availability of nursing or medical care, the length of stay, or the number of people in the institution. The institutionalized population does not make trips and is therefore not modeled.

The non-institutionalized population includes people who live in group quarters other than institutions. The non-institutionalized population includes college students in dormitories, military personnel living in barracks and dormitories on base, farm workers, nuns living in parochial schools, nurses and interns in hospitals, and many other groups. Also, it includes staff residing in military and non-military group quarters on institutional grounds who provide formal authorized supervised care or custody for the institutionalized population. Unlike the institutionalized population, the non-institutionalized population is modeled.

3. Household

A household includes all of the people who occupy a housing unit. A housing unit is a house, an apartment, a mobile home, a group of rooms, or a single room occupied (or if vacant, intended for occupancy) as a separate living quarters. Separate living quarters are those in which the occupants live separately from any other people in the building and that have direct access from the outside of the building or through a common hall. The occupants may be a single family, one person living alone, two or more families living together, or any other group of related or unrelated people who share living quarters.

In 100-percent tabulations, the count of households always equals the count of occupied housing units. In sample tabulations, the numbers may differ as a result of the weighting process. Like population, the 2000 CTPP household tabulations have been adjusted slightly by DVRPC to minimize the errors in the zonal data included in this report.

4. Vehicles Available

These data show the number of passenger cars, vans, and pickup or panel trucks of 1-ton capacity or less kept at home and available for the use of household members. Vehicles rented or leased for one month or more, company vehicles, and police and government vehicles are included if kept at home and used for non-business purposes. Dismantled or immobile vehicles are excluded. Vehicles kept at home but used only for business purposes also are excluded. The 2000 CTPP vehicle availability data have been adjusted slightly by DVRPC to be consistent with household zonal data.

5. Employed Persons

Employed persons includes all civilians 16 years old and over who live in the region and were either (1) "at work" - those who did any work at all during the reference week (census week) as paid employees, worked in their own business or profession, worked on their own farm, or worked 15 hours or more as unpaid workers on a family farm or in a family business; or (2) were "with a job but not at work" - those who did not work during the reference week but had jobs or businesses from which they were temporarily absent due to illness, bad weather, industrial dispute, vacation, or other personal reasons. Excluded from the employed persons are people whose only activity consisted of work around the house or unpaid volunteer work for religious, charitable, and similar organizations; also excluded are people on active duty in the United States Armed Forces. The reference week is the calendar week preceding the date on which the respondents completed their questionnaires or were interviewed. This week may not be the same for all respondents. The number of employed persons by place of residence has been adjusted slightly to minimize the errors in the sample data.

6. Employment

The 2000 employment data were derived from answers to long-form questionnaire Items 21 and 25, which were asked of a sample of the population 16 years old and over. The series of questions on employment status was designed to identify, in this sequence: (1) people who worked at any time during the reference week; (2) people who did not work during the reference week, but who had jobs or businesses from which they were temporarily absent (excluding people on layoff); (3) people on temporary layoff who expected to be recalled to work within the next 6 months or who had been given a date to return to work, and who were available for work during the reference week; and (4) people who did not work during the reference week, who had looked for work during the reference week or the three previous weeks, and who were available for work during the reference week. The census employment data, by place of work, have been adjusted to obtain total employment (jobs) at the county, municipal, and zonal levels.

7. Industry

Information on industry relates to the kind of business conducted by a person's employing organization. For employed people, the data refer to the person's job during the reference week. For those who work at two or more jobs, the data refers to the job at which the person works the greatest number of hours. Some examples of industrial groups include agriculture, forestry, and fisheries; construction; manufacturing; wholesale trade; retail trade; transportation and communication; personal, professional and entertainment services; and public administration. The 2000 Census classifies establishments according to the North American Industry Classification System (NAICS). NAICS codes replace the Standard Industrial Classification (SIC) codes used in previous censuses. NAICS classifies industries using 2-, 3-, 4-, 5-, and 6- digit levels of detail. 2-digit codes represent sectors, the broadest classifications, while 6-digit codes represent individual industries. Industrial sectors in this document have been adjusted slightly by DVRPC to be consistent with total employment estimates for the 2000 TAZs. The employment sectors used by DVRPC are shown in the following listing:

- Agriculture, Forestry, Mining, and Fisheries
- Construction
- Manufacturing
- Transportation, Communication and other Public Utility
- Wholesale Trade
- Retail Trade
- Finance, Insurance and Real Estate (FIRE)

- Service
- Government and Public Administration
- Armed Forces

B. 2005 Demographic Estimates

Estimates for the 2005 demographics came from a number of sources. This section discusses how population estimates were made at the county, MCD, and TAZ level for 2005.

1. County Population Estimates

Actual counts for population and other demographics are not available for 2005 as the US Bureau of the Census only conducts complete counts once every ten years. For this reason, estimates were made for 2005 demographic figures. DVRPC started with four existing data sets in estimating the 2005 county and municipal population:

a. 1990 and 2000 census counts (counts as of April 1st of each Census year, based on the "short form," 100 percent sample count).
b. 2005 population estimates from the Census Bureau's Population Estimates Program.
c. 2005 American Community Survey (ACS) data, which are based only on household population and only for geographic areas over 65,000 people.
d. Previously prepared DVRPC 2005 forecasts.

DVPRC reviewed and compared the results of four methods to estimate the 2005 county population:

- The method utilized by the 2005 Census population estimates program, which incorporates information from existing data series such as birth and death records, federal tax returns, Medicare enrollment, and immigration data. These estimates are released as of July 1st of each year; current releases may include revisions to previous years' estimates based on newly reviewed data.

- The estimation method utilized by the ACS. The limitations of using ACS data include its extremely small sample size (approximately 1 percent of all households) and the exclusion of the population living in group quarters in 2005. Reviews of the ACS data to date have found numerous errors, including significant under-counting in urbanized areas such as Philadelphia.
- A simple trend method based on population growth rates between 1990 and 2000.
- A cohort-component model. DVRPC's cohort model estimates county population by applying known birth and death rates to individual age cohorts over time. Population migration, the third component of population change, is also factored into the estimate, applying different migration rates dependent on known growth rates in each county. In Philadelphia, for example, the model uses a negative migration factor (meaning that more people are moving out than moving in); in stable or slow growth counties (such as Delaware County) a modest migration factor is applied. In faster growing counties (such as Chester and Gloucester counties), a higher migration rate is used.

DVRPC arrived at an initial set of 2005 county estimates by comparing the 2005 Census estimates with the results of the simpler trend analysis and the more complex cohort-component model. The results were reviewed and revised as appropriate to correct for counties that were significantly over-estimated or under-estimated until an acceptable set of county level estimates was produced. These estimates were then sent to the county planning directors for their review and comment. County comments were incorporated to produce a final set of county estimates, which served as a control total for the development of municipal population estimates.

2. Municipal and TAZ Population Estimates

DVRPC developed 2005 municipal level population estimates utilizing the following methodology:

a. The 2005 Census municipal estimates were used as a base and adjusted to be consistent with the established county control total.
b. Growth rates between 1990 and 2000 were applied to the municipal population numbers from the 2000 Census. The municipal population numbers were then adjusted to equal the county control totals.
c. The 2005 estimated population for every township was reviewed to ensure that the estimate was reasonable. This review incorporated both the growth

rate analysis and known information about municipal population numbers from previous and ongoing DVRPC work. These analyses resulted in some minor changes, in cases where the population was deemed either under or over-estimated.

d. These new 2005 municipal population estimates were sent to the county planning directors for review and comment.

e. The 2005 municipal population estimates were finalized by incorporating the county comments.

To obtain TAZ estimates, the 2000 TAZ population and households by vehicle availability data were extrapolated to 2005 based on the growth or decline of municipal population from 2000 to 2005. This method is accurate as it is based on Census 2000 and the growth or decline from 2000 to 2005, which is very small (about 2 percent at the regional level).

Group quarters 2005 population estimates were updated from 2000 estimates using population growth. The estimates are shown in ***Table IV-1***. Chester County had the

Table IV-1 Group Quarters Population Estimates

County	**Non-institutionalized**		**Difference**	**% Change**
Year	**2000**	**2005**	**2005-2000**	**2005-2000**
Bucks	3,229	3,391	162	5.0%
Chester	8,822	9,642	820	9.3%
Delaware	12,933	13,011	78	0.6%
Montgomery	9,269	9,630	361	3.9%
Philadelphia	34,320	34,457	137	0.4%
PA Counties	**68,573**	**70,131**	**1,558**	**2.3%**
Burlington	2,312	2,430	118	5.1%
Camden	2,804	2,843	39	1.4%
Gloucester	3,675	3,914	239	6.5%
Mercer	13,944	14,516	572	4.1%
NJ Counties	**22,735**	**23,703**	**968**	**4.3%**
Region	**91,308**	**93,834**	**2,526**	**2.8%**

Source: DVRPC July, 2008

largest group quarters population change from 2000 – 2005 at 9.3 percent. The smallest increase was for Philadelphia County at 0.4 percent. Overall the group quarters population increased by 2.3 percent for Pennsylvania counties. The New Jersey county with the largest group quarters population growth between 2000 and 2005 was Gloucester, with a 6.5 percent increase. Camden County had the smallest increase for a New Jersey county with a 1.4 percent increase. Overall the New Jersey counties saw a 4.3 percent increase in group quarters population between 2000 and 2005.

C. Regional Demographic Trends

The latest Census data show that the major trend of suburbanization in the region continued during the last 15 years. The change in distribution of regional activity has major implications for the transit and highway facility volumes. ***Table IV-2*** displays the county-level population trend in the region from 1990 to 2005. It shows that rural counties such as Bucks, Chester, Burlington, and Gloucester grew significantly in population; the growth rate in older areas, such as Camden County, was relatively flat, while Philadelphia County lost population.

In 2000 the region was home to just over 5.5 million residents, an increase of only about 335,000 people, or 6.5 percent, over the 1990 regional population. However, the distribution of population throughout the region has continued to change in a manner consistent with the long-term trends of suburbanization, decentralization, and sprawl. While the rate of population loss was not as great as in preceding decades, Philadelphia lost 68,028 people from 1990 to 2000, a loss of 4.3 percent. Delaware County, which had also been loosing population, showed a slight gain in population both from 1990 to 2000 and 2000 to 2005. The remaining suburban Pennsylvania counties continued their long-term trends of growth. Montgomery County had the largest growth in absolute numbers adding 102,433 people from 1990 to 2005. Chester County had an almost as large growth of 97,484 people in the same time period, with the largest percentage growth of 26 percent. New Jersey counties showed similar growth. The more urbanized Camden County grew slightly by 2.4 percent from 1990 to 2005. Burlington, Gloucester, and Mercer Counties all showed significant growth with Burlington leading in absolute growth (51,800) and Gloucester leading in percentage growth (19 percent).

Figure IV-1 shows the population density of the DVRPC region. It can be seen that the main concentration of population is in Philadelphia. Several other concentrations can be seen such as in the cities of Chester, Camden, Trenton, and Norristown. ***Figure IV-2*** shows the populations trends for the Pennsylvania Counties, while ***Figure IV-3*** shows the populations trends for the New Jersey counties. These figures illustrate some of the population trends discussed above. The increases in population in Chester and Bucks counties can be seen in ***Figure IV-2***, which also shows the decline in population in the City of Philadelphia. Gains can be seen for Mercer, Burlington, and Gloucester counties in ***Figure IV-3***, which shows that the population of Camden County was relatively flat over the 15 years from 1990 to 2005. The trend toward suburbanization is also apparent in the occupied housing unit, or household, estimates given in ***Table IV-3***. However, the regional total of households has increased much faster than the population total. This is due to a continuing trend toward smaller average household or family sizes. In 1990 there was an average of 2.73 people per occupied housing unit. By 2005 this value had decreased to only 2.67 persons per household. This implies that the region would have needed an additional 49,200 housing units over 1990 levels had population not changed at all. When population growth is included, the region has added over 175,300 occupied housing units between 1990 and 2005.

As one would expect, the counties with the largest increases in population during this time also added the most new households. Chester County had the largest growth rate (29 percent), while Montgomery County added about 44,500 new households since 1990. Philadelphia was the only county that lost households during the last 15 years, losing nearly 19,100 households.

On the New Jersey side of the region, Burlington County added the most new households during the last 15 years, about 26,700. Gloucester County, with about 19,300 new households, grew by the fastest rate with an increase of 25 percent from 1990 to 2005.

Another major indicator of propensity to travel is vehicle ownership, indicated by the number of personal transportation vehicles (automobiles) per household. ***Table IV-4*** provides the total vehicle estimates by county from 1990 to 2005. In 1990 there were almost 2.8 million vehicles. This increased to over 3.0 million by 2000 and to over 3.1 million by 2005. All suburban counties recorded large increases in vehicle availability.

Figure IV-4 contains vehicle trends from 1990 – 2005 for Pennsylvania counties. Chester, Montgomery, and Bucks counties show large increases in the number of vehicles, while Delaware and Philadelphia counties show slight increases. ***Figure IV-5*** contains vehicle trends from 1990 – 2005 for New Jersey counties. Burlington and Gloucester show large increases in the number of vehicles. Camden County had a slight growth in vehicles and Mercer County had moderate growth from 1990 – 2005.

Table IV-5 displays household vehicle availability by county from 1990 to 2005. The trends of increased vehicles per-household is evident by examining ***Tables IV-3, 4***, and ***5***. In 1990, there was an average of 1.46 vehicles per household; by 2000 this had increased to 1.61 vehicles per household, even as the average household size decreased from 3.73 to 2.67 people.

The main factor driving this change is the decrease in households with no vehicles. These households are dependent on public transit for much of their trip making. About 18.0 percent of the region's households did not own a single automobile in 1990. Two-thirds of these households were located in Philadelphia where 38.1

Table IV-2 Population Trends in the DVRPC Region by County

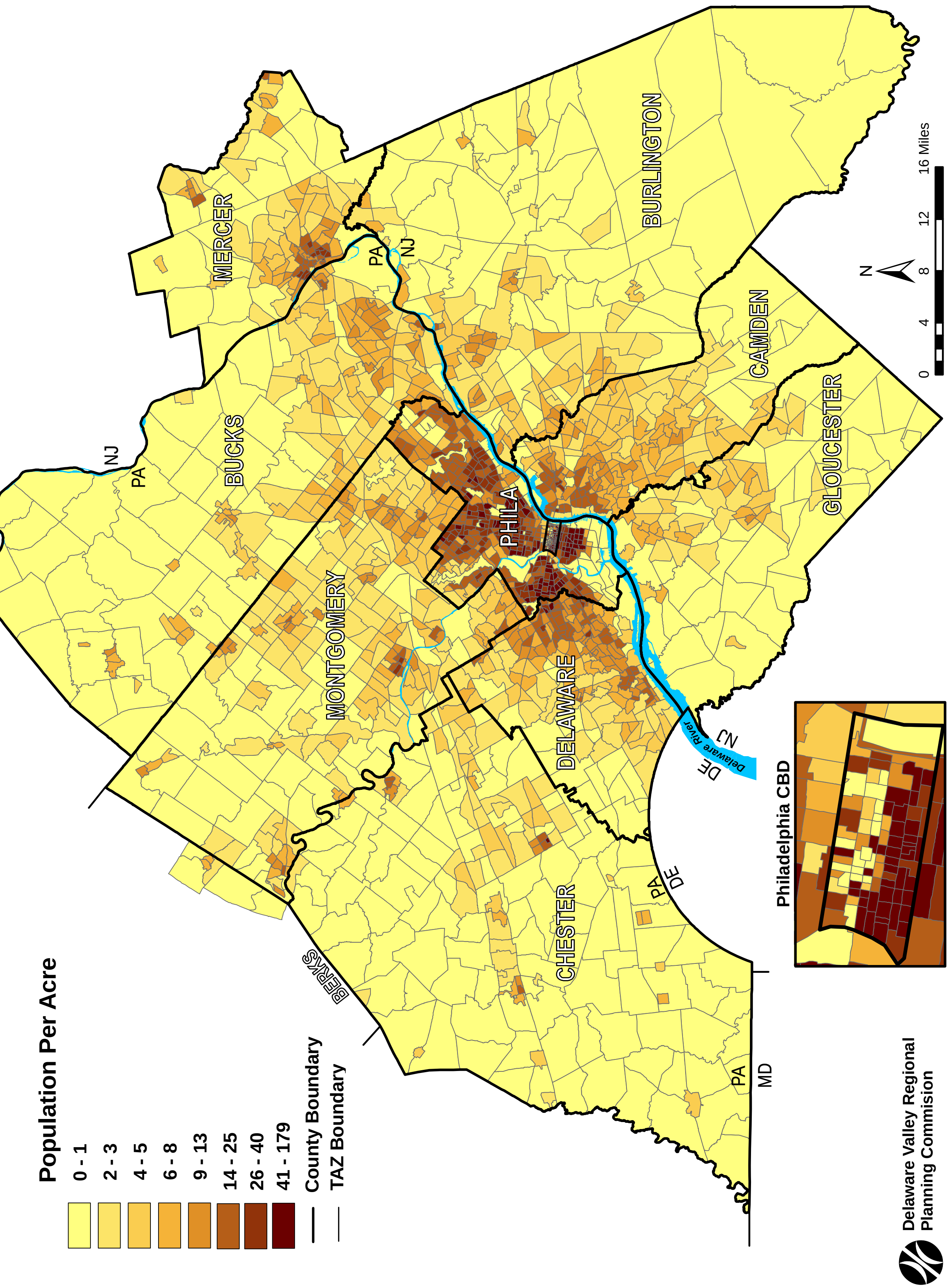
County	Census Population Counts* 1990	Census Population Counts* 2000	DVRPC Estimates** 2005	1990 - 2000 Change Difference	1990 - 2000 Change Percent	2000 - 2005 Change Difference	2000 - 2005 Change Percent
Bucks	541,174	597,636	624,351	56,462	10.4%	26,715	4.5%
Chester	376,396	433,512	473,880	57,116	15.2%	40,368	9.3%
Delaware	547,651	551,989	555,206	4,338	0.8%	3,217	0.6%
Montgomery	678,111	748,978	780,544	70,867	10.5%	31,566	4.2%
Philadelphia	1,585,577	1,517,549	1,483,851	-68,028	-4.3%	-33,698	-2.2%
PA Total	**3,728,909**	**3,849,664**	**3,917,832**	**120,755**	**3.2%**	**68,168**	**1.8%**
Burlington	395,066	423,397	446,866	28,331	7.2%	23,469	5.5%
Camden	502,824	507,889	515,027	5,065	1.0%	7,138	1.4%
Gloucester	230,082	255,719	274,229	25,637	11.1%	18,510	7.2%
Mercer	325,824	350,752	365,097	24,928	7.7%	14,345	4.1%
NJ Total	**1,453,796**	**1,537,757**	**1,601,219**	**83,961**	**5.8%**	**63,462**	**4.1%**
Region Total	**5,182,705**	**5,387,421**	**5,519,051**	**204,716**	**3.9%**	**131,630**	**2.4%**
Berks County (part)	12,798	12,537	12,812	-261	-2.0%	275	2.2%

* Developed by DVRPC based on Census population counts and Census Transportation Planning Package (CTPP)

** Adopted by DVRPC based on the Cohort Component Model data, 2005 Census population estimates, other secondary sources, and County comments

Source: DVRPC July, 2008

Figure IV-1 2000 Population Density



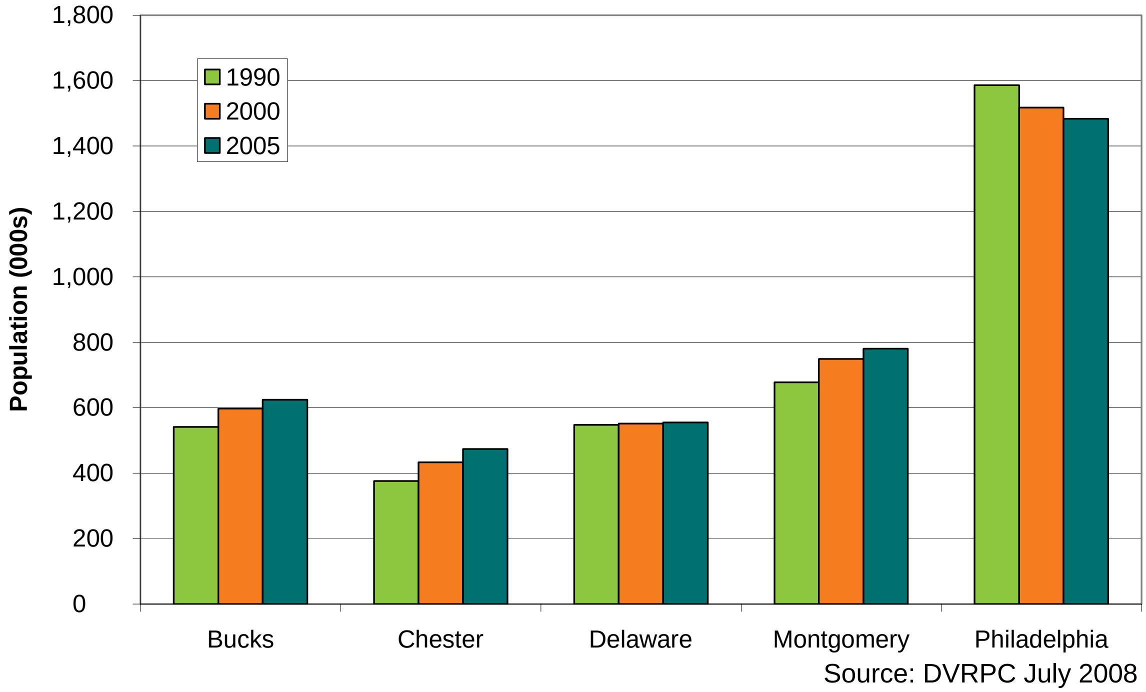


Figure IV-2 Population Trends in Pennsylvania Counties 1990 – 2005

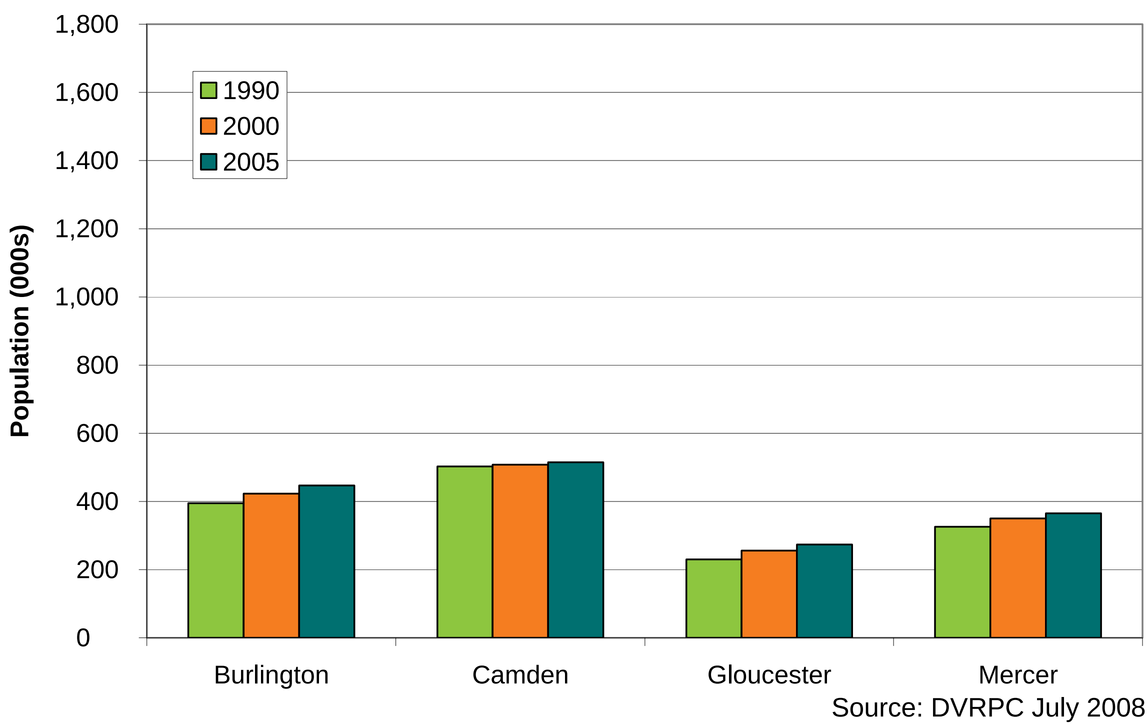


Figure IV-3 Population Trends in New Jersey Counties 1990 - 2005

Table IV-3 1990 to 2005 Households Trends in the DVRPC Region by County

	Households*		DVRPC Estimates *	1990 - 2000 Change		2000 - 2005 Change	
County	**1990**	**2000**	**2005**	**Difference**	**Percent**	**Difference**	**Percent**
Bucks	190,507	218,745	229,839	28,238	14.8%	11,094	5.1%
Chester	133,257	157,869	171,987	24,612	18.5%	14,118	8.9%
Delaware	201,374	206,312	207,606	4,938	2.5%	1,294	0.6%
Montgomery	254,995	286,119	299,455	31,124	12.2%	13,336	4.7%
Philadelphia	603,076	590,081	584,004	-12,995	-2.2%	-6,077	-1.0%
PA Total	**1,383,209**	**1,459,126**	**1,492,891**	**75,917**	**5.5%**	**33,765**	**2.3%**
Burlington	136,554	154,340	163,204	17,786	13.0%	8,864	5.7%
Camden	178,758	185,270	187,978	6,512	3.6%	2,708	1.5%
Gloucester	78,845	91,225	98,147	12,380	15.7%	6,922	7.6%
Mercer	116,941	125,816	130,394	8,875	7.6%	4,578	3.6%
NJ Total	**511,098**	**556,651**	**579,723**	**45,553**	**8.9%**	**23,072**	**4.1%**
Region Total	**1,894,307**	**2,015,777**	**2,072,614**	**121,470**	**6.4%**	**56,837**	**2.8%**
Berks County (part)	4,744	5,004	5,149	260	5.5%	145	2.9%

* Developed by DVRPC based on Census counts and Census Transportation Planning Package (CTPP)

* * Developed by DVRPC based on the 2005 American Community Survey (ACS) data and other secondary sources

Source: DVRPC July, 2008

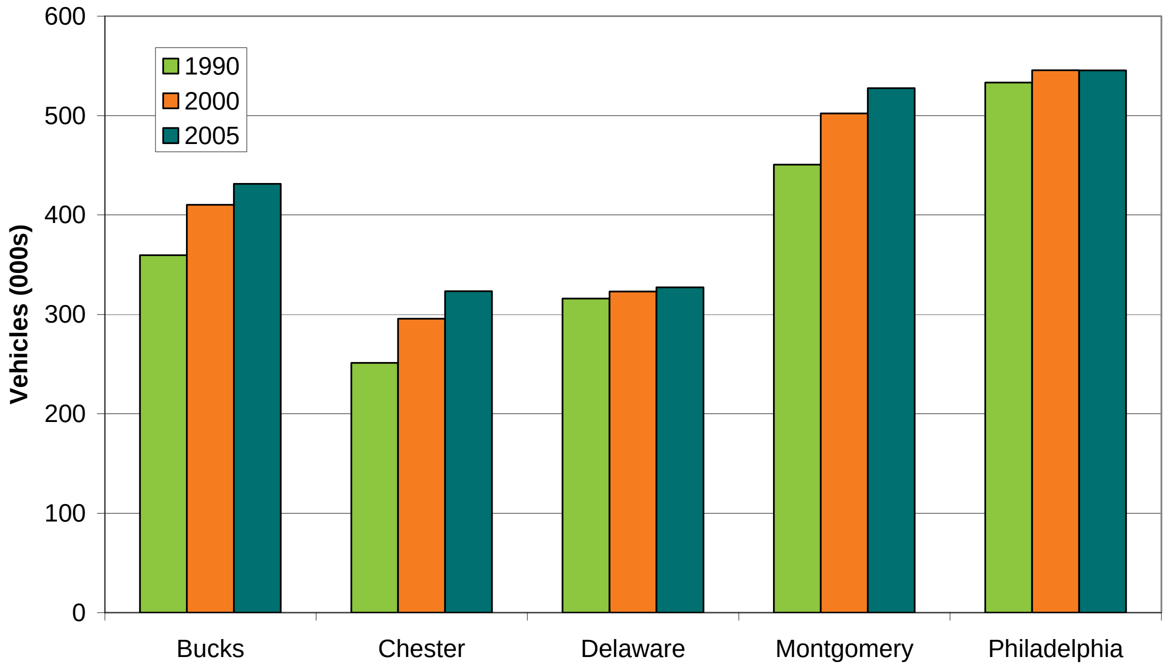
Table IV-4 1990 to 2005 Vehicles Available Trends in the DVRPC Region by County

	Vehicles Available*		DVRPC Estimates **	1990 - 2000 Change		2000 - 2005 Change	
County	**1990**	**2000**	**2005**	**Difference**	**Percent**	**Difference**	**Percent**
Bucks	359,451	410,389	431,391	50,938	14.2%	21,002	5.1%
Chester	251,320	295,691	323,271	44,371	17.7%	27,580	9.3%
Delaware	315,970	323,031	327,038	7,061	2.2%	4,007	1.2%
Montgomery	450,510	502,028	527,638	51,518	11.4%	25,610	5.1%
Philadelphia	533,212	545,611	545,235	12,399	2.3%	-376	-0.1%
PA Total	**1,910,463**	**2,076,750**	**2,154,573**	**166,287**	**8.7%**	**77,823**	**3.7%**
Burlington	251,344	279,051	296,047	27,707	11.0%	16,996	6.1%
Camden	280,459	288,678	294,525	8,219	2.9%	5,847	2.0%
Gloucester	142,129	165,233	178,463	23,104	16.3%	13,230	8.0%
Mercer	187,505	203,235	213,187	15,730	8.4%	9,952	4.9%
NJ Total	**861,437**	**936,197**	**982,222**	**74,760**	**8.7%**	**46,025**	**4.9%**
Region Total	**2,771,900**	**3,012,947**	**3,136,795**	**241,047**	**8.7%**	**123,848**	**4.1%**
Berks County (part)	9,019	9,384	9,673	365	4.0%	289	3.1%

* Developed by DVRPC based on Census counts and Census Transportation Planning Package (CTPP)

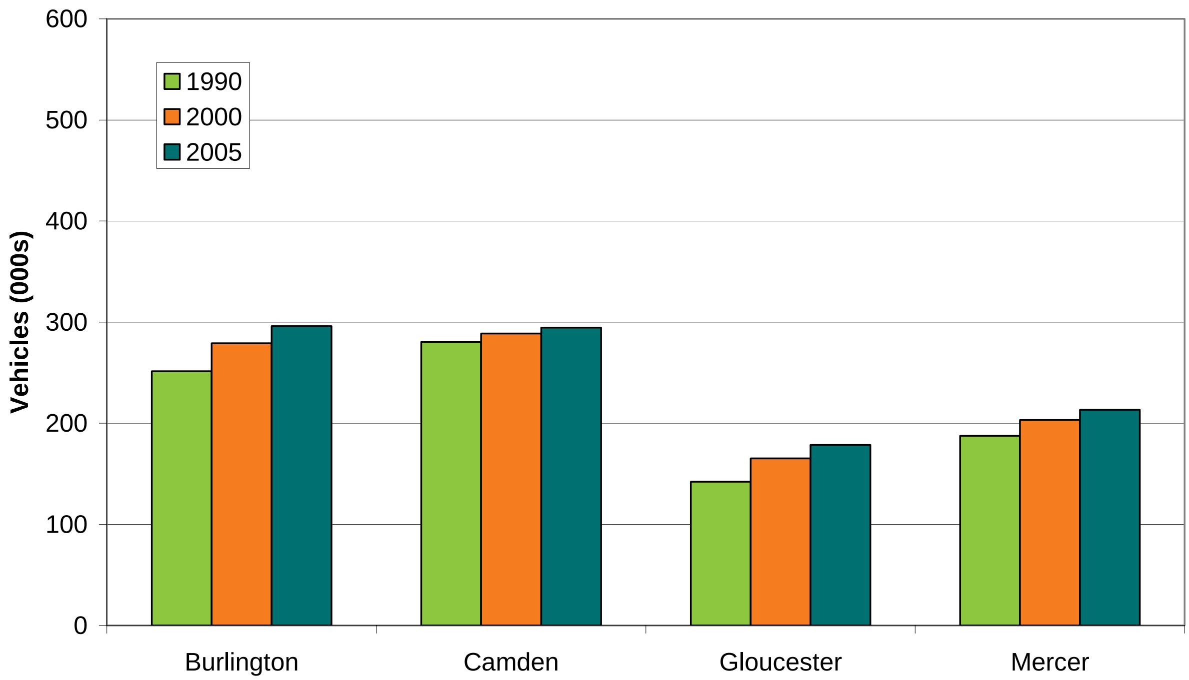
* * Developed by DVRPC based on the 2005 American Community Survey (ACS) data and other secondary sources

Source: DVRPC July, 2008



Source: DVRPC July 2008

Figure IV-4 Vehicle Trends in Pennsylvania Counties 1990 - 2005



Source: DVRPC July 2008

Figure IV-5 Vehicle Trends in New Jersey Counties 1990 - 2005

Table IV-5 1990 to 2005 Vehicles Available to Households in the DVRPC Region by County

	1990 Households with:				2000 Households with:				2005 Households with:			
County	**0 veh.**	**1 veh.**	**2 veh.**	**3+ veh.**	**0 veh.**	**1 veh.**	**2 veh.**	**3+ veh.**	**0 veh.**	**1 veh.**	**2 veh.**	**3+ veh.**
Bucks County	10,035	54,375	87,166	38,931	11,148	63,252	102,049	42,296	11,564	66,361	107,629	44,285
Chester County	7,653	36,638	61,902	27,064	8,204	44,731	74,471	30,463	8,852	48,788	81,214	33,133
Delaware County	24,591	74,534	75,034	27,215	23,335	77,791	78,880	26,306	23,307	78,110	79,739	26,450
Montgomery County	17,878	83,154	110,184	43,779	18,159	93,848	129,463	44,649	18,681	98,110	136,217	46,447
Philadelphia County	229,814	244,325	106,007	22,930	210,862	248,094	106,084	25,041	206,655	244,108	108,185	25,056
Pennsylvania Counties	**289,971**	**493,026**	**440,293**	**159,919**	**271,708**	**527,716**	**490,947**	**168,755**	**269,059**	**535,477**	**512,984**	**175,371**
Burlington County	6,715	43,582	60,299	25,958	7,920	50,488	68,601	27,331	8,309	53,486	72,653	28,756
Camden County	23,758	63,692	66,152	25,156	23,301	67,633	69,958	24,378	23,442	68,654	71,206	24,676
Gloucester County	5,359	24,339	34,801	14,346	5,902	28,208	40,557	16,558	6,203	30,158	43,887	17,899
Mercer County	14,735	40,318	44,653	17,235	14,681	43,028	49,756	18,351	14,876	44,458	51,805	19,255
New Jersey Counties	**50,567**	**171,931**	**205,905**	**82,695**	**51,804**	**189,357**	**228,872**	**86,618**	**52,830**	**196,756**	**239,551**	**90,586**
Region Total	**340,538**	**664,957**	**646,198**	**242,614**	**323,512**	**717,073**	**719,819**	**255,373**	**321,889**	**732,233**	**752,535**	**265,957**
Berks County (part)	346	1,243	2,075	1,080	303	1,519	2,064	1,118	316	1,589	2,108	1,136

Source: DVRPC July, 2008

percent of households were autoless. By 2005 the region wide percentage of households with no vehicles had decreased to 15.5 percent, and by 2005 the percent of autoless households in Philadelphia dropped to 35.4 percent.

Another important demographic statistic which affects trip making is the number of employed resident workers. This variable is used in the trip generation model to estimate the number of work trips produced by the residents of each traffic analysis zone. These trips are then "matched" to the work trips attracted to each TAZ as a function of its employment in the trip distribution model. The spatial distributions of both workers and jobs have large effects on regional travel patterns. Large differences in the number of workers and jobs in any given area will necessarily lead to a large in-commute or out-commute in that area.

Table IV-6 displays the trend in employed persons from 1990 to 2005. Generally, the trend in employed persons has followed the trends in population and households, with strong growth in the suburban counties and a corresponding decline in the City of Philadelphia. However, the numbers for the region as a whole are less dramatic. After a period of sharp growth in the 1980s, the number of employed persons was flat in the 1990s, growing by only a tenth of a percent. Regional growth picked up again from 2000-2005, with the number of employed persons increasing 2.4 percent to almost 2.56 million. Employment density is shown in ***Figure IV-6*** for the DVRPC region.

D. Estimation of 2000 and 2005 Employment

Accurate zonal employment data are required for travel analysis, travel modeling, transportation planning, and economic development projects. This section describes the methodology used by DVRPC to develop 2000 zonal employment data or total job estimates for the Delaware Valley region based on the Census employed persons at work, which are included in the CTPP 2000 and the journey-to-work traffic flows. County, municipal, and zonal employment estimates were developed for the region. The Census Bureau (CB) is the only agency that provides employment data at the zonal level. Employment estimates from the Bureau of Economic Analysis (BEA), Bureau of Labor Statistics (BLS), Pennsylvania and New Jersey Departments of Labor, and local data such as the Pennsylvania occupational privilege tax records were used to compare the employment estimates developed by DVRPC. This section also describes how 2005 data were obtained from the CB and other data sources.

Table IV-6 1990 to 2005 Employed Persons Trends in the DVRPC Region by County

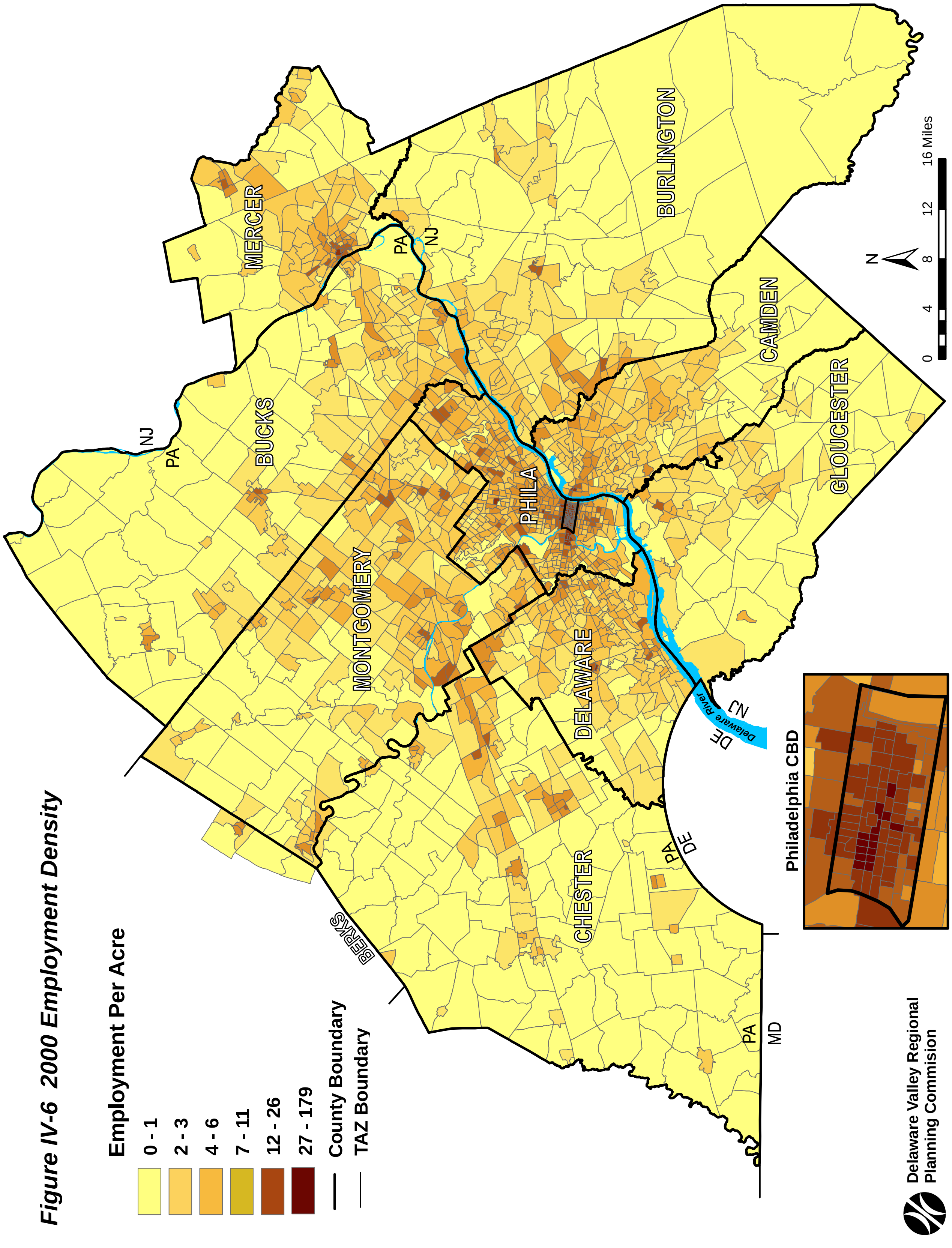
	Employed Persons*		DVRPC Estimates **	1990 - 2000 Change		2000 - 2005 Change	
County	**1990**	**2000**	**2005**	**Difference**	**Percent**	**Difference**	**Percent**
Bucks	284,984	308,969	319,738	23,985	8.4%	10,769	3.5%
Chester	198,869	221,433	236,881	22,564	11.3%	15,448	7.0%
Delaware	266,760	258,958	258,601	-7,802	-2.9%	-357	-0.1%
Montgomery	359,659	385,612	397,594	25,953	7.2%	11,982	3.1%
Philadelphia	657,387	585,353	573,723	-72,034	-11.0%	-11,630	-2.0%
PA Total	**1,767,659**	**1,760,325**	**1,786,537**	**-7,334**	**-0.4%**	**26,212**	**1.5%**
Burlington	209,378	211,395	224,263	2,017	1.0%	12,868	6.1%
Camden	239,526	234,905	238,420	-4,621	-1.9%	3,515	1.5%
Gloucester	112,964	125,631	135,301	12,667	11.2%	9,670	7.7%
Mercer	166,688	167,364	174,792	676	0.4%	7,428	4.4%
NJ Total	**728,556**	**739,295**	**772,776**	**10,739**	**1.5%**	**33,481**	**4.5%**
Region Total	**2,496,215**	**2,499,620**	**2,559,313**	**3,405**	**0.1%**	**59,693**	**2.4%**
Berks County (part)	6,797	6,726	6,916	-71	-1.0%	190	2.8%

* Developed by DVRPC based on Census counts of workers by place of residence and Census Transportation Planning Package (CTPP)

* * Developed by DVRPC based on the 2005 American Community Survey (ACS) data and other secondary sources

Source: DVRPC July, 2008

Figure IV-6 2000 Employment Density



1. Development of County Employment Estimates

The 2000 county employment numbers from the CB include the number of employed persons at the place of work, not the number of total jobs because the census data do not include employed persons who did not work during the census week and because only the principal job was counted for workers having more than one job. As stated before, workers with multiple jobs are included in the census as employed, but their extra jobs are not captured. Three adjustments to the census employed persons at work, including resident and non-resident workers (workers who live and work in the DVRPC region and workers who live outside the region and work in the region), were required for the estimation of 2000 employment for the nine counties of the DVRPC region.

The first adjustment was made to account for absentee rates, which were obtained from census data (responses to Question 25b in the long-form). Specifically, the percentage of employed persons that did not work during the census week due to illness, vacation, labor dispute, etc. was determined. This information is readily available from census data at the county level and ranges from 1.5 to 2.7 percent. The absentee rates for the DVRPC region are consistent with the national average of about two percent.

Secondly, an adjustment was made to account for workers who have not been included in the number of employed persons. Some workers are probably not included in the census tabulations because they are illegal workers, students, or temporary low wage earners. Most of these missing workers are in the farming and retail sectors. CTPP 2000 data indicate that these sectors are underestimated compared to secondary sources and county records of employment. For example, CTPP 2000 indicates that only 10,728 persons were employed in the agriculture and mining sectors compared to 31,956 workers estimated by the BEA and 25,326 estimated from unemployment compensation claims (ES-202 data). Agriculture and retail employment sectors were examined and adjusted upward to account for missing workers in each county. The analysis of adjusted employment sectors indicates that missing workers represent about 2.4 percent of employed persons at work in the region, ranging by county from 1.9 to 4.0 percent.

Thirdly, the census employed persons data at the place of work were adjusted to account for multiple job-holding. The percentage of persons who had two or more jobs had to be estimated. Fortunately, the rate of multiple job-holding is available from the Household Travel Survey for the Delaware Valley Region which was conducted in 2000. This value averages 6.5 percent for the region, although it varies significantly by county and by employment sector. For example, the rate for the City of Philadelphia is about 7.7 percent and the rate for construction workers is less than 5.0 percent. The multiple job-holding rate, which ranges from 5.3 to 7.7 percent, was determined for each county in the region.

For 2005, DVRPC used the CB's recently initiated ACS to estimate employment at the county level. These estimates are based on a smaller sample than the Long-Form of Census 2000. DVRPC developed estimates of 2005 county-level employment according to the following process:

1. Extract the 2005 Employed Persons at the Place of Work data at the county level from the CB's ACS.
2. Factor these data to account for workers with more than one job, workers who were absent from work during the survey period, and the workers who were not included in the census data.
3. Extrapolate the 1990 to 2000 employment trend to 2005 and compare the adjusted estimate from Step (2) to this value.
4. Compare the Step (2) estimate to secondary source estimates, such as the BAE county-level estimates.
5. Based upon the comparisons in Steps (3) and (4), adjust the factored ACS estimates that are significantly over or underestimated.
6. Transmit these preliminary county-level employment estimates to the county governments for review and comment.
7. Incorporate county comments and finalize the 2005 county employment estimates. These final values serve as controls totals for the development of municipal employment estimates.

Since employed persons data from the CB are obtained from respondents in households, they differ from statistics based on reports from individual business establishments, farm enterprises, and certain government programs. In statistics based on reports from business and farm establishments, people who work for more than one establishment may be counted more than once by some agencies such as BEA. Moreover, some establishment-based tabulations may exclude private household workers, unpaid family workers, and self-employed people, but may include workers less than 16 years old. Census tabulations count people who had a job but were not at work among the employed, but these people may be excluded from employment figures based on establishment payroll reports used to estimate employment by some agencies such as BLS.

Also, the unemployment figures of the CB are not comparable with published figures on unemployment compensation claims (ES-202). For example, figures on unemployment compensation claims exclude people who have exhausted their benefit rights, new workers who have not earned rights to unemployment insurance, and people who lost jobs not covered by unemployment insurance systems.

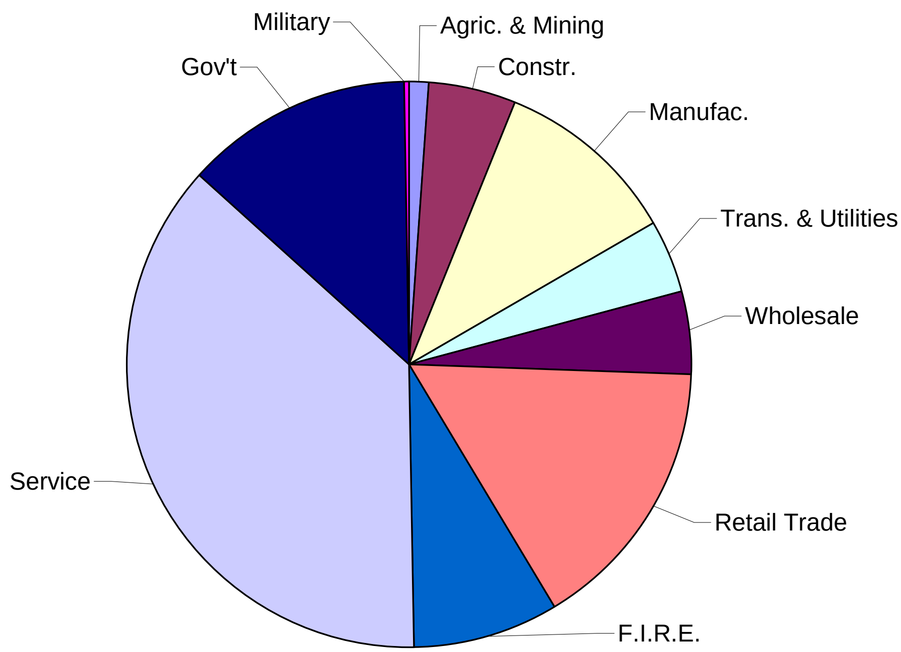
2. Employment Estimates by Industrial Sector

Employment in the DVRPC region must be disaggregated to industrial sectors for travel forecasting. In 1990 the census industry classification was based on the Standard Industrial Classification (SIC) Manual. Census 2000 classification was developed from the 1997 North American Industry Classification System (NAICS). NAICS is an industry description system that groups establishments into industries based on the activities in which they are primarily engaged. Presently, DVRPC uses 10 SIC sectors in travel simulation and economic development projects. CTPP 2000 data for some sectors such as retail trade, services, and governments are not comparable with SIC and cannot be used for estimating 2000 employment sectors. The public administration sector is especially underestimated; it is limited to regular government functions, such as legislative, judicial, administrative, and regulatory activities of governments. Other government organizations, such as schools, hospitals, and bus lines, are classified by industry according to the activity in which they are engaged. To be consistent with SIC sectors, DVRPC reviewed census data on Occupation and Class of Worker and sector data from the BEA and ES-202 to determine reasonable employment sector estimates for the region. The average of BEA and ES-202 numbers was used to estimate DVRPC employment sectors within the regional and county employment control totals. ***Table IV-7*** displays the 2005 employment estimates by sector and county.

Figure IV-7 shows a pie chart of the regional employment by sector for 2000. From the pie chart it can be observed that the service sector dominates the economy. The retail and government sectors also comprise significant portions of the DVRPC region's employment.

3. Municipal and Zonal Employment Estimates

The CB's municipal-level journey-to-work data was used to develop 2000 municipal-level employment estimates. The number of employed persons at work in each municipality was tabulated from the worker flows and expanded to be equal to the estimated county totals. Each of these expanded municipal estimates was then reviewed for possible errors in the place of work coding and adjusted if necessary within the county control total. The review process involved examining the 1990 municipal employment values, the change in employment generating land use by municipality from 1990 to 2000, the 2000 ES-202 employment estimates by municipality for the New Jersey portion of the region, and the number of employees who paid an occupational privilege tax in those Pennsylvania municipalities that collect it. ES-202 employment estimates for 2000 were not available at the municipal level in Pennsylvania. These municipal estimates obtained from various sources were reviewed by DVRPC's member governments.



Source: DVRPC July 2008

Figure IV-7 2005 Distribution of Employment by Industrial Sector in the DVRPC Region

Part 2 of the CTPP 2000 includes the number of employed persons at the place of work for all 1,912 TAZs in the region. CTPP 2000 zonal data were increased to be equal to the municipal employment estimates and then compared with historic DVRPC estimates, such as the 1990 zonal employment estimates. Based on this comparison, some minor changes were made to produce the final 2000 zonal estimates. These changes were made within the county control totals that were previously established. Employment sector estimates were also developed for each TAZ within the county employment sectors discussed previously.

Unfortunately, there are no 2005 municipal or zonal level employment estimates available from the ACS, BLS, BEA, or other sources. Since the CB did not provide municipal-level tabulations of employed persons at work, DVRPC developed its 2005 municipal employment estimates as described below. For the city of Philadelphia, CPAs are substituted for municipalities.

Table IV-7 2005 Employment Estimates by Sector and County

County	Agric. & Mining	Constr.	Manufac.	Trans. & Utilities	Whole-sale	Retail Trade	F.I.R.E.	Service	Gov't	Mtry.	Total**
Bucks County	4,368	18,685	39,840	8,158	14,699	55,424	17,536	94,144	24,747	285	277,886
Chester County	7,783	15,666	31,434	10,998	13,670	40,591	23,409	89,566	20,359	153	253,629
Delaware County	2,058	15,810	21,053	11,911	10,623	38,344	19,990	92,960	24,678	155	237,581
Montgomery County	4,602	29,269	76,976	18,758	27,544	85,277	51,541	176,596	34,078	1,310	505,950
Philadelphia County	979	24,178	50,344	33,898	23,508	97,009	61,597	318,823	117,041	678	728,055
Pennsylvania Counties	**19,790**	**103,608**	**219,647**	**83,722**	**90,044**	**316,645**	**174,073**	**772,089**	**220,903**	**2,581**	**2,003,101**
Burlington County	4,269	9,876	20,659	9,132	14,020	37,881	17,714	65,055	30,492	5,553	214,651
Camden County	1,463	13,085	19,549	9,898	13,034	37,804	16,549	77,438	33,635	266	222,721
Gloucester County	2,966	7,474	12,366	3,790	6,640	22,937	4,881	30,420	16,698	57	108,230
Mercer County	1,792	9,016	16,783	8,309	7,493	29,367	16,191	78,906	60,325	322	228,503
New Jersey Counties	**10,490**	**39,450**	**69,357**	**31,129**	**41,187**	**127,989**	**55,335**	**251,819**	**141,150**	**6,199**	**774,105**
Region Total	**30,279**	**143,058**	**289,004**	**114,851**	**131,231**	**444,633**	**229,408**	**1,023,908**	**362,053**	**8,780**	**2,777,206**
Berks County (part)	106	277	1,702	291	231	928	448	2,154	633	0	**6,770**

* Developed by DVRPC based on the 2005 American Community Survey (ACS) data, other sources, and county comments

** Total may differ slightly from Board adopted numbers due to rounding

Source: DVRPC July, 2008

1. Develop a 2000-2005 employment growth rate for each municipality based upon its household growth rate during this same period (which is based on the population growth from the Census estimates). For most municipalities, the relative change in employment closely tracks the relative change in households because the number of workers per household is relatively constant and because new households require goods and services that create jobs.
2. Aggregate the resulting employment for each municipality in a given county and factor all municipalities to equal the county-level control total that was previously established.
3. Compare the resulting 2005 employment estimate to an estimate derived from extrapolating the 1990-2000 municipal employment change to 2005.
4. Adjust individual municipal employment estimates within the county control total based on historical trends, recently constructed commercial developments, and other known data from local land use and transportation studies.
5. Transmit these preliminary municipal-level employment estimates to the county governments for review.
6. Incorporate county comments and finalize the 2005 municipal employment estimates.

To obtain 2005 TAZ estimates, the 2000 TAZ employment and employed persons was extrapolated to 2005 based on the growth or decline of municipal employment or population from 2000 to 2005. This method is accurate as it is based on Census 2000 and the growth or decline from 2000 to 2005, which is very small (about 2 percent at the regional level).

E. Regional Employment Trends

Table IV-8 shows the trends in regional employment by county from 1990 to 2005. Generally, the trend in county-level employment follows the trends in the demographic variables. The significant loss in Philadelphia employment was more than made up for by large gains in the suburban counties resulting in modest growth for the region. However, this trend has not been as uniform over time as the trends in demographic variables have been. Between 1990 and 2000, the region gained only 24,000 jobs. Between 2000 and 2005, the employment growth was more than twice as large, 59,300 jobs, in half the time.

Philadelphia lost 95,500 jobs between 1990 and 2000, representing 11.4 percent of its employment. But between 2000 and 2005, Philadelphia lost only 13,300 jobs.

Table IV-8 1990 to 2005 Employment Trends in the DVRPC Region by County

County	Census Employment*		DVRPC Estimates **	1990 - 2000 Change		2000 - 2005 Change	
	1990	2000	2005	Difference	Percent	Difference	Percent
Bucks	245,360	267,124	277,886	21,764	8.9%	10,762	4.0%
Chester	197,752	238,641	253,628	40,889	20.7%	14,987	6.3%
Delaware	230,459	238,164	237,582	7,705	3.3%	-582	-0.2%
Montgomery	457,501	492,677	505,952	35,176	7.7%	13,275	2.7%
Philadelphia	836,874	741,397	728,054	-95,477	-11.4%	-13,343	-1.8%
PA Total	**1,967,946**	**1,978,003**	**2,003,102**	**10,057**	**0.5%**	**25,099**	**1.3%**
Burlington	191,345	202,535	214,621	11,190	5.8%	12,086	6.0%
Camden	227,933	216,931	222,721	-11,002	-4.8%	5,790	2.7%
Gloucester	86,079	99,467	108,229	13,388	15.6%	8,762	8.8%
Mercer	220,592	220,915	228,502	323	0.1%	7,587	3.4%
NJ Total	**725,949**	**739,848**	**774,073**	**13,899**	**1.9%**	**34,225**	**4.6%**
Region Total	**2,693,895**	**2,717,851**	**2,777,175**	**23,956**	**0.9%**	**59,324**	**2.2%**
Berks County (part)	7,247	6,580	6,770	-667	-9.2%	190	2.9%

* Developed by DVRPC based on Census counts of workers by place of work and Census Transportation Package (CTPP)

* * Adopted by DVRPC based on the 2005 American Community Survey (ACS) data, other secondary sources, and county comments

Source: DVRPC July, 2008

The only other county in the region to lose employment over the course of the decade 1990-2000 was Camden County, which lost 11,000 jobs. Delaware County was the only other county besides Philadelphia to lose jobs from 2000-2005, with a loss of 600 jobs. In the 1990-2005 time period, all the suburban Pennsylvania counties gained jobs. Chester County's employment growth was the most dramatic with a gain of 55,900 jobs, equivalent to a 28.3 percent gain. Burlington County added the most new jobs on the New Jersey side between 1990 and 2005, increasing its employment by 23,300 jobs. Gloucester County, which added 22,200 jobs during this time, grew at the fastest rate (25.7 percent).

Table IV-9 displays the regional employment trend from 2000 – 2005 by industrial sector. This comparison shows a decline in manufacturing jobs (23,100) and a large gain in service sector jobs (41,600). Smaller gains were also made in FIRE (finance, insurance, and real estate – 16,500), retail trade (8,783), construction (12,200), and government jobs (10,800). Small losses were seen in the agriculture and mining (-857), transportation and utilities (-3,339), and wholesale trade (-2,692) sectors.

Table IV-9 2000 - 2005 Regional Employment by Industrial Sector

	Regional Employment		**2000 - 2005 Change**	
Employment Sector	**2000***	**2005****	**Diff.**	**Percent**
Agriculture and Mining	31,136	30,279	-857	-2.8%
Construction	130,814	143,058	12,244	9.4%
Manufacturing	312,145	289,005	-23,140	-7.4%
Transportation and Utilities	118,190	114,851	-3,339	-2.8%
Wholesale Trade	133,923	131,231	-2,692	-2.0%
Retail Trade	435,850	444,633	8,783	2.0%
Finance/Insurance/Real Estate	212,911	229,408	16,497	7.7%
Services	982,294	1,023,908	41,614	4.2%
Government	351,222	362,053	10,831	3.1%
Military	9,366	8,780	-586	-6.3%
Region Total	**2,717,851**	**2,777,206**	**59,355**	**2.2%**

* Developed by DVRPC based on the Census counts of workers by sector at place of work and Census Transportation Planning Package (CTPP)

* * Developed by DVRPC based on the 2005 American Community Survey (ACS) data and other secondary sources. Region total may differ slightly from Board adopted number due to rounding

Source: DVRPC July 2008

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V. HIGHWAY AND TRANSIT NETWORK PREPARATION

The highway and transit networks need to be represented in such as way as to be understood by the computer models used in the travel simulation process. This preparation of the networks is often called coding. This chapter discusses the coding of both the highway and transit networks. Two appendices are associated with this chapter. **Appendix V-1** has detailed technical information on highway network coding. Section A documents file formats. Section B discusses the process for updating, coding, and building the highway network. **Appendix V-2** contains detailed technical information on transit network coding and processing. Section A discusses procedures for coding the transit network. Section B contains details on processing the transit network. Section C contains detailed information for both coding and processing, including file names and step-by-step directions. Section D contains a methodology for updating highway and transit speeds for FHWA and EPA modeling, while Section E gives detailed instructions for FHWA and EPA speed updating. Section F discusses the methodology for updating highway and transit speeds for FTA compliant modeling. Section G provides tables of codes for transit coding.

A. Highway Network Preparation

The highway network coding is one of the main inputs to the modeling process. The 2000 highway network was updated from the 1997 network. This section lists the changes and additions made to update the 1997 network for use in the 2000 network. Detailed network coding instructions are included in **Appendix V-1**. Statistics on the network are also presented in this section. Some coding procedures for network peculiarities are discussed, as are the derivation of highway capacities and free-flow speeds.

While the 2000 base network was derived from the 1997 base network, it underwent a series of extensive changes and checks. All freeways in the region were recoded so that all interchange ramps were explicitly modeled. Every link in the highway network was remeasured to check for accuracy using new GIS capabilities. Links were also recoded, where necessary, to reflect the updated federal function classification.

Because of the addition of new TAZs and cordon stations in 2000, some highway nodes required renumbering because of the requirement of consecutive numbering for TAZs. Node numbers 2069 through 2268 were left unused by design. This provides the ability to add additional TAZs for focused networks for traffic studies and other purposes without having to renumber highway network nodes. The creation of new TAZs by splitting some 1990 TAZs required additional changes to the highway network. Additional centroid connector links were created, and existing connector links were adjusted. The 2005 highway network uses the 2000 network with minor additions to account for new facilities that were opened to traffic between 2000 and 2005.

1. Highway Network Additions

For the 2000 highway network various additions were made to reflect changes that had occurred in the physical system since 1997. A partial list of changes that were incorporated into the network include:

- Widening of Swedesford Road to four lanes from Drummer Lane to Warner Road.
- Construction of Hightstown bypass from NJ 33 east of Hightstown to CR 571, Princeton Pike, west of Hightstown.
- Widening of PA 113 from PA 100 to US 30.
- Construction of connection to Aramingo Avenue. at I-95 Betsy Ross Bridge Interchange.
- Construction of full interchange between the NJ Turnpike Extension and US 130.
- Construction of interchange between the Atlantic City Expressway and CR 689.
- Opening of one lane of Chestnut Street. in Philadelphia from 18th to 8th Street to auto traffic.

In addition to these changes, tolls throughout the region were examined and updated where necessary. Several more changes were made to the 2000 highway base network for the 2005 validation. A partial list includes:

- Major reconstruction in the Valley Forge area including new ramps between I-76, PA 422, and US 202 and a widening of US 202 to six lanes between North Valley Road and Gulph Road.
- Opening of 1.8 mile tunnel for NJ 29 in Trenton.
- Widening of PA 100 between US 30 Business to Shonen Road.
- Widening of Christopher Columbus Boulevard from Race Street to Richmond Street.
- Widening of CR 689 to four lanes between the Atlantic City Expressway ramps and CR 704.

Tolls were also updated to reflect changes between 2000 and 2005.

2. Description of Highway Coding

The actual highway network is represented in the transportation simulation model by a connected network of links and nodes. Each node is a point in space; each link is a one-way connection from one node to another node. Each link has a number of properties such as distance and functional class. These properties are later used to determine the impedance to travel on that link. Between any two given nodes there can only be two links, one for each direction of travel.

The primary highway network information is stored in three parts within a single file, referred to as a "card" file for historical reasons. The first part of the highway cards file contains a speed and capacity reference table. This table gives daily capacities and free-flow speeds for all permutations of roadway functional class, area type, and number of lanes. The determination of the capacities and speeds is discussed in sections 6 and 7 below.

The second part of the highway cards file provides node information. Each node is given a unique identifying number. The node section also lists the X and Y coordinates as expressed in hundredths of a mile using the US Geological Survey's 1927 Universal Transverse Mercator, zone 18 projection with a "False Northing" of -2000 miles.

The third part of the highway cards file contains information about each link. The beginning and ending nodes are identified by node number. Note that each link in the highway cards file is not given a link number and is only identified by its beginning and ending nodes. The link part also contains area type, distance, direction codes, functional class, number of lanes, and DVRPC's county planning area codes for each link. Specific formats and other details for the highway cards file are given in **Appendix V-1**.

3. Highway Network Statistics

The 2005 highway network is compared to the 1990 and 2000 networks by directional miles by functional class in ***Table V-1***. While freeways are the most critical piece of infrastructure in the highway network, they comprise a relatively small percentage of the overall route miles.

A complete listing of link counts by area type and functional class for the 2005 highway network can be found in ***Table V-2***. Between the 2000 and 2005, a net 805 links were added. The biggest change in the network in terms of link counts is the addition of links in every functional classification for the suburban area type and a loss of links in every functional classification for the rural area type. There are 53,599 total links in the 2005 network. This compares with the national average of 20,038. A graphical representation of the highway network appears in ***Figure V-1*** along with the external cordon stations. Different classes of facilities are distinguished by color.

Table V-1 Directional Route Miles by Functional Class for the 1990, 2000, and 2005 Networks

DVRPC Functional Classification	1990 Directional Route Miles	2000 Directional Route Miles	2005 Directional Route Miles
Freeway	883	1,114	1,116
Parkway	217	368	372
Principal Arterial	3,315	3,096	3,067
Secondary Arterial	5,139	5,241	5,280
Collector/Local	4,423	4,812	4,999
Centroid Connector	4,147	5,962	5,724
Ramp	64	247	249
Dummy/Toll	6	8	9
Total	**18,194**	**20,848**	**20,816**

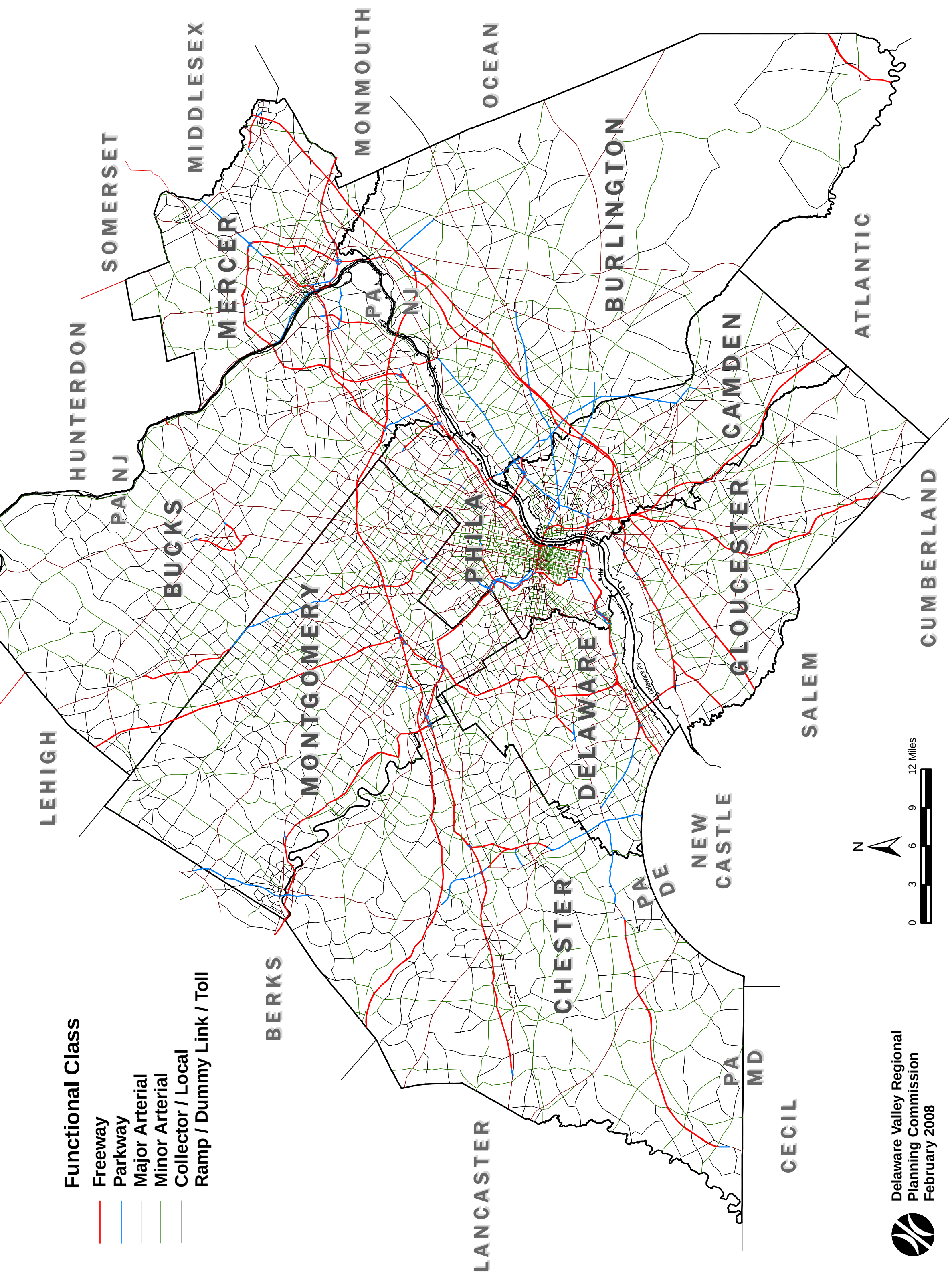
Source: DVRPC July 2008

Table V-2 Link Counts by Functional Class and Area Type for the 2005 Network

	Area Types					
Functional Class	**1**	**2**	**3**	**4**	**5+6**	**Total**
Freeway	14	55	149	1,278	850	2,346
Parkway	2	22	145	672	293	1,134
Major Arterial	359	243	3,056	4,699	2,228	10,585
Minor Arterial	480	446	3,534	5,338	4,891	14,689
Collector/Local	35	78	1,364	3478	5,421	10,376
Centroid Connector	570	292	3,062	4,702	4,118	12,744
Ramp	16	40	109	785	337	1,287
Dummy/Toll	11	8	120	193	106	438
Total	**1,487**	**1,184**	**11,539**	**21,145**	**18,244**	**53,599**

Source: DVRPC July 2008

Figure V-1 2000 Highway Network



4. Centroid Access Coding

Most links represent travel on the highway system. A subset of links, called centroid connectors, represents access to the highway system. They connect the centroid, which is where trips originate or terminate in a zone, to the highway network. The centroid connectors represent access to the modeled highway network using all the smaller local roads that are not typically modeled. Centroid connectors are modeled as having a fixed distance dependant on the TAZ's area type, as shown below.

Area Type	Connector Length (Miles)
CBD	0.12
CBD Fringe	0.20
Urban	0.25
Suburban	0.50
Rural	0.70
Open Rural	0.75

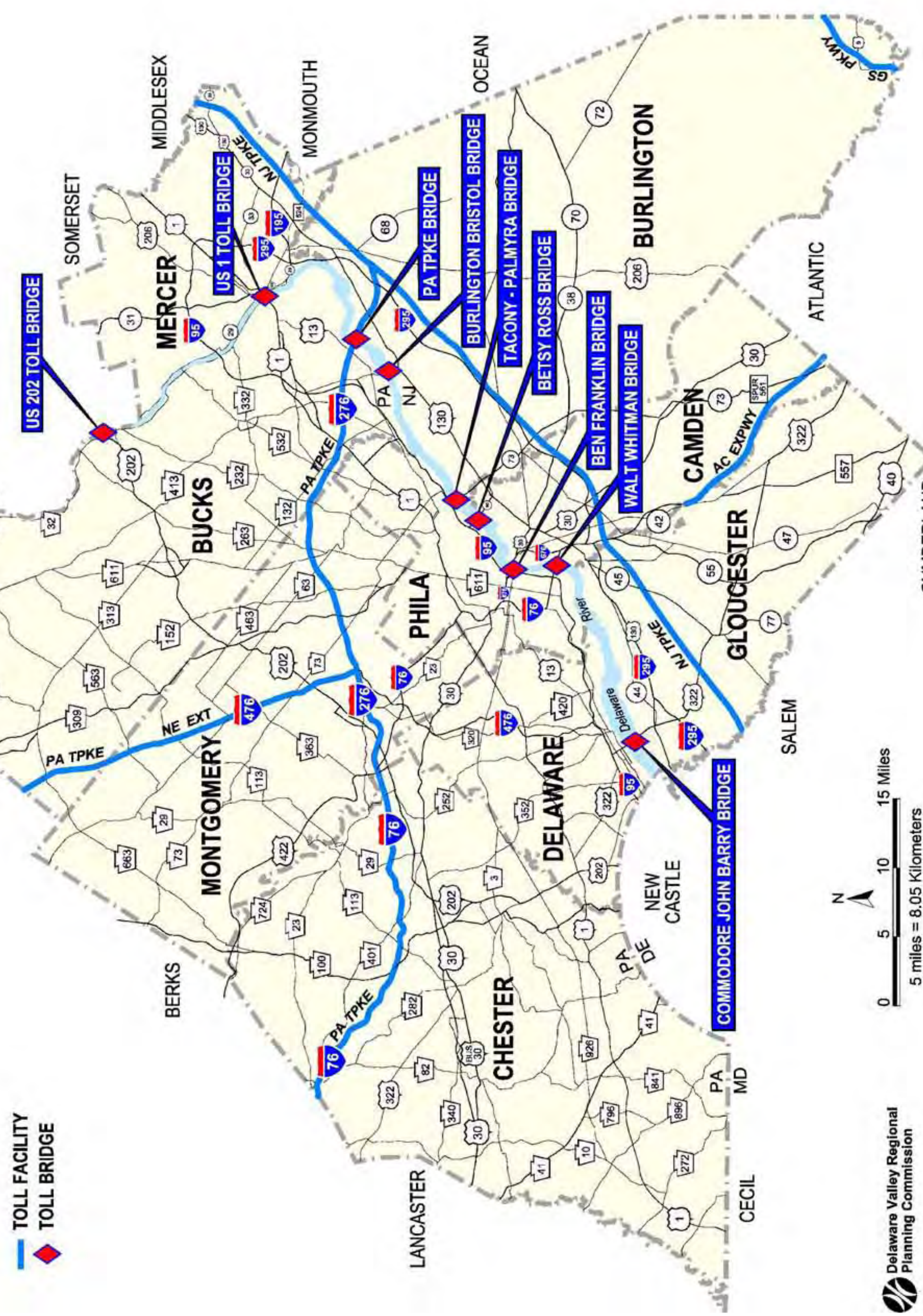
Source: DVRPC July 2008

Thus, if a zone is assigned area type 3 (Urban), then all centroid connectors for that TAZ will be coded as having a length of 0.25 miles. This incorporates the assumption that on average people in that zone will travel 0.25 miles before reaching the coded portion of the highway network. By convention there are a maximum of eight links permitted between each centroid and the highway network – four that go from the centroid to the network and four that go from the network to the centroid.

5. Toll Facility Coding

The DVRPC region contains a number of toll facilities. A map of the various toll facilities can be seen in ***Figure V-2***. The tolls represent an impedance to travel and thus are represented in the model. This impedance takes two forms – the cost of the actual toll and the time required to pay the toll. These two impedances, the toll cost and the toll collection delay, are modeled separately. There are two types of toll facilities in the DVRPC region – fixed cost toll facilities (bridges) and distance based toll facilities (the PA and NJ Turnpikes).

Figure V-2 Map of Toll facilities in the Region



The toll cost impedance for distance based toll facilities is modeled by the insertion of "dummy" links into the highway network between turnpike interchanges. These links have a fixed impedance related to the level of toll charge on the facility. The fixed impedance reflects the marginal toll to travel between two interchanges. This, however, is a simplification of the actual system. Both the NJ Turnpike and the PA Turnpike do not have fixed marginal toll rates between interchanges, but have variable toll rates dependant on how far one travels. For example, the marginal toll rate for a vehicle traveling between Interchange 28 (Delaware Valley) and Interchange 27 (Philadelphia) headed westbound on the PA Turnpike is heavily dependant on where the vehicle boards. The marginal toll is 30 cents if a vehicle enters the turnpike at Interchange 29 (Delaware River Bridge). However, the marginal toll is 60 cents if a vehicle enters the turnpike at Interchange 28. This situation is simplified by using the weighted average marginal toll. This average marginal toll is calculated using interchange to interchange data obtained from the NJ Turnpike and PA Turnpike authorities. The weighted average toll for each interchange-to-interchange link is calculated by multiplying each marginal toll value by the proportion of travelers that pay that toll and exit at the next interchange. For example, the weighted average toll between Interchange 28 and Interchange 27 headed westbound on the PA Turnpike is calculated as:

$$28 \rightarrow 27 \text{ dummy link toll} = \frac{0.6 \bullet (241{,}537) + 0.3 \bullet (1{,}262{,}592)}{241{,}537 + 1{,}262{,}592} = 0.35$$

Where 241,537 is the number of vehicles entering at Int. 28 and exiting at Int. 27 and 1,262,592 is the number of vehicles entering at Int. 29 and exiting at Int. 27.

The toll impedance for bridges is modeled by the insertion of dummy links at the toll booths. Facilities that only toll in one direction are modeled as having half a toll in each direction.

The impedance on the dummy links for both the fixed and distance based facilities are handled differently than normal links. While the links are represented in the highway file, the toll values are represented in a separate file. After the binary representation of the highway network is built with TRANPLAN, the toll impedance values are inserted via a macro program. However, because of a limitation in TRANPLAN, there can only be 20 unique toll values. The toll values must therefore be rounded to the nearest unique value for both the bridge and turnpike tolls. The values in dollars are:

TOLL VALUES – 0.05, 0.10, 0.15, 0.20, 0.25, 0.30, 0.00, 0.40, 0.45, 0.50, 0.55, 0.60, 0.65, 0.70, 0.75, 0.80, 0.85, 0.90, 1.00, 2.00.

These values are in 1990 dollars and are indexed forward based on the assumption that they will rise at the rate of inflation.

The toll collection delay represents the time required due to toll collection. This is modeled using TRANPLAN which includes a formal toll booth queuing delay model based on the Poisson distribution of vehicle arrivals. This model calculates total delay as the sum of vehicle deceleration time, toll booth queuing delay, and vehicle acceleration time. This model is an implementation of the Florida Turnpike Toll Facilities model, and is described in the TRANPLAN User Manual as follows:

Vehicles using a toll plaza decelerate to a stop, queue at the toll booths to pay the tolls, and accelerate back to speed. The toll links are divided into three segments with the following traffic operations:

1. Vehicles enter the first segment traveling at the free-flow speed, or possibly the congested link speed on the upstream link, and decelerate at a constant rate to a stop. The travel time and delay depend on the link speed and deceleration rate.
2. Traffic operations in the second segment can be described with a simple queuing model. Vehicles arrive at the toll plaza in a Poisson distribution, at some known average arrival rate per lane. Tolls are also collected in a Poisson distribution with a known average service time. The queuing model depicts the number of vehicles in the queue and the total time necessary to traverse this segment. The travel time and delay depend on the number of toll booth lanes, the traffic volume, and the average service time.
3. Vehicles in the third segment accelerate at a constant rate from a full stop up to the free-flow, or congested, link speed on the downstream link. Travel time and delay are functions of the link speed and constant acceleration rate. A toll facility may be coded as three one-way segments: segment 1 (a-b), segment 2 (b-c), and segment 3 (c-d).

Deceleration (Segment 1):

$$t_1 = \frac{V_1}{a'}$$

$$d_1 = V_1 \frac{t_1}{2}$$

Queuing (Segment 2):

$$N = \frac{\mu}{\mu - \lambda}$$

$$t_2 = \frac{1}{\mu - \lambda}$$

$$d_2 = N \cdot L$$

Acceleration (Segment 3):

$$t_3 = \frac{V_3}{a''}$$

$$d_3 = V_3 \frac{t_3}{2}$$

Aggregate:
Total travel time = $t_1 + t_2 + t_3$
Combined length = $d_1 + d_2 + d_3$
Delay at plaza = $(t_1 + t_2 + t_3) - \left(\frac{d_1}{V_1} + \frac{d_3}{V_3} \right)$

where:

V_1, V_3	Link speed on first and third links, respectively
a', a''	Constant deceleration and acceleration rates, respectively
N	Number of vehicles in the queue
λ	Arrival rate per lane, or the traffic volume per toll late
L	Length of vehicles, including the gap between vehicles
t_i	Travel time on link i
d_i	Delay for link i

The actual delay at the plaza is the total time from the three segments minus the time spent traveling at a uniform speed on the segments preceding and following the toll link. The parameter values for acceleration, deceleration, and vehicle length were obtained from AASHTO's "Policy on Geometric Design of Rural Highways." The program does utilize a varying deceleration rate based on the speed on the upstream link (Segment 1). This is accomplished via a linear interpolation of deceleration rates provided for the range of approach speeds. The upper limit for deceleration is 6.2 mph/sec at 70 mph and 4.0 mph/sec at 30 mph. The acceleration rate is set at 2.5 mph/sec.

Detailed instructions about needed files, format, and procedures for highway network coding are located in **Appendix V-1**.

6. Highway Capacities

The vehicle travel times on the highway links in the DVRPC model are calculated as follows:

$$T = T_{FF} \left(1 + A \left(\frac{V}{C} \right)^B \right)$$

where T is the travel time, T_{FF} is the travel time under free-flow conditions, V is the volume on the link, C is the capacity of the link, and A and B are calibration constants. DVPRC uses A = 0.15 and B = 7. These have been determined by empirical study to best represent traffic flow conditions in the DVPRC region. The accurate determination of link capacities and travel times is important to the model calibration.

- Vehicle Travel Time
- Free-flow Travel Time
- Traffic Volume
- Link Capacity

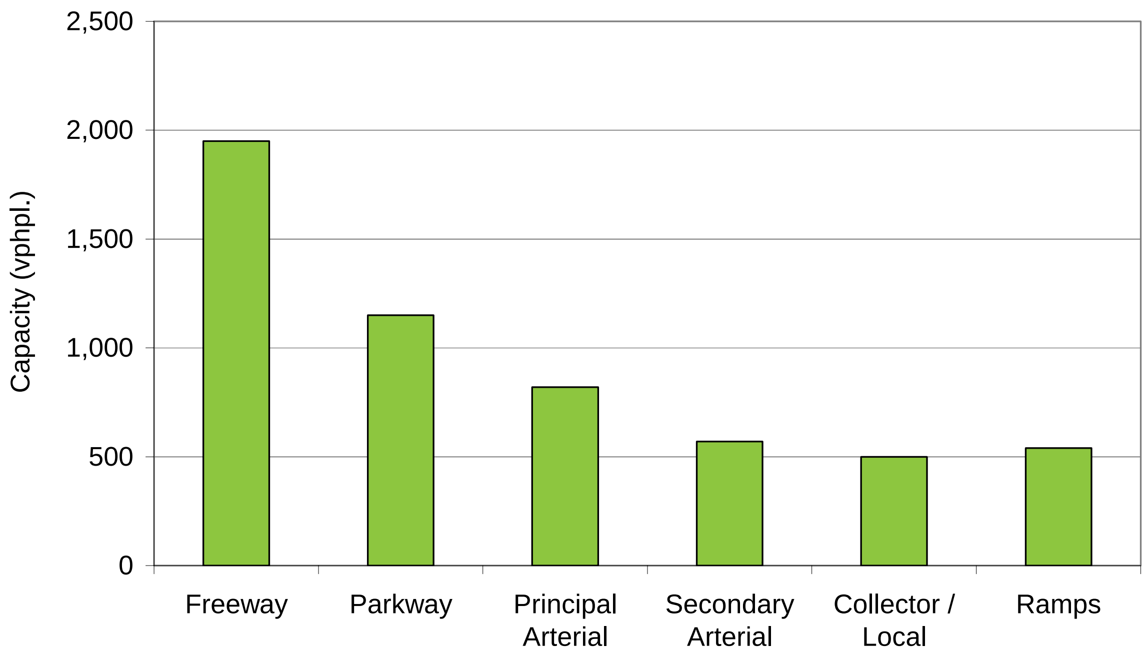
Link vehicle capacities are determined by the DVRPC functional classification (six possible FCs) of the link and the area type (six possible area types) where the link exists. This results in 30 different "per lane hourly capacity" FC/area type permutations (area types 5 and 6 combined). These capacities were derived in large part from the 1994 Highway Capacity Manual (HCM) given appropriate assumptions about roadway conditions. Each of the FC/area type permutations is then broken down into three categories – high, medium, and low. This reflects the wide range of capacities that are observed on the various highway types due to differences in lane width; lateral clearance; truck use; density of ramps, signals, and/or driveways; median treatment; sub-standard geometry; etc. that cannot be completely accounted for simply by varying capacity by area type and functional classification. Also, the number of lanes for a link is taken as the number of mid-block lanes. The designation of high, medium, or low capacity allows for the representation of differing types of intersection treatments (signals, turn lanes, jug handles, etc.) at the approach end of each link. The medium value is used by default in the base network. The high and low values are used in more detailed traffic studies. Employing three values for each functional classification/area type permutation allows for more tailored model calibrations. ***Table V-3*** shows the complete set of different per lane hourly capacities. These values assume a three lane per direction roadway. The per-lane hourly capacity is adjusted down by 4% for 1 and 2 lane facilities and up by 3% for facilities with more than 3 lanes. These are the per lane hourly capacities at level of service (LOS) E, which is typically the greatest.

Figure V-3 shows the capacities for the urban area type. The per-lane freeway capacity is about twice the capacity of the parkway and principal arterial facility types. The collector area type has the lowest capacity, about 25 percent of the freeway per-lane hourly capacity.

Table V-3 Hourly Capacities per Lane by Area Type (vphpl.)

Functional Classification			CBD (1)	Fringe (2)	Urban (3)	Suburban (4)	Rural (5&6)
1	Freeway	High	2,320	2,320	2,330	2,430	2,490
		Medium	1,950	1,950	1,950	2,000	2,100
		Low	1,450	1,450	1,450	1,590	1,730
2	Parkway	High	1,190	1,190	1,290	1,390	1,530
		Medium	1,060	1,060	1,150	1,240	1,370
		Low	960	960	960	960	1,120
3	Principal Arterial	High	760	800	1,060	1,290	1,500
		Medium	600	640	820	950	1,100
		Low	460	540	690	810	910
4	Secondary Arterial	High	520	620	760	920	1,150
		Medium	410	460	570	680	800
		Low	310	360	460	590	680
6	Collector/Local	High	560	630	700	840	980
		Medium	400	450	500	600	750
		Low	320	360	400	480	600
8	Ramps	High	590	610	700	810	910
		Medium	460	490	540	680	800
		Low	330	370	390	540	680

Source: DVRPC July 2008



Source: DVRPC July 2008

Figure V-3 Urban Hourly Capacities Per Lane by Facility Type

The per-lane hourly capacities are converted to link daily capacities by a set of standard 2KD (2 indicates both directions, K is the % of traffic in the peak hour, D is the directional split) conversion factors. The conversion factors are disaggregated by functional classification; area type; and DVRPC high, medium, and low categories. The 2KD factors are listed in ***Table V-4***. The conversion from hourly per lane capacity to daily total capacity is done by the following equation:

$$C_D = \frac{C_H N}{2KD}$$

where: C_D = Daily total capacity
C_H = Hourly per lane capacity
N = Number of lanes
2KD = Standard conversion factors

These daily capacities are used as the capacity element in the speed/capacity lookup table at the beginning of the highway network cards file. The capacity of a link is then found by referring to the lookup table using the link's functional classification, area type, and number of lanes as listed in the links sections of the highway cards file

Table V-4 Standard Conversion Factors (2KD)

Functional Classification			CBD (1)	Fringe (2)	Urban (3)	Suburban (4)	Rural (5)
1	Freeway	High	0.081	0.081	0.084	0.087	0.094
		Medium	0.081	0.081	0.084	0.087	0.094
		Low	0.081	0.081	0.084	0.087	0.094
2	Parkway	High	0.081	0.081	0.092	0.094	0.096
		Medium	0.081	0.081	0.092	0.094	0.096
		Low	0.081	0.081	0.092	0.094	0.096
3	Principal Arterial	High	0.083	0.083	0.084	0.086	0.090
		Medium	0.083	0.083	0.084	0.086	0.090
		Low	0.083	0.083	0.084	0.086	0.090
4	Secondary Arterial	High	0.085	0.085	0.094	0.098	0.100
		Medium	0.085	0.085	0.094	0.098	0.100
		Low	0.085	0.085	0.094	0.098	0.100
6	Collector/Local	High	0.076	0.089	0.089	0.114	0.120
		Medium	0.076	0.089	0.089	0.114	0.120
		Low	0.076	0.089	0.089	0.114	0.120
8	Ramps	High	0.058	0.068	0.075	0.082	0.089
		Medium	0.058	0.068	0.075	0.082	0.089
		Low	0.058	0.068	0.075	0.082	0.089

Source: DVRPC July 2008

As discussed in **Chapter II**, the DVRPC model uses several different time periods to accurately model the differing transportation system characteristics that occur throughout the day. The daily capacities are too large to represent the capacity for a peak, midday, or evening time period. Nor is it sufficient to merely factor the daily capacities for the length of the time period, as the traffic volume is typically not constant throughout the time period. In order to conduct a capacity restrained time period assignment, the daily capacity is divided by the CONFAC (Capacity Conversion Factor), which converts daily capacities to time period hourly capacities. The CONFAC is included in the parameter set of the TRANPLAN equilibrium traffic assignment program. These values are determined during the validation process in part by the output time period speeds and the VMT resulting from the assignment. They are also determined in part by the hourly distribution of traffic within each time period and the magnitude of time period traffic versus the daily total.

7. Highway Travel Times and Speeds

The travel time function discussed above requires link free-flow travel time in addition to link capacity. The free-flow travel time is calculated from the distance for each link divided by the free-flow speed. Free-flow speeds, similar to link capacities, are not specific for each link, but are generally disaggregated by functional class and area type. Unlike capacity, there are no high, medium, or low categories for link speed. For each FC/area type permutation, the free-flow speed is taken from two sources – average posted speed and average off-peak speed from the 1997 Highway and Transit Travel Time Survey. Both of these numbers were examined and adjusted to determine final free-flow speed values. A free-flow speed represents the speed that a normal driver would drive on a highway facility if there was little or no congestion. The free-flow and calibration speeds actually used in the models will be discussed in **Chapter VIII**

In summary, the highway network is coded as a system of links, nodes, and speed/capacity/volume relationships. Special procedures are used to model bridge, turnpike toll facilities, and access to the network. Travel over the DVRPC region's complex, congested highway network can be accurately simulated through these techniques.

B. Transit Network Preparation

The transit network in the Delaware Valley is both extensive and complex, comprising multiple modes (rail, subway & elevated, bus, light rail) and operating agencies. The transit network coding procedure is meant to construct a computer representation of the transit network that can be integrated with the various engineering and behavioral models used in the DVRPC travel simulation process. The transit network coding uses links and nodes similar to the highway coding; the transit network coding also uses lines or routes that connect sequences of links. The starting point for transit network coding is the current transit schedule as published by the transit operators. The transit schedule provides detailed information on route service patterns, travel times between published control points, and vehicle headways. The service patterns are used to geographically define the transit routes in terms of underlying streets, stops, stations, rail, and other fixed guideway facilities. The scheduled travel times are allocated to the intervening highway and transit network nodes based on distance and other factors. Vehicle headways are used in the path building, modal split, and transit assignment models to calculate waiting times to board transit.

Different transit networks are needed for each of the three time periods because the provision of transit service is substantially different between the peak, midday, and evening time periods. Differences between the networks include the routes and service patterns represented as well as the headways on each line. The headways are determined by the number of runs on each line as presented in the schedule. The AM peak period network represents service in the peak period, when service is the densest and frequency of service is the greatest (the PM peak period does not need to be represented separately as it is roughly the inverse of the service present in the AM peak period network). To qualify as AM peak period service, the majority of the run must occur between the hours of 7:00 AM and 9:00 AM

The midday period network represents service in the balance of the non-peak period day. To qualify as midday period service, the majority of the run must occur between the hours of 11:00 AM and 1:00 PM

The evening period network represents service in the evening portion of the day. Generally, this service varies from the peak or midday service and is therefore of interest when simulating an entire weekday. To qualify as evening service, the majority of the run must occur between the hours of 8:00 PM and 10:00 PM

This section discusses the preparation of the transit network. The integration of the transit and highway networks is discussed and statistics on the transit network are given. Detailed coding procedures are discussed in **Appendix V-2**.

1. Integration of Highway and Transit Networks

Previous versions of the DVRPC simulation models had completely separate transit and highway networks. The two networks only shared the TAZ centroids in common. The two networks were fully integrated in the 2000 model in order to better represent the effects of changing highway speeds on transit run times.

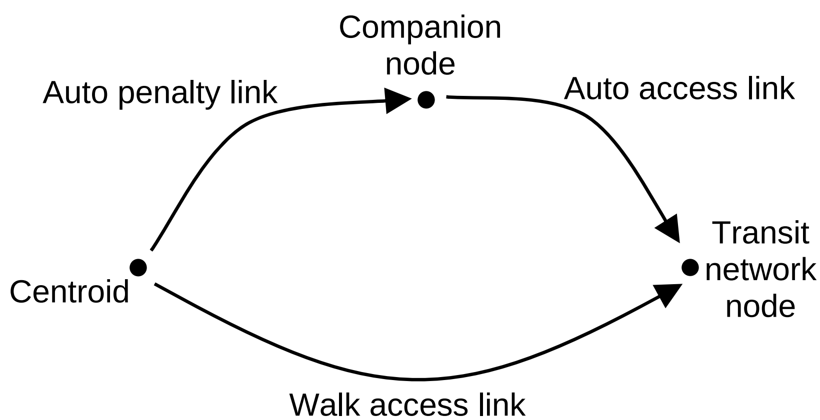
Because of the integration of the highway and transit networks, the 1997 transit network could not be easily updated to produce the 2000 transit network. For this reason, the 2000 transit network was completely coded from scratch. Operating agency schedules and maps were used in conjunction with GIS tools to recode each route's sequence of used links, headway, and link travel times.

The 2005 network was produced by updating the 2000 network. Agency data for each line was examined for schedule changes, alignment changes, and run-time changes. The most significant change to the 2005 network was the addition of the new RiverLine LRT service, running from Camden to Trenton, NJ.

2. Transit Network Coding Procedures

The transit network, similar to the highway network, is modeled by a network of links and nodes. In addition to links and nodes, the transit network also contains routes or service patterns. Each service pattern runs over a sequence of links. The highway file and four transit specific files are used to represent the transit network. The transit system references the highway links used by the transit system (i.e. bus service). The four transit specific files are a coordinate file, a non-highway link file, a highway-link transit travel time file, and a route file. Each is now described.

The coordinate file (typically tran**.cor) contains nodes that are used by the transit network but not by the highway network such as rail stations. This file has a format similar to the highway node listing in the highway cards file. Many of the nodes in the coordinate file are companion nodes used to connect the node centroid to the transit network as shown below.



The non-highway link file (typically nhwyl**.ref) contains links used by the transit network but not by the highway network. These include walking links, auto access links, and auto penalty links as shown above. The file also contains alignment links for modes that do not travel on the highway network, such as railroad, subway, and busway alignment links. Data for mode, distance, travel time or speed, beginning and ending nodes, and fare are coded for each link.

For transit modes operating over the highway network (bus and surface trolleys), the highway network cards contain the basic data for the links. This data is augmented because transit run times, as obtained from schedules, are typically longer than the highway travel times. The degree to which the transit run time exceeds that for highway vehicles on a particular link depends on vehicle characteristics, the number of stops, and roadway characteristics and cannot be generalized. The highway-link transit travel time file (typically hud****.red) contains node to node transit travel times for all highway links used by the transit network.

Scheduled run times over a given link vary between peak and off-peak times, among separate routes operating over the same alignment, and even among separate runs for the same transit route. Therefore, the travel times listed in both the non-highway links file and the highway-link transit travel time file must be determined by averaging the scheduled run times for all the routes that operate on the facility. Separate files are kept for the different time periods – one for the peak period and another used by both the midday and evening time periods. These run times are used as-is for current simulations. For future simulations, the highway-link transit travel times are either increased or decreased based on future changes in highway speeds and a highway-speed/transit-speed relationship:

$$T_f = T_s \frac{H_f}{H_c}$$

where:

Tf	Future of build alternative congested transit speed
Ts	Scheduled or No-build transit speed
Hf	Simulated future of build alternative congested highway speed
Hc	Simulated current or No-build highway speed

This is done by using the same node numbers for the same locations in both the transit and highway networks. A correspondence file is then generated during the process of building the transit network. Details on this process are in **Appendix V-2**.

The transit route file (typically TROUTE.CDS) contains information on the different transit routes that operate over the transit network formed by both the highway-links and the non-highway links. A single transit route will often have various service patterns (skip-stop service, short turns, express service, etc.). Each of the various service patterns is coded separately, in effect as a separate route. The transit route file contains the mode number, line number, operating company number, headway, and sequence of nodes used by the line. This sequence of nodes is then used to identify the links used by the service pattern. There are separate transit route files for each of the three time periods.

The various files are built into a binary format readable by TRANPLAN by a series of programs – INETLINE, ALLOETIM, DVFARELG, and HUDNET. The INETLINE and ALLOETIM programs convert the TROUTE file to the proper format (HUDNET) and produce a correspondence file between highway links and transit links. DVFARELG inserts and updates fares and converts the time and monetary disutility components into a common impedance measure. The HUDNET program called through TRANPLAN builds the final binary version of the transit network.

3. Transit Fare Coding

The transit fare can be divided into three components – base fare, zonal increments, and transfer fare. The base fare is the charge that is levied regardless of how far a passenger travels on a given transit facility. The zonal increment is an additional fare charged when a trip crosses one of the fare zone boundaries established by the operating agencies. Examples include the SEPTA railroad system and the PATCO line. A transfer charge is levied when a rider transfers from one vehicle to another and pays a charge less than the full fare. An example would be the fare charged when transferring between two SEPTA buses.

Transit fares are coded in the following manner. One half of the base fare less one half of the transfer charge for a given transit facility is included on each approach/transit walk link. This arrangement allows the full base fare to be levied while allowing for complete flexibility in point of ingress and egress. The transfer charge in included through the add penalty option in the path building program. The fare zone increments are added to the transit facility links as appropriate. One half of the transfer charge is subtracted from the fare on each approach/transit walk link because the add penalty assesses a transfer charge on the initial boarding as well as to subsequent boardings. Fare levels are not exactly equal to actual fare levels, but decreased to account for the use of weekly and monthly passes. Different operators charge transit fares through a variety of discount passes and tokens, as well as through cash fares. The per ride fare varies significantly depending on the type of fare instrument used and usage. For purposes of travel simulation, weighted average fares over the applicable fare instruments are utilized. With the exception of PATCO and Pottstown Urban Transit, this value is always significantly less than the cash base fare. The actual fares used for the 2000 and 2005 models are listed in **Chapter IX**.

4. Transit Network Statistics

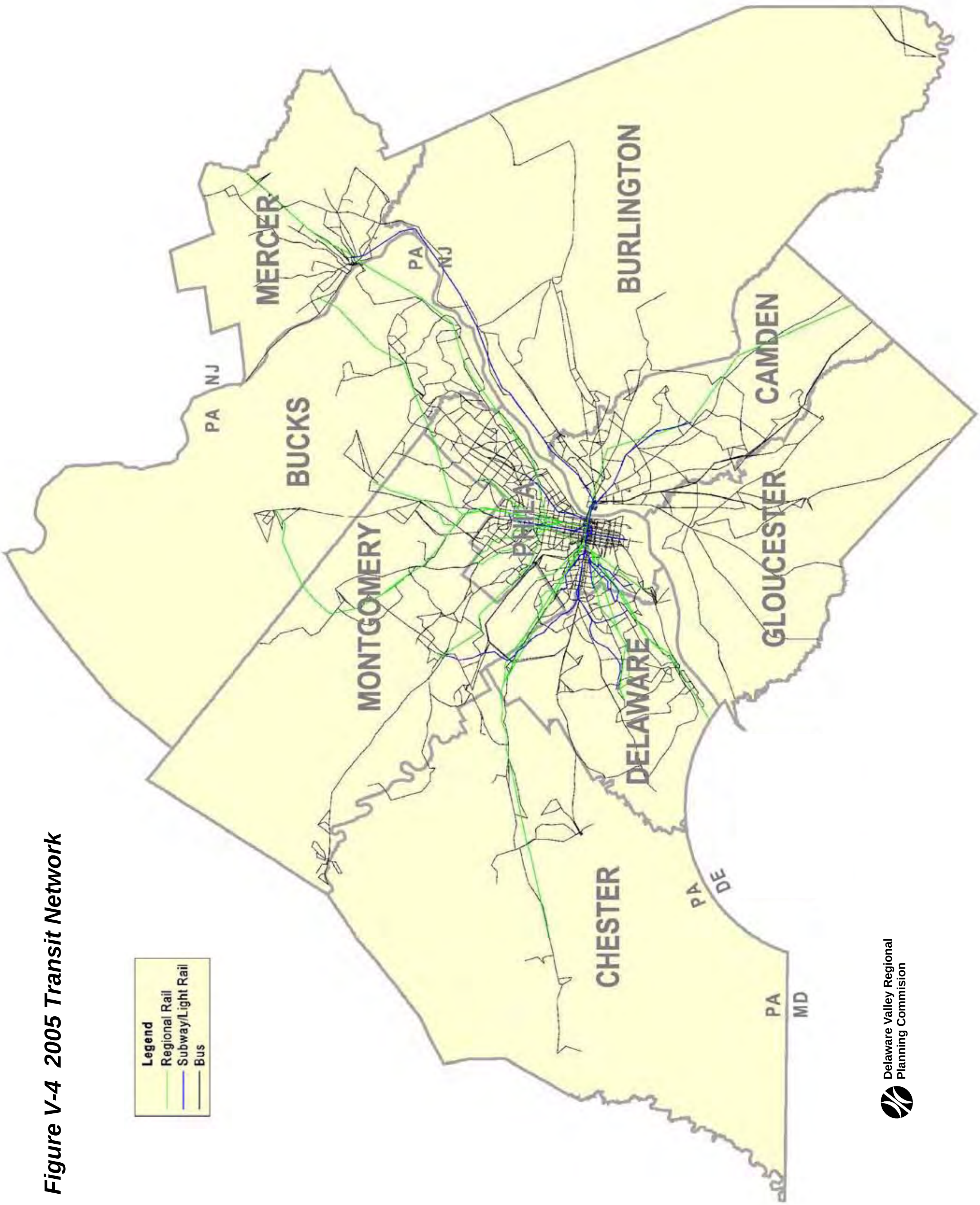
Table V-5 lists transit statistics for the 2000 transit network by submode and time period. The 2000 transit network has 693 separate service patterns, 23,998 nodes, 11,358 transit links, and 24,443 links when auxiliary links are included. A map of the transit network can be seen in ***Figure V-4***. As can be seen from ***Table V-5***, the peak transit network is much more extensive than the midday or evening networks. This reflects the elimination of express and turn-back service on some routes, and the elimination of some lower ridership, commuter only routes. Average speeds increase from the peak to the midday to the evening time periods. This is due to shorter dwell times and increased running speeds due to lower congestion levels.

Table V-5 2000 Transit Network Statistics

Mode#	Mode	Service Patterns			Route Miles			Average Speeds (MPH)			Links		
		Peak	Midday	Evening	Peak	Midday	Evening	Peak	Midday	Evening	Peak	Midday	Evening
1	Walk	-	-	-	-	-	-	4.0	4.0	4.0	7,535	7,303	6,425
2	Auto Connector	-	-	-	-	-	-	-	-	-	3,150	3,150	3,150
3	Auto Approach	-	-	-	-	-	-	-	-	-	2,400	2,358	2,362
4	PA Std. Bus 1	236	142	134	1,994	1,515	1,208	12.1	12.0	13.4	4,207	4,138	3,828
5	PA Std. Bus 2	179	123	79	2,004	1,623	1,002	15.7	16.1	17.6	2,933	2,846	1,897
6	NJ Std. Bus	123	93	70	2,301	1,944	1,513	17.3	17.8	19.1	2,190	2,166	1,916
7	PA Express Bus	33	3	2	366	39	17	16.4	18.6	22.4	610	71	30
8	NJ Express Bus	15	4	4	396	78	78	23.8	37.0	37.0	301	50	50
9	Inter-city Bus	17	29	24	864	1,543	1,417	43.5	43.3	46.8	261	358	299
10	Subway Surface	20	7	12	143	88	95	11.0	12.0	13.1	292	288	290
11	Subway-Elevated	7	5	8	137	100	110	22.4	21.6	22.3	166	152	152
12	SEPTA Reg. Rail	43	12	12	1,310	707	724	25.5	25.0	25.6	324	301	303
13	PATCO	5	1	1	65	28	28	30.1	30.4	30.4	25	24	24
14	NJ Reg. Rail	8	4	6	124	103	103	41.2	41.7	41.7	18	16	16
15	AMTRAK	7	4	6	410	321	370	53.3	55.6	53.5	31	20	26
	TOTAL	**693**	**427**	**358**	**10,113**	**8,087**	**6,663**	**17.8**	**19.0**	**21.5**	**24,443**	**23,241**	**20,768**

Source: DVRPC July, 2008

Figure V-4 2005 Transit Network



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VI. HIGHWAY TRAFFIC COUNTS, TRAVEL SURVEYS, AND MODEL PARAMETERS

This chapter covers the various data inputs that were not discussed in the previous chapters. The first section covers various forms of highway data that are used to validate the models. Section B covers the transit ridership data used for model verification. Section C discusses various travel surveys that are used to calibrate the models. Finally, section D contains tables of parameters used in the model.

Appendix VI-1 shows the forms for surveys conducted in the past for the purpose of travel modeling and various transportation studies. The survey forms are:

A. 2000 Household travel survey recruitment interview.
B. 2000 Household travel survey retrieval interview.
C. Cordon line survey questionnaire.
D. Transit on-board survey forms.
E. Truck survey form.
F. Bridge survey form.

A. DVRPC Highway Traffic Count Program

DVRPC has an extensive highway traffic counting program. Traffic counts are performed for many purposes, including model calibration and validation. This section discusses in general the type of counts performed by DVRPC. This is followed by a more specific description of the counts used for model validation.

The DVRPC Travel Monitoring Unit conducts traffic counts for both DVRPC and member government's traffic studies. Traffic data are collected to describe the use and performance of the roadway system. About 4,000 counts are collected annually and provided to requesting parties, primarily the Pennsylvania and New Jersey Departments of Transportation and the City of Philadelphia, in addition to count requests submitted by project managers within DVRPC.

1. Traffic Counting Program

Two types of counts, volume counts and vehicle classification counts, are provided by DVRPC. Traffic volume counts are the most common measure of roadway use. They are required as input to most traffic engineering analyses. Both electronic (pneumatic tube recorder - PTR) and manual methods (Denominator mechanical counter, JAMAR DB-100, and TDC-8 intersection counters) are utilized in the collection of traffic volume data.

The PTRs are set for a minimum three-day period, enabling traffic data to be recorded for a full 24-hour, midnight-to-midnight cycle. Permanent in-pavement sensors (loops) require a 48-hour count (two midnight-to-midnight cycles), while certain NJ counts are set for a full eight days. The short count program is designed to provide roadway segment-specific traffic count information on a cyclical basis. To compute the annual average daily traffic (AADT), the volume data from the short counts must be adjusted to annual conditions. The adjustments include:

- axle correction (for counts taken with single axle sensors).
- seasonal correction (to account for volume changes from month to month).

Manual traffic volume counts are generally limited to turning movement counts, although manual volume counts may occasionally be performed on high-speed, high-volume roads. Turning movement counts are requested for intersection studies for upgrading or traffic signal timing purposes.

Vehicle classification counts are the second type of count provided by DVRPC. These counts are performed to ensure that requesting agencies have valid truck volume information for the roadways requested. Classification data is needed to better understand truck travel on highways. PTR counts use the standard FHWA 13 vehicle categories. Field personnel set counting equipment, which classify vehicles by type based on axle configuration. A small number of manual classification counts are also performed annually, employing the New Jersey vehicle classification designation as required. This system has 15 classes. A manual classification is also based on axle configuration.

DVRPC performs counts for many outside agencies including the NJ and PA DOTs, the City of Philadelphia, and Gloucester County. The traffic monitoring unit also conducts counts for other units within DVRPC in connection with planning or engineering projects/studies. These requests number approximately fifteen per year and involve approximately 500 additional counts. The counts may be requested on state, county, or local roadways located throughout the nine-county DVRPC region and include PTR volume counts, manual turning movement counts, and vehicle classification studies.

2. 2005 Screenline and Cordon Traffic Count Results

Region-wide screenline and cordon traffic counts are collected every five years. The most recent was performed in 2005. The purpose of these counts was for travel simulation model validation and for traffic growth monitoring. Modeled volumes for various screenlines and cordons are compared with measured volumes.

Except for toll roads and Delaware River bridges, DVPRC personnel performed all counts. DVRPC counting equipment was generally set up at each location for a minimum of 48 continuous hours of a weekday (Monday through Friday) and checked for satisfactory performance. Approximately 500 counts total were gathered at selected stations on screenlines, cordon lines, river crossings, and turnpike segments.

Traffic counts were gathered along two cordon lines (inner and outer), 10 screenlines (seven screenlines and three screenline extensions), and two turnpikes within the DVRPC boundaries. Effort was made to ensure that the screenlines and cordons for the 2005 count were identical to those used in 2000. In this way, the data from the 2005 highway traffic count can be directly compared to counts performed in 2000 and pervious years. For more details on the 2005 highway traffic count see the DVRPC report **"*1985-2005 Highway Traffic Trends in the Delaware Valley Region* (DVRPC report # 07036)."** The major findings of the study are:

Screenlines - The 10 regional screenlines recorded a total traffic volume of about three million vehicles per day, which represents a 1.5 percent annual increase over the last decade. There has been an increase of nearly 7.5 percent since the count of 3.35 million taken in 2000. The Crosswicks Creek screenlines had the smallest volumes, with a combined annual average of 257,400 vehicles per day, while the Upper Schuylkill segments had the highest volumes, with a combined volume of about 778,300. Overall growth was spread evenly among screenlines.

Outer Cordon - The outer cordon, defined by the perimeter of the nine-county region, recorded nearly 1.62 million vehicles per day. The compound rate of growth of was about 2.9 percent annually from the 1995 count of 1.22 million.

Pennsylvania Turnpike - The Pennsylvania Turnpike is one of the fastest growing facilities in the region. Traffic volumes on the Turnpike between Downingtown and the Delaware River have increased by a compound average of 2.7 percent annually since 1995. Along the Northeast Extension, growth has been even higher, at a compound annual average of 3.6 percent since 1995.

New Jersey Turnpike - Generally speaking, the total volumes for the New Jersey Turnpike are about 15 percent greater than those for the Pennsylvania Turnpike. Although the New Jersey Turnpike volumes grew at an average annual rate of 3.0

percent from 1995 to 2000, this growth slowed to just 0.8 percent between 2000 and 2005.

Hourly Variation - No major changes were evident in the curves depicting the hourly distribution of traffic crossing the screenlines, although as noted previously, total traffic has generally increased in the region. A common feature of all these variations is a broader PM peak and, where there has been robust growth across a screen line, a flattening of the afternoon "trough." 2005 AM peak hour values range from 5.5 to 8.8 percent of the daily traffic volume, while PM peak volumes range from 5.9 to 9.0 percent of the daily traffic volume.

See the report ***"1980 – 2005 Travel Trends in the Philadelphia Central Business District"*** **(DVRPC report # 07034)** for a more detailed analysis of travel trends in the Philadelphia CBD. The Philadelphia CBD showing cordon line locations can be seen in ***Figure VI-1***.

The CBD study counted both highway and transit volumes into and out of the Philadelphia CBD. Highway data was collected by pneumatic tube counters. Transit ridership data was collected by SEPTA personnel. Regional Rail, Subway/Elevated, and trolley ridership data were derived from SEPTA counts.

B. Transit Ridership Data

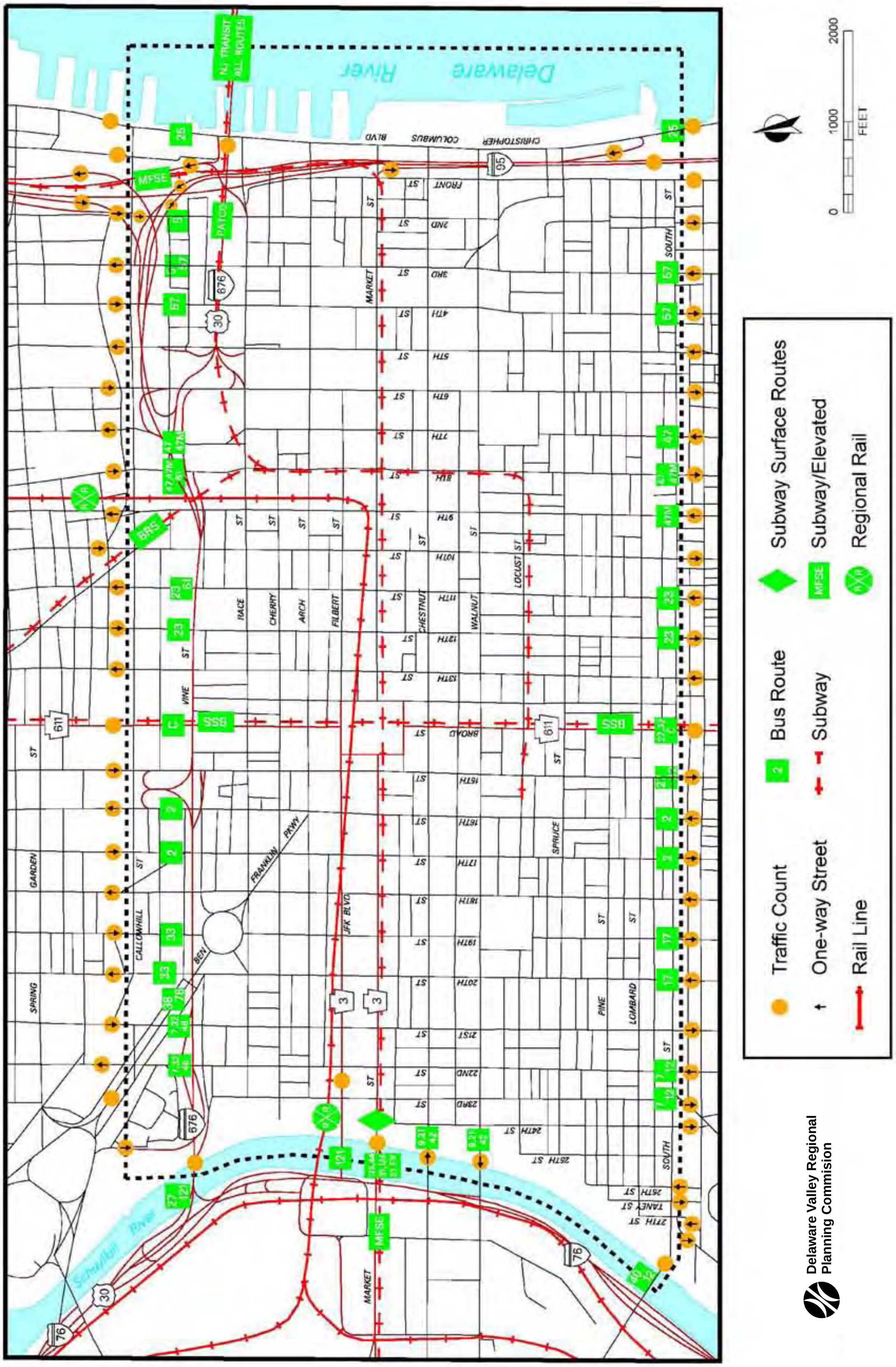
Internal transit ridership data is needed to calibrate and validate the travel simulation models. External transit ridership data is used to estimate the volume of external-internal travel. The collection of both types of transit ridership data is discussed in this section.

1. Internal Transit Ridership

Internal transit ridership data is needed in the modeling process to predict future transit ridership. For this reason DVRPC collects data on internal transit ridership from the various transit operators (SEPTA, NJT, and PATCO), both public and private, in the DVRPC region.

For internal transit ridership, DVRPC obtains ridership data from SEPTA from the ***"Annual Service Plan."*** These data are augmented by the bi-annual ***"Regional Rail Ridership Census."*** If necessary, more detailed, disaggregated, ridership is available upon request. DVRPC also receives the ***"Quarterly Ridership Trends Report"*** from New Jersey Transit (NJT). These reports detail various ridership trends. DVRPC also receives the separate *"Median Ridership"* spreadsheet from

Figure VI-1 Philadelphia CBD 2005 Cordon Line Count Locations



NJT with bus ridership disaggregated by line and day of week. Data from other public transit providers is available by request only. Private providers do not share their ridership data with DVRPC. This, however, is not a serious concern, as they only represent a small proportion of total transit ridership.

2. External Transit Trips

External transit ridership data is used differently than internal transit data. While internal (transit trips where both ends of the trip are in the DVRPC region) trips are determined form the trip generation, distribution, and mode split models, data on external trips (transit trips where one trip end is outside of the DVRPC region) are used directly.

As part of the regional cordon line survey discussed below, DVRPC prepared ridership data for scheduled rail and bus routes that carry people in and out of the DVRPC region. These transit crossings are identified as transit cordon stations and included in the transit network for transit assignment. The external transit cordon stations are shown in ***Figure VI-2***. The AMTRAK Northeast Corridor (north and south) and Harrisburg Line both cross the DVRPC cordon. NJT operates local rail service on the Northeast corridor between Trenton and New York; while SEPTA operates on the Northeast Corridor between Philadelphia and Newark, DE. NJT also operates local trains on the Atlantic City Line. Scheduled bus services, operated by one public and nine private carriers, cross the cordon line at 27 locations, some of the more important being: I-95, the NJ Turnpike, and the Atlantic City Expressway. The distribution of intercity bus traffic is based on average passenger loads by route, whereas AMTRAK and NJT traffic is based on rider counts. Some of the bus trips using the NJ Turnpike are through trips to/from New York which do not stop within the DVRPC region.

An origin and destination matrix is prepared for all transit cordon stations. Like highway trips, external transit trips occur between the transit cordon stations and stops inside the DVRPC region for inbound trips. Outbound external transit trips are those with origins inside the region and destinations at the cordon stations for the purpose of the DVRPC traffic simulation study. Through trips have both origins and destinations at cordon stations for traffic simulation.

Unlike highway traffic, DVRPC did not conduct a 2000 or 2005 survey for through and external-internal transit trips. Rather, data on bus trips crossing the DVRPC cordon line were obtained from a number of sources. For NJT routes, scheduled information was gleaned from published schedules while ridership across the cordon line was taken from the **"Bus Ridership and Fare Zone Profile"** provided by NJT staff. The major source of schedule information for intercity buses was obtained from ***"Russell's Official National Motor Coach Guide for the United States and Canada."*** Additional schedule information was obtained from published schedules for New York and Atlantic City service. Ridership information for these routes is proprietary, but the service providers provided DVRPC with average loads crossing the cordon line. Rail ridership data was provided by Amtrak.

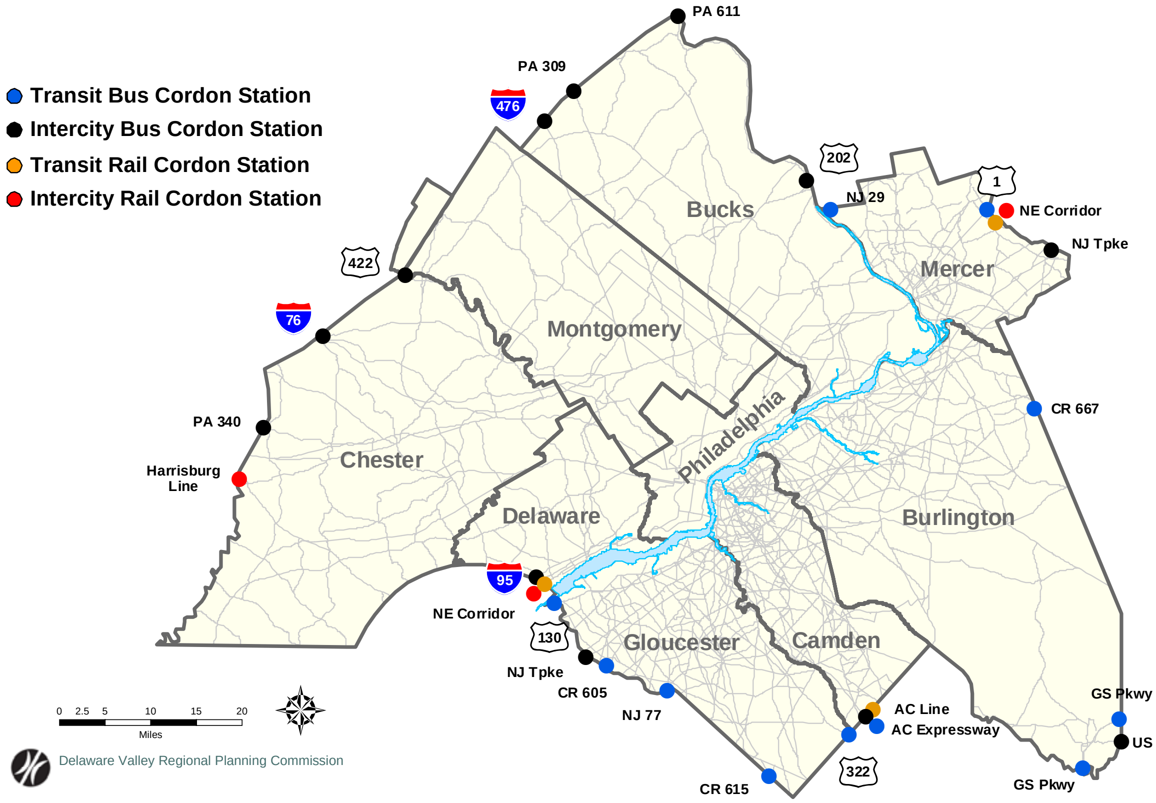


Figure VI-2 2000 External Transit Cordon Stations.

External bus travel was assigned to routings throughout the region based on scheduled stop locations. Based on these patterns, the number of trips crossing a particular cordon station was totaled and then multiplied by the average load factor at the cordon for runs of each carrier to attain the total number of passengers at a given cordon station (through and external-internal travel).

Bus routings in the Delaware Valley region developed for through travel analysis were used for external-internal travel. Boarding and alightings were established depending on whether the stop was a major bus terminal or other stop location. Catchment areas were established around each stop location and divided into distance based rings centered on the bus stop location. Trips were allocated to TAZs in the rings based on percentages of trips accessing the stop from each ring. Where the number of trips was large, such as for the Philadelphia bus terminal, groupings of three to five TAZs were created and the trips assigned to a representative TAZ for the group. Trips access the bus stop via the transit system, where available, or via drive access links which were coded as part of that effort.

The total external-internal trips for a given cordon station is equal to the total traffic volume crossing the cordon station minus the through trips. There are 16,717 total transit through trips per day, including 10,973 daily person trips on , 1,286 on intercity buses, and 4,470 on NJ TRANSIT buses. The number of external-internal transit trips is 61,975 rail and bus person trips per day. Rail passenger person trips per day carried by , SEPTA, and NJT are 24,850, 2,745, and 24,226 respectively. There are 4,236 external bus trips carried by intercity buses and 5,918 carried by NJT per day. Transit trips crossing the cordon line account for 3.7 percent of highway trips. Unlike external highway trips which are distributed by the gravity model, external transit trips are distributed based on carrier schedule. Through and external-internal trips for 2005 were calculated using the same methodology as for 2000.

C. Travel Surveys

DVRPC conducted many travel surveys and data collection activities in anticipation of the 2000 simulation model update and the 2000 and 2005 model validations. These included **a Household Travel Survey**, **a Cordon Line Traffic Survey**, **a Highway and Transit Travel Time Survey, and a Truck Survey.** Origin-Destination surveys conducted for the Pennsylvania and New Jersey Turnpikes were also made available to DVRPC. In addition, extensive highway traffic volume and transit ridership counts were collected and a special tabulation of the 2000 Census data, the Census Transportation Planning Package (CTPP), was tabulated according to DVRPC's traffic analysis zones. The resulting data provides numerous statistics on the spatial, temporal, and modal distribution of travel throughout the region.

1. Household Travel Survey

Household travel surveys are used to obtain information about work and non-work trip generation, trip distribution, modal split, and average vehicle occupancy. Updated household travel information can be used for modeling purposes as well as transportation planning projects such as high occupancy vehicle lanes, bicycle, and pedestrian studies, welfare-to-work programs, and traffic control studies. The most recent household travel survey, called the **Transportation for the 21st Century Household Travel Survey**, was conducted from March through December 2000 under the auspices of DVRPC and the South Jersey Transportation Planning Organization (SJTPO). SJTPO represents Salem, Cumberland, Atlantic, and Cape

May Counties. Detailed information on the survey can be found in the document *"**Transportation for the 21st Century Household Survey – Travel Survey Results for the DVRPC Region."*** **Appendix VI-1** shows the recruitment interview and retrieval interview questions used in the survey.

Like all recent household travel surveys, the 2000 survey relied on the willingness of area residents to complete diary records of all travel for a 24-hour period. It was based on telephone interviews of randomly selected households from the 14 county study area. Household recruitment for the study was conducted through the use of a "recruitment interview" in which respondents were informed of the survey, its purpose, and the obligation of all household members to complete the survey. Data on the household and household members were also collected during the recruitment interview. Participating households were assigned a specific "travel day" or 24-hour period on which to record their travel and activities. This travel day typically took place 7-10 days after the recruitment interview. Collection of the travel information was done through the use of a "retrieval interview."

There were 4,271 Delaware Valley households that responded to the survey. Out of these, 2,666 came from PA and 1,551 from NJ. Based on the 1997 DVRPC estimates of 1,964,507 households in the DVRPC region, each household surveyed represented 466 households in the region when expanded. The 4,217 households were comprised of 9,348 people who had 4,926 vehicles available to them.

Detailed information was collected on 32,328 trips, including 25,250 automobile trips, 1,648 transit trips, 3,555 walk trips, and 285 bicycle trips. Trip ends were geocoded and processed to develop trip length frequency distributions and average trip lengths by travel mode and trip purpose. For automobile trips, the number of occupants and parking charges, if any, were recorded. For transit trips, the access and egress modes, number of transfers, and fares were recorded.

2. Cordon Line Traffic Survey

The Cordon Line Traffic Survey was designed to gather information from a sample of drivers crossing the boundary of the DVRPC region. The survey was done to collect current information on traffic volumes and to determine the origin-destination travel patterns, travel activity, and travel mode of vehicles crossing the nine-county DVRPC cordon line. The external and through trip travel patterns are especially critical for transportation facilities located near the nine-county boundary, as this is an area where major new development has occurred in recent years. **Appendix VI-1** shows the questionnaire used for the roadside interview.

The survey was conducted in the spring and summer of 2001 and consisted of roadside interviews at 12 locations representing a broad range of highway types, from local to interstate facilities. A map of the locations can be seen in ***Figure VI-3***, along with the sample locations of the earlier 1988 cordon survey. About 338,000 vehicles entered or exited the Delaware Valley Region at these 12 locations on a typical day during the study period. The information gathered in the survey was supplemented by PA and NJ Turnpike surveys (discussed below in section 7), transit cordon counts, and traffic counts taken on an additional 140 highway facilities crossing the regional boundary.

The survey consisted of roadside interviews at each location. The survey asked questions about trip origin, destination, and purpose; highway use and vehicle type; and vehicle occupancy. The questionnaire also asked about the reasons for travel, how people make their travel decisions, and how people plan their daily trips. Truck type, garaging, and commodities carried were also recorded for commercial vehicles.

Hourly traffic and classification counts were performed for each location. Based on these volumes, standard statistical methods were applied and a sample size was established for each location. The sample was then disaggregated into an appropriate number of surveys for passenger and commercial vehicles for each survey period. A total of 18,577 survey forms were completed: 15,476 were interviews with drivers of passenger vehicles, and 3,101 were interviews with commercial vehicle drivers. The sample size for the aggregated cordon stations was about 92 percent of the desired sample goal of 20,300 surveys. For each location there were eight hour-long survey periods, four in the morning and four in the afternoon. More detail on the conduct and results of the survey can be found in the document **"*Cordon Line Highway Traffic Survey for the Delaware Valley Region* (DVRPC report #02044) "**

The survey results were used to determine the proportions of external-internal and through trips at each cordon, to develop trip length frequency distributions for the external-internal trips by facility type, and to produce a through trip matrix for those trips that pass through the region without stopping.

3. Transit On-Board Surveys

DVRPC conducts railroad, heavy rail, light rail, and bus on-board transit surveys for travel modeling and service evaluation purposes. Various types of data are gathered depending on the survey. Information is usually solicited from passengers in three areas: trip data, usage, and attitudes towards the service. Trip data includes information on trip origin and destination, access and egress to and from the station or stop, fare paid, travel time, and distance. Characteristics of usage were determined from questions about trip-purpose, frequency of use, and duration of use. Attitudes about service quality were elicited by questions that requested the

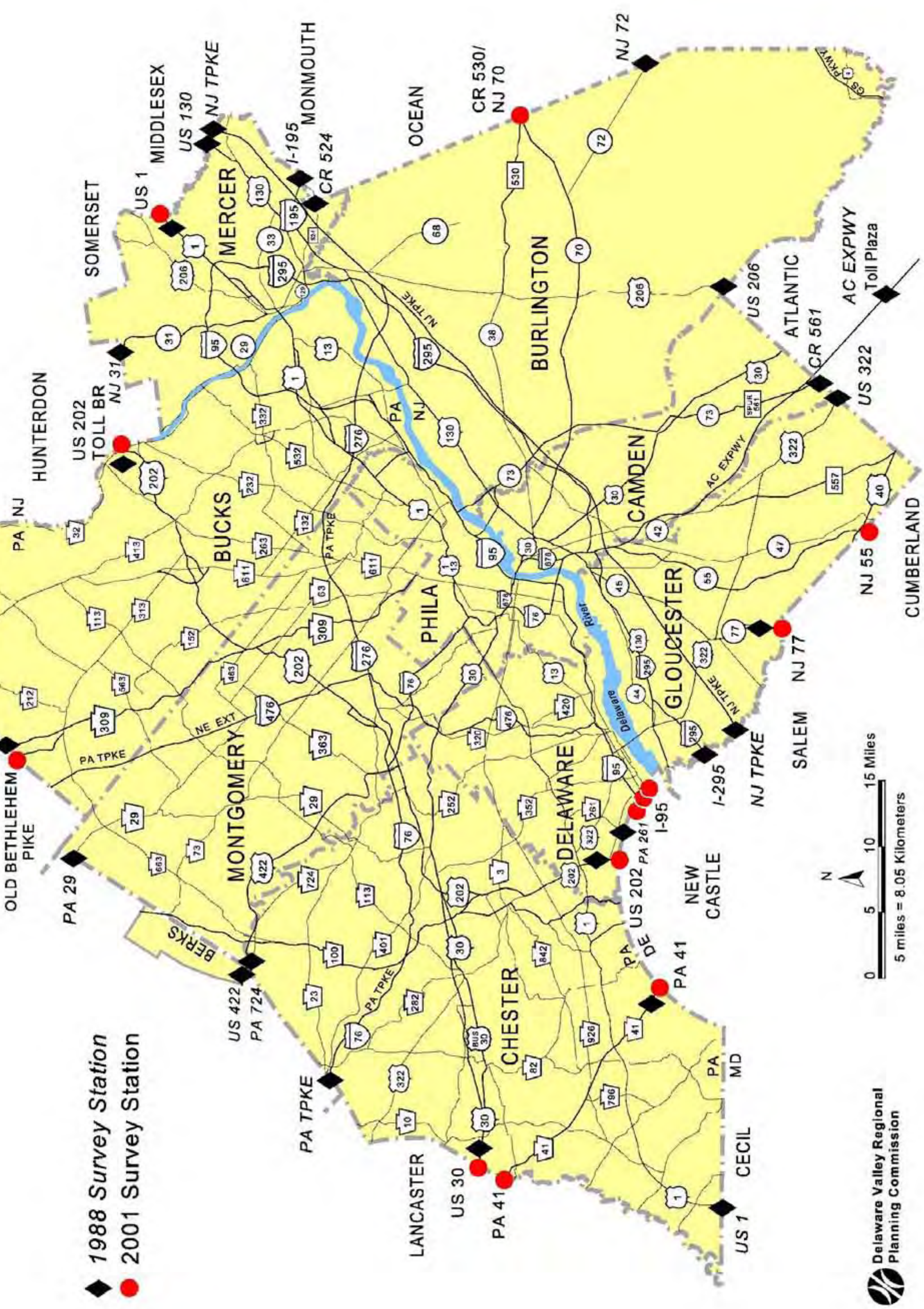


Figure VI-6 Cordon-Station Survey Locations rider to rate the quality of transit service, automobile availability, and service ratings on aspects such as cost, frequency of service, and comfort. Socio-economic characteristics, such as age, employment status, and income, are usually requested as well.

The results of transit on-board surveys are used for a number of purposes including:

- Transit network coding.
- Calibration of the modal split model and transit assignment model.
- Evaluation of transit stations, routes, and services.
- Transit system marketing.

Examples of transit on-board surveys are located in **Appendix VI-1**. Included are three examples – a SEPTA railroad on-board survey, a NJ TRANSIT on-board survey, and a PATCO on-board survey.

4. Highway and Transit Travel Time Survey

A survey of highway and transit travel time and speed throughout the DVRPC region was conducted in the mid-90s. Approximately 1,700 miles of roadway, representing all functional classes, were surveyed with floating car techniques during the AM and PM peak periods and the midday time period. The highway travel time survey was then processed to produce average travel speeds by area type, functional class, and time of day. These speeds were then used to update the travel simulation model's speed-capacity lookup tables.

Transit speeds for individual routes, including railroad, subway, and bus routes, were determined from the published schedules. Transit travel times between various location pairs were calculated from the scheduled times, together with time for accessing and egressing the system and transferring between transit lines, where necessary. The transit and highway travel times from this survey were used during the calibration and validation of the modal split model.

5. Truck Survey

The Truck Travel Survey was conducted to collect current information on truck travel activity, origin and destination patterns, trip length frequency, and commodity data in the Delaware Valley region. The data from the Truck Travel Survey responses, combined with data from DVRPC's Cordon Line Highway Traffic Survey, Pennsylvania and New Jersey truck registration files, and other secondary sources, were used to develop commercial truck trip rates and trip length distribution data for the 2000 travel simulation model and the 2000 and 2005 validation of the DVRPC models. The survey form is shown in **Appendix VI-1**.

The survey was conducted in late 2000 and 2001. Weekday Truck Travel Diary survey forms were sent to almost 500 trucking and freight handling establishments, including shippers and truck owners/drivers. Detailed information was collected on up to 12 trips per day per truck. Questions were asked about the number of daily trips; trip origin, destination, and purpose; truck type, garaging, and commodity information; land use at each stop location; time of day; and the odometer reading at the beginning and end of each trip. Although a very large number of survey forms were mailed out, and extensive efforts were made to follow-up with each trucking and shipping firm, only 155 completed survey forms were returned. The results of the survey are summarized below.

Tractor-trailers comprise 97 of the trucks surveyed, about 63 percent. Single-unit trucks account for 32 of the trucks surveyed, or about 20 percent. Also included in the survey were one pickup truck, four dump trucks, five flatbeds, and no double-trailer trucks. Ninety-nine of the surveyed trucks (64 percent) are garaged in the Pennsylvania portion of the region when not in service, 49 are garaged in the New Jersey counties, and only seven are garaged outside the region.

A total of 2,825 one-way trips were made by the surveyed trucks. Although only 12 of 155 trucks surveyed are panel trucks, they account for over half of all trips. All of the panel trucks included in this survey were used to drop off and pick up parcels, and thus tended to make large numbers of short trips, between 66 and 168 trips per day. Tractor-trailers account for the next highest number of trips at 760 (27 percent), followed by single-unit trucks with 340 trips, or 12 percent of the total. Panel trucks average 133 trips per day, single-unit trucks 10.63 trips per day, and tractor-trailers 7.84 trips per day. The average number of truck trips per day made by all trucks surveyed is 18.23.

In addition to stop location, the truck travel diary survey form asked three questions about each trip stop - stop purpose, commodity carried to stop, and land use at stop location. The responses to these questions were tabulated for the 1,183 trips for which this information is available.

There were a total of 922 internal trips for which distance could be determined, 280 light truck trips and 642 heavy truck trips. The light trucks had an average trip length of 4.70 miles. Only nine trips (3.2 percent) were greater than 20 miles; 199, or 71.1 percent were five miles or less. Heavy trucks tend to make longer trips compared to light trucks. Their average internal trip length was 11.78 miles. While trips of 5 miles or less are still the most prevalent, they account for 250 out of 642, or 38.9 percent, of heavy truck trips, compared to 71.1 percent for light trucks. In addition, 117 heavy truck trips (18.2 percent) were 20 miles or greater in length. When light trucks and heavy trucks are combined, their average internal trip length is 9.63 miles, with 449 (48.7 percent) trips of five miles or less.

6. Taxi Survey

For the 2000 travel simulation, no taxi survey by DVRPC was conducted. Instead, the 2000 taxi trip generation model was updated from the 1990 model. In order to derive the 2000 model, the 1990 model was reviewed and adjusted based on recent data from other regions. In 2000 the Allegheny Institute for Public Policy conducted a telephone taxi survey for 10 cities, including Philadelphia, (see ***An Analysis of the Demand for Taxicabs in the Pittsburgh Area***, by Frank Gamrat, March 2001). According to this survey, the average number of daily trips per taxicab in Philadelphia was 54 and the average trip length was about 4.0 miles. The data from the Pittsburgh survey indicate that the daily taxi trips vary significantly from one city to another (from 36 in Pittsburgh, Seattle, and Atlanta to 72 in Cincinnati and Indianapolis).

7. Bridge Survey

DVRPC conducts surveys of the bridges crossing the Delaware River in order to improve travel simulation results and to aid in the analysis of new and existing services. An example of a bridge survey is the Burlington/Gloucester Corridor Assessment conducted by DVRPC in the spring of 1990. This bridge survey was conducted in conjunction with two surveys of transit usage in the corridor. The Walt Whitman, Ben Franklin, Betsy Ross, and Tacony-Palmyra bridges were surveyed as part of the study. The form used in the survey appears in **Appendix VI-1**. The purpose of the survey was to provide basic data on trip origin-destination, mode, purpose, frequency, and socio-economic characteristics of “Trans-Delaware” travelers between Pennsylvania and New Jersey. Bridge surveys are used to provide a better understanding of mode choice behavior in the transportation markets surveyed. Market specific data gathered through bridge surveys, in conjunction with transit surveys, are used to adjust the travel simulation models and to refine alternatives in transit studies.

8. Turnpike Surveys

In October 1997 the NJ Turnpike conducted a postcard travel survey as part of a larger traffic and revenue study. The primary objective of the survey was to collect data on the travel patterns and characteristics of motorists who used the NJ Turnpike. Motorists were handed the survey in the form of a prepaid postcard when they received their toll ticket upon entering a turnpike interchange. The survey consisted of two parts – a travel pattern and characteristics survey and an electronic toll collection (ETC) survey. The travel survey asked motorists about their trip origin, destination, purpose, and frequency; vehicle occupancy, type, and state of registration; exiting interchange; and whether or not they participated in the EZ-pass program. The ETC survey asked ten additional questions regarding traveler's current and potential use of the EZ-Pass program. Every fourth postcard contained an ETC survey.

A total of 409,411 motorists passed through the survey stations during the hours of survey operations. Of these, approximately 65 percent were given surveys. A total of 34,634 valid questionnaires were returned, representing 9.4 percent of all traffic during the study period. The information from the returned surveys was then coded into electronic format.

A separate survey was conducted on the PA Turnpike in the summer of 1999. All surveys were conducted on a non-Friday weekday. The survey had two components – a passenger car survey and a commercial truck survey. The passenger car survey was conducted by handing drivers mailback surveys just prior to exiting the turnpike. The survey contained questions regarding vehicle type, occupancy, and state of registration; trip origin, entering interchange, purpose, and frequency; time saved by using the PA Turnpike; and participation in other states' EZ-Pass programs (the PA Turnpike did not have an EZ-Pass program at this time). In addition to these questions, the surveys handed to motorists in urban areas also asked about motorists' willingness to shift travel times in order to receive a toll discount. There were 33,322 responses to the survey.

The commercial truck survey was slightly different because of the historically low return rate for mailback surveys of commercial trucks. Instead, a direct survey approach was used. However, drivers were given a mailback survey and allowed to proceed when long queues developed due to the direct survey. The truck survey performed 2,953 direct surveys and received 1,775 mailback surveys.

Both the NJ and PA Turnpike surveys provided important information for DVRPC's travel demand models. Both the Pennsylvania and New Jersey Turnpikes cross the region's cordon in two locations and trips on the turnpikes tend to serve longer distance trips than the other cordon stations. The information from these surveys was used to separate the turnpike cordons from the other cordon stations and develop different trip length frequency distributions for external-internal turnpike travel.

D. Travel Parameters for the DVRPC Enhanced Simulation Model

There are many parameters used in the modeling process. Some are discussed in the previous chapters, such as capacities in ***Table V-3*** (page 84). Several others are discussed below and in the following chapters

The percent of external and though highway trips was determined by the cordon line survey. The percentage of through trips by time period and the percentage of external trips by time period and facility type are shown below in Table VI-1. In total there are 336,000 through trips and 1,234,000 external-internal trips in the 2000 travel simulation. These figures are used for external trip generation.

Table VI-1 Percentage of Through and External-Internal Highway Trips by Time Period and Facility

Facility Type	Peak	Midday	Evening
Through Trips	38.1%	31.3%	30.6%
Expressway/Pkwy	38.5%	35.2%	26.3%
Arterial	40.6%	35.7%	23.7%
Collectors/Local/Ramps	42.1%	33.1%	24.8%
Turnpikes	37.7%	29.4%	32.9%
Total External-Internal	**39.6%**	**33.7%**	**26.7%**

Source: DVRPC July 2008

The percent of internal trips by trip purpose and time period is shown in ***Table VI-2*** and are used for internal trip generation. These figures are also shown below aggregated by time period and trip purpose respectively. Following these tables is the percent of daily internal truck and taxi trips by time period in ***Table VI-3***. This is also used for internal truck trip generation.

Table VI-2 Percent of Internal Peak, Midday, and Evening Travel by Trip Purpose

Time Period	HBW	HBNW	NHB	Total
Peak Period	55.0%	40.1%	30.2%	42.4%
Midday Period	17.8%	32.9%	55.4%	32.6%
Evening	27.2%	27.0%	14.4%	25.0%
Total	**25.3%**	**35.1%**	**39.6%**	**100%**

Source: DVRPC July 2008

Table VI-3 Percent of Internal Daily Truck and Taxi Traffic by Time Period

Time Period	Light Trucks	Heavy Trucks	Taxi
Peak Periods	36.5%	29.7%	36.5%
Midday Period	34.0%	41.8%	34.0%
Evening Period	29.5%	28.5%	29.5%

Source: DVRPC July 2008

The DVRPC model uses a combined AM and PM peak period in the standard travel simulation. However, different conditions typically exist for the two peak periods. ***Table VI-4*** contains the proportion of AM and PM peak period traffic by direction. For separate AM and PM peak period assignments, ***Table VI-5*** contains the percent of AM and PM trips by trip purpose. ***Table VI-6*** contains different auto occupancies in the different peak periods. These figures are used whenever travel simulations require separate assignments for the AM and PM peak periods.

Table VI-4 Proportion of AM and PM Peak Periods by Direction

Route Type	% of Traffic in AM Period	% of Traffic Inbound in AM Period	% of Traffic in PM Period	% of Traffic Inbound in PM Period
Fwy./Expwy./Parkway	15.1%	50.2%	23.4%	48.5%
Arterials	15.5%	47.9%	25.0%	52.0%
Collectors/Local/Ramps	15.0%	43.6%	27.1%	55.2%
Turnpikes	13.8%	52.0%	24.0%	48.5%
Total	**15.0%**	**48.9%**	**24.7%**	**50.8%**

Source: DVRPC July 2008

Table VI-5 Percent of Peak Period Trips by Trip Purpose

Trip Purpose	AM Peak	PM Peak	Total
Home-Based Work	42.5%	23.0%	29.3%
Home-Based Non-Work	35.1%	49.2%	44.7%
Non-Home Based	22.4%	27.7%	26.0%

Source: DVRPC July 2008

Table VI-6 Auto Occupancy by Time Period

Trip Purpose	PM Peak	AM Peak	Total Peak	Daily
Home-Based Work	1.17	1.14	1.16	1.20
Home-Based Non-Work	1.53	1.57	1.55	1.52
Non-Home Based	1.41	1.35	1.39	1.40
Total				**1.35**

Source: DVRPC July 2008

VII. TRIP GENERATION MODEL

This chapter discusses trip generation, the first model in the travel simulation process. Each aspect of trip generation will be discussed in detail including theory, data, procedures, and results. The generation of internal trips, both motorized and non-motorized, is covered, followed by a discussion of external trip generation. The disaggregation of trips into different time periods as well as model operation is covered next, followed by model results and validation.

This chapter has eight appendices. **Appendices VII-1 through VII-4** contain cordon station counts and other data for the generation of external trips. **Appendix VII-5** contains descriptions of the computer programs used for trip generation. Appendix **VII-6** contains descriptions of the data and formats used for the inputs to the trip generation model. **Appendices VII-7 and VII-8** contains summaries of the 2000 and 2005 trip generation results.

A. Introduction

Trip generation is the process of estimating the total number of trips for each TAZ, both those internal to the region and those external to the region. Trips are separated into various categories based on purpose and type. The 2000 model generates 17 different trip types.

1. Trip Purposes and Types

Trips are generated as either person trips or vehicle trips, depending on trip purpose. The person trip purposes are home-based work (HBW), home-based non-work (HBNW), non-home based (NHB), and external transit trips. The vehicle trip types are light truck, heavy truck, and taxi trips, as well as the four external-internal vehicle trip types. These are turnpike external-internal vehicle trips, freeway/ expressway external-internal vehicle trips, arterial external-internal vehicle trips, and local street external-internal vehicle trips.

Vehicle trips automatically use the highway system. Person trips, however, can be highway, transit, walk, or bicycle trips. Person trips are subdivided into motorized and non-motorized travel in the trip generation step. Motorized person trips are divided into transit person trips and auto person trips in the modal split step. Auto person trips are further divided into auto driver and auto passenger trips by applying auto occupancy factors after modal split. Non-motorized trips are divided into walk and bike trips in trip generation.

Person Trips	**Vehicle Trips**
1. Home-based work (HBW)	1. Light Truck
2. Home-based non-work (HBNW)	2. Heavy Truck
3. Non home-based (NHB)	3. Taxi
4. External Transit Trips	4. External-Internal Vehicle Trips
	(Turnpike, Fwy/Expwy, Arterial, Local)

Trips can be further categorized as internal or external. Internal trips have both ends of the trip (origin and destination) inside of the DVRPC region. But not all travel that occurs in the DVRPC region has both trip ends within the region. There are three types of trips with at least one trip end external to the region – external – internal, internal – external, and external – external. These trips constitute a significant proportion of travel within the DVRPC region. Trips with only one trip external to the region are modeled identically regardless of whether it is the trip beginning or end that is external to the region, and are henceforth both referred to as external-internal trips. External-external trips are commonly referred to as through trips.

Trip ends are estimated for each trip purpose. These trip ends take two forms depending on the trip purpose – productions and attractions or origins and destinations. Trip types such as home-based work are generated in production – attraction format where the home always produces the trip (even the afternoon trip home from work), and the place of work attracts the trip. Other types of trips, such as heavy truck trips, are produced in origin – destination format. The origin is the beginning of the trip and the destination is the end of the trip. Production and attraction trip ends will later be transformed into origins and destinations in the trip distribution stage. For external-internal trips all productions occur on the nine-county cordon line and all corresponding attractions are allocated to internal traffic zones. Trip generation procedures for both internal and external trips are discussed in subsequent sections.

2. DVRPC Trip Generation Model

The inputs to and outputs from the trip generation model are shown in ***Figure VII-1***. The household, truck, and taxi surveys are used to generate trip rates. Zonal socioeconomic data is estimated for each TAZ. This data is used in conjunction with the trip rates to generate internal trips. External trips are estimated based on the highway and transit cordon line survey data.

The trip generation model provides outputs of motorized and non-motorized trips. Separate trips are generated for walk and bicycle trips. For motorized trips, 11 different types of trips are generated. Three different types of non-motorized trips are generated for walk and bike each.

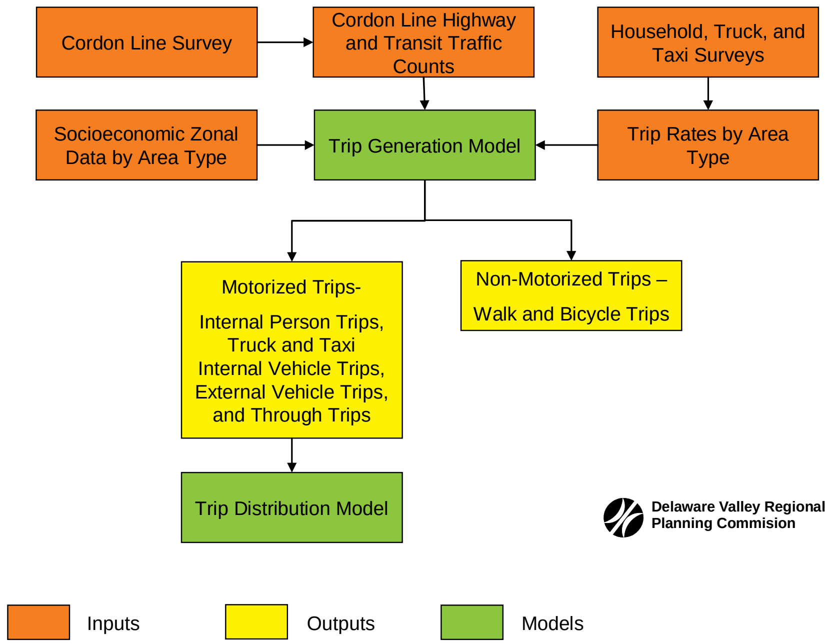


Figure VII-1 2000 DVRPC Trip Generation Model

The trip generation model used in the 2000 validation is largely taken from the 1990 and 1997 model. Eight significant enhancements were made, however:

- Methodologies to separate trip generation into three time periods - peak, midday, and evening, for use in separate travel simulation models for each time period
- Disaggregation of DVRPC external-internal trip generation estimates for turnpike, freeway, arterial, and local cordon stations
- Recalibration of internal-internal trip generation models using data from the 2000 Household Travel Survey
- Recalibration of external-internal trip generation rates based on the Cordon Line Highway Survey
- Recalibration of the light and heavy truck trip generation rates based on the Truck Survey
- Development and implementation of a group quarters trip generation model
- Generation of non-motorized travel
- Streamlined computer operating procedures

The trip generation model is implemented by a series of computer programs, TRIPGEN A-E. The end result of running the trip generation model is lists of trip productions, attractions, origins, and destinations by TAZ. The trips are listed by trip and vehicle type.

B. Internal Trip Generation

Internal trips are trips where both trip ends occur inside the DVRPC region. Internal trips include both motorized and non-motorized trips. They also include person as well as vehicle trips. The internal trip generation procedures were developed, for the most part, during earlier travel simulation studies. Although several alternative methods were evaluated during these studies, the process that was selected is referred to as disaggregate trip generation analysis. Internal trips are generated based on the value of socioeconomic variables for each TAZ (e.g. 2 car households). Trip rates are then established per dwelling unit of a specified type. The number of trips generated in each TAZ is calculated by multiplying the trip rates by the socioeconomic variables. This approach is taken rather than an aggregate approach where a single equation produces zonal aggregate data on the basis of the average characteristics of all dwelling units in the zone.

Although this method of generating trip ends is relatively common for contemporary transportation studies and is, perhaps, the best procedure developed thus far, it does have two minor limitations. First, the number of trip ends generated in a zone is independent of the quality of transportation service provided to the area (elasticity of demand). In effect, a land development pattern will generate a certain amount of travel regardless of the scale or quality of the transportation network.

Secondly, the procedure is relatively insensitive to unique generators such as sports complexes, educational institutions, and airports. This limitation is partially overcome in several ways. The inclusion of trip generation for group quarters generates trips for unique travel generators such as educational and other institutions. Additionally, an “external” cordon zone is created for the airport to represent the large number of trips generated at this location. Additional factors such as trip surcharges are used in more detailed corridor studies after Origin-Destination (O-D) travel surveys have measured the trip generation propensity and distribution of special generators.

1. Motorized Person Trips

Motorized person trip ends are estimated for the three trip categories of home-based work, home-based non-work, and non-home based. These trips include travel by all significant motorized modes – auto driver, auto passenger, and transit passenger. Auto here consists of passenger cars, SUVs, and pickup trucks used for non-commercial trips.

Trip productions and attractions are estimated for home-based work and home-based non-work, while origins and destinations are estimated for non-home based trips. Home based work trip productions are estimated on the basis of employed residents (workers at their place of residence); home-based work trip attractions are estimated on the basis of employment (workers at their place of employment). Home based non-work trip productions are computed on the basis of households by vehicle availability (0, 1, 2, 3+ vehicle households). Non-home based trip origins and destinations are estimated based on the number of households, basic employment, retail employment, and total other employment.

The socioeconomic data used in internal motorized person trip generation is shown in ***Table VII-1*** and ***Figure VII-2***. Land use information, or acres of land by category, is not required for the DVRPC trip generation model and is therefore absent from ***Table VII-1***. Socioeconomic data, however, reflects land use and is used as a proxy for land use information. Additionally, the trip generation rates may vary by area type, which does depend on land use. Income at the zonal level is also not required as an input for the trip generation model, although it is used as a regional parameter for the modal split model. The corresponding trip rates are applied to the socioeconomic variables for each trip category. The sum is then accumulated for each of the 1912 internal zones.

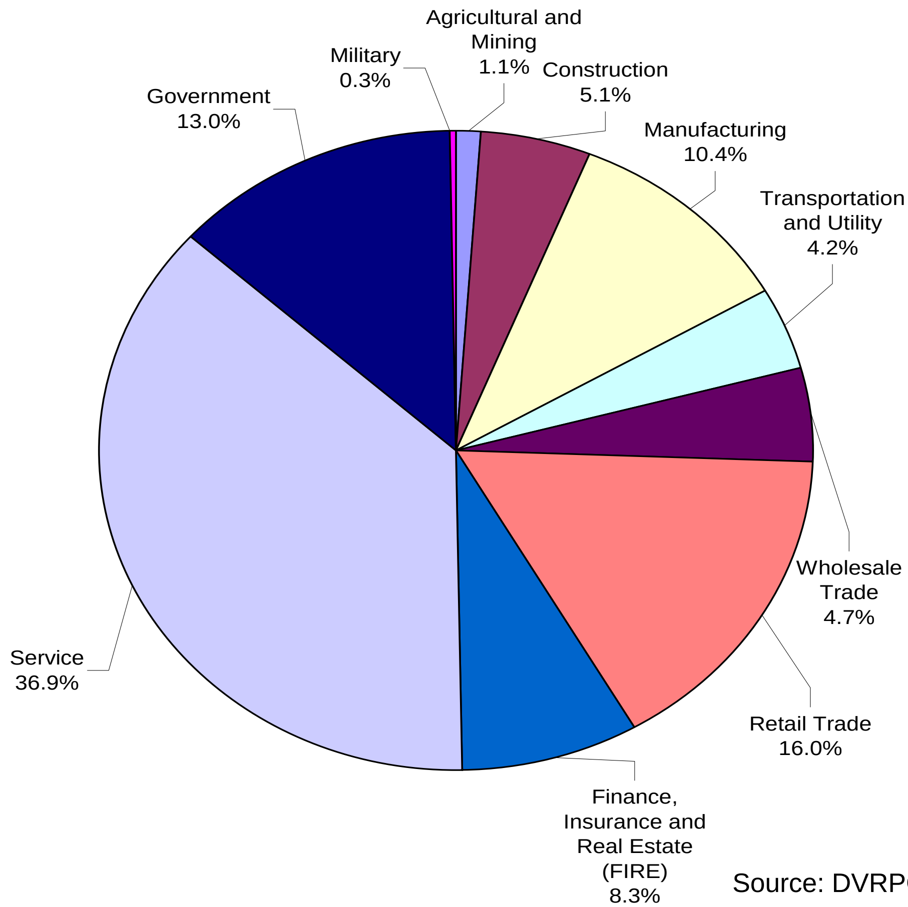
The data from the 2000 Household Travel Survey is used to develop trip rates. The data sample was sizeable, 10,391 individuals. This is much larger than the surveys used in the 1990 model validation. The surveys for the 1990 model validation were conducted in 1987 and 1988. The trip rates for the 2000 validation are more accurate than those for the 1990 survey because the survey was taken in the validation year and because of the larger sample size on which the trip rates were based.

Table VII-1 1990 to 2005 Socioeconomic Data for Trip Generation Analysis

Variable	1990 Regional Totals	2000 Regional Totals	2005 Regional Totals	% Change 1990-2000	% Change 2000-2005
Population	5,195,503	5,399,958	5,531,863	3.9%	2.4%
Group Quarters Population*	—	91,308	93,761	—	2.7%
Households	1,899,050	2,020,781	2,077,763	6.4%	2.8%
0-Vehicle Households	340,844	323,815	322,205	-5.0%	-0.5%
1-Vehicle Households	666,200	718,592	733,822	7.9%	2.1%
2-Vehicle Households	648,273	721,883	754,643	11.4%	4.5%
3-or-More-Vehicle Households	243,693	256,491	267,093	5.3%	4.1%
Employed Residents	2,503,012	2,505,646	2,566,229	0.1%	2.4%
Total Employment	**2,721,126**	**2,724,431**	**2,783,985**	**0.1%**	**2.2%**
Agricultural and Mining Employment	56,738	31,252	30,372	-44.9%	-2.8%
Construction Employment	141,191	131,081	143,290	-7.2%	9.3%
Manufacturing Employment	386,207	313,997	290,702	-18.7%	-7.4%
Transportation and Utility Employment	113,369	118,491	115,782	4.5%	-2.3%
Wholesale Employment	150,502	134,159	131,515	-10.9%	-2.0%
Retail Employment	428,578	436,758	444,889	1.9%	1.9%
Finance, Insurance and Real Estate (FIRE) Employment	218,406	213,304	229,829	-2.3%	7.7%
Service Employment	865,439	984,198	1,026,124	13.7%	4.3%
Government Employment	342,616	351,825	362,707	2.7%	3.1%
Military Employment	18,080	9,366	8,775	-48.2%	-6.3%

* Group quarters population was not included in the 1990 trip generation.

Source: DVRPC July 2008



Source: DVRPC July 2008

Figure VII-2 2005 Employment by Industrial Sector

2. Trip Generation Rates

The 2000 Household Travel Survey, as discussed in **Chapter VI.C**, was tabulated in activity-based travel format. This format is fundamentally different from the more conventional production/attraction format used in the DVRPC models. This difference centers on the definition of a trip. As the name suggests, activity-based tabulations of travel form trip chains associated with a specific activity. For instance, the work activity might include travel from home to a donut shop, travel from the donut shop to the place of work, and travel back home. This constitutes a single activity trip chain but three trips in production-attraction format – one home-based non-work; one non-home based; and one home-based work.

The 2000 Household Travel Survey collected a great deal of detailed information about trip makers and the characteristics of their travel. The survey detail made it possible for DVRPC staff to re-tabulate the survey into production/attraction format for use in estimating internal trip generation rates to validate the existing DVRPC model. Also, the detailed address information included in the survey allowed DVRPC staff to correct certain 1990 traffic zone digitization errors and re-tabulate the survey directly in terms of 2000 traffic zones.

Even after re-tabulation, the 2000 travel survey data may not have included all motorized and non-motorized trips made by all members of the participating households. This under-reporting of trips occurs in all travel surveys because of the difficulty of filling out the trip diaries and the difficulty in remembering and accounting for all trips made, particularly in cases when a specific diary is being completed by someone other than the trip maker. Improvements in home interview survey data collection methods have significantly reduced the level of trip under-reporting; however, an iterative trip rate estimation procedure is still needed to correct rates based on comparisons between assigned and counted travel estimates from highway screenline studies and public transit ridership checks, and from production/attraction balance requirements.

The estimation methodology for updating motorized trip production and trip attraction rates differs significantly. Trip production rates can be estimated directly from the home interview survey using cross-classifications of disaggregate data. The estimation of trip attraction rates from small sample surveys is much more difficult because of the absence of reliable estimates of attractions for specific geographical areas. Trip attraction rates are registered to various categories of employment which are highly specific geographically. While productions and attractions might be different at the local level, at the regional level the total trip attractions estimated by the trip generation model must equal trip productions. This provides a basis for factoring trip attraction rates to obtain a balance. Also, the detailed analysis of highway screenline volumes and transit ridership assignment errors may also provide a basis for adjusting some trip attraction rates.

Table VII-2 contains the final validated motorized internal person trip rates by trip purpose. Trip rates are separated by area type and by dependent variable. As noted above, the final trip generation rates were determined by adjustments to the surveyed trip rates that were required to achieve highway screenline and transit ridership model validation. In CBD and fringe areas, motorized trip production rates are significantly less than those associated with urban, suburban, and rural development patterns because of the prevalence of trips made by walking and other non-motorized travel modes.

Since neither end of a NHB trip is at the place of household residence, trip generation rates for this trip purpose are registered to variables that reflect the location of other residences, shopping, basic employment, and other categories of employment. The NHB trip rates for households, basic employment, retail employment, and other employment are given in ***Table VII-2***. The households variable here relates to NHB trips made to/from other households for social, recreation, business, and other types of personal activities.

Table VII-2 2000 Internal Motorized Person Trip Rates

		Trip Rates by Area Type					
Trip Category	**Variable**	**1**	**2**	**3**	**4**	**5**	**6**
Home-Based Work Person-Trip Productions	Employed Residents	0.850	0.910	1.390	1.670	1.690	1.710
Home-Based Work Person-Trip Attractions	Total Employment	1.360	1.300	1.320	1.550	1.550	1.550
Home-Based Non-Work Person Trip Productions	Households with 0 Vehicles	0.710	1.320	2.130	1.880	2.020	2.250
	Households with 1 Vehicles	1.430	2.330	3.990	4.190	4.470	4.660
	Households with 2 Vehicles	2.370	2.360	4.960	6.610	7.700	7.800
	Households with 3 or More Vehicles	3.660	3.780	6.390	7.030	7.960	8.120
Home-Based Non-Work Person-Trip Attractions	Households	0.662	0.772	0.882	1.544	1.544	1.654
	Basic Employment	0.221	0.276	0.386	0.772	0.772	0.772
	Retail Employment	2.206	2.541	4.175	9.066	11.60	12.72
	Other Employment	0.662	0.882	1.103	3.750	3.750	4.963
Non-Home-Based Person-Trip Origins or Destinations	Households	0.870	0.970	1.020	1.140	1.150	1.160
	Basic Employment	0.400	0.380	0.600	0.620	0.620	0.640
	Retail Employment	1.130	1.260	1.570	2.130	3.160	3.220
	Other Employment	0.140	0.230	0.550	0.710	0.940	0.970

Notes: For home-based non-work attractions, total employment excludes military employment; for home-based non-work attractions, basic employment includes agricultural, mining, construction, manufacturing and wholesale employment; for non-home-based trips, basic employment includes the same employment categories as for home-based non-work attractions, except for mining, which is included in other employment.

Source: DVRPC July 2008

The internal trip generation for 2005, like all internal trip generation, uses the 2000 trip rates with 2005 demographic data. This is done because trip rates do not change radically in a five year time period. Additionally, the 2000 Household Travel Survey was very complete, while performing an additional travel survey of similar quality would be prohibitively expensive. Also, the 2000 trip rates were validated and found to be reasonable.

3. Group Quarters Trip Generation

Trips for the three internal person trip purposes were also generated for the group quarters population for the first time in 2000. The group quarters population can be seen in ***Table VII-1*** (page 118). The group quarters population makes up about 3.3 percent of the total population, with the institutionalized and non-institutionalized portions each representing about half of the total group quarters population. There were 91,308 people living in non-institutionalized group quarters in 2000. The institutionalized portion of the group quarters population is assumed not to make daily trips.

It is assumed that the non-institutionalized group quarters population makes similar trips to those who live in housing units and have similar socioeconomic characteristics. Therefore the trip rates for the non-institutionalized population are assumed to be similar to those persons that have similar characteristics to the non-institutionalized population - students, the elderly, one-person households, and zero-car households. Specifically, the average trip rate per person living in a non-institutionalized setting is calculated from the 2000 Household Travel Survey as follows:

Population Group	Daily Person Trips
Students	3.36 trips per student
Persons 65 and over	2.89 trips per person
One-person households	3.39 trips per person
Zero-car households	3.18 trips per person
Group Quarters	**3.205 trips per person, per day**

Source: DVRPC July 2008

To be consistent with DVRPC trip generation procedures, the average trip rate per person in group quarters (3.205) is stratified into motorized and non-motorized travel by area type based on the 2000 DVRPC Household Travel Survey data. ***Table VII-3*** shows the 2000 motorized trip rates per person for non-institutionalized group quarters population. The trip rates in ***Table VII-3*** were developed to estimate the magnitude of motorized travel using the highway and transit systems.

Table VII-3 Non-Institutional Group Quarters Motorized Trip Rates by Area Type

	CBD	Fringe	Urban	Suburban	Rural	Open Rural
Home-Based Work Trips	0.18	0.18	0.20	0.20	0.24	0.24
Home-Based Non-Work Trips	0.48	0.82	0.95	1.33	1.45	1.45
Non-Home Based Trips	0.44	0.50	0.52	0.60	0.60	0.63

Source: DVRPC July 2008

Daily trips from the group-quarters population are estimated as origins and destinations, not as productions and attractions. These trip origins are then added to the trips generated by people living in housing units to estimate total travel in the region. The final average trip rate per person used to generate trips from group quarters population is about one percent higher than that obtained from the survey (3.24 vs. 3.205). The application of the group quarters population trip rates to 2000 socioeconomic variables has produced about 169,000 motorized trips. This is broken down into about 18,300 HBW, 100,400 HBNW, and 50,300 NHB trips. This represents about 0.9 percent of internal person trip production.

4. Total Internal Motorized Trips

A tabulation of internal-internal motorized trip ends, including those from the group quarters population, is shown below by trip purpose. Home-based non-work trips are the largest trip category, with more trip ends than both home-based work and non-home based combined. Each of the latter two categories has about the same number of trip ends, with non-home based trips beings slightly greater than home-based work trips. The number of productions and attractions for home-based work and home-based non-work trips are approximately equal. The difference for home-based work trips is less than one half of one percent, while the difference for home-based non-work trips is about 3.5 percent. The number of origins and destinations for non-home based work trips are by definition equal.

Trip Purpose	2000 Trip Ends
Home-Based Work Person-Trip Productions	4,209,197
Home-Based Work Person-Trip Attractions	4,188,794
Home-Based Non-Work Person-Trip Productions	10,802,846
Home-Based Non-Work Person-Trip Attractions	10,423,936
Non-Home-Based Person-Trip Origins	4,746,636
Non-Home-Based Person-Trip Destinations	4,746,636

Source: DVRPC July 2008

A map of total motorized person trips is shown in ***Figure VII-3***. This figure shows the sum of productions and attractions for HBW and HBNW trips plus the sum of the origins and destinations for NHB trips in each zone. The total number of trip ends in each zone includes trips ends from both the regular population and the non-institutionalized group quarters population.

5. Non-motorized Person Trips

DVRPC developed non-motorized trip rates as part of the 2000 model validation. This is the first time that DVRPC has modeled non-motorized trips, which include walk and bicycle trips. These rates are structured by trip purpose and area type using the same categories as internal person motorized travel.

A binary (motorized or non-motorized) logit mode choice model was developed for DVRPC by Cambridge Systematics in the late 1990s. This model determined the share of non-motorized trips for each TAZ as a function of vehicle availability, population density, area type, and pedestrian environment (see ***Cambridge Systematics' Report for DVRPC, Task 9,*** November 1996). In 2003 this detailed and data intensive model was substituted for a disaggregate approach, similar to DVRPC's motorized internal person trip generation models. Based on the 2000 Household Travel Survey, non-motorized travel rates were estimated by area type and trip purpose and then correlated with the same socioeconomic variables used to generate motorized travel.

Like motorized travel, the 2000 non-motorized trip rates are used to generate non-motorized trips by purpose and by area type. The average non-motorized trip rate per household used in the 2000 simulation is 0.68 trips per day. Non-motorized trip rates are much smaller than those estimated for motorized travel. About 7 percent of household trips are non-motorized (walk and bicycle).

Table VII-4 presents 2000 non-motorized trip rates for productions and attractions for HBW and NHBW purposes and for origins and destinations for NHB trips. As can be expected, the denser area types of CBD, CBD fringe, and urban have significantly higher trip generation rates than suburban, rural, and open rural area types. More noticeable is the fact that HBNW trip productions are higher for two and three car households than for zero car households. This is presumably because households with more vehicles have different socioeconomic characteristics (age, income, people per household, etc.) than households with fewer people. Hence, these households not only make more motorized trips, but more non-motorized trips as well.

Figure VII-3 2000 Mortorized Person-Trip Ends by TAZ

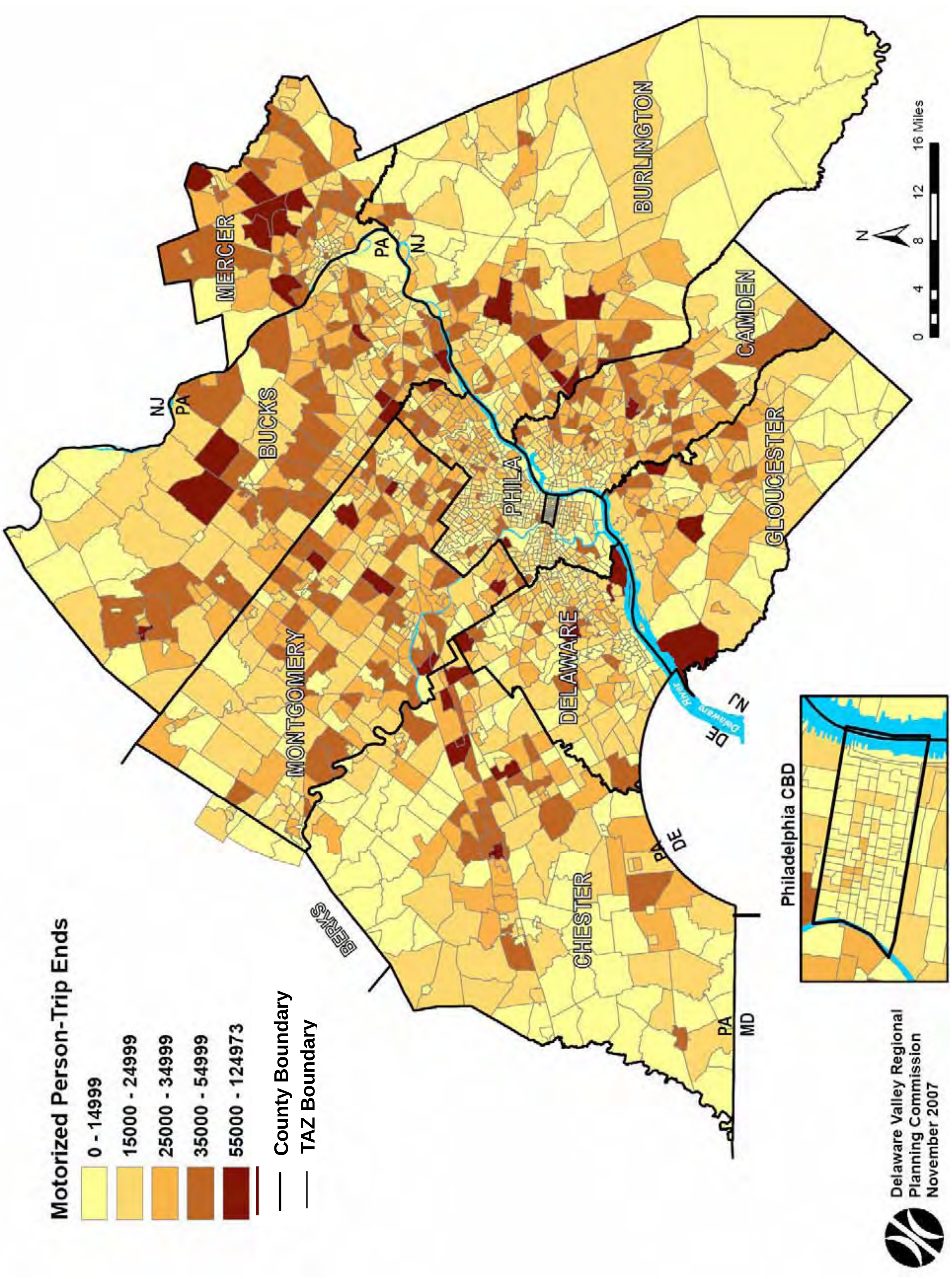


Table VII-5 presents a summary of 2000 and 2005 non-motorized travel by trip purpose. The change between 2000 and 2005 is due to changes in the underlying socioeconomic variables. The 2000 trip rates for non-motorized trip generation are also used for 2005 trip generation. The average increase for productions and origins was 1.3 percent and the average increase for attractions and destinations was 1.2 percent between 2000 and 2005. Home-based work and non-home based trip ends increased at rates slightly below the average, while home-based non-work trip rates increased at rates slightly above the average. Examining ***Table VII-5*** one can see that HBW trips comprise a relatively small percentage of non-motorized trips. This is noticeably different than motorized trips where the share of HBW motorized trips is substantial.

Figure VII-4 shows non-motorized trip ends by TAZ for 2000. Similar to ***Figure VII-3,*** this figure displays the sum of non-motorized person trip ends for HBW and HBNW productions and attractions plus NHB origins and destinations. The non-motorized trip ends tend to be located in the dense urban areas, such as Philadelphia and Trenton, and the older suburbs and boroughs

After non-motorized trips are generated, they are split into walk and bicycle trips by area type. Walk trips are by far the largest part comprising about 91 percent of all non-motorized trips. The percentage of walk trips for each area type for attractions and productions is presented in the ***Table VII-6***. The proportion of bicycling trips is highest in the CBD, is lower in the Fringe, Urban, and Suburban area types, and is higher again in the rural area types. For example, the CBD and Urban area types have about 35,000 bicycle attractions, even though the Urban area type has more than twice as many attractions as the CBD (540,601 vs. 209,913).

Non-motorized trips comprise a relatively small portion of overall trips. Motorized travel constitutes about 93 percent of weekday travel internal to the region. More than 97 percent of HBW travel is motorized. HBNW and NHB travel is about 92 percent motorized. Although relatively small in percentage terms, about 1.5 million daily trips are made by non-motorized means. Walk trips comprise almost 1.4 million trips in the region, while bicycle trips comprise about 140,000 trips. This total number of non-motorized trips is comparable to total transit trips in the region, although transit carries predominately work travel which is significantly longer in length and tends to occur during peak travel hours.

Figure VII-4 Non-mortorized Trip Ends by TAZ

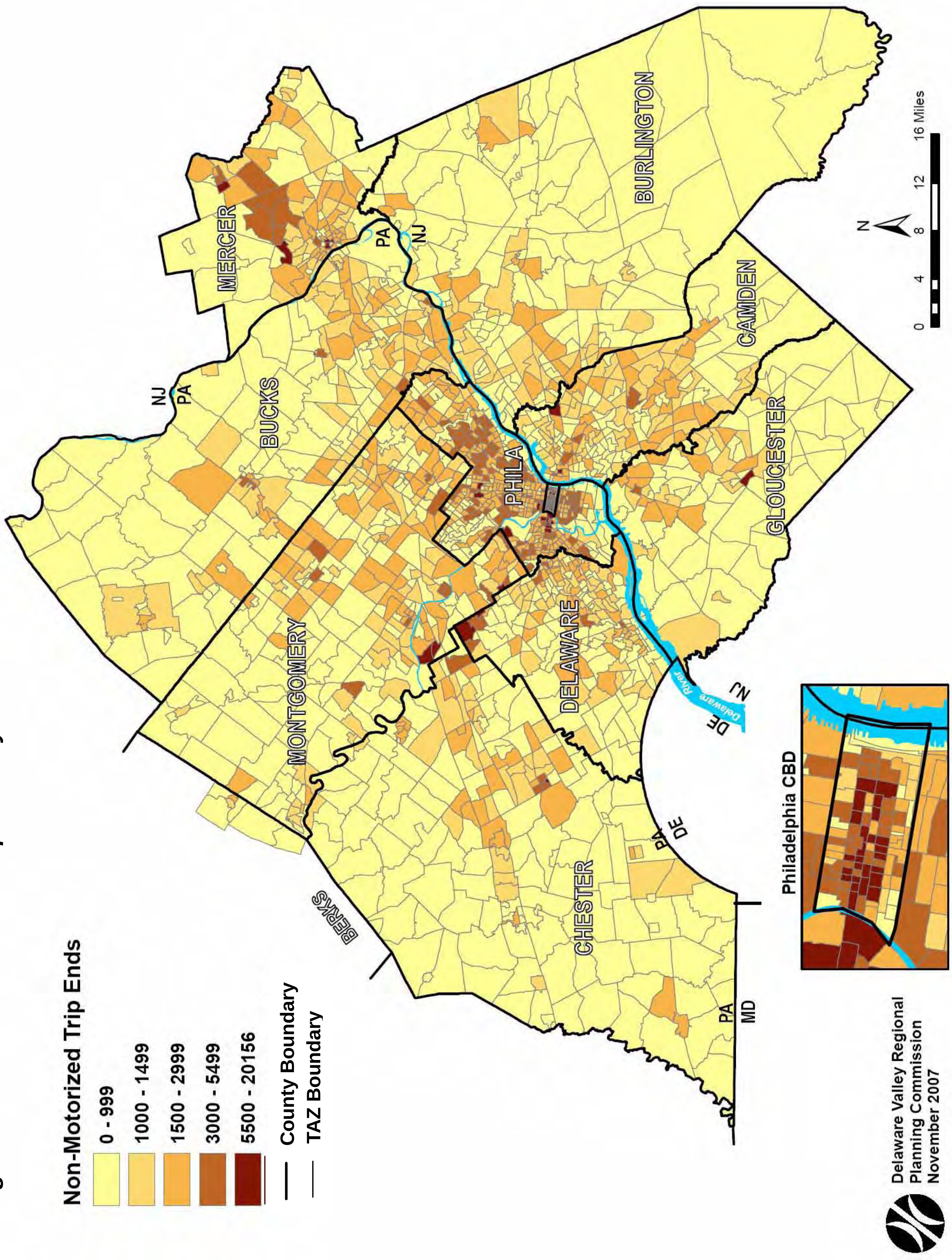


Table VII-4 Non-motorized Internal-Internal Trip Generation Rates by Trip Type and Area Type

Trip Category	Variable	Trip Rates by Area Type: CBD	Fringe	Urban	Suburban	Rural	Open Rural
Home-Based Work Person-Trip Productions	Employed Residents	0.480	0.430	0.090	0.030	0.010	0.010
	Group Quarters Population	0.180	0.180	0.160	0.140	0.120	0.120
Home-Based Work Person-Trip Attractions	Total Employment	0.120	0.120	0.040	0.030	0.010	0.010
Home-Based Non-Work Person Trip Productions	Households with 0 Vehicles	2.290	1.710	0.910	0.630	0.620	0.250
	Households with 1 Vehicles	2.620	1.690	0.560	0.280	0.120	0.100
	Households with 2 Vehicles	2.710	2.150	0.610	0.340	0.200	0.130
	Households with 3 or More Vehicles	2.900	2.900	0.510	0.260	0.140	0.030
	Group Quarters Population	1.950	1.250	1.040	0.860	0.620	0.620
Home-Based Non-Work Person-Trip Attractions	Households	1.040	0.910	0.330	0.160	0.070	0.040
	Basic Employment	0.060	0.120	0.100	0.050	0.020	0.040
	Retail Employment	0.580	0.810	0.770	0.330	0.16	0.08
	Other Employment	0.320	0.220	0.220	0.070	0.060	0.020
Non-Home-Based Person-Trip Origins or Destinations	Households	0.510	0.110	0.110	0.070	0.060	0.050
	Basic Employment	0.520	0.500	0.060	0.030	0.010	0.010
	Retail Employment	0.850	0.800	0.240	0.080	0.030	0.010
	Other Employment	0.120	0.080	0.070	0.030	0.010	0.010
	Group Quarters Population	0.380	0.240	0.220	0.200	0.180	0.180

Notes: For home-based non-work attractions, basic employment includes agricultural, mining, construction, manufacturing and wholesale employment; for non-home-based trips, basic employment includes the same employment categories as for home-based non-work attractions, except for mining, which is included in other employment.

Source: DVRPC July, 2008

Table VII-5 2000 and 2005 Non-motorized Trip Productions and Attractions

Trip Category	2000	2005	Change Number	Change Percent
Person Trips*				
Home-Based Work Person-Trip Productions	128,786	129,741	955	0.7%
Home-Based Work Person-Trip Attractions	127,009	128,456	1,447	1.1%
Home-Based Non-Work Person Trip Productions	981,426	996,114	14,688	1.5%
Home-Based Non-Work Person-Trip Attractions	981,196	993,541	12,345	1.3%
Non-Home-Based Person-Trip Origins or Destinations	381,551	385,508	3,957	1.0%
Total Person-Trip Productions	**1,491,763**	**1,511,363**	**19,600**	**1.3%**
Total Person-Trip Attractions	**1,489,756**	**1,507,505**	**17,749**	**1.2%**

* Includes group quarters non-motorized trips

Source: DVRPC July 2008

Table VII-6 2000 Non-Motorized Sub-mode Split by Area Type

	Area Type					
Non-Motorized Trips	**CBD**	**Fringe**	**Urban**	**Suburban**	**Rural**	**Open Rural**
Productions						
Percentage Walk Trips	85.7%	94.5%	94.3%	90.5%	88.6%	85.7%
Walk Trips	125,994	38,287	605,469	517,827	74,485	5,066
Percentage Bike Trips	14.3%	5.5%	5.7%	9.5%	11.4%	14.3%
Bike Trips	21,023	2,228	36,598	54,357	9,584	845
Attractions						
Percentage Walk Trips	85.2%	94.2%	93.9%	90.0%	88.0%	85.1%
Walk Trips	209,913	38,453	540,601	499,334	59,480	3,772
Percentage Bike Trips	14.8%	5.8%	6.1%	10.0%	12.0%	14.9%
Bike Trips	36,464	2,368	35,119	55,482	8,111	660

Source: DVRPC July 2008

Group quarters trips are also separated into motorized and non-motorized trips. The average trip rate per person in group quarters population (3.205) is stratified into motorized and non-motorized travel by area type. ***Table VII-4*** also contains non-motorized group quarters population trip rates.

As can be seen from ***Table VII-5***, non-motorized trips from 2000 to 2005 increased at about 1.3 percent. This is less than the rate of increase of population (2.4 percent) or employment (2.2 percent). This incongruity has two sources. The population and employment increases were not uniform throughout the region. Most of the growth occurred in lower density areas where non-motorized trip rates are low, while there was actually negative growth in Philadelphia and other high density areas which have high rates of non-motorized travel. Additionally, the non-motorized share of travel has been steadily decreasing over the last 30 years due to factors such as increasing auto ownership and income.

Non-motorized travel is not incorporated into the trip distribution, mode split, and traffic assignment models. That is, estimates are made of non-motorized trip ends in the trip generation stage, but not modeled further. However, consideration of non-motorized trips is essential for walk and bicycle planning and for highway design data in areas where large volumes of pedestrian and bicycle travel should be accommodated.

In theory, the DVRPC Cambridge Systematics non-motorized travel model discussed above had the capability to divert travel from motorized to non-motorized modes in response to land use design factors such as street connectivity, provision of sidewalks, building setbacks, etc. In practice, this model was difficult to apply with traffic zone data because changes in land use variables occur at the parcel level in response to detailed development proposals, not for an entire traffic zone. DVRPC intends to review the existing motorized and non-motorized travel models and may develop new models that will produce traffic volumes in a predictive and policy sensitive manner from the total generated trips.

6. Truck Vehicle Trips

Commercial trucks are divided in the DVRPC simulation models into two categories - light trucks and heavy trucks. This classification is consistent with the FHWA vehicle classification system. Commercial pickup, panel, and single unit (two axle long) trucks are classified as light trucks while large single unit (six or more tires), dump, flatbed, tractor-trailer, and double-trailer trucks are classified as heavy trucks.

Internal-internal truck trips are generated by the DVRPC model based on the number of households, manufacturing jobs, retail employment jobs, and other types of employment. Truck trip rates per household or per job are estimated and then multiplied by the number of zonal households or jobs to obtain the number of truck trip origins or destinations. These rates are shown in ***Table VII-7***.

In order to update the 1990 truck trip rates, the truck survey discussed in **Chapter VI.C** was conducted in 2001. In addition to the DVRPC survey, DVRPC reviewed a truck survey prepared in 1999 by Jack Faucett Associates for the Greater Buffalo Regional Transportation Council to compare results. The Buffalo survey was also small but larger than DVRPC's (322 trucks vs. 155 trucks). The numbers of trips per truck per type generated by the rates in ***Table VII-7*** were compared to the number of trips per truck from the two surveys in order to validate the trip generation rates. The two surveys have produced trip rates for parcel and non-parcel trucks as shown below:

	Average Daily Trip Rate Per Truck	
Truck Type	**Buffalo Survey**	**DVRPC Survey**
Trip Rate for All Trucks	19.7 trips	18.2 trips
Trip Rate for Non-Parcel Trucks	10.4 trips	8.7 trips
Trip Rate for Parcel Trucks	109.6 trips	133.0 trips

Source: DVRPC July 2008

As can be seen from this tabulation, the results of the two surveys are similar. There is a large variation in trip rates between parcel and non-parcel trucks (8.7 - 133.0). If the DVRPC survey is corrected for sampling bias due to parcel trucks and missing samples, the average daily trip rate per truck will be 13.1 and 8.2 for light and heavy trucks, respectively.

A review of the current truck registration files of Pennsylvania and New Jersey indicates that there are approximately 160,000 and 51,000 light and heavy trucks, respectively, registered in DVRPC’s nine counties. Using the truck rates from the DVRPC survey, these trucks make about 2,514,000 trips per day, 2,096,000 by light trucks and 418,000 by heavy trucks. It should be noted that there are many heavy trucks operating in the region that are not registered in Pennsylvania or New Jersey. In order to obtain another independent estimate of truck trips, the DVRPC vehicle classification traffic counts were reviewed to determine the percent of light and heavy truck total traffic volumes. The DVRPC counts show that 13.2 and 7.5 percent of total traffic are light and heavy trucks, respectively.

Table VII-7 Trip Rates for Generating Truck and Taxi Trip Origins and Destinations

Variable	Trip Rates by Area Type*					
	CBD	Fringe	Urban	Suburban	Rural	Open Rural
Trip Rates for Light Trucks						
Per Household	0.10	0.17	0.29	0.43	0.51	0.59
Per Retail Employment Job	0.30	0.44	0.29	1.04	1.15	1.15
Per Other Employment Job	0.16	0.17	0.32	0.38	0.48	0.60
Trip Rates for Heavy Trucks						
Per Household	0.07	0.07	0.08	0.10	0.12	0.13
Per Manufacturing/Wholesale Job	0.08	0.10	0.13	0.14	0.15	0.16
Per Retail Employment Job	0.12	0.16	0.35	0.36	0.52	0.56
Per Other Employment Job	0.06	0.12	0.21	0.27	0.36	0.36
Trip Rates for Taxis						
Per Household	0.20	0.10	0.01	0.01	0.01	0.01
Per Transportation Job	0.50	0.14	0.04	0.02	0.01	0.01
Per Other Job	0.18	0.14	0.03	0.01	0.01	0.01

* Rounded to two decimals

Source: DVRPC July 2008

These two truck trip estimates are used as guidelines for modifying 1990 truck trip rates to generate truck trips for 2000 (origins and destinations). The following is a tabulation of 2000 light and heavy truck trips from three different estimation methods. The current rates are slightly higher than the 1990 rate for heavy trucks but they are much higher than the 1990 rate for light trucks. Using the 2000 rates to estimate light and heavy trucks will produce about 2.8 million truck trips per day in 2000.

Basis for Estimation	Light Trucks	Heavy Trucks	Total
Trip rate per registered truck	2,096,000	418,000	2,514,000
Percent of trucks of total traffic volumes	1,936,000	1,144,000	3,080,000
2000 DVRPC truck trip rate per household, etc.	1,959,900	840,400	2,800,300

Source: DVRPC July 2008

It is clear from this tabulation that the estimation of heavy truck trips on the basis of trip rate per registered truck produces a low figure, and the truck traffic counts produce higher estimates than the 2000 trip rates for heavy trucks. In general, the three methods produce similar estimates for light trucks. The final 2000 estimate of truck trips is 1,959,856 for light trucks and 840,356 for heavy trucks. This is almost equal to the originally estimated number of trips in the tabulation shown above.

The 2000 light and heavy truck trip rates seem reasonable and produce light and heavy truck trips consistent with the average of two independent estimates based on traffic counts and truck survey results. Commercial truck trips are a significant portion of highway traffic volumes and represent about 20.0 percent of total vehicle trips. ***Figure VII-5*** shows total truck trip ends by TAZ for 2000. This is the sum of origins and destinations for both heavy and light trucks.

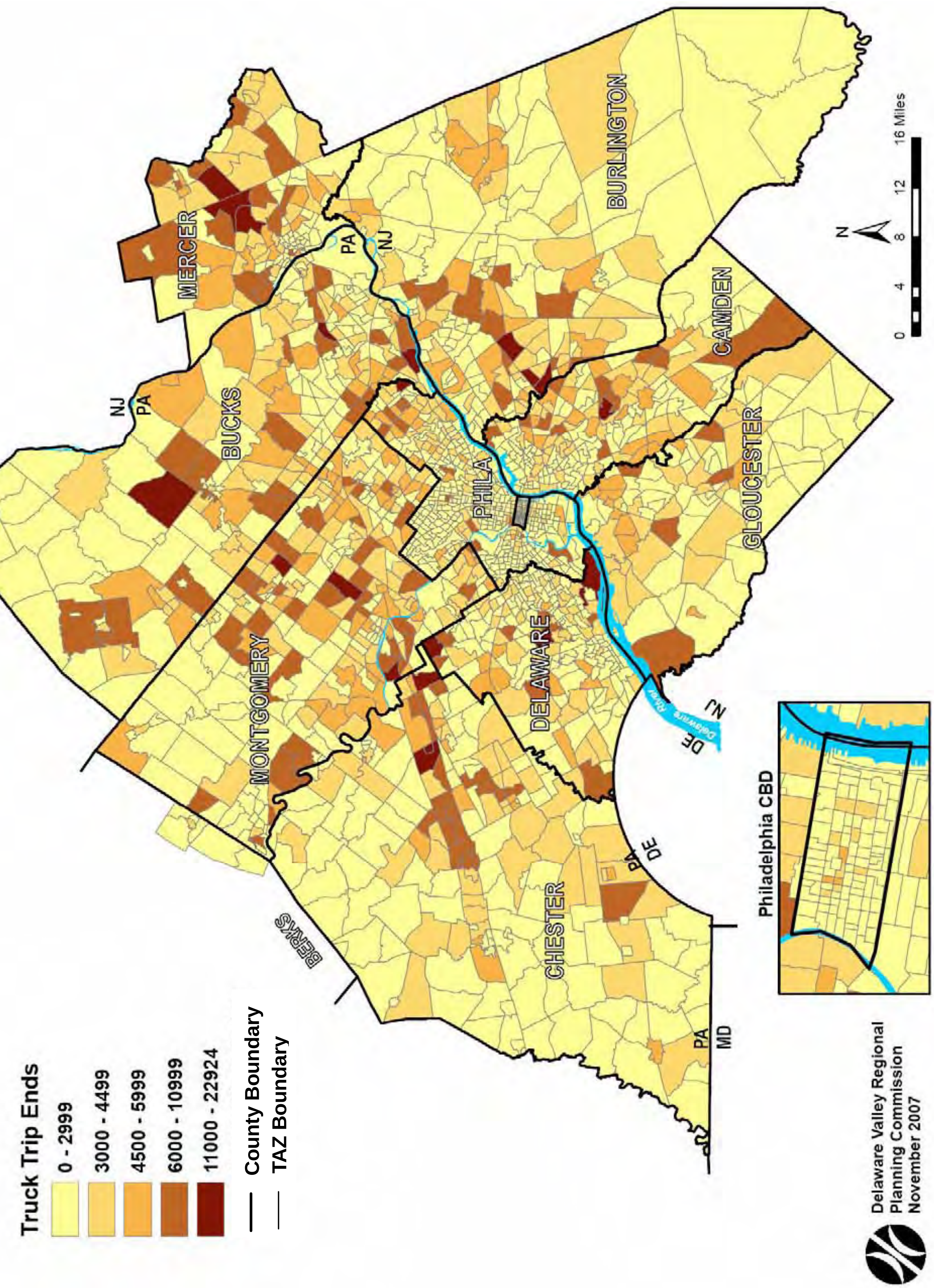
The 2005 model validation uses the 2000 light and heavy truck trip rates together with 2005 demographic data. This produces 2,021,665 light truck trips and 869,434 heavy truck trips for 2005. This is about 2.4 percent higher than the 2000 truck trips.

7. Taxi Vehicle Trips

Although insignificant at the regional travel scale, taxi service plays an important role in dense urban areas where parking facilities are limited. Also, it accommodates out-of-town visitors and tourists, residents who cannot drive, and those who do not have access to an automobile when they need one. Taxi trips are significant in Center City Philadelphia, at Philadelphia International Airport, at the University of Pennsylvania, and at many other colleges and hospitals in urban areas. They are also important at intermodal transportation terminals and major railroad and bus stations in the region. Taxi trips are therefore modeled for these reasons.

Taxi trip rates are generated based on the socioeconomic variables of households, transportation jobs, and other jobs. The trip generation rates for each of these three socioeconomic variables vary depending on area type. Taxi trip ends are generated in origin/destination format instead of production/attraction format. Taxi trip rates were developed in the past based on old taxi surveys and used for the 1990 travel simulations. For the 2000 travel simulation, no taxi survey by DVRPC was conducted. Instead, the 2000 rates were derived by updating the 1990 rates. The updated 2000 taxi trip generation rates can be seen in ***Table VII-7***.

Figure VII-5 2000 Truck Ends by TAZ



In order to derive the 2000 rates, the 1990 trip rates were reviewed and adjusted based on recent data from other regions, such as Pittsburgh and Atlanta. Specifically, the total number of trips generated using 1990 rates and 2000 socioeconomic figures was calculated. This number was then compared to the total number of trips generated by considering the number of taxis in the region times appropriate per taxi trip rates. The details of this comparison follow.

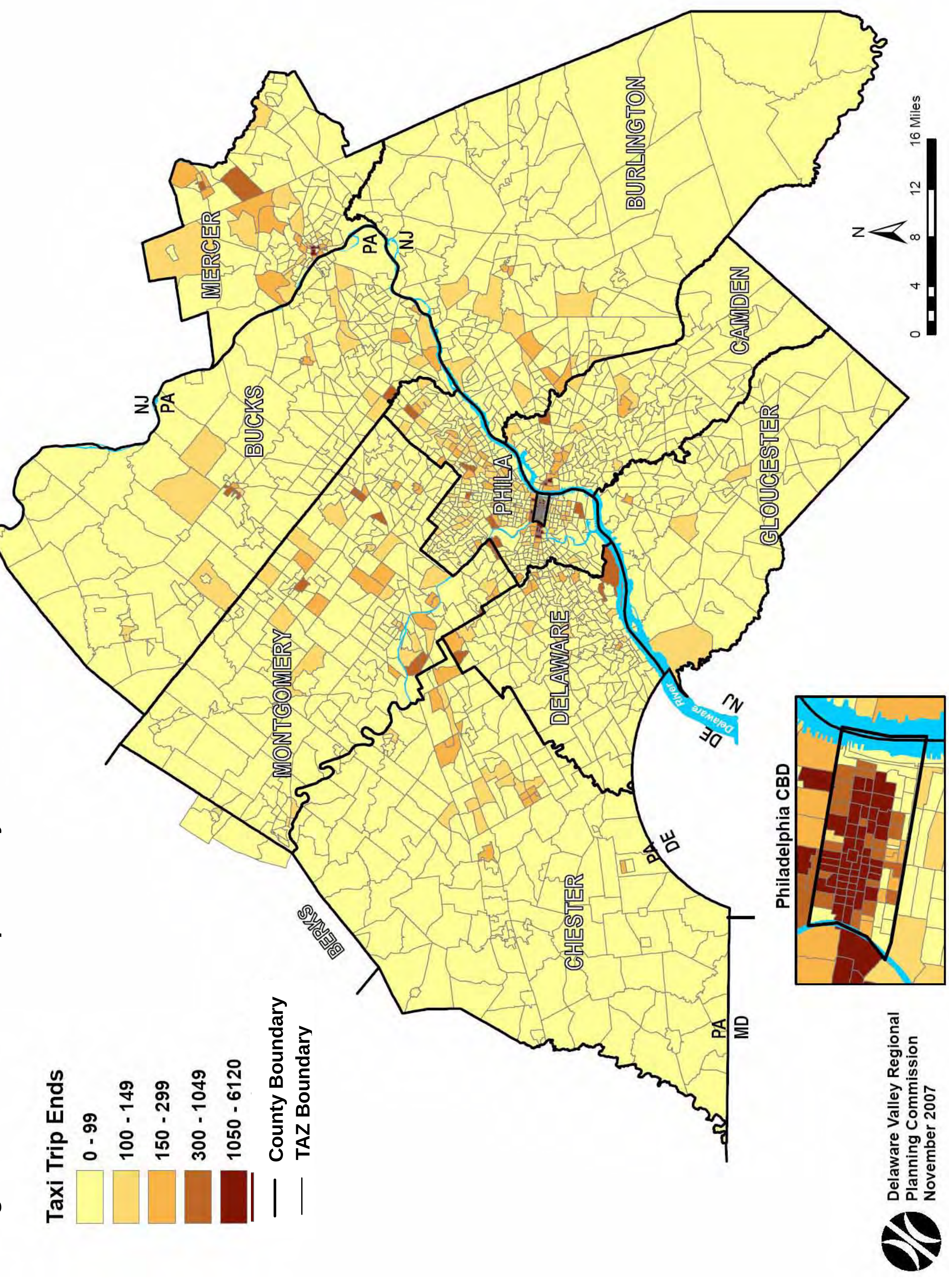
In 2000 the Allegheny Institute for Public Policy conducted a telephone taxi survey for 10 cities, including Philadelphia, (**see *An Analysis of the Demand for Taxicabs in the Pittsburgh Area*,** by Frank Gamrat, March 2001). According to this survey, the average number of daily trips per taxicab in Philadelphia was 54 and the average trip length was 4.0 miles. The data from the Pittsburgh survey indicate that daily taxi trips vary significantly from one city to another (from 36 in Pittsburgh, Seattle, and Atlanta to 72 in Cincinnati and Indianapolis).

Currently, there are 2,522 taxicabs operating within the DVRPC region, 1,600 in the city of Philadelphia, 531 in the four Pennsylvania suburban counties, and 391 in the four New Jersey counties. Assuming the average number of trips per taxi is 54 in Philadelphia and 36 in the suburbs, the total number of daily taxi trips in the region would be about 120,000. This regional number was used to adjust the 1990 taxi trip rates and prepare the updated 2000 rates.

The application of these trip rates to 2000 zonal households and employment data produced a regional total of about 128,145 taxi trip origins per day. A map of taxi trip ends can be seen in ***Figure VII-6***. This is a reasonable estimate compared with the estimate from observed data mentioned above. The difference between the simulated and observed data is only 5.8 percent. The distribution of the simulated taxi trips shows that about 50 percent of the regional taxi trips occur in the Philadelphia Central Business District and less than 5 percent in the rural areas of the DVRPC region.

The 2005 validation uses 2000 taxi trip rates along with 2005 demographic data to generate taxi trips. This was done because taxi trip rates are not thought to change significantly in the short five year period between 2000 and 2005 (128,145 vs. 128,808 taxi trips per day in 2000 and 2005, respectively).

Figure VII-6 2000 Taxi Trip Ends by TAZ



C. External Trip Generation

External trip ends and internal trip ends are significantly different. Internal trip ends inside the region are estimated based on trip rates tied to socioeconomic variables. External trip ends at the cordon stations, however, are determined directly by counts and surveys. There are two types of external trips – external highway trips and external transit trips. External highway trips are modeled solely as vehicle trips, not person trips. Transit trips are modeled as person trips.

1. External-Internal Auto and Truck Vehicle Trips

DVRPC defined 155 highway cordon stations as part of the 2000 travel simulation. The 155 cordon stations are sufficient to intercept about 98 percent of the total traffic crossing the regional cordon line. The cordon stations are divided into four groups based on facility type for the purposes of trip generation and distribution:

- Turnpikes
- Freeways and expressways
- Arterials and parkways
- Local roads

The generation of external vehicle trips at the cordons was determined from three sources – the 2001 External Cordon Survey, the 2000 cordon station counts, and the turnpike surveys.

External trip estimation for turnpikes came from the turnpike surveys discussed in **Chapter VI.C**. For the other facilities, traffic counts were taken at each of the cordon stations using pneumatic tube technology. These counts were then converted to daily traffic counts (AADT) by the use of annualization factors from PENNDOT, NJDOT, and DVRPC. The complete set of highway cordon station vehicle counts for 2000 and 2005 can be found in **Appendix VII-1**. The state and regional summary is shown below.

Location	2000 Cordon Station Counts	2005 Cordon Station Counts	% Diff.
Pennsylvania	636,547	695,133	9.2%
New Jersey	917,870	931,567	1.5%
Region	**1,554,417**	**1,626,700**	**4.7%**

Source: DVRPC July 2008

The daily counts for the cordon stations are disaggregated using data from the cordon line survey. The DVRPC cordon line survey provided information on vehicle destination, vehicle trip length distribution, occupancy, and vehicle type for freeways, arterials, and local roads. Daily counts were disaggregated by time period, vehicle type, and trip ends location. The traffic volume at each cordon station was divided into passenger vehicles, commercial light trucks, and commercial heavy trucks. For each vehicle type, the traffic counts were separated into peak, midday, and evening time periods based on the figures for each particular cordon station. For each time period/vehicle type combination, the volumes were disaggregated into through and external-internal trips by factors specific to each cordon station.

The external-internal trips by vehicle type for each cordon station were reviewed for consistency and accuracy. The tables of trip ends by vehicle type and cordon station are passed in the simulation process to the various trip distribution models, depending on the facility type. All the trip ends at cordon stations for external-internal auto trips are considered productions. All the trip ends inside the region for external-internal trips are attractions. The principal advantage of this methodology is that all external-internal auto driver productions are linked with internal attractions. This method ensures that no external-internal productions are inadvertently attracted to the same or other external stations when running the trip distribution model and hence becoming a de facto through trip. This methodology was not possible for truck trips since they are in origin/destination format. Half of external truck trip ends are added to the truck origins and half to the truck destinations for both light and heavy trucks. A summary of the external – internal trip generation is shown below:

		2000 External - Internal Trips		
Location	**Total**	**Pass. Vehicle**	**Light Truck**	**Heavy Truck**
Pennsylvania	573,605	448,205	84,165	41,235
New Jersey	649,684	500,612	98,481	50,591
Region	**1,223,289**	**948,817**	**182,646**	**91,826**

Source: DVRPC July 2008

2. Highway Through Trips

Through trip origins and destinations are determined by splitting out the through trips from the total cordon station counts using the cordon survey data. The through trips are further divided into passenger vehicle, commercial light truck, and commercial heavy truck trips, similar to external-internal trips. A summary of the data is shown below. The full list of through cordon station trips by vehicle type is shown in **Appendix VII-2.**

		2000 Through Trips		
Location	**Total**	**Pass. Vehicle**	**Light Truck**	**Heavy**
Pennsylvania	62,942	47,562	4,256	11,125
New Jersey	268,185	206,309	17,701	44,176
Region	**331,128**	**253,871**	**21,956**	**55,301**

Source: DVRPC July 2008

The final products of external trip generation for each cordon station are:

- Through trip origin and destination (total, light trucks, heavy trucks)
- External-internal trip end generation by facility type (total, passenger vehicles, light trucks, heavy trucks)

Table VII-8 summarizes external travel by vehicle type and trip end location. Passenger vehicles comprise the largest portion of external trips (77.4 percent). There are about four times as many external-internal trips as external-external trips (1.2 million vs. 0.3 million).

Table VII-8 2000 External Trip Generation by Vehicle Type and Trip Type

Category	**Vehicles per day**	**Percent of Total**
Total volume of external travel	1,554,417	100%
External Passenger vehicles	1,202,688	77.4%
External Light trucks	204,602	13.2%
External Heavy trucks	147,127	9.4%
External-internal trips	1,223,289	78.6%
Through Trips	331,128	21.4%

Source: DVRPC July 2008

3. Philadelphia International Airport Cordon Station

The Philadelphia International Airport (PHL), although not on the cordon boundary, provides a portal for a large amount of daily external-internal person trips by both highway and transit. External zone number 2068 was assigned to PHL in order to model the effect of this facility on regional travel patterns. The PHL cordon station does not capture all trips to the airport, only trips made by people flying into or out of PHL. Other trips, such as work trips, are modeled as internal-internal trips. For highway trips, the PHL cordon represents vehicle trip ends utilizing the I-95 interchange ramp complex to the airport. For transit trips, the PHL cordon station represents travel to the airport using the SEPTA R1 regional rail line. Three SEPTA bus lines, routes 37, 108, and 305, also serve PHL. These lines, however, predominately carry internal-internal airport employee trips. The volume of external transit trips that is carried to the airport on the three bus lines is very small. For this reason they are not used to carry external cordon station transit passenger trips from the PHL cordon station in the model.

4. External-Internal Transit Person Trips

There are a number of transit facilities on the regional border that generate both external-internal and through transit trips. While the transit cordon station volumes are not as large as the external highway trips, the transit trips are still important and hence included in the regional simulation model. A summary of transit cordon line volumes is shown below. The complete listing is shown in **Appendix VII-3**.

	Transit Cordon Line Trips	
Category	**2000**	**2005**
Pennsylvania	20,992	22,563
New Jersey	57,712	64,073
Regional Total	**78,704**	**86,636**

Source: DVRPC July 2008

D. Disaggregation of Trips by Time Period

As mentioned earlier, DVRPC increased the number of time periods from two (peak and off-peak) to three (peak, midday, and evening) for the 2000 simulation. The internal and external trips generated as discussed above need to be disaggregated by time period. The disaggregation is done by a set of time factors.

1. Person Trips

The temporal distribution of trip making recorded in the 2000 DVRPC Household Travel Survey provides the basis for disaggregating average week day person trips. This disaggregation is accomplished by estimating the percentage of travel that occurs in the peak, midday, and evening time periods. Peak is defined as trips that end (reach their destination) between 7:00 AM and 9:00 AM or 3:00 PM and 6:00 PM Midday trips end between 9:00 AM and 3:00 PM; evening trips end between 6:00 PM and 7:00 AM Person travel temporal factors from the 2000 home interview survey are given *in **Table VII-9.***

Table VII-9 Temporal Factors to Disaggregate Daily Person Trip Generation

	Trip Purpose			
Time Period	**HBW**	**HBNW**	**NHB**	**Average**
Peak	55.0%	40.1%	30.2%	41.8%
Midday	17.8%	32.9%	55.4%	35.4%
Evening	27.2%	27.0%	14.4%	22.9%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Source: DVRPC July 2008

Generally, these factors are similar to the temporal factors used in the 1997 model validation. The 2000 travel factors for HBW show approximately a two percentage point increase in peak and midday travel at the expense of evening trip making. For HBNW travel, there was a more substantial, about eight percentage points, shift from evening to peak travel. And for NHB travel there was a four percentage point shift from midday to peak travel. On average there was a four percentage point shift in the temporal distribution of travel from evening to peak. This increase in the percent of peak period travel probably does not indicate a change in traveler behavior. Rather, the 1990 model estimates were partially based on data collected outside of the DVRPC region, while the 2000 Household Travel Survey was adequate to estimate these percentages without recourse to outside data. The 2005 simulation uses the same factors as the 2000 simulation for disaggregating travel by time period.

2. Truck and Taxi Travel

Data on the temporal distribution of truck travel was not available from the 2000 Household Travel Survey, although limited taxi trip data was included. Limited temporal information was available from the 2000 Truck Survey collected by DVRPC. Secondary source temporal data on truck movements including the FHWA

Quick Response Freight Manual was also consulted. The resulting temporal distribution of truck and taxi trips is given in ***Table VII-10***. In these tabulations, separate factors are given for light truck (four-tire) and heavy truck (average of 6 tire and combinations).

Table VII-10 Temporal Factors to Disaggregate Daily Vehicle Trip Generation

	Vehicle Type		
Time Period	**Light Truck**	**Heavy Truck**	**Taxi**
Peak	36.5%	29.7%	36.5%
Midday	34.0%	41.8%	34.0%
Evening	29.5%	28.5%	29.5%
Total	**100.0%**	**100.0%**	**100.0%**

Source: DVRPC July 2008

3. External Cordon Station Vehicle Trips

Vehicular traffic including autos, trucks, and buses must also be separated by time period. The temporal distribution of the 2000 traffic counts taken by DVRPC as part of the 2000 model validation study are used for this purpose. **Appendix VII-4** presents the percentages utilized to separate cordon station external-internal traffic into peak, midday, and evening components. The correspondence between cordon station number in **Appendix VII-4** and cordon station description can be found in **Appendix VII-1**.

4. Through Trips

Through trips including autos, trucks, and buses are disaggregated into the peak, midday, and evening time periods based on the average time period factors from the cordon traffic count data presented above. The factors used to disaggregate through travel are 0.33 in the peak, 0.34 for the midday time period, and 0.33 during the evening.

E. Model Operation

A series of six programs are run in order to compute trip generation. The first, EXTERN00, calculates the number of external-internal trip productions. The other five, TRIPGEN A-E, calculate internal-internal trip productions and attractions and external-internal trip attractions. TRIPGEN A calculates "raw" internal-internal trip productions and attractions for all trip purposes. It reads in the needed socioeconomic and trip rate data and calculates internal trips by TAZ. TRIPGEN B calculates a preliminary set of external-internal auto driver trip attractions. The attractions are calculated from each zone's attractions as calculated by TRIPGEN A and by the distance to the regional cordon. TRIPGEN C adjusts the internal-external auto driver productions. TRIPGEN D makes final adjustments to zonal trip data and adds the external production and attraction records. TRIPGEN E separates the generated trips by time period. TRIPGEN E uses the time period disaggregation factors and applies them to the totals that were compiled by TRIPGEN D.

A detailed description of these programs is given in **Appendix VII-5**. Detailed instructions for trip generation model execution are listed in **Appendix VII-6**. File formats and parameter definitions are also included.

F. 2000 Trip Generation Results

This section contains summaries of various trip generation figures at the regional, county, and state level. A complete listing of internal trips generated by CPA by trip type can be found in **Appendix VII-7**. All regional and state controls were checked by examining overall trip rates from model outputs by person and occupied dwelling unit for 1990 and 2000.

Table VII-11 presents the percentage of trip end totals in each trip generation category for 2000. These trip estimates reflect the output of the 2000 validated models. Work trips constitute about 22 percent of total person trip ends in 2000. The number of work trips has increased by more than 9 percent during the decade 1990 – 2000. In 1990 HBW trips constituted about 24 percent of total trips, although they now constitute 22 percent because of the growth in other trip categories. Home based non-work trips have increased by a slightly above average rate and now constitute 55 percent of person travel, up from 52.4 percent of regional trips in 1990. Non-home based trips have grown the fastest (30.3 percent) as a result of increased trip chaining in work and non-work related activities. This travel category in 2000 represents 24 percent of person trips. ***Figure VII-7*** shows the number of internal person trips by trip end category.

Vehicle trips in total grew by 31.2 percent between 1990 and 2000. Light truck travel was the fastest growing category of vehicle trips (61.2 percent over the decade). This resulted primarily from increased trip rates from 1990 to 2000. Much of this growth was not due to growth in the actual rate of travel, but due to problems with the 1990 light truck trip rates. The trip rates for light trucks in 1990 were significantly underestimated. Growth in households and employment between 1990 and 2000 were secondary reasons for the high growth rates in light truck trips. External-internal auto driver trips (freeway, arterial, local, and turnpike together), heavy truck trips, and taxi trips declined somewhat as a percentage of vehicle trips because all grew at below average rates. ***Figure VII-8*** shows the distribution of vehicle trips by trip end category.

A summary of trip end generation by trip category, county, and state is shown in **Appendix VII-8**. It should be noted that external trips are all vehicle trips. Also, there are no external-internal trip productions in the region, and no external-internal trip attractions outside of the region in the travel simulation of external trips.

G. Validation of the Trip Generation Model

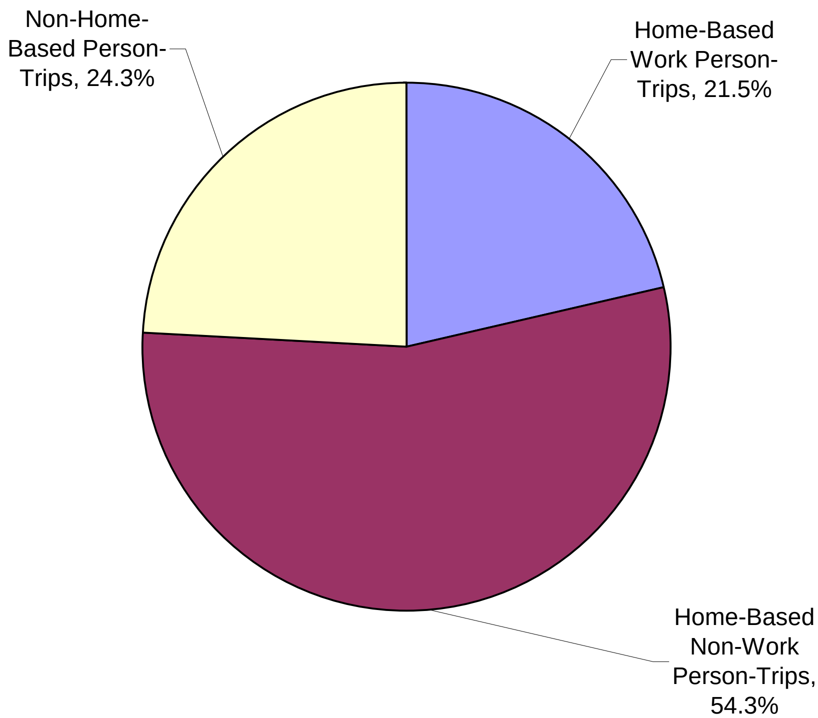
In general, the outputs from the trip generation model appear reasonable and are able to reproduce 2000 and 2005 highway screenline volumes and transit ridership by company. Trip attractions and productions balance reasonably on a regional level. The validation process for matching screenline volumes is iterative and involves not only adjustments to the trip generation model, but to the trip distribution, mode choice, and assignment models as well. The preliminary trip rates were changed slightly to achieve screenline validation of better than 10 percent for each screenline.

Table VII-11 1990 to 2005 Internal and External Motorized Trip Ends by Trip Category

Trip Category	1990 Total Trip Ends (1)	2000 Total Trip Ends	% of Total	2005 Total Trip Ends	% Change 2000-2005
Internal-Internal Person Trips					
Home-Based Work Person-Trips (Productions)	3,964,641	4,209,197	11%	4,320,588	2.6%
Home-Based Work Person-Trips (Attractions)	3,980,520	4,188,794	11%	4,290,141	2.4%
Home-Based Non-Work Person-Trips (Productions)	8,377,838	10,802,846	28%	11,205,083	3.7%
Home-Based Non-Work Person-Trips (Attractions)	8,402,884	10,423,936	27%	10,367,613	-0.5%
Non-Home-Based Person-Trips (Origins)	3,649,608	4,746,636	12%	4,885,958	2.9%
Non-Home-Based Person-Trips (Destinations)	3,649,608	4,746,636	12%	4,885,958	2.9%
Total Person Trip Ends	**32,025,099**	**39,118,045**	**100%**	**39,955,341**	**2.1%**
Internal and External Vehicle Trips					
Light Truck Vehicle Trips (Origins)	1,212,291	1,959,856	29%	2,021,665	3.2%
Light Truck Vehicle Trips (Destinations)	1,212,291	1,959,856	29%	2,021,665	3.2%
Heavy Truck Vehicle Trips (Origins)	746,860	840,356	12%	869,434	3.5%
Heavy Truck Vehicle Trips (Destinations)	746,860	840,356	12%	869,434	3.5%
Taxi Vehicle Trip Trips (Origins)	157,039	128,145	2%	128,808	0.5%
Taxi Vehicle Trips (Destinations)	157,039	128,145	2%	128,808	0.5%
Freeway/Expressway External-internal Veh. Trips	349,456	247,021	4%	259,717	5.1%
Arterial External-internal Veh. Trips	516,516	502,380	7%	519,831	3.5%
Local External-internal Vehicle Trip Veh. Trips (2)	—	110,394	2%	118,851	7.7%
Turnpike External-internal Vehicle Trip Veh. Trips (3)	—	132,888	2%	144,799	9.0%
Total Vehicle Trip Ends	**5,098,352**	**6,849,397**	**100%**	**7,083,012**	**3.4%**

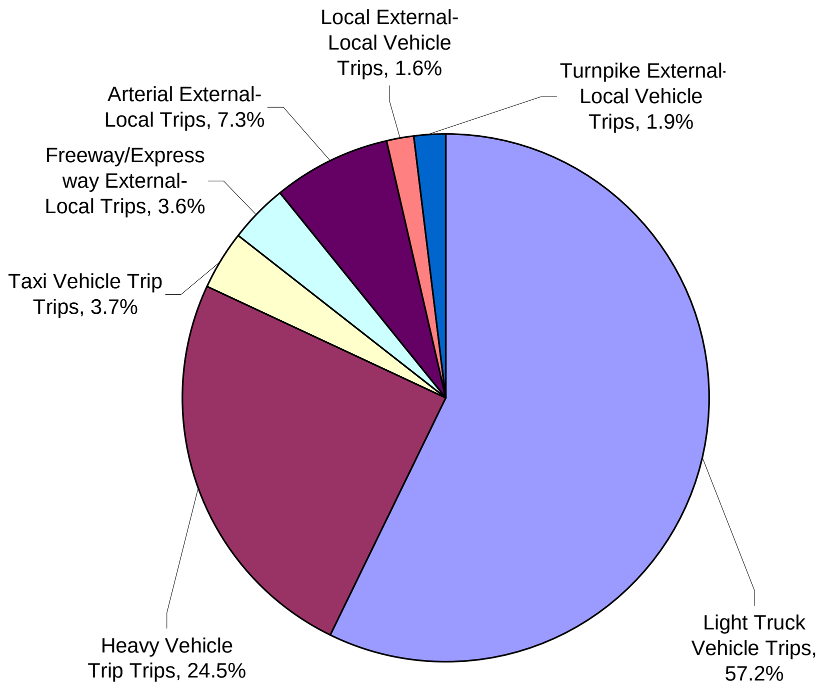
Note: (1) Trips from three Berks County MCDs excluded in 1990, but included in 2000 and 2005; (2) Local vehicle trips combined with Arterial trips in 1990; (3) Turnpike vehicle trips included with Freeway/Expressway trips in 1990

Source: DVRPC July 2008



Source: DVRPC July 2008

Figure VII-7 Internal – Internal Person Trip Ends by Purpose



Source: DVRPC July 2008

Figure VII-8 Vehicle Trip Ends by Trip Type

1. Comparison of 2000 Rates to 1990 Rates

Table VII-12 presents a comparison of the final motorized trip rates from the 1990 and 2000 model validations for HBW trip productions, HBNW trip productions, and NHB trip origins. No large changes occurred between the 1990 and 2000 trip rates for HBW trip productions. Since rates in the two surveys were very similar, only marginal changes were made to the 2000 validated model rates. The 2000 simulated model HBW trip production rates for CBD residents were increased slightly and the rate for urban travel was decreased by about 8 percent. On average, the HBW trip production rates in the 1990 and 2000 validated models were almost identical (1.33 versus 1.37 trips produced per employed resident). Using 2000 Census data as inputs, the 2000 validated trip rates increased HBW trip generation to 4,020,576 daily productions (1.7 percent) from 3,952,423 productions with the 1990 validated model rates.

A larger difference between the 1990 and 2000 trip rates was recorded in the home interview surveys for home-based non-work (HBNW) trips. There was a significant increase in the vehicular trip rates for zero-car households across all area types. The average HBNW motorized trip rate for zero-car households increased from 0.992 to 1.718 between 1990 and 2000. This is a 73 percent increase. Part of this increase may have resulted from improved data collection techniques in the 2000 survey. On average, HBNW trip production rates were decreased slightly (by about 4 percent) for vehicle owning households.

Table VII-12 1990 to 2000 Validated Model Motorized Internal Trip Generation Rates

Trip Category	Variable		Trip Rates by Area Type						Avg
			1	2	3	4	5	6	Rate
Home-Based Work Person-Trip Productions	Employed Residents	1990 Validated Model	0.650	0.920	1.510	1.630	1.620	1.620	*1.325*
		2000 Validated Model	0.850	0.910	1.390	1.670	1.690	1.710	*1.370*
Home-Based Non-Work Person Trip Productions	Households with 0 Vehicles	1990 Validated Model	0.540	0.570	1.000	1.280	1.280	1.280	*0.992*
		2000 Validated Model	0.710	1.320	2.130	1.880	2.020	2.250	*1.718*
	Households with 1 Vehicles	1990 Validated Model	2.360	2.490	2.500	4.250	4.980	4.980	*3.593*
		2000 Validated Model	1.430	2.330	3.990	4.190	4.470	4.660	*3.512*
	Households with 2 Vehicles	1990 Validated Model	3.740	3.940	4.050	6.640	7.780	7.780	*5.655*
		2000 Validated Model	2.370	2.360	4.960	6.610	7.700	7.800	*5.300*
	Households with 3 or More Vehicles	1990 Validated Model	4.240	4.460	4.570	7.530	8.920	8.920	*6.440*
		2000 Validated Model	3.660	3.780	6.390	7.030	7.960	8.120	*6.157*
Non-Home-Based Person-Trip Origins	Households	1990 Validated Model	0.216	0.271	0.324	0.541	0.541	0.541	*0.406*
		2000 Validated Model	0.870	0.970	1.020	1.140	1.150	1.160	*1.052*
	Basic Employment	1990 Validated Model	0.108	0.163	0.216	0.324	0.216	0.216	*0.207*
		2000 Validated Model	0.400	0.380	0.600	0.620	0.620	0.640	*0.543*
	Retail Employment	1990 Validated Model	0.649	1.297	1.946	4.001	4.650	4.650	*2.866*
		2000 Validated Model	1.130	1.260	1.570	2.130	3.160	3.220	*2.078*
	Other Employment	1990 Validated Model	0.324	0.432	0.649	1.081	1.297	1.297	*0.847*
		2000 Validated Model	0.140	0.230	0.550	0.710	0.940	0.970	*0.590*

Source: DVRPC July, 2008

The 2000 model NHB trip rates in ***Table VII-12*** differ from the corresponding 1990 validated model values in that the rates per household and basic employee are increased substantially (more than doubled). Some of the NHB per-household and basic-employee rates for the denser area types increased by at least 300 percent.

NHB trip rates per retail employee are increased somewhat for CBD and fringe area types, but reduced for urban, suburban, rural, and open rural area types. The average trip rate for retail employment decreased 37 percent. The 2000 validated model trip rates for the "other employment" category decreased for all area types with the average rate across area types decreasing 30 percent from 1990 rates.

All average rates changed between 1990 and 2000. Most of these changes were not large, however. Only the average rates for zero vehicle households for HBNW productions and households for NHB origins increased significantly. Only the rate for other employment for NHB origins decreased significantly.

Table VII-13 compares the final 2000 internal trip summaries by purpose and vehicle with the corresponding 2005 values. It also shows the final internal and external vehicle trips - external-internal auto drivers, light and heavy trucks, and taxis. The 2000 to 2005 changes were small and completely due to changes in the underlying socioeconomic variables. The largest change was in external-internal trips, which increased by about 5 percent. The three internal trip categories increased by about 3 percent, with HBNW trips showing the largest increase. Taxis showed the smallest increase, about a half of a percent. All of the trip changes seem reasonable given regional changes in population, employment, and the geographical distribution of activities.

Table VII-13 Summary of Daily Person and Vehicle Trip Growth (2000 – 2005)

Internal Person Trips	2000	2005	% Change 2000-2005
HBW (Prod.)	4,209,197	4,320,588	2.6%
HBNW (Prod.)	10,802,846	11,205,083	3.7%
NHB (Orig.)	4,746,636	4,885,958	2.9%
Total	**19,758,679**	**20,411,629**	**3.3%**
Vehicle Trips			
Ext. Auto Driver (Attr.)	992,683	1,043,198	5.1%
Light Trucks (Orig.)	1,959,856	2,021,665	3.2%
Heavy Trucks (Orig.)	840,356	869,434	3.5%
Taxis (Orig.)	128,145	128,808	0.5%
Total	**3,921,040**	**4,063,105**	**3.6%**

Source: DVRPC July 2008

2. Comparison of 2000 Validated Results to Survey Data

Most of the initial estimates for trip rates were found to be acceptable when the screenline validation was performed. The aggregate motorized trip rate for 2000 is 9.02 trips per household. This figure is 12 percent higher than the surveyed figure (8.05) and 6 percent higher than the national average (8.50).

The main changes to motorized trip rates in the validation process occurred in the trip rates for home-based non-work attractions. Of these, only the changes to the retail employee trip rate for the three low density area types were significant. The HBNW attraction retail employee trip rate for the suburban, rural, and open rural area types were increased by 3.68, 5.73, and 6.72 respectively.

The difference between the original and validated generated motorized person trip ends appears in ***Table VII-14***. These trip numbers are used in the trip distribution model which will be discussed in **Chapter VIII**. The differences between the original and final generated trips are due not only to changes in the trip rates, but also due to fine adjustments in the underlying socioeconomic figures. There was a maximum change of less than 8 percent between the survey and validated trip ends for each trip category. Both HBW productions and attractions increased by about 5 percent. HBNW productions increased by 7.6 percent, while HBNW attractions increased by a lesser amount, about 5 percent. NHB trip ends increased by about 6.5 percent. Both the heavy and light truck trips were unchanged in the validation process. The taxi trips increased by less than one percent.

Table VII-14 Survey and Validated Internal Motorized Trips*

Trip Category	Survey	Validated	Diff.	% Diff
Home-Based Work Person-Trip Productions	4,002,300	4,209,197	206,897	5.17
Home-Based Work Person-Trip Attractions	3,994,800	4,188,794	193,994	4.86
Home-Based Non-Work Person-Trip Productions	10,037,700	10,802,846	765,146	7.62
Home-Based Non-Work Person-Trip Attractions	9,976,700	10,423,936	447,236	4.48
Non-Home-Based Person-Trip Origins or Destinations	4,454,800	4,746,636	291,836	6.55
Light Truck Vehicle Trips	1,959,900	1,959,900	—	0
Heavy Truck Vehicle Trips	840,400	840,400	—	0
Taxi Vehicle Trip Trips	127,000	128,000	1,000	0.79

* Vehicle trip figures rounded

Source: DVRPC July 2008

For HBW trips the census journey to work data provides a second data source to validate the simulation results beyond the survey. The census journey to work reported 4,286,800 motorized work trips. This compares to 4,209,197 motorized trips estimated by the simulation model. This is a -1.8 percent difference, which is very reasonable.

Table VII-15 contains survey and validated non-motorized trips. The aggregate non-motorized trip rate used in the regional travel simulation model is 0.68 trips per household. This is about 4.4 percent higher than the surveyed aggregate trip rate of 0.65 per household. This aggregate trip rate results in about 1,494,700 non-motorized productions and 1,492,200 non-motorized attractions from the total population (regular population plus group quarters population).

For HBW trip purpose only, there are about 128,800 non-motorized daily work trips. The survey was about 123,400. The HBW trip is the only trip category for which census data is available. According to the census there was about 121,300 daily non-motorized HBW trips made in the DVRPC region in 2000. This is about 6 percent lower than the figure produced by the DVRPC simulation model and about a percent and a half lower than the survey.

Table VII-15 Survey and Validated Internal Non-Motorized Trips

Trip Category	Survey	Validated	Difference
Home-Based Work Person-Trip Productions	123,377	128,786	5,409
Home-Based Work Person-Trip Attractions	121,675	127,009	5,334
Home-Based Non-Work Person-Trip Productions	921,473	961,872	40,399
Home-Based Non-Work Person-Trip Attractions	920,830	961,200	40,370
Non-Home-Based Person-Trip Origins or Destinations	387,070	404,040	16,970
Total Non-motorized Trip Ends	**2,861,495**	**2,986,947**	**125,452**

Source: DVRPC July 2008

The group quarters population has a much higher non-motorized trip rate. In total, the group quarters population makes about 127,000 non-motorized trips daily. This increases the overall trip rate from 0.68 to 0.74. The vast majority of non-motorized trips are walking trips. The composite trip rate of 0.74 is disaggregated into 0.67 waking trips per household and 0.07 bicycling trips per household.

The total number of HBW trips for both motorized and non-motorized modes is 4,337,983. This compares with 4,408,190 journey-to-work trips reported by the census. The simulation results are 1.6 percent lower than the census results. The travel simulation model on a regional level makes a good prediction of the total volume of journey-to-work trips.

VIII. TRIP DISTRIBUTION MODEL

This chapter describes the DVRPC trip distribution model, which is the second step in the conventional four-step travel demand model. The trip distribution model creates trip tables (i.e. tables of zone to zone trip interchanges) from the lists of trip ends by trip purpose and trip type by TAZ that are estimated in the trip generation step. DVRPC uses a gravity type model for trip distribution. This standard model had been shown in past studies to replicate well the travel patterns in the DVRPC region. The gravity model estimates the number of trips between any two zones based on the difficulty of traveling, called impedance, between the two zones; the number of trip ends generated in each zone; and the characteristics of the specific trip type.

Also described in this chapter is the theory and application of the gravity model. Inputs to the gravity model are discussed, as is the data used to calibrate the model. Validation results are presented that show good agreement between surveyed trip making patterns and those simulated by the DVRPC trip distribution model for both 2000 and 2005.

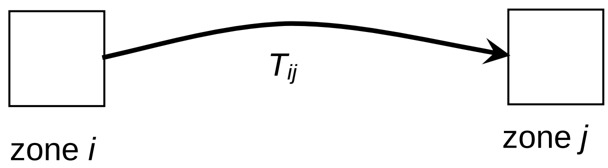
A. Trip Distribution Theory and Application

As described in **Chapter VII** the trip generation step estimates productions and attractions or origins and destinations for each trip end category for each TAZ. The number of internal-internal and external-internal trips to be distributed by the gravity model are:

Trip Type	Regional 2000 Trips per-day
Internal-Internal Trips	
Home-based work person trips	4,209,197
Home-based non-work person trips	10,802,846
Non-home based person trips	4,746,636
Light truck vehicle trips	1,959,856
Heavy truck vehicle trips	840,356
Taxi vehicle trips	128,145
External-Internal Trips	
Turnpike external-internal vehicle trips	132,888
Expressway external-internal vehicle trips	247,021
Arterial external-internal vehicle trips	502,380
Local external-internal vehicle trips	110,394

Source: DVRPC July 2008

The trip generation step does not determine, for example, how many of the HBW trips produced in zone *i* are attracted by zone *j*. This process of aligning or matching productions with attractions or origins with destinations occurs in trip distribution. The trip distribution step matches productions to attractions and origins to destinations for each trip category.



DVRPC uses a gravity type model to match trips. It is called a "gravity" model because it acts in a similar way to the force of gravity. The force of gravity between any two objects is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. Similarly, the number of trips between any two TAZs is proportional to the number of trip ends generated in each TAZ and inversely proportional to the difficulty of traveling between them. A generic gravity model for the number of trips *T* of a certain category between two TAZs, *i* and *j*, would be:

$$T_{ij} = C \frac{P_i}{d_{ij}^2} \frac{A_j}{\sum_{\forall k} A_k}$$

where:

- i,j TAZs
- T_{ij} number of trips produced in *i* and attracted to *j*
- P_i productions in zone *i*
- A_j attractions in zone *j*
- $\sum_{\forall k} A_k$ sum of attractions over all zones, *k*
- d_{ij} distance between *i* and *j*
- C calibration factor

The quantity $\frac{A_j}{\sum_{\forall k} A_k}$ is the relative attractiveness of zone j compared to all other zones. The gravity model used by DVRPC is similar:

$$T_{ij} = P_i A_j f(I_{ij})$$

where:

- I_{ij} impedance to travel from *i* to *j*
- $f(I_{ij})$ travel propensity function

The DVRPC model uses impedance, also referred to as generalized cost or disutility, to measure the difficulty of traveling between *i* and *j*. The impedance to travel from *i* to *j*, I_{ij}, is a combination of all the direct time and monetary elements encountered by trip makers. For travel by highway it includes in-vehicle travel time, out of vehicle time, parking charges, tolls, and direct vehicle operating costs. For travel by transit, impedance consists of in-vehicle travel time, out of vehicle time (including waiting time), transit fare, and a transfer penalty.

The impedance, I_{ij}, is not used directly in the above equation, but is used with a travel propensity function, $f(I_{ij})$, that is specific for each trip purpose. The travel propensity functions are also referred to as friction factor functions. The travel propensity functions are decreasing non-linear functions of the impedance. When the impedance is very low, the travel propensity is very high, indicating a high number of trips between two zones. When the impedance is high, the travel propensity will be very low, and the above equation will produce a smaller number of trips. The travel propensity curves include both the effect of distance on trip making as well as the calibration factor in the generic equation. Separate travel propensity functions are used for each distribution model.

The travel propensity functions from the 1990 model were used as a base for the 2000 travel propensity functions. The travel propensity functions were modified based on trip length frequency distribution data. Trip length frequency distribution curves show the percentage of total trips in a trip category that have a given impedance. Different trip purposes typically have different length distributions. External-internal turnpike trips, for example, have much longer average trip lengths than external-internal trips using local streets. For this reason trips from different categories are distributed separately. DVRPC uses ten trip distribution models which are listed below in the same order as they appear in the TRANPLAN data files:

- Home-based work
- Home-based non-work
- Non-home based
- Light Truck
- Heavy Truck
- Taxi
- Freeway/Expressway External-internal
- Arterial External-internal
- Local External-internal

- Turnpike External-internal

Additional background on gravity models can be found in Ortúzar and Willumsen. The 2000 and 2005 validations use the same factors and procedures for the trip distribution model.

1. Distribution of Internal-Internal and External-Internal Trips

The trip length frequency distributions for the three internal-internal person trip distribution models (HBW, HBNW, NHB) came from the 2000 Household Travel Survey. The trip length frequency distributions for the light and heavy truck distribution models came from the truck survey. The trip length frequency distribution for the turnpike external-internal models came from the turnpike surveys. The data from the freeway/expressway, arterial, and local external-internal trip distribution models came from the cordon line traffic survey. For each of these models, the 1990 travel propensity curves were adjusted to better match travel patterns as revealed in the trip length frequency distributions from the respective studies. The taxi travel propensity function from the 1990 model was used unmodified as a new taxi survey was not conducted.

2. Distribution of External-External Vehicle Trips

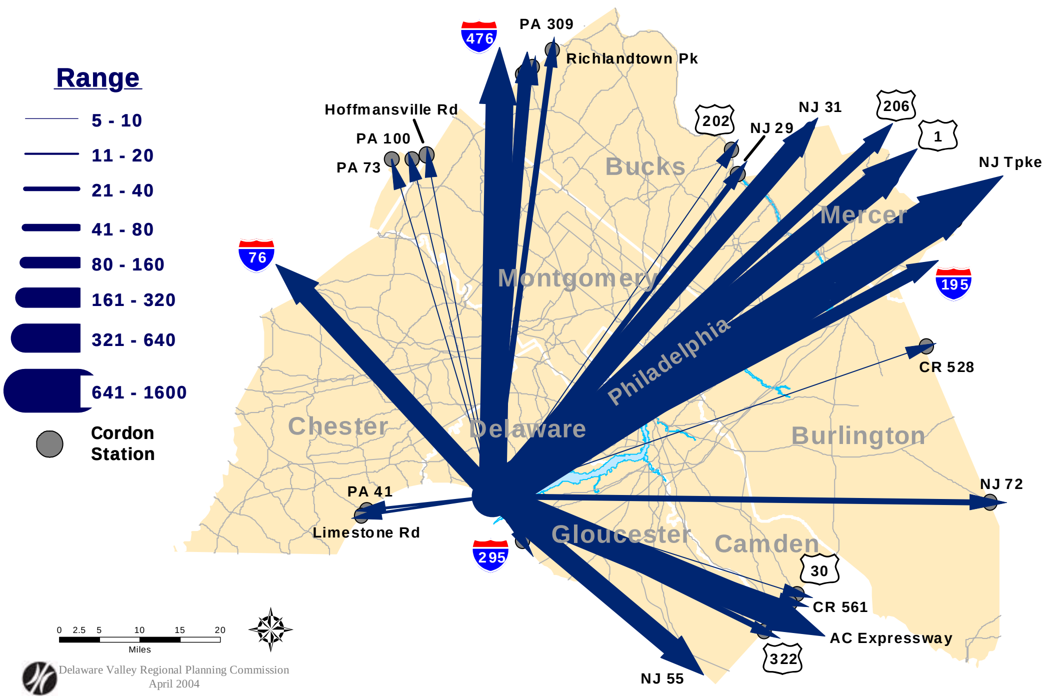
Unlike internal-internal and external-internal trips, through vehicle trips are distributed directly based on the cordon survey results. This is done via origin/destination data gathered by the cordon line survey. For example, ***Figure VIII-1*** schematically illustrates the destinations for all inbound traffic for I-95 north-bound traffic entering the region at the Delaware State line. Most of the through traffic exits the region via other high capacity facilities (i.e. turnpikes, freeways, and expressways). A relatively small proportion exits the region using lower capacity facilities. The origin/destination pattern of through trips was determined based on the cordon line survey. The total number of highway through trips for 2000 and 2005 are:

Category	2000 Trips	2005 Trips
Passenger vehicle through trips	257,616	266,525
Light truck through trips	22,278	23,048
Heavy truck through trips	56,106	58,053
Total	**336,000**	**347,626**

Source: DVRPC July 2008

The trip matrix that results from the generation and distribution of through trips was checked for consistency and accuracy. After the through trip matrix is generated, it is input directly to the highway assignment model in the modeling process.

Figure VIII-1 Through Trips Pattern for I-95 North Inbound



While the distribution of current through trips is taken directly from the external cordon station survey and not from the gravity model, a method is needed to update current trips for future year simulations. DVRPC uses a Fratar model, also called a Furness model, for this purpose.

The Fratar model is an iterative process that extrapolates an origin-destination matrix to a future year. The Fratar model requires a set of growth factors, *F*, as inputs to determine how much through trip ends for each cordon station will increase. The following model is then applied:

$$T_{ij}^{k} = T_{ij}^{k-1} F_{j}^{k-1} F_{i}^{k-1}$$

where:

- k iteration number
- F_i^k growth factor applied at iteration *k* for zone *i*
- F_j^k growth factor applied at iteration *k* for zone *j*

For the first iteration $k=1$, and F_i^0 and F_j^0 are the desired growth factors. After the zone to zone interchanges are calculated for the next iteration, the growth factors are recalculated:

$$F_j^k = \frac{A_j}{\sum_{i=1}^{n} T_{ij}^k}$$

$$F_i^k = \frac{P_i}{\sum_{j=1}^{n} T_{ij}^k}$$

This iterative process is repeated until the updated through trip matrix converges to a final solution.

Similar to external-external trips, the highway trips to the airport are not distributed with the external-internal gravity models. Because of their unique nature, these trips are Fratared with the highway through matrix to forecasted future cordon station totals. The initial estimate for the Frataring process was based on airport passenger surveys conducted in 1992 and 1997.

3. Distribution of External Transit Trips

Transit external-internal trips, unlike highway external-internal trips, are not distributed via a gravity model. Rather, their origin-destination structure is determined in the trip generation stage. This is done by assuming that each internal transit stop used for making an external-internal trip has a relatively small catchment area determined from previous rail and bus surveys. The O-D trip table for external-internal trips and through trips is then input to the transit assignment step along with the internal-internal transit trips determined in later stages of the regional simulation model.

Transit through trip distribution is determined similar to highway through trips. Cordon line volumes and destinations are determined directly from count and survey results. Future trip distribution is determined by updating the trip distribution matrix based on a Fratar model and projected cordon station volumes.

The complete list of transit volumes by cordon station can be found in **Appendix VII-2.** A summary of external-internal and external-external transit volumes for 2000 are as follows:

Category	2000 Trips	2005 Trips
Transit through trips	16,729	18,415
External-internal trips	61,975	68,221
Cordon Station Total	**78,704**	**86,636**

Source: DVRPC July 2008

B. Trip Distribution Model Inputs

Various inputs are needed in order to run the trip distribution model. The trip distribution model uses the trip end outputs produced by TRIPGEN E. The estimation of impedances and travel propensity functions are discussed in this section. Average speed, travel time, and trip length frequency distribution data are required in order to estimate the travel propensity functions. These data are discussed in this section before travel propensity functions.

1. Impedance

The impedance of travel from one zone to another is determined by finding minimum impedance paths through the highway network, a process known as “skimming.” The cost of travel by transit is included later by a correction factor in the modal split model. The impedance to travel by auto can be defined as:

$$I_{ij} = K_1 \frac{Y}{P} w_{ij} + K_2 \frac{Y}{P} \sum_{a \in R_{ij}} c_a + K_3 \frac{1}{P} \left(\sum_{a \in R_{ij}} k_a + s_j \right)$$

where:

- $K_{1,2,3}$ conversion factors from time or cost to impedance
- Y change in average household income in the region, expressed as an index with 1990 as the base year
- P change in the consumer price index for the region, expressed as an index with 1990 as the base year
- a a link in the highway network
- c_a in-vehicle time to travel on link a
- R_{ij} the minimum cost highway route from i to j
- k_a the vehicle operating cost for link a
- s_j parking cost for zone j
- w_{ij} out of vehicle travel time for i and j

The various elements of impedance are either monetary and measured in dollars, or time and measured in minutes. These elements are combined to form the impedance that travelers face when making mode choice decisions. Conversion factors, called "K" factors, are used to transform the various impedance elements into a common impedance measure. These factors incorporate changes in income and inflation for future year simulations. The "K" factors for 1990 were:

$$K_1 = 3.48$$
$$K_2 = 2.23$$
$$K_3 = 1.0$$
$$K_4 = 16.0$$

The highway network skims are produced by considering each centroid separately. With the cost of travel on each link temporarily fixed, a shortest path tree is created from any centroid (the origin) to all the other centroids in the network (the destinations). The impedance to travel from zone *i* to zone *j* is not necessarily the same as the impedance to travel from zone *j* to zone *i* because of one-way streets, directional travel, and other factors.

The highway skim tree determines the in-vehicle travel time on the network given the current network loading condition. In order to obtain the impedance, the in-vehicle travel time from the skim tree is combined with the auto operating cost, parking cost, and highway terminal times. The auto operating cost is 49.1 cents/mile for 2000 and 52.2 cents/mile for 2005. The parking and terminal times depend on area type and can be found in **Appendix IX-1**. The end result of the skim trees and impedance calculations is a matrix of travel impedance from each TAZ to every other TAZ.

The impedance measure described above includes all the time and out of pocket monetary disutilities highway travelers face. Trip makers face some additional factors when making travel decisions. Two of the factors, crossing the Delaware River and traveling to or from Philadelphia, are taken into account by the trip distribution model when computing zone to zone impedances.

The gravity model utilizes a system of "River Penalties" to accurately model the number of trips crossing the Delaware River. Without the river penalties, the gravity model would produce too many trips crossing the river. The 2000 model adds a penalty of 16 minutes to all trips crossing the Delaware River.

The gravity model also assesses a penalty to all trips entering or leaving Philadelphia. Without the Philadelphia penalty, the model would predict too much traffic to and from Philadelphia. The 2000 model uses a penalty of 3 minutes to all trips to or from Philadelphia. This penalty applies only to trips to or from Philadelphia, not those that merely travel through Philadelphia. Furthermore, the three minute penalty is in addition to the Delaware River crossing penalty. Trips from a New Jersey county to or from Philadelphia would encounter both the 3 minute Philadelphia penalty and the 16 minute Delaware River penalty.

2. Transit Impedance Adjustment

A correction procedure is used to adjust the trip distribution results for zone interchanges with transit service since the trip distribution model does not consider the transit impedance. While this adjustment procedure occurs in the mode split program because of computational reasons, it is properly part of the trip distribution model and is therefore discussed here. Other procedures, such as using joint highway/transit impedance, are possible, but the procedure detailed below has shown to best represent travel patterns in the DVRPC region.

The first step in adjusting the trip distribution results to account for the transit bias is to calculate the impedance difference. This is the difference between the highway impedance and the transit impedance and is defined as:

$$ID = K_1 \frac{Y}{P}(w_{ijt} - w_{ija}) + K_2 \frac{Y}{P}(c_{ijt} - \sum_{a \in R_{ij}} c_a) + K_3 \frac{1}{P}(k_{ijt} - \sum_{a \in R_{ij}} k_a - s_j) + K_4 TRFR_{ij}$$

where:

- c_{ijt} transit in-vehicle travel time between *i* and *j*
- k_{ijt} transit cost, including fare, between *i* and *j*
- w_{ijt} transit out of vehicle travel time for travel between *i* and *j*
- $TRFR_{ij}$ number of transfers in transit route from *i* to *j*
- K_4 conversion factor to convert the number of transfers to impedance, 16.0 in 1990

A small impedance difference means that there is good transit service, while a large impedance difference means that the transit service between *i* and *j* is poor. The various “K” conversion factors used in calculating both the impedance difference and the highway impedance presented earlier assure that all disutility factors are in the same measurement units. Also included are the real income and consumer price indexes to update the factors from the years when they were developed.

The impedance difference is used in the following equation to compute and adjustment factor (*y*):

$$y = 1.299 - 0.0087(ID) \qquad 0.80 \leq y \leq 1.2$$

The adjustment factor is held to a maximum value of 1.20 and a minimum value of 0.80. This factor shows the compensation needed to the trip interchange to account for the quality of transit service. The number of trips for each interchange and trip purpose as determined from the highway gravity model is multiplied by the adjustment factor to compensate for the impedance of travel by transit. The correction factor equation was obtained from pervious travel simulation studies and has been found to well represent the effect of good transit service on travel propensity.

3. Intrazonal Trips

Not all travel that occurs is interzonal. Some travel occurs where both trip ends are in the same TAZ. The travel impedance for an intrazonal trip can not be determined by building skim trees from the network, as the network only models interzonal travel. Fixed intrazonal impedances which depend on area type are used to estimate the amount of intrazonal travel. The intrazonal impedances are shown in **Appendix IX-1**.

4. Survey Input Data

The household travel survey was used to determine trip length frequency distributions for HBW, HBNW, and NHB trips. Distributions for light and heavy truck trips were determined from the truck travel survey. The trip length distribution for turnpike trips was determined from the turnpike surveys. Trip length distributions for freeway/expressway, arterial, and local external-internal trips were determined from the cordon line traffic survey.

The household travel survey asked respondents for the locations of trip ends. These data were geocoded and trip lengths determined. The graph of trip frequency for all trip types is shown in ***Figure VIII-2***. This figure shows that a significant number of shorter trips were captured. It can also be seen that trips of 30 minutes, 45 minutes, and 60 minutes have a higher frequency than trips of slightly less or more travel duration. This can be attributed to bias and rounding on the part of household members in reporting trip length.

The average trip length from the household travel survey for all internal-internal trips is about 19 minutes. The trip length distribution is clearly skewed towards shorter trips (under 30 minutes). Trips over 30 minutes comprise a relatively small portion of internal-internal person trips.

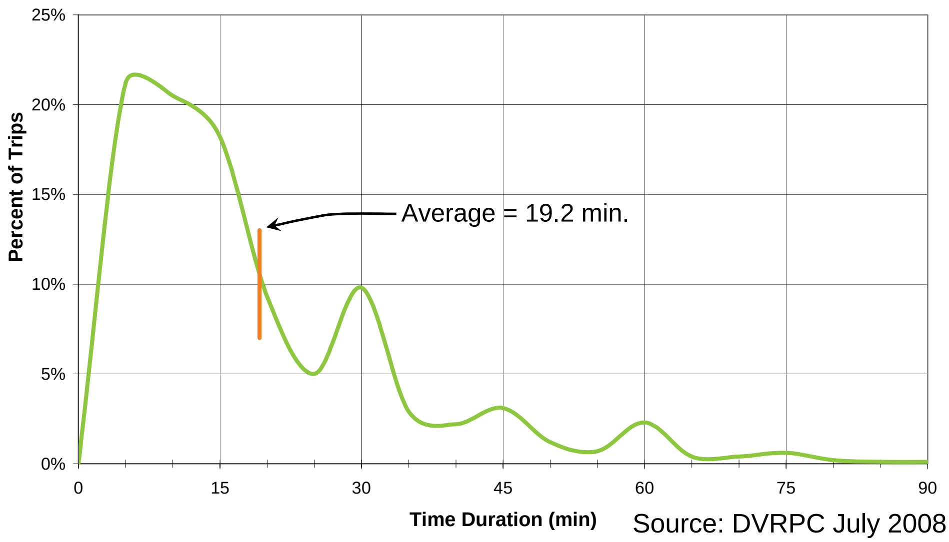


Figure VIII-2 2000 Trip Length Frequency Distribution for all Internal Trips

Because of the biases in the reported travel times from the home interview survey, the geocoded determined trip length distances were used. These were transformed into travel times with travel speeds determined from the 1997 travel time survey. The regional highway travel speeds can be seen in ***Table VIII-1*** and ***Figure VIII-3***. As expected, the speeds for all roadway functional classifications increase from the CBD to rural area types. This is true for all three time periods. Also, speeds decrease from the higher to lower type roadway facilities, with some variation in the difference in speeds. The greatest speed differences by facility type are evident in the CBD, while the least difference is located in the open rural areas.

County and CPA speeds were prepared for the links in the travel simulation network. ***Table VIII-2*** presents the speeds for each county with subtotals by state and region. As might be expected, speeds are lower in Philadelphia than in the suburban counties. The speeds in the denser counties of Camden, Delaware, and Mercer are lower than in the less dense counties of Bucks, Chester, Montgomery, Burlington, and Gloucester. Speeds are slightly higher in the midday than in either of the peak periods.

The input highway speeds actually used in the trip distribution, modal split, and assignment models are shown in ***Tables VIII-3 to VIII-6***. These speeds were derived from the 1998 surveys and other sources as will be discussed below for free-flow and calibration speeds. The speeds in ***Tables VIII-3*** are used for most modeling, including FHWA and EPA related modeling. The speeds in ***Tables VIII-4 to VIII-6*** are uses for FTA compliant modeling.

Table VIII-1 1997 Average Highway Travel Speeds by Functional Class and Area Type

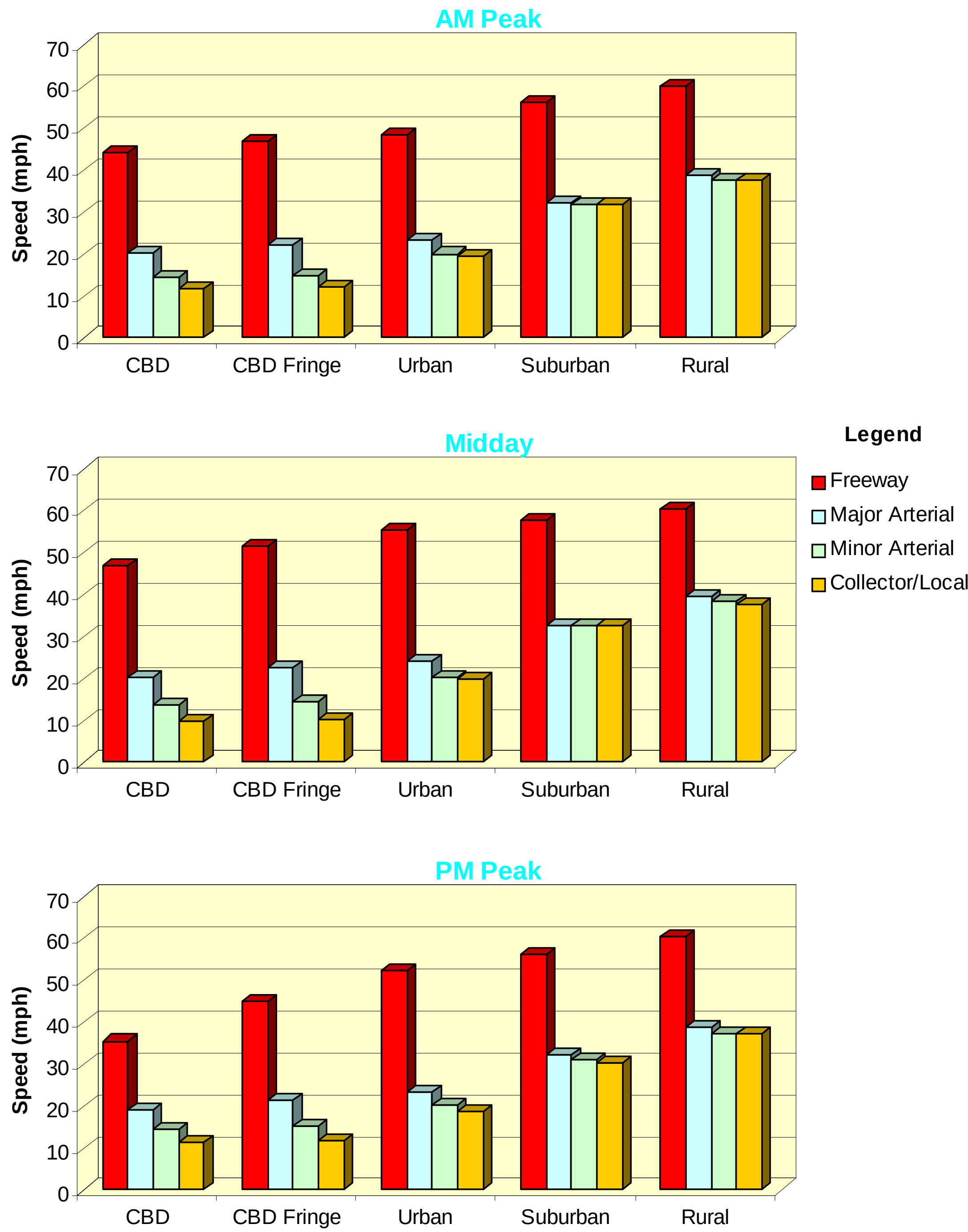
Average AM Peak Speed (mph)	Area Type				
Functional Classification	**CBD**	**CBD Fringe**	**Urban**	**Suburban**	**Rural**
Freeway	44.28	46.99	48.60	56.33	60.31
Major Arterial	20.47	22.33	23.23	32.11	38.84
Minor Arterial	14.36	15.04	20.10	32.00	37.74
Collector/Local	11.60	12.16	19.60	31.80	37.73
Freeway Ramps	20.10	21.70	24.71	32.87	39.16
Centroid Connectors	16.00	16.10	18.80	19.80	20.40
Non-Network Local	11.60	12.16	19.60	25.80	31.73

Average Midday Speed (mph)	Area Type				
Functional Classification	**CBD**	**CBD Fringe**	**Urban**	**Suburban**	**Rural**
Freeway	46.96	51.71	55.38	57.96	60.69
Major Arterial	20.15	22.69	24.03	32.83	39.48
Minor Arterial	13.89	14.47	20.20	32.79	38.60
Collector/Local	9.70	10.27	20.00	32.50	37.63
Freeway Ramps	19.70	21.60	25.15	33.70	39.01
Centroid Connectors	16.00	16.10	18.80	19.80	20.40
Non-Network Local	9.70	10.27	20.00	26.50	31.63

Average PM Peak Speed (mph)	Area Type				
Functional Classification	**CBD**	**CBD Fringe**	**Urban**	**Suburban**	**Rural**
Freeway	35.57	44.88	52.29	56.14	60.60
Major Arterial	19.08	21.36	23.45	32.32	38.76
Minor Arterial	14.46	15.30	20.40	31.22	37.38
Collector/Local	11.30	11.75	18.90	30.30	37.24
Freeway Ramps	19.50	21.30	25.02	32.74	38.84
Centroid Connectors	16.00	16.10	18.80	19.80	20.40
Non-Network Local	11.30	11.75	18.90	24.30	31.24

Source: DVRPC July 2008

The free-flow speeds shown in ***Table VIII-3*** are used the Evans equilibrium process mandated by the EPA and FHWA for transportation air quality, long-range plan development, highway alternatives analysis, and highway traffic design studies. The initial highway network speeds were tabulated from the travel time survey and selected secondary source data to reflect free-flow speeds (speed limits or measured operating speeds, whichever is higher). These free-flow highway input speeds do not vary by time period. The input highway network free-flow speeds are



Source: DVRPC July 2008

Figure VIII-3 1997 Average Highway Travel Speeds by Functional Class and Area Type

Table VIII-2 1997 Average Highway Travel Speeds by County, State, and Region

County	AM Peak	Midday	PM Peak
Bucks	31.5	32.2	30.7
Chester	32.5	32.7	31.9
Delaware	27.4	27.9	26.8
Montgomery	29.3	30.0	28.4
Philadelphia	21.6	22.1	21.5
PA Total	**27.9**	**28.5**	**27.4**
Burlington	32.0	32.3	31.1
Camden	28.6	29.2	27.7
Gloucester	32.9	33.1	31.9
Mercer	28.2	28.5	27.6
NJ Total	**30.4**	**30.7**	**29.5**
DVRPC Region	**28.7**	**29.2**	**28.1**

Source: DVRPC July 2008

Table VIII-3 Free-flow Speeds by Area Type (mph)

	Area Type					
Facility Type	**CBD**	**Fringe**	**Urban**	**Suburban**	**Rural**	**Open Rural**
Freeway/Expressway	55.0	60.0	65.0	70.0	70.0	70.0
Parkway	35.0	35.0	40.0	45.0	50.0	50.0
Major Arterial	25.0	25.0	30.0	37.0	45.0	45.0
Minor Arterial	20.0	20.0	27.0	34.0	42.0	42.0
Collector/Local	15.0	20.0	24.0	31.0	37.0	37.0
Ramp	20.0	35.0	40.0	45.0	45.0	45.0

Source: DVRPC July 2008

Table VIII-4 FTA Process Peak Period Speeds by Area Type (mph)

	Area Type					
Facility Type	**CBD**	**Fringe**	**Urban**	**Suburban**	**Rural**	**Open Rural**
Freeway/Expressway	44.28	46.99	48.60	56.33	60.31	60.31
Parkway	39.28	41.99	43.60	51.33	55.31	55.31
Major Arterial	20.47	22.33	23.23	32.11	38.84	38.81
Minor Arterial	14.36	15.04	20.10	32.00	37.74	37.74
Collector/Local	11.60	12.16	19.60	31.80	37.73	37.73
Ramp	20.10	21.70	24.71	32.87	39.16	39.16

Source: DVRPC July 2008

Table VIII-5 FTA Process Midday Period Speeds by Area Type (mph)

	Area Type					
Facility Type	**CBD**	**Fringe**	**Urban**	**Suburban**	**Rural**	**Open Rural**
Freeway/Expressway	46.96	51.71	55.38	57.96	60.69	60.69
Parkway	41.96	46.71	50.38	52.96	55.69	55.69
Major Arterial	20.15	22.69	24.03	32.83	39.48	39.48
Minor Arterial	13.89	14.47	20.20	32.79	38.60	38.60
Collector/Local	9.70	10.27	20.00	32.50	37.63	37.63
Ramp	19.70	21.60	25.15	33.70	39.01	39.01

Source: DVRPC July 2008

Table VIII-6 FTA Process Evening Period Speeds by Area Type (mph)

	Area Type					
Facility Type	**CBD**	**Fringe**	**Urban**	**Suburban**	**Rural**	**Open Rural**
Freeway/Expressway	50.92	54.04	55.89	64.78	69.36	69.36
Parkway	45.92	49.04	50.89	59.78	64.36	64.36
Major Arterial	23.54	25.68	26.71	36.93	44.67	44.67
Minor Arterial	16.51	17.30	23.12	36.80	43.40	43.40
Collector/Local	13.34	13.98	22.54	36.57	43.39	43.39
Ramp	23.12	24.96	28.42	37.80	45.03	45.03

Source: DVRPC July 2008

listed by highway facility type and area type ***(Table VIII-3)***. Model runs for peak, midday, and evening time periods associated with both current and future travel simulations start with this speed lookup table which is assumed to represent the maximum highway operating speed for a given link. The highway operating speeds produced by the model as the Evans process converges to the equilibrium solution represent congested facility operating speeds. Forecasted congested operating speeds for a given link are somewhat slower than forecasted travel speeds because of the growth in link volumes resulting from forecasted increases in demographics and employment. In some cases, however, future highway speeds may be higher because of roadway improvements.

As discussed in **Chapter II**, the FTA stipulates a much simpler more traditional four step modeling process that is closely registered to scheduled/surveyed transit and highway speeds. Because the Evans algorithm is not used to bring the system to equilibrium, actual operating speeds must be used for FTA modeling. Calibration year highway speeds are taken directly from the 1997 highway travel time survey by calculating cell value averaged speeds from the detailed highway link speeds collected by the travel time survey. FTA modeling also uses a system whereby highway links are categorized through a lookup table defined by facility type and area type. The actual highway operating speeds vary significantly by time period; there are separate lookup tables for the peak, midday, and evening time periods that were prepared from survey data. The peak, midday, and evening period lookup tables are shown in ***Tables VIII-4, VIII-5, and VIII-6*** respectively. The variation between the peak and midday highway speed estimates is not large; both are significantly lower than the free-flow speeds given in ***Table VIII-3*** due to prevailing congestion levels. The evening speeds, however, are much higher than either the peak or midday speeds because of significantly lower congestion levels.

Transit travel times were also developed as part of the travel time survey. Average transit travel times by county and time of day are shown in ***Table VIII-7***. Average transit speeds are higher in the suburban counties than in Philadelphia. Average transit speeds are also slightly higher in the AM peak than in the midday for all counties except Gloucester. Travel speeds are either the same or slightly slower in the midday than in the AM peak when compared by mode, except for commuter rail in the suburban or rural area types.

A comparison of transit speeds to highway speeds shows that freeway speeds are higher than transit speeds for all modes for all area types. Bus speeds tend to be lower than highway speeds for all facility types across area types. For the other modes and facility types, there is some overlap of speeds depending on area type. The rail transit modes (rapid transit, commuter rail, and PATCO) have speeds higher than local roads for all area types. Rapid transit has speeds higher than minor arterials but lower than major arterials for all area types. Commuter rail is slower in the CBD, fringe, and suburban area types than both categories of arterials, but is faster than both in the urban and rural area types. PATCO's speed falls between minor and major arterial's speeds in the CBD area type, but is faster than both in the urban and suburban area types.

When compared on an aggregated county wide basis, transit speeds are slower for every county and time period than the highway speeds. Transit speeds are about half as fast as highway speeds on a region wide basis. Transit speeds compare favorably to highway speeds when compared by mode and area type. However, transit speeds compare poorly to highway speeds when compared on a county-by-county and region wide basis. There are two reasons for this. First, bus is the predominate mode of transit in the Delaware Valley. For this reason, average transit speeds skew towards average bus speeds and away from the higher speed modes. Secondly, a large portion of transit travel occurs in Philadelphia where both transit and highway speeds are lower. However, a large portion of highway travel occurs in the suburban counties where both transit and highway speeds are higher. This is why AM peak speeds for transit are half that of AM peak speeds for highway travel on a region wide basis, even though the difference is not as stark when compared by a county by county basis.

Table VIII-7 Average Transit Speeds by Mode, County, and Time of Day

Average Speeds By Area Type and Mode (mph)

Average AM Peak Speed (mph)

Mode	CBD/Fringe	Urban	Suburban	Rural
Bus	8.9	10.8	16.6	27.4
Rapid Transit	18.3	21.1	30.9	--
Commuter Rail	13.9	27.0	30.3	40.9
PATCO	16.7	26.8	35.5	--

Average Midday Speed (mph)

Mode	CBD/Fringe	Urban	Suburban	Rural
Bus	8.3	10.5	16.5	29.8
Rapid Transit	18.0	19.5	29.0	--
Commuter Rail	11.4	27.0	32.6	40.8
PATCO	16.7	26.8	34.3	--

Source: DVRPC July 2008

Average Speeds By County and Time of Day (mph)

County	AM Peak	Midday
Bucks	23.2	20.7
Chester	20.7	20.5
Delaware	16.4	15.6
Montgomery	18.1	17.9
Philadelphia	11.7	11.1
PA Counties	**13.0**	**12.5**
Burlington	21.1	20.9
Camden	19.5	19.2
Gloucester	24.6	26.7
Mercer	15.7	15.6
NJ Counties	**19.4**	**19.2**
DVRPC Region	**14.0**	**13.5**

Source: DVRPC July 2008

5. Travel Propensity Functions

The travel propensity functions, also referred to as friction factors, represent the propensity to travel with respect to a given impedance value. The travel propensity functions for the 2000 model validation were initially taken from the 1990 model validation. These functions were calibrated to data from the household travel, cordon line, and truck surveys. The taxi travel propensity function from the 1990 model was used without adjustment. The travel propensity functions were adjusted so that the trip frequency distributions in time predicted by the various gravity models matched the actual trip frequency distributions from the surveys. Trip length distribution curves in distance were obtained from the surveys. This was transformed into trip length distribution curves in time based on the travel time survey.

The travel propensity functions were calibrated for trip balance in addition to trip length frequency distribution. The productions P_j determine the number of trips distributed, while attractions A_i merely determine the attractiveness of zone *i* versus all other zones. An iterative calibration technique was used in order to obtain a good match to the surveyed trip distribution curves and to match productions to attractions.

The travel propensity functions are implemented by a lookup table that gives the travel propensity for each whole number value of impedance. Since the travel propensity curves are highly non-linear, using a lookup table is preferable to the use of a mathematical equation for calculating the travel propensity given a value of impedance. The value given by the lookup table is multiplied by the productions and attractions to obtain the trip interchange, T_{ij}. Graphs of the travel propensity functions are shown in the trip length frequency distribution results that follow.

C. Gravity Model Calibration

The TRANPLAN gravity model calibration program was used to adjust the 1990 travel propensity functions in order to achieve acceptable agreement between the trip length frequency distribution from the household survey and the trip length frequency distribution produced by the gravity model. The travel propensity functions are calibrated by an iterative process where they are adjusted until a sufficiently close match between survey and model results is achieved. A schematic of the processes is shown in ***Figure VIII-4***. The gravity model calibration program takes as inputs the trip generation output, highway travel times, surveyed trip length frequencies, and the current friction factors. The trip distribution is then computed along with the gravity model based trip length frequency distributions for each trip category. From these results each discrete section of the travel propensity function lookup table is adjusted according to the following equation:

$$f_{new}(x) = \frac{survey_x\%}{gravity_x\%} f_{old}(x)$$

where:

- $f_{old}(x)$ travel propensity from previous iteration
- $f_{new}(x)$ updated travel propensity
- x impedance range for which the travel propensity function is being adjusted

After the travel propensity functions have been adjusted, the trip distribution results are checked against survey data. If the results are sufficiently close, the process concludes. If there is still significant disagreement, the travel propensity functions are adjusted again until the gravity model results are sufficiently close to the surveyed data.

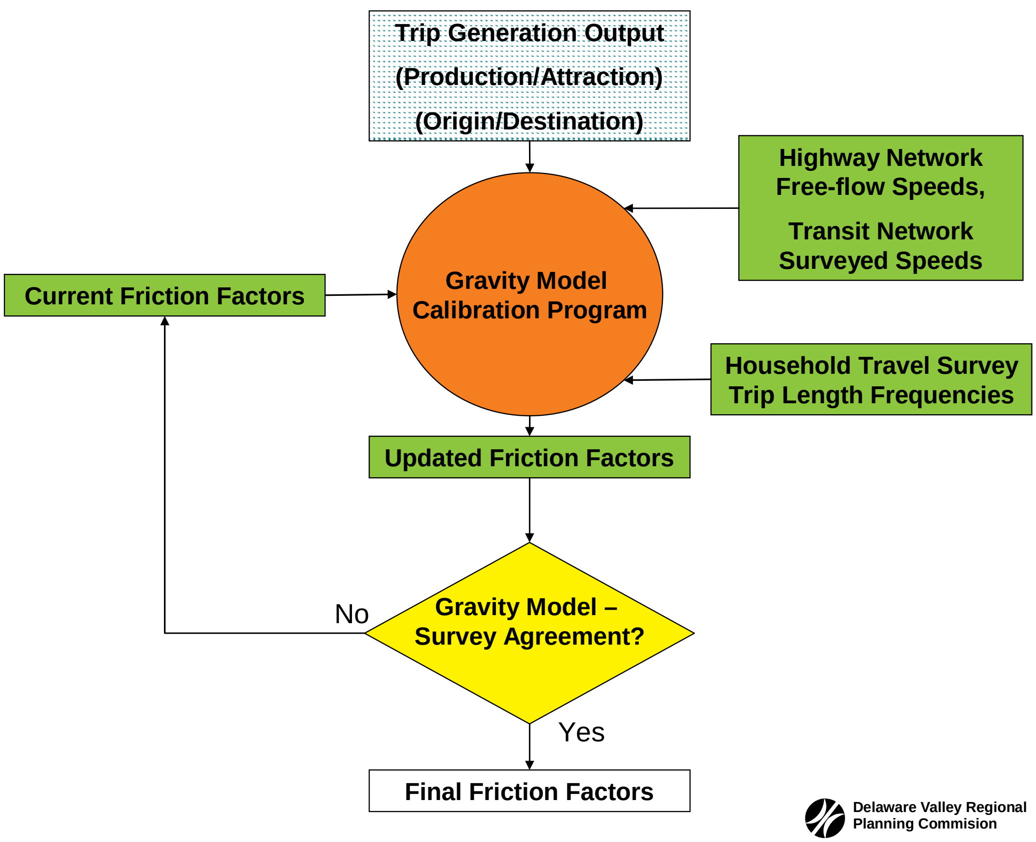


Figure VIII-4 2000 Gravity Model Calibration Process

D. Model Operation

The gravity model is executed using the GMODEL program. Separate streams are used for each of the three time periods. The trip generation tables for each trip purpose are input to the gravity model program. The gravity model program produces trip interchange matrices as outputs for each trip purpose. This is then fed as input into the modal split model.

E. 2000 Trip Distribution Results

The trip distribution model produces zone-to-zone interchanges for each trip purpose. The zone-to-zone interchange for each trip purpose is essentially a matrix listing the trips from *i* to *j* for all pairs of TAZs. Summary statistics are also produced to evaluate the quality of the calibration and to validate the model. These statistics compare the surveyed data to the simulated data. Results for average trip length and trip length frequency distribution produced by the simulation for the different trip categories are presented in this section and compared to survey results. Validation results for the Delaware River crossings and the intrazonal trips produced by the simulation are also presented.

1. Average Trip Length

Table VIII-8 compares the surveyed and simulated average trip lengths as measured in units of impedance. This table shows good agreement between simulated and surveyed trip lengths. The difference between simulated and surveyed trip lengths in impedance is 3 percent or less for internal-internal person trips. Light truck simulated average trip lengths exceed surveyed results by 4.6 percent, while simulated results for heavy truck trips are lower than surveyed results by 3 percent. External-internal vehicle trips all have simulated trip length results within 3 percent of surveyed results.

Table VIII-9 also compares the surveyed average trip length with the simulated average trip length and presents the results in minutes. This table shows that the trip distribution model is well calibrated in terms of matching the surveyed average trip length. The difference between surveyed and simulated results for internal person trips is 3 percent or less for each of the 3 trip purposes. In each case the simulated results are slightly higher than the survey. The difference for external-internal vehicle trips is less than or equal to 2.7 percent after adjustment of both surveyed and simulated trip lengths. Except for local roads, the trip lengths for external trips were overestimated. For internal vehicle trips the light truck simulated average trip length is 4.6 percent higher than surveyed, while the heavy truck simulated average is 3 percent lower than the survey. Unlike external travel, the trip lengths of truck trips were slightly under estimated. The taxi average trip length is 5.3 percent higher than the surveyed average.

Table VIII-8 2000 Average Trip Length in Impedance by Trip Purpose

Trip Type	Trip Length Surveyed (impedance)	Trip Length Simulated (impedance)	Difference	Percent Difference
Internal - Internal Trip Productions				
Home-based Work	95.3	97.1	1.8	1.9%
Home-based Non-work	61.0	63.2	2.2	3.6%
Non-home based	65.0	67.8	2.8	4.3%
External-Internal Trip Attractions				
Turnpikes	255.9	257.0	1.1	0.4%
Freeways	151.8	154.5	2.7	1.8%
Arterials	127.8	127.3	-0.5	-0.4%
Local Streets	101.8	102.8	1	1.0%
Truck Trip Origins				
Light Truck	63.5	66.8	3.3	5.2%
Heavy Truck	86.1	83.6	-2.5	-2.9%

Source: DVRPC July 2008

Table VIII-9 2000 Average Trip Length in Minutes by Trip Purpose

Trip Type	Trip Productions or Origins Simulated	Trip Length Surveyed (minutes)	Trip Length Simulated (minutes)	Diff.	Percent Difference
Internal - Internal Trip Productions					
Home-based Work	4,209,197	26.1	26.8	0.7	2.7%
Home-based Non-work	10,802,846	16.7	17.3	0.6	3.6%
Non-home based	4,746,636	17.8	18.6	0.8	4.5%
External-Internal Trip Attractions					
Turnpikes	132,888	70.1	70.4	0.3	0.4%
Freeways	247,021	41.6	42.3	0.7	1.7%
Arterials	502,380	35	34.9	-0.1	-0.3%
Local Streets	110,394	27.9	28.2	0.3	1.1%
Truck Trip Origins					
Light Truck	1,959,856	17.4	18.3	0.9	5.2%
Heavy Truck	840,356	23.6	22.9	-0.7	-3.0%
Taxi Trip Origins	128,145	15.2	15.9	0.7	4.6%

Source: DVRPC July 2008

The simulated average trip length for HBW trips of 26.6 minutes is significantly longer than the average for all internal-internal person trips from the household travel survey of 19.2 minutes. It should be noted that the trip length of HBW trips from Census 2000 is 26.7 minutes for commuters who drove alone. As expected, the average trip lengths for HBNW and NHB trips are shorter than the average length for all trips, which is 19.2 minutes

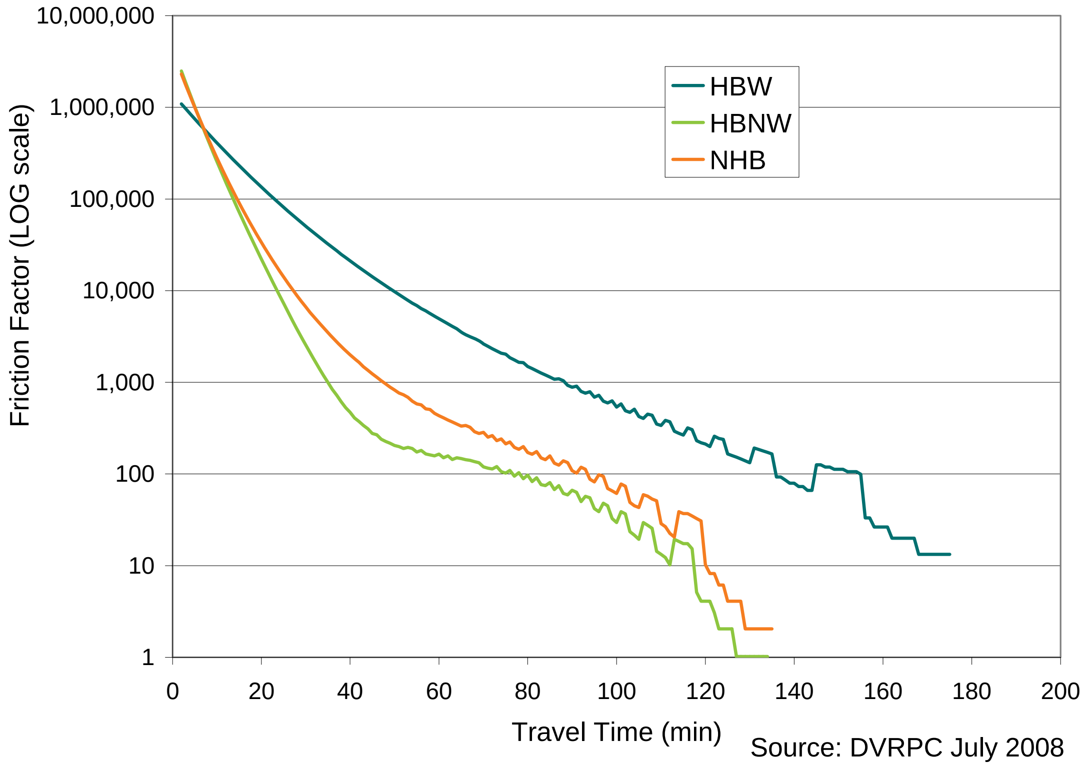
The average trip lengths for all four external-internal trip categories are longer than 19.2 minutes. Average trip lengths decrease monotonically from Turnpike external-internal trips to local street external-internal trips. The former is about 45 percent longer than the latter (41.9 vs. 28.8 minutes).

The simulated light truck average trip length at 18.2 minutes is slightly shorter than the household travel survey average length. The heavy truck average trip length is 22.9 minutes, slightly shorter than the average from the survey. Taxi trips are the shortest trip category with a simulated average trip length of 16.0 minutes.

2. Trip Length Frequency Distribution

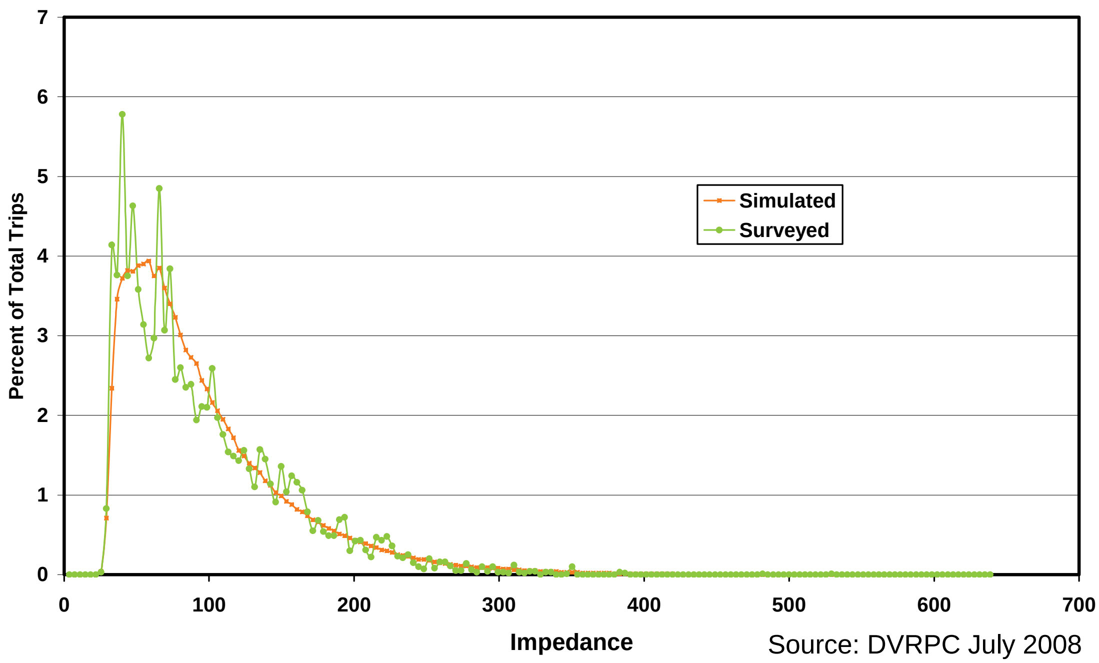
The travel propensity functions for HBW, HBNW, and NHB trips are shown in ***Figure VIII-5*** in log scale. All three curves have been normalized. The travel propensity curves for HBNW and NHB trips are similar in shape, with the NHB curve having a steeper slope. The HBNW curve has shallower slope than the NHB curve, especially in the middle time range of 30 to 70 minutes. The HBW travel propensity curve is less steep than the HBNW and NHB trip purposes. All three curves are fairly smooth for low travel times, but show considerable oscillation for higher travel times.

The surveyed and simulated trip length frequency distributions for HBW trips are shown in ***Figure VIII-6***. This figure shows that the model replicates the surveyed trip length frequency distribution for HBW trips well. One can see that the model smoothes the scatter in the survey data. The gravity model simulates the surveyed data for longer trips more accurately than for shorter trips. For shorter trips, those with an impedance of less that about 100, the gravity model is unable to match the oscillations in the data. The gravity model first underestimates then overestimates somewhat the distribution of shorter trips.



Source: DVRPC July 2008

Figure VIII-5 2000 HBW, HBNW, and NHB Travel Propensity Functions



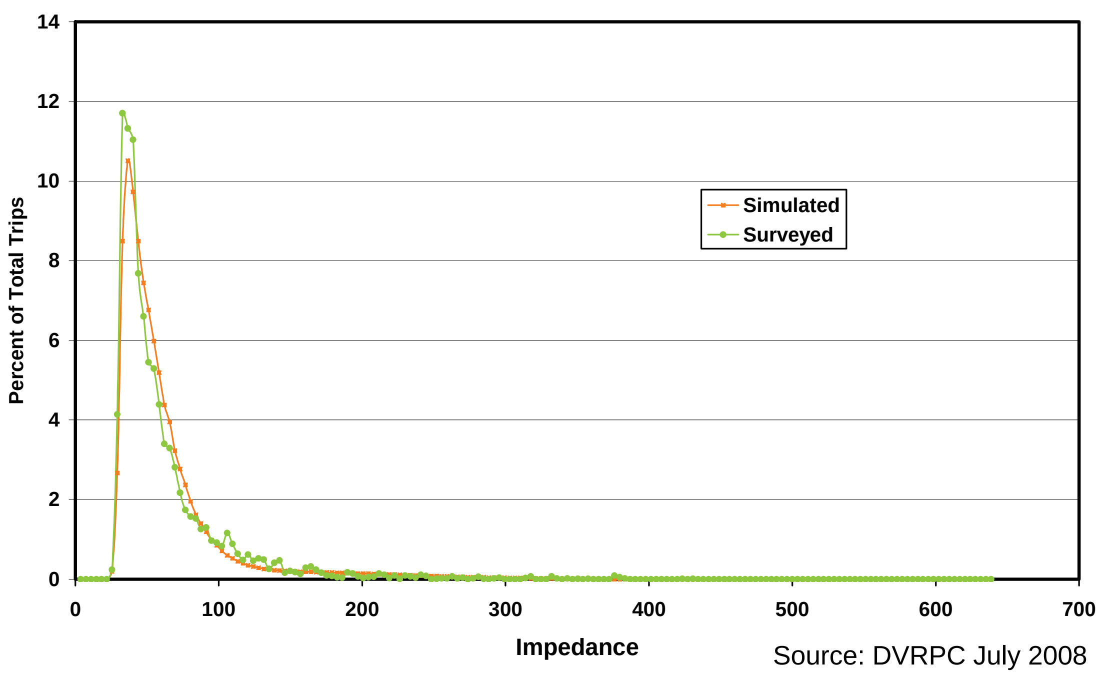
Source: DVRPC July 2008

Figure VIII-6 2000 HBW Trip Length Frequency Distribution

The surveyed and simulated trip length frequency distributions for HBNW trips are shown in ***Figure VIII-7***. The simulated trip length distribution curve reasonably matches the surveyed curve. The peak of the simulated curve is somewhat lower than the peak of the surveyed curve, but shows agreement for trips longer and shorter than the peak.

The surveyed and simulated trip length frequency distributions for NHB trips are shown in ***Figure VIII-8***. The simulated frequency distribution curve for NHB trips matches well to the surveyed curve. Similar to the HBNW curves, the peak of the NHB simulated trip length distribution curve is slightly less than the surveyed curve. Overall the agreement between the simulated and surveyed curves for NHB trips is quite close.

The normalized travel propensity functions for light truck, heavy truck, and taxi trips are shown in ***Figure VIII-9***. The taxi and light truck curves have a similar shape, with the taxi curve being less steep. The heavy truck curve falls in between the light truck and taxi curves.



Source: DVRPC July 2008

Figure VIII-7 2000 HBNW Trip Length Frequency Distribution

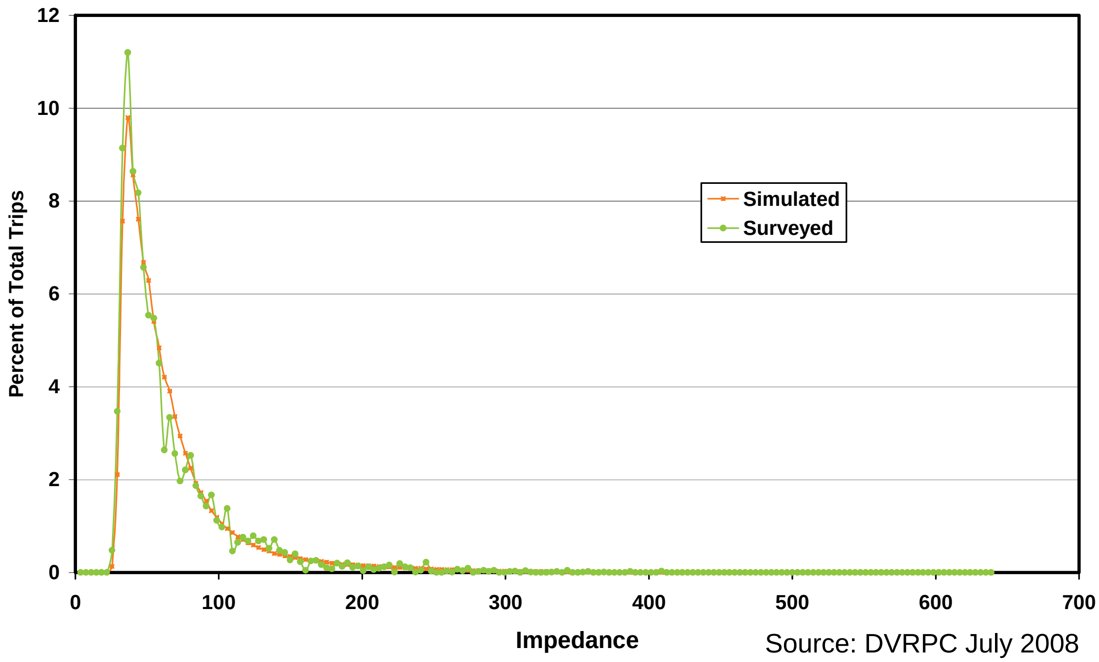


Figure VIII-8 2000 NHB Trip Length Frequency Distribution

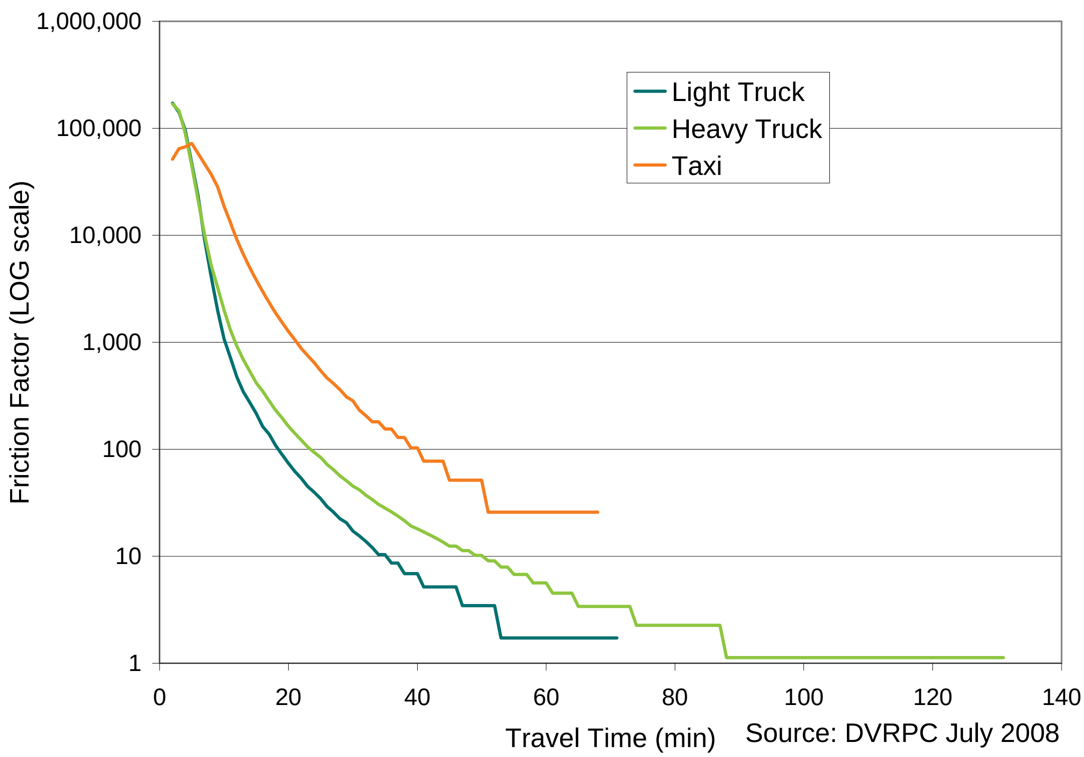
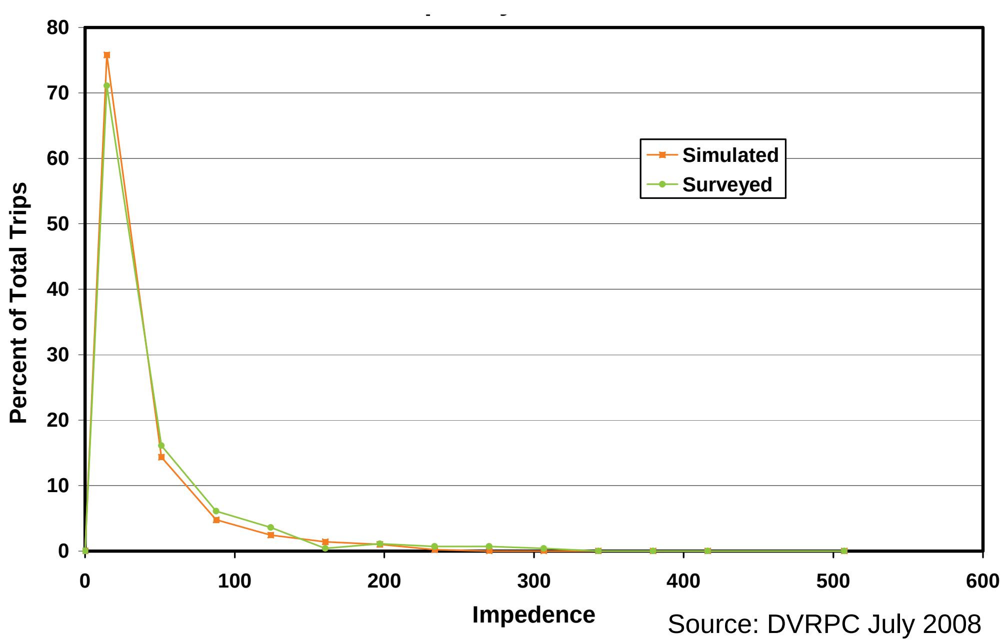


Figure VIII-9 2000 Light Truck, Heavy Truck, and Taxi Travel Propensity Function

The surveyed and simulated trip length frequency distributions for light trucks are shown in ***Figure VIII-10***. The light truck simulated trip length frequency distribution shows agreement with the surveyed trip length frequency distribution. The peak of the simulated curve is slightly greater than the surveyed curve, while the next few simulated points are slightly less than the surveyed curve. Overall, the gravity model appears to well replicate light truck trip making patterns.

The surveyed and simulated trip length frequency distributions for heavy trucks are shown in ***Figure VIII-11***. While the overall shape of the simulated curve is similar to the surveyed curve, there are some notable differences. The simulated curve is higher than the surveyed curve for shorter trips (those less than about 100 impedance) and lower than the surveyed curve for longer trips.

For reference, a graph of the trip length frequency distribution from the Truck Travel Survey is shown in ***Figure VIII-12***. Distributions for all trucks, light trucks, and heavy trucks are shown. These distributions only contain data for internal-internal truck trips. The average trip length for light trucks from the survey was 4.7 miles. Only 3.2 percent of trips were greater than 20 miles. By comparison, heavy trucks make longer trips. The average internal trip length for heavy trucks was 11.8 miles. About 18 percent of heavy truck trips had lengths greater than 20 miles.



Source: DVRPC July 2008

Figure VIII-10 2000 Light Truck Trip Length Frequency Distribution

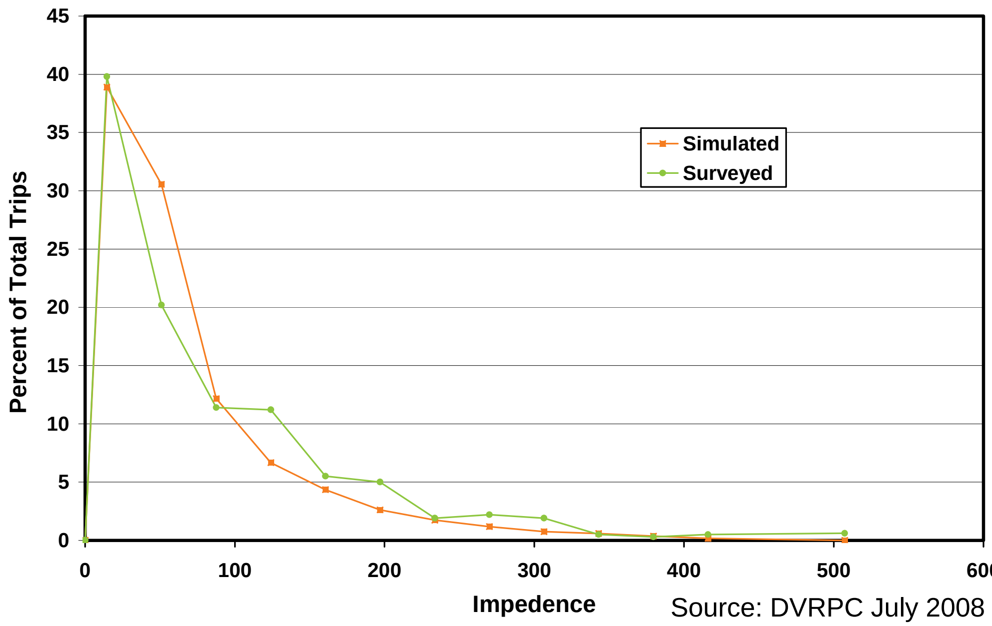


Figure VIII-11 2000 Heavy Truck Trip Length Frequency Distribution

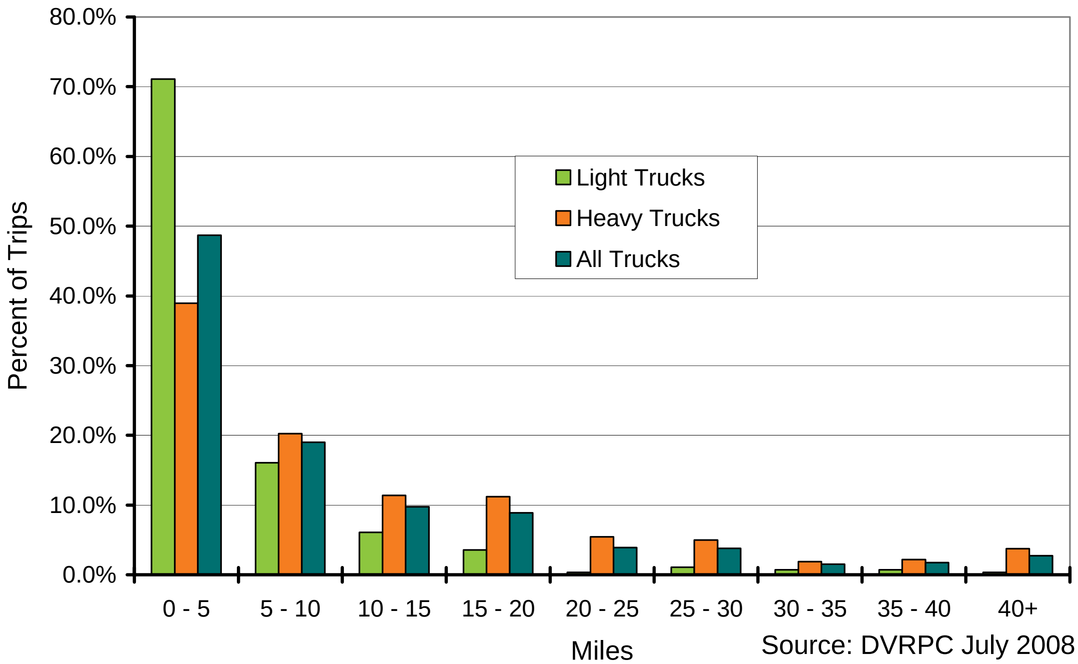


Figure VIII-12 2002 Surveyed Internal-Internal Truck Trip Length Distribution

The travel propensity curves for all four external-internal trip categories are shown in ***Figure VIII-13***. The turnpike curve is the least steep, while the local curve is the steepest. The turnpike, freeway, and arterial curves are largely log-linear in shape.

The trip length frequency distributions for both simulated and surveyed data for external-internal trips are located in ***Figures VIII-14, VIII-15, VIII-16,*** *and* ***VIII-17***. ***Figure VIII-14*** contains the chart for turnpike external-internal trips. Both the simulated and surveyed data for turnpike trips contains scatter, with the scatter being quite severe in the surveyed data. This is in part due to the limited access nature of turnpike travel, where there are significant distances between interchanges. The external-internal turnpike gravity model replicates well trips with impedances larger than about 400. The surveyed data shows a spike at about 50. This represents trips that only use one turnpike segment. The simulation model does not match this trip making pattern well. The simulation reasonably matches the trip length distribution for trips between about 100 and 200. The simulated curve tends to be higher than the surveyed curve for trips that have impedances between 200 and 300.

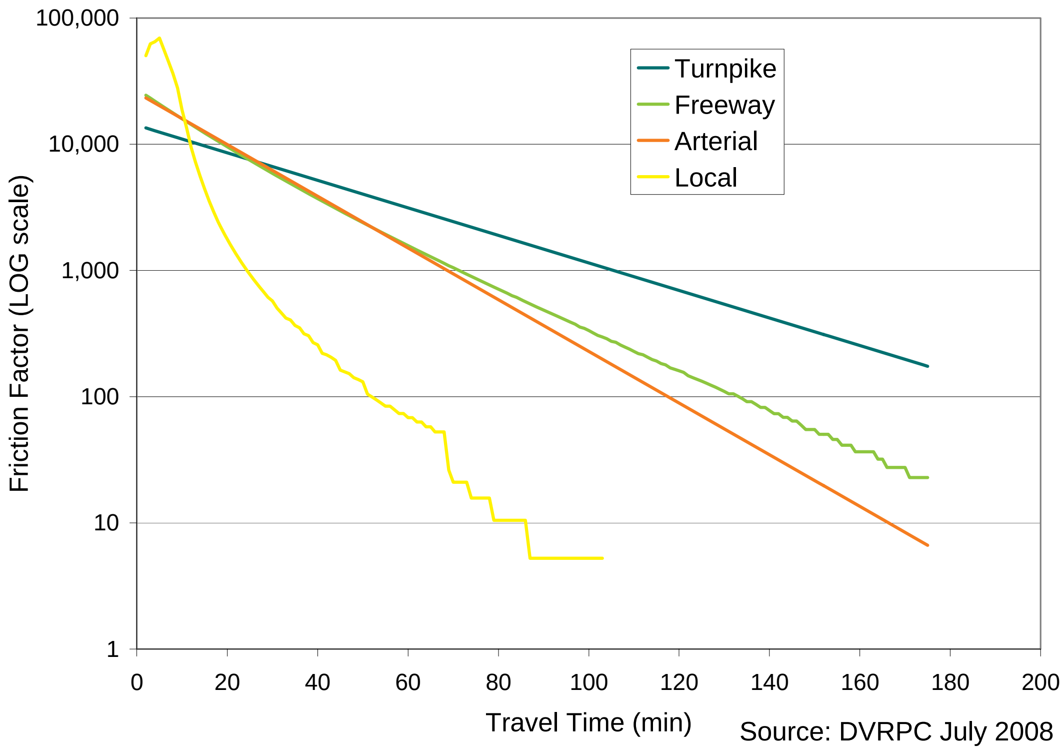


Figure VIII-13 2000 External-Internal Travel Propensity Functions

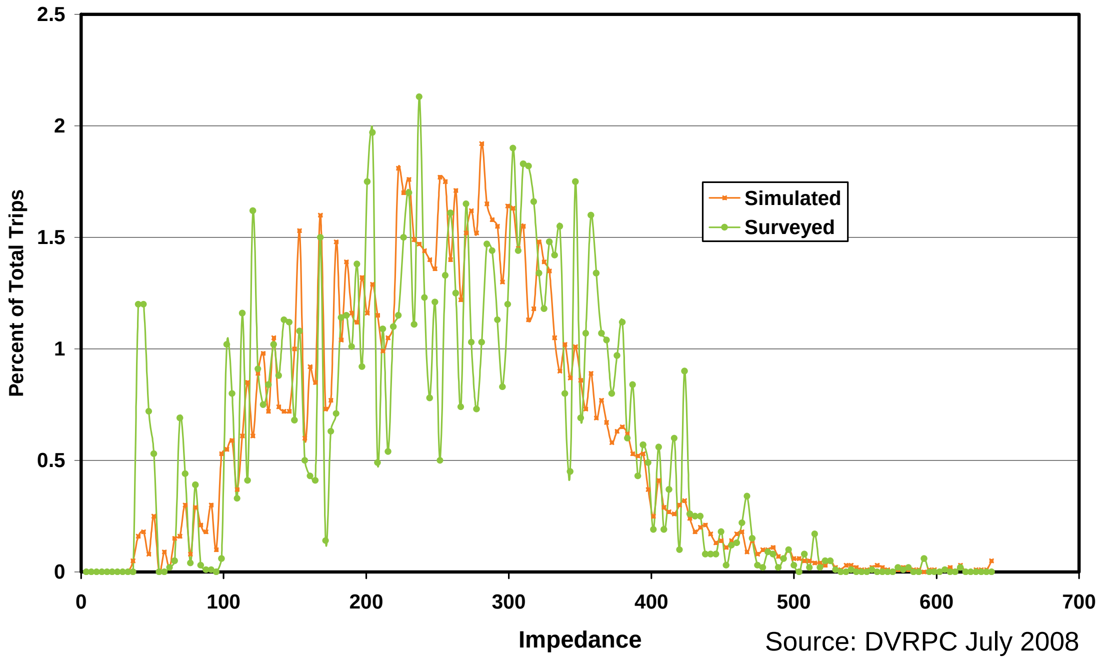


Figure VIII-14 2000 Turnpike External-Internal Trip Length Frequency Distribution

Figure VIII-15 contains the trip length frequency distributions for simulated and surveyed freeway/expressway external-internal trips. The peak of the simulated curve matches the peak of the surveyed curve well. The surveyed data contains two smaller peaks, one at about 150 and the other at about 175, that are not replicated in the simulated trip length frequency distribution. Overall, however, the simulated trip length frequency distribution matches the surveyed trip length frequency distribution quite well.

Figure VIII-16 contains the trip length frequency distributions for simulated and surveyed arterial external-internal trips. It can be seen that the arterial external-internal gravity model replicates the surveyed trip making pattern very well except for the peak. The surveyed data has a single peak that is mirrored by the simulated data, but about a percent and a half lower. However, the simulated trip length frequency distribution curve has a second peak that is not contained in the surveyed data.

Figure VIII-17 contains the trip length frequency distributions for simulated and surveyed local external-internal trips. Between the peak at about 30 and 100 the surveyed data has significant scatter that is not replicated by the simulation. But the simulation replicates the surveyed peak well and is also a good match for trips with impedances over 100. Overall the simulated trip length frequency distribution is a good match to the surveyed trip length frequency distribution.

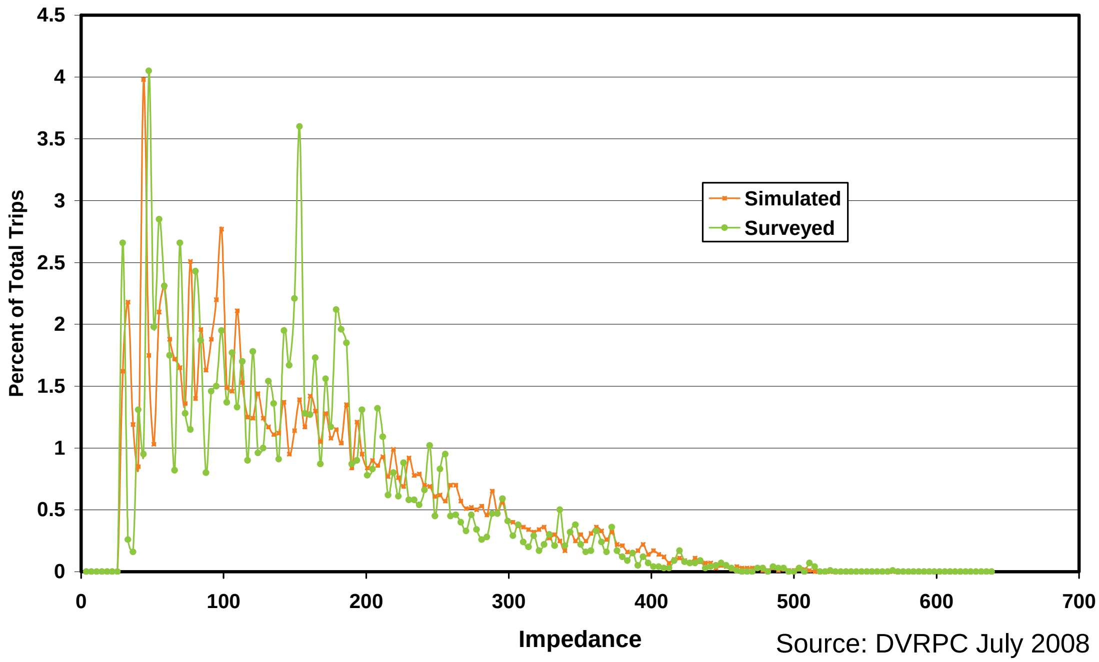


Figure VIII-15 2000 Freeway/Expressway External-Internal Trip Length Frequency Distribution

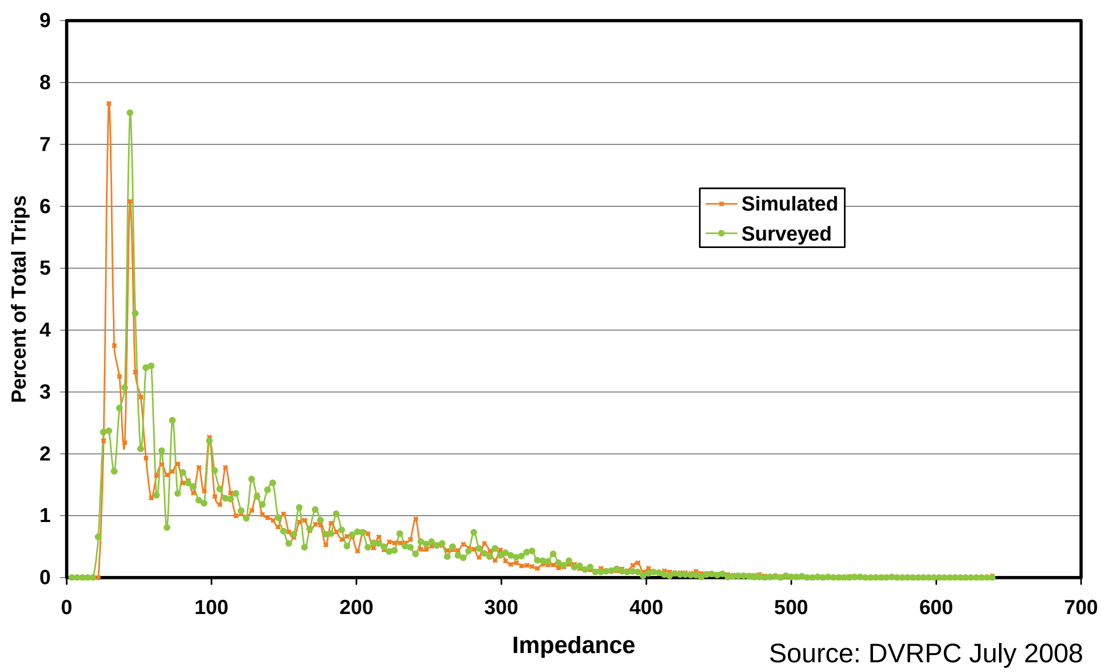
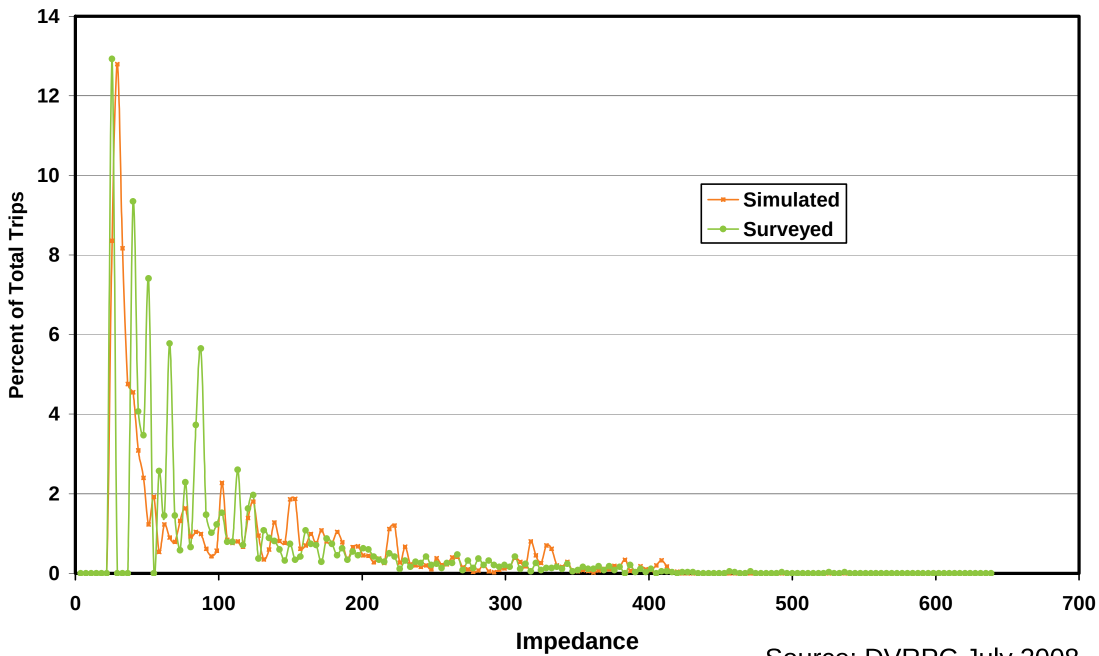


Figure VIII-16 2000 Arterial External-Internal Trip Length Frequency Distribution



Source: DVRPC July 2008

Figure VIII-17 2000 Local External-Internal Trip Length Frequency Distribution

3. River Crossing Data

Special river crossing penalties were applied to the Delaware River bridges to represent the barrier of crossing the Delaware River, which is a state boundary, and to obtain reasonable crossing volumes. This produces acceptable results for the temporal distribution of river crossing as shown in ***Table VIII-10*** for the Delaware River Port Authority (DRPA) bridges. This comparison is limited to the DRPA bridges because the hourly distribution of toll collections was not available for the other bridges on the Delaware River screenline. It is clear from this table that the temporal breakdown of DRPA bridge crossings is reasonably accurate in both absolute and percentage terms. These results verify both the temporal trip generation factors and the gravity model river penalties. The difference between the 2000 total counted traffic and simulated traffic is 6.0 percent. The difference is 3.7 percent in 2005.

Table VIII-10 2005 Traffic Volumes on DRPA Bridges by Time Period

Time Period	Counted Traffic	Simulated Traffic	Difference	Percent Difference
Peak	53,825	58,285	-4,460	-8.3 %
Midday	54,284	47,589	6,695	12.3 %
Evening	51,415	47,832	3,584	7.0 %
Total	**159,524**	**153,705**	**5,819**	**3.7 %**

Source: DVRPC July 2008

4. Intrazonal Trips

The trip distribution model determines that some trips will be attracted to the same zone in which they are produced. ***Table VIII-11*** shows a summary of intrazonal trips by trip purpose and trip type. There are no intrazonal trips for the external-internal trip purposes, as external-internal trips are prevented from being attracted to the same station where they are produced.

For internal person trips, the percentage of intrazonal HBW trips is quite low, at 3 percent. The percentage of HBNW and NHB intrazonal trips is much higher. This indicates that people tend to make shorter trips for purposes such as shopping and recreation than they do for the journey to work. The percent of intrazonal trips in 2000 is consistent with the results from the 1990 model. For internal-internal person trips the 1990 model estimated that 16.4 percent of trips were intrazonal, compared to 14.5 percent for 2000.

In general the intrazonal trips are overestimated. The HBW trip purpose is the only one not overestimated. However, only truck intrazonal trips have been adjusted to reasonable levels. The figures in ***Table VIII-11*** reflect this adjustment.

Table VIII-11 2000 Intrazonal Trips by Trip Purpose

Trip Type	Trip Productions or Origins Simulated	Number of Intrazonal Trips	2000 Percent of Trip Productions
Internal - Internal Trip Productions			
Home-based Work	4,209,197	126,276	3.0%
Home-based Non-work	10,802,846	1,868,892	17.3%
Non-home based	4,746,636	878,128	18.5%
Total Internal-Internal Trips	**19,758,679**	**2,873,296**	**14.5%**
Truck Trip Origins			
Light Truck	1,959,856	423,329	21.6%
Heavy Truck	840,356	117,650	14.0%
Total Truck	**2,800,212**	**540,979**	**19.3%**
Taxi Trip Origins	128,145	22,682	17.7%

Source: DVRPC July 2008

F. Comparison of 2005 and 2000 Results with 1990 Results

The previous figures show that the gravity model is well calibrated to reproduce regional trip making patterns. Surveyed average trip lengths are well replicated by the gravity model, as are trip length frequency distributions for all trip categories. The Delaware River crossing volumes are also well replicated by the model.

Table VIII-12 contains a comparison of simulated trip lengths in units of impedance for 2005 and 2000. The results for the two simulations are quite similar, especially for internal person trips. HBW and HBNW trip lengths agree within less than a percent. NHB trip lengths have a 1.8 percent difference between 2000 and 2005. Vehicle trip lengths show reasonable agreement between the two years, within several percent. The one outlier is taxi trip lengths which have an 11.1 percent difference between 2000 and 2005.

Table VIII-13 contains a comparison of simulated average trip lengths in minutes for 2005, 2000, and 1990. The HBW and HBNW trip lengths are slightly shorter in 2000 than in 1990, while the NHB simulated trips are longer. Comparisons are difficult for external-internal vehicle trips as 1990 used only two categories, while the 2000 and 2005 models uses four categories. The 1990 trip length for the combined turnpike/freeway category falls in-between that of the separate categories in the 2000 model. But the 1990 trip length for the combined arterial/local external-internal category is longer than both the 2000 arterial and local categories. Both taxi and light truck trip lengths are longer in the 2000 model than in the 1990 model.

Table VIII-12 Comparison of 2000 and 2005 Simulated Average Trip Lengths

Trip Type	2000 (impedance)	2005 (impedance)	Percent Difference
Internal - Internal Trip Productions			
Home-based Work	97.1	96.7	0.4%
Home-based Non-work	63.2	63.1	0.2%
Non-home based	67.8	66.6	1.8%
External-Internal Trip Attractions			
Turnpikes	257.0	255.6	0.5%
Freeways	154.5	145.9	5.6%
Arterials	127.3	129.1	-1.4%
Local Streets	102.8	95.7	6.9%
Truck Trip Origins			
Light Truck	66.8	66.1	1.1%
Heavy Truck	83.6	81.4	2.6%
Taxi Trip Origins	58.3	51.8	11.1%

Source: DVRPC July 2008

Table VIII-13 Comparison of 1990, 2000, and 2005 Simulated Average Trip Lengths

Trip Type	1990 (minutes)	2000 (minutes)	2005 (minutes)	Difference 2000-2005	Percent Diff.
Internal - Internal					
Home-based Work	28.8	26.8	26.5	0.3	1.1%
Home-based Non-work	17.7	17.3	17.3	0.0	0.0%
Non-home based	16.6	18.6	18.3	0.3	1.6%
External-Internal Trip Attractions					
Turnpikes	58.5*	70.4	70.0	0.4	0.6%
Freeways		42.3	40.0	2.3	5.4%
Arterials	42.8*	34.9	35.4	-0.5	-1.4%
Local Streets		28.2	26.2	2.0	7.1%
Truck Trip Origins					
Light Truck	10.9	18.3	18.1	0.2	1.1%
Heavy Truck	n/a	22.9	22.3	0.6	2.6%
Taxi Trip Origins	14.8	15.9	14.2	1.7	10.7%

* Turnpike and Freeways were combined into a single class in 1990, as were Arterial and Local

Source: DVRPC July 2008

Table VIII-14 contains a comparison of intrazonal trips between the 2005, 2000, and 1990 models. The 2000 model has fewer intrazonal trips for all trip categories than the 1990 model. The difference for internal-internal person trips is small, about a 4 percentage point difference at most for NHB trips. The difference for light truck trips is larger, 4.3 percent. There are 5.3 percent fewer intrazonal taxi trips in 2000 than in 1990.

The intrazonal trip percentages for 2005 are close to that for 2000, and fall in between the 1990 and 2000 values. The two exceptions to this are NHB trips and taxi trips, which are 1.2 percent and 2.8 percent lower than the 2000 results.

Table VIII-14 Comparison of 1990, 2000, and 2005 Percent Intrazonal Trips

Trip Type	1990	2000	2005	Difference 2000-2005
Internal - Internal Trip Productions				
Home-based Work	4.1%	3.0%	3.5%	-0.5%
Home-based Non-work	19.4%	17.3%	19.0%	-1.7%
Non-home based	22.7%	18.5%	17.3%	1.2%
Truck Trip Origins				
Light Truck	n/a	21.6%	22.1%	-0.5%
Heavy Truck	n/a	14.0%	14.1%	-0.1%
Taxi Trip Origins	23.0%	17.70%	14.9%	2.8%

Source: DVRPC July 2008

IX. MODAL SPLIT MODEL

The purpose of the modal split model, also called mode choice, is to allocate the internal person trips that were developed in the trip distribution model to either the highway network or the transit network. The modal split model works on each person trip interchange, or TAZ pair, in each trip table. The percent of each interchange using transit is calculated. This is done by calculating the impedance difference (ID) between the highway and transit networks for travel between TAZs and then inputting this impedance difference into a model. The percentage of transit trips is subtracted from the total interchange volume. The remaining trips are allocated to the highway system. The DVRPC modal split model is nested by mode of approach – walk/bus versus auto.

After the modal split model, the highway person trips are further divided into auto driver and auto passenger trips by the auto occupancy model, which is discussed in the next chapter. The auto driver trips are added to the truck, taxi, and external vehicle trips in preparation for traffic assignment to the highway network.

The DVRPC modal split model does not determine the submode (commuter rail, subway-elevated, or surface bus and trolley) of travel for the transit trips. The model only determines the total number of transit trips that will be allocated to the transit system. The transit submode used for travel between any two TAZs is determined based on the minimum impedance path through the transit network. The minimum impedance mode together with the transit/auto impedance difference determines the modal split.

In the DVRPC modeling scheme, the choice of mode is determined after trip distribution. This is referred to as a post-distribution modal split model. Other models, such as that used by small urban areas without extensive transit systems, allocate the trips to either the transit or highway systems during the trip generation phase of the process, before trip distribution is made.

The relationship of the modal split model to the other models in the travel simulation process is shown in ***Figure IX-1***. The trip distribution model feeds person trip tables to the modal split model. The trip tables determined in the trip distribution model are input to the modal split model after the transit bias adjustment. The total number of trips by purpose and time period input to the modal choice model for 2000 and 2005 are shown in ***Table IX-1***.

Highway and transit travel times are determined from the highway and transit networks and then input to the modal split model. Separate transit travel times are needed for each major submode – Subway/Elevated, Regional Rail, and Surface (Bus and Trolley). The least impedance mode is used as the default submode for each particular zone-to-zone interchange.

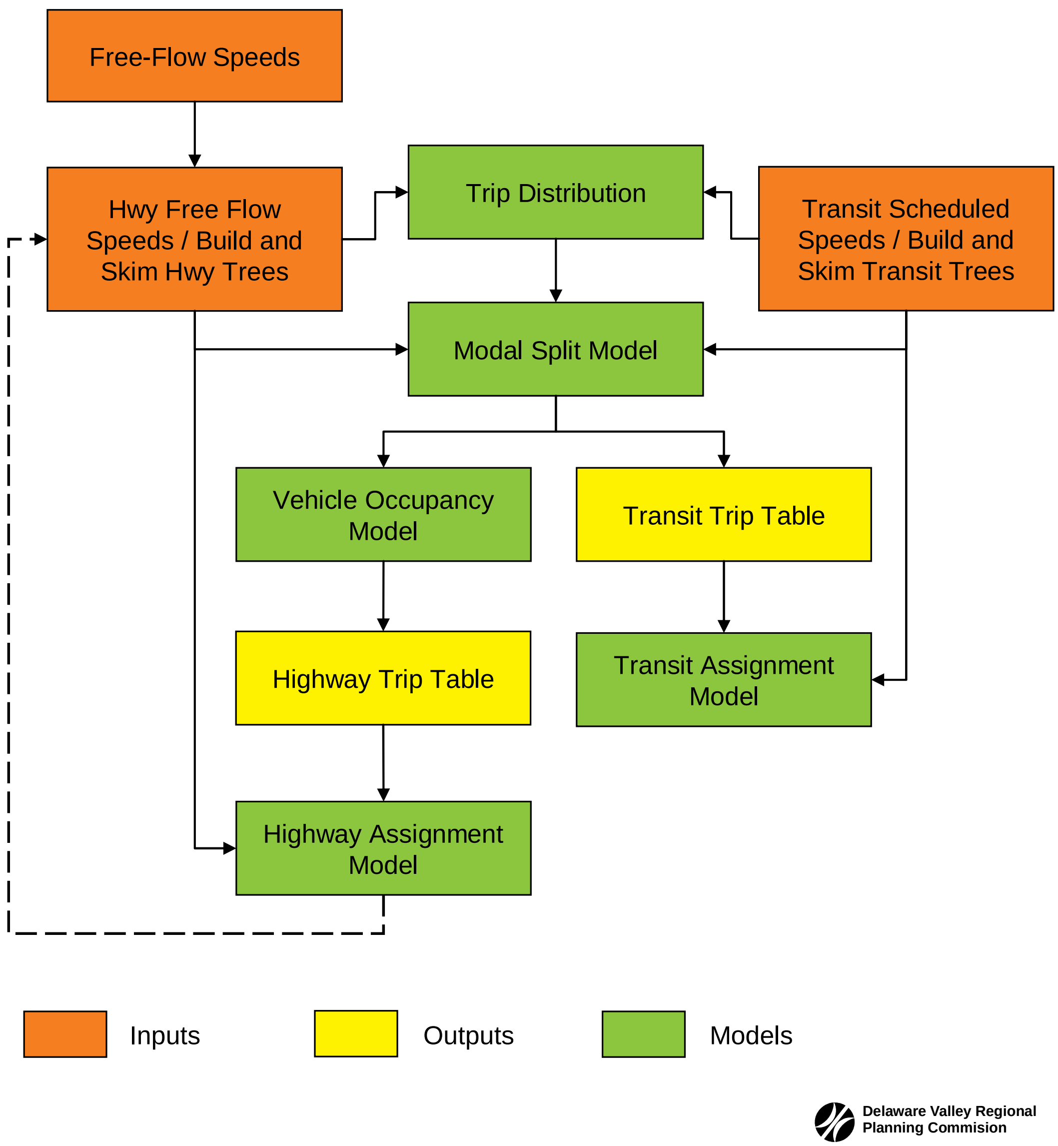


Figure IX-1 Modal Split and Vehicle Occupancy Models in the DVRPC Modeling Process

Table IX-1 Trip Inputs to the Modal Split Model after Transit Bias Adjustment

2000

Trip Purpose	Peak	Midday	Evening	Total
HBW	2,320,770	751,169	1,144,155	4,216,094
HBNW	4,334,953	3,556,166	2,916,659	10,807,778
NHB	1,433,683	2,582,373	730,972	4,747,028
Total	**8,089,406**	**6,889,708**	**4,791,786**	**19,770,900**

2005

Trip Purpose	Peak	Midday	Evening	Total
HBW	2,381,625	770,928	1,174,463	4,327,016
HBNW	4,496,076	3,688,365	3,025,282	11,209,723
NHB	1,475,714	2,658,147	752,435	4,886,296
Total	**8,353,415**	**7,117,440**	**4,952,180**	**20,423,035**

Source: DVRPC July 2008

Given the input trip tables and impedance difference the modal split model produces highway and transit person trip tables by purpose using diversion curves derived from the calibrated logit model. The highway person trip tables are fed into the vehicle occupancy model to produce vehicle trip tables. These are assigned to the highway network in highway assignment. The transit trip table is assigned to the transit network in transit assignment.

This chapter fully describes the DVRPC nested modal split model for the 2000 and 2005 simulations. The model used in the 1990 travel simulation is described first. The transition from the probit type model used in 1990 to the logit type model used in 2000 and 2005 is described next. The updated model is then described in detail including input data, model operation, special requirements for FTA projects, and model results. Finally, the results from the 2000 and 2005 simulations are compared to the 1990 model results.

A. Description of the 1990 Modal Split Model

The 1990 travel simulation used a binary probit model to predict modal split. The term binary refers to the choice between two options – transit and highway. The term probit refers, mathematically, to the assumption that the errors in measuring the factors that travelers use to make mode choice decisions are normally distributed. The probit model can be stated mathematically as:

$$\%Transit_{ij} = \Phi(X) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{a+bX} \exp\left(-\tfrac{1}{2} Z^2\right) dZ$$

where:

- $\Phi(\cdot)$ Normal cumulative distribution function (CDF)
- Z integration variable
- a+bX linear predictor
- a,b additive and multiplicative calibration constants, respectively
- X independent variable upon which modal split depends
- $\exp(\cdot)$ exponential function, $\exp(x) = e^x$, $e \approx 2.71828...$

The independent variable used to predict modal split is the difference in impedance between transit and highway to travel from *i* to *j*. This is consistent with the theory of individual disutility minimization behind travel forecasting – that travelers will choose the least cost (impedance) option that meets their travel needs. The measure X could be used directly to predict mode split instead of being used in conjunction with the probit function if the measure X were complete enough to capture all the factors that individuals use in making travel decisions. But since it is impossible to estimate all factors used by every individual, the probit function adds some "dispersion" to the modal split model to account for these unincluded factors.

The definition of impedance difference used in the modal split probit model is very similar to the one used in the trip distribution model to correct for transit bias (**Chapter VIII**)

$$ID = K_1 \frac{Y}{P}(w_{ijt} - w_{ija}) + K_2 \frac{Y}{P}(c_{ijt} - \sum_{a \in R_{ij}} c_a) + K_3 \frac{1}{P}(k_{ijt} - \sum_{a \in R_{ij}} k_a - s_j) + K_4 TRFR_{ij} + IF$$

where the following variables were defined and used earlier:

- $K_{1,2,3,4}$ factors to convert to impedance
- Y change in average household income in the region, expressed as an index with 1990 as the base year
- P change in the consumer price index for the region, expressed as an index with 1990 as the base year
- a a link in the highway network
- c_a in-vehicle time to travel on link *a*
- R_{ij} the minimum cost highway route from *i* to *j*
- k_a the vehicle operating cost for link *a*
- s_j parking cost for zone *j*
- w_{ij} out of vehicle travel time for *i* and *j*

- c_{ijt} transit in-vehicle travel time between *i* and *j*
- k_{ijt} transit cost, including fare, between *i* and *j*
- w_{ijt} transit out of vehicle travel time for travel between *i* and *j*
- $TRFR_{ij}$ number of transfers in transit route from *i* to *j*
  and where the following additional factor is used:
- *IF* Factor to express the impact of land use on modal split

As in trip distribution, the impedance by highway consists of in-vehicle and out-of-vehicle travel time, auto operating costs, and parking charges. The highway travel cost is the perceived operating cost, including gas, oil, tires, maintenance, and insurance. Parking charges are based on the zone of trip attraction (or destination). Toll charges are incorporated into the highway network as time penalties, as discussed in **Chapter V**. The highway in-vehicle times were determined by constructing minimum cost trees (skims) from the highway network with the link costs fixed.

Transit impedance consists of in-vehicle time, out-of-vehicle time, fare, and transfer penalty. The transit impedance was also determined by constructing trees of minimum cost through the network. The minimum cost route determined the submode, the in-vehicle time, the affect of wait time on out-of-vehicle time, and the transfer penalty.

The affect of land use is considered at both the origin (production) end of the trip and the destination (attraction) end by explicit network coding of certain impedance values on the approach links. Land use is also considered by the inclusion of the impedance factor, *IF*. The *IF* depends on the origin and destination area types. The inter-area impedance factors used for the 2000 and 2005 models came from the 1990 model unchanged and appear in ***Table IX-2***.

Table IX-2 Impedance Factors for Land Use by Area Type for the 1990, 2000, and 2005 Models

From Area Type	To Area Type	Factor
1	1	-100
1	2,3	-45
1	4,5,6	0
2,3	1	+20
2,3	2,3	-15
2,3	4,5,6	+30
4,5,6	1	+5
4,5,6	2,3	+5
4,5,6	4,5,6	+100

Source: DVRPC July 2008

As is well known, the integral in the above normal CDF for the probit model can not be computed in closed form, but must be computed numerically. These computations have been compiled into lookup tables. In practice, the 1990 DVRPC binary probit model involved calculating the linear predictor *a+b(ID)*, also referred to as the "standard score," to assess the relative competitiveness of transit versus highway for any given trip interchange *i* to *j*. The standard score was then used with a normal CDF lookup table to determine the percent transit.

The use of the linear predictor based on the *ID* together with the normal CDF lookup table produced diversion curves to estimate the percent transit for a given *ID*. The diversion curves relate a stratum of impedance difference to the percent of transit for a trip interchange. In general the greater, the impedance difference (poor transit), the lower the standard score and the lower the percent allocated to transit. In order to sufficiently capture the various factors that affect modal split, 18 different diversion curves were used. These different diversion curves were obtained by adjusting the "*a*" and "*b*" parameters. The 18 different curves were formed from all the permutations of trip purpose (3), transit submode (3), and auto ownership (2):

- Trip Purpose (3)
  1. Home-based work
  2. Home-based non-work
  3. Non-home based
- Transit Submode (3)
  1. Regional Rail
  2. Subway-elevated
  3. Surface bus/trolley
- Auto Ownership (2)
  1. Trip interchanges by autoless households
  2. Trip interchanges by car-owning households

The eighteen diversion curves for the 1990 model are shown below. Each of the curves has a sigmoid or "S" shaped function. ***Figure IX-2*** shows the diversion curves for HBW trips for zero vehicle households for all three transit submodes, while ***Figure IX-3*** shows the curves for HBW trips for all three submodes for vehicle owning households

It should be noted that for HBW trips the bus modal split is smaller than that for the other two transit modes, except for zero-car households with high impedance differences. Also, the modal splits for transit are uniformly lower for auto owning households than for non-auto owning households.

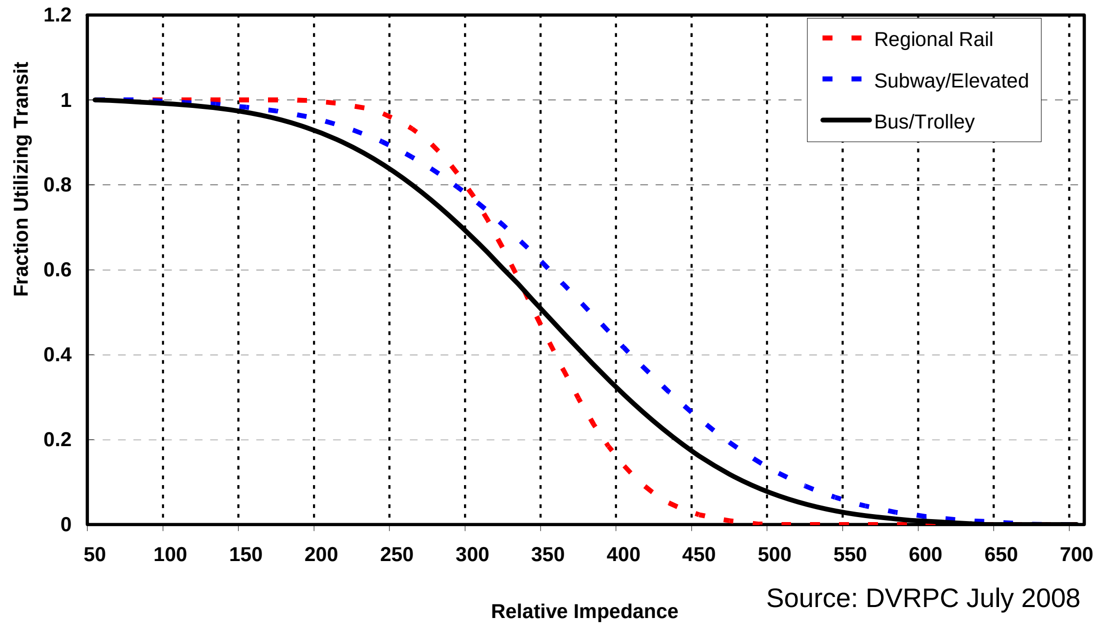


Figure IX-2 1990 Probit Modal Split Diversion Curves for HBW Trips for Zero Vehicle Households

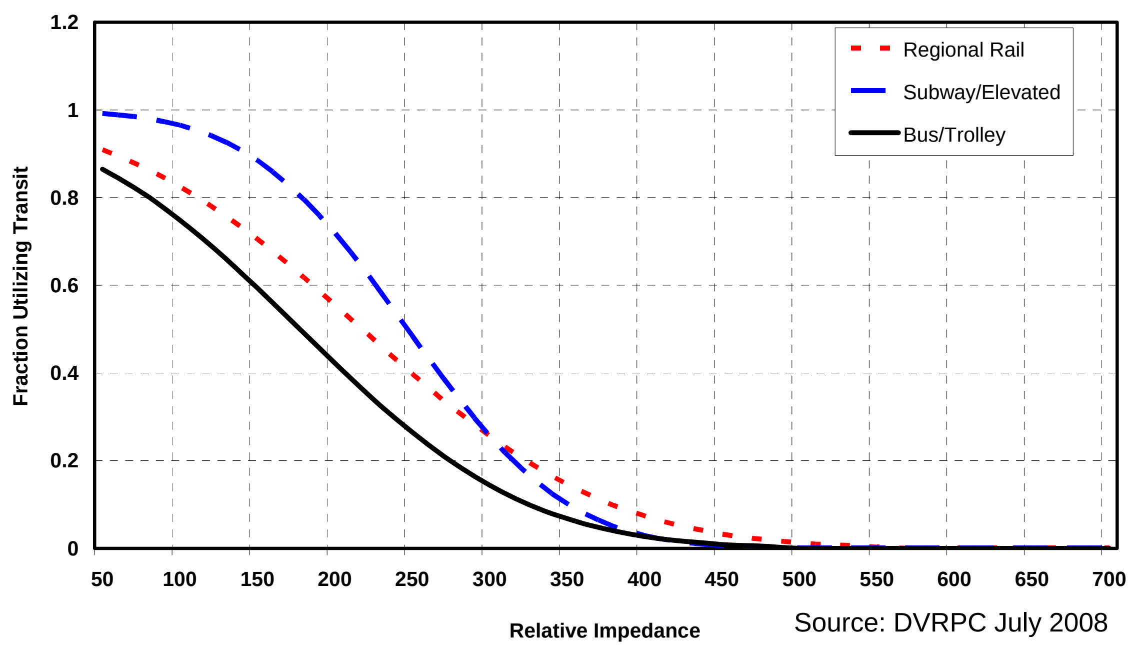


Figure IX-3 1990 Probit Modal Split Diversion Curves for HBW Trips for Vehicle Owning Households

Figure IX-4 contains the 1990 probit diversion curves for home-based non-work trips for non zero vehicle households. ***Figure IX-5*** contains the 1990 probit diversion curves for home-based non-work trips for vehicle owning households. These curves predict a lower transit modal split than the HBW curves. Similar to the HBW diversion curves, the curves for the auto owning households have lower transit modal splits than the non auto-owning households. For most trips the subway/elevated transit sub-mode has higher mode splits than the other modes. For the non-auto owning households the bus mode has lower modal splits for the same impedance difference than either subway/elevated or railroad up till about 330, after which bus/trolley outperforms regional rail.

Figure IX-6 contains the 1990 probit diversion curves for non-home based trips for zero vehicle households. ***Figure IX-7*** contains the 1990 probit diversion curves for non-home based trips for vehicle owning households. The subway/elevated mode does not outperform the other modes as much for NHB trips as for the other two purposes.

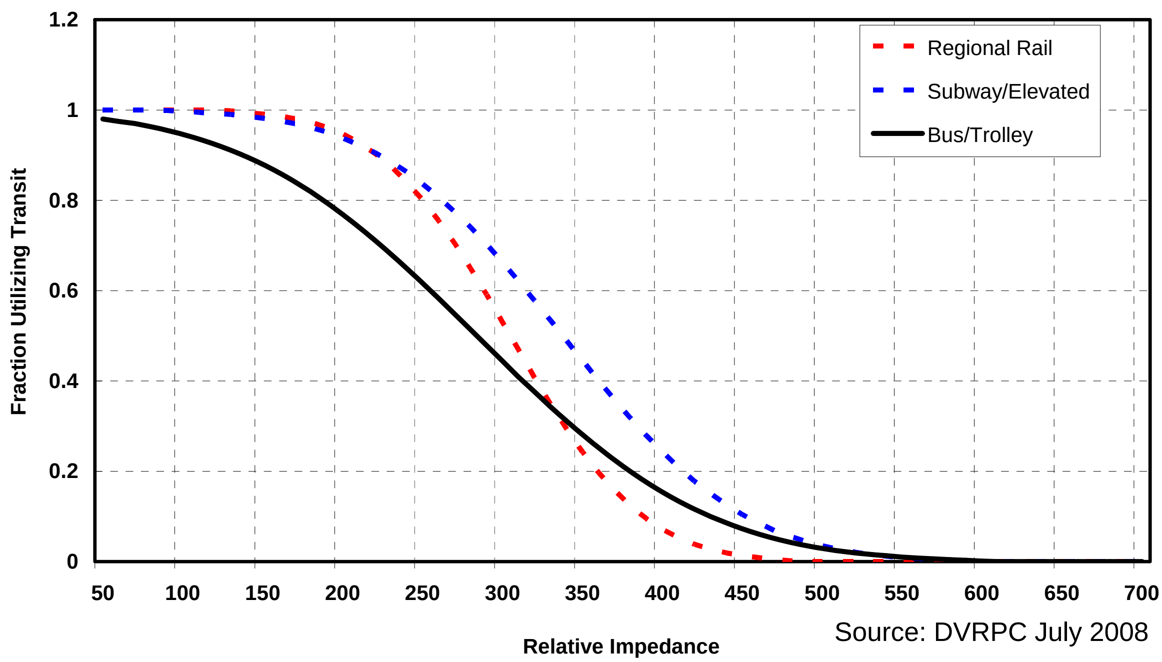


Figure IX-4 1990 Probit Modal Split Diversion Curves for HBNW Trips for Zero Vehicle Owning Households

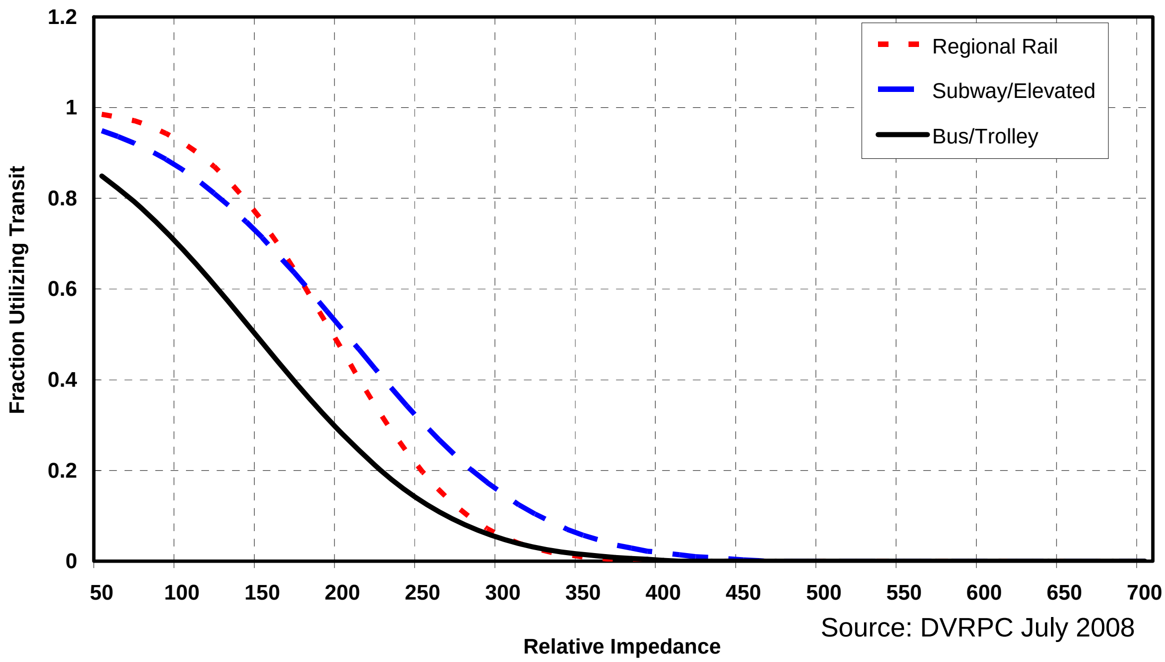


Figure IX-5 1990 Probit Modal Split Diversion Curves for HBNW Trips for Vehicle Owning Households

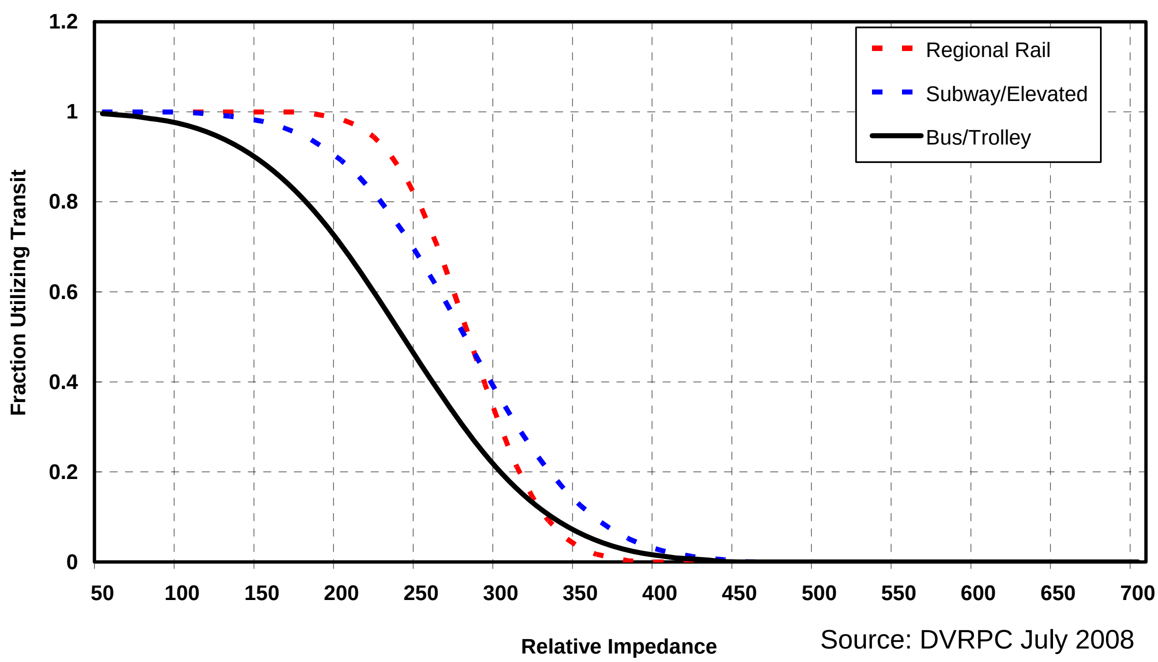


Figure IX-6 1990 Probit Modal Split Diversion Curves for NHB Trips for Zero Vehicle Owning Households

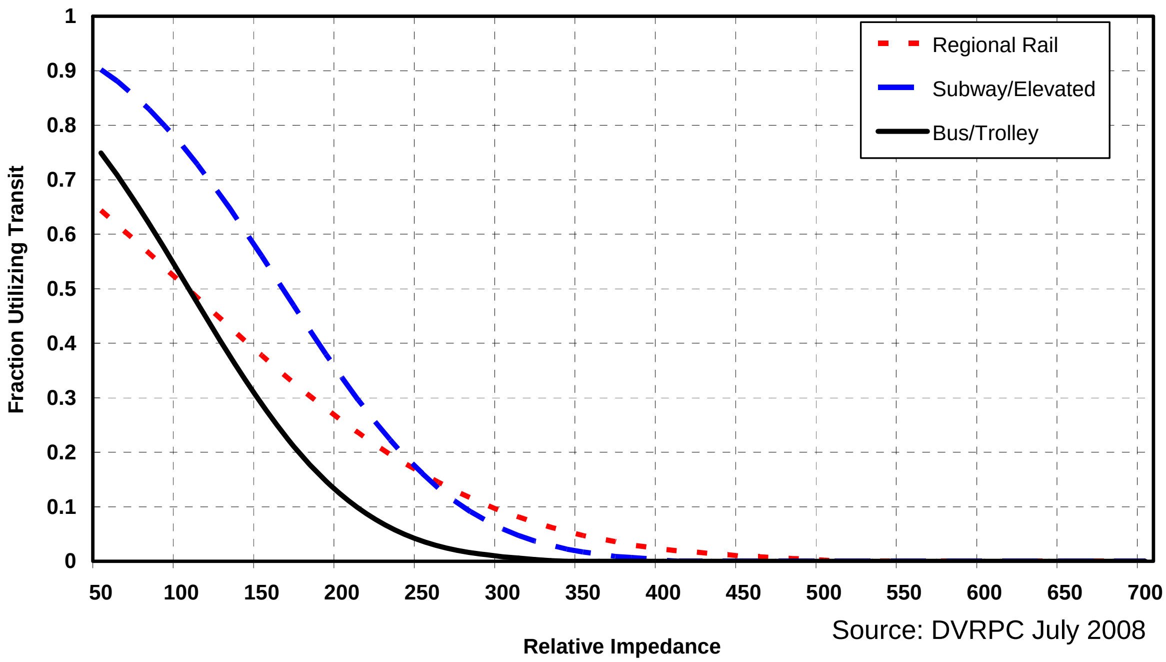


Figure IX-7 1990 Probit Modal Split Diversion Curves for NHB Trips for Vehicle Owning Households

The transit modal split as determined by the probit model diversion curves was bounded above and below by a set of mode captivities. These figures set a floor and ceiling on the transit mode share by assuming that some portion of travelers will always choose either auto or transit, regardless of the impedance difference. These mode captivities depend on the time of day and the individual transit submode.

The 1990 probit model predicted transit boardings satisfactorily. The overall transit ridership was within 1.2 percent of average daily transit boardings as obtained from transit traffic counts. The error by mode was equal to or less than 3 percent. Subway-elevated ridership was under predicted by about 2 percent, while overall bus and trolley ridership was over predicted by about 3 percent. Regional rail ridership was over predicted by about 0.5 percent.

Data from both the census and the household travel survey was used to evaluate the HBW model results. Unfortunately, there was significant disagreement between the census and household travel survey results for CBD HBW mode split, as seen below.

Percent of HBW Trips by Transit

Source	1990 Philadelphia CBD	1990 DVRPC Region
1990 Census CTPP	48.7	12.4
1987-88 Home Interview	61.3	12.9
Employee Trip Reduction	55.0	11.0
1990 Calibrated Modal Split	54.9	12.4

Source: DVRPC July 2008

For CBD trips, the census appears to be biased against transit. This is largely due to the occasional rider phenomenon, where individuals usually drive and hence indicate this on the census form, but also occasionally use transit. To reconcile the differences between the census and the household travel survey estimates, the Employee Trip Reduction (ETRP) Survey was considered. The ETRP survey, taken in 1992, was limited to work trip modal usage, but was based on a much larger sample than the household travel survey. The ETRP survey estimated the modal split for Center City HBW trips at 55 percent. This is above the average of the census and household travel survey estimates. This was assumed to be the correct estimate. The 1990 calibrated modal split model produces CBD results close to this estimate, within one tenth of one percent.

B. Conversion of the DVRPC Modal Split Model from a Probit to Logit Formulation

The probit modal split model used in the 1990 simulation adequately estimated transit boardings by mode. However, the probit formulation is not compatible with the FTA's New Starts transit evaluation criteria. The FTA SUMMIT evaluation process requires logit formulation parameters to estimate user benefits from the proposed facility. For this reason the 2000 model used a logit formulation to comply with FTA requirements. The 2005 model uses the same logit formulation as the 2000 model. Fortunately, conversion of the DVRPC modal split model from probit to logit was relatively straight forward. The 1990 probit model was converted to a logit model for the 1997 simulation, as described below.

The standard binary logit formulation to determine transit mode share is:

$$\%\,\text{Transit} = \frac{\exp(-\mu c_t)}{\exp(-\mu c_t) + \exp(-\mu c_a)} = \frac{1}{1 + \exp(-\mu(c_a - c_t))}$$

where:

- $\exp(\cdot)$ the exponential function

- μ dispersion parameter
- $c_{a,t}$ cost (impedance) of either auto or transit

The quantity $-\mu(c_a - c_t)$ is the linear predictor used in the logit model, similar to the one used in the probit formulation. The dispersion parameter governs how strictly individuals will choose the least cost modal alternative.

The probit curve has some slight theoretical advantages over the logit formulation because it is based on the normal distribution. However, the shape of the logit modal split curve is nearly identical to the probit curve. The logit model has the added advantage that it can be stated and solved in simple closed form, unlike the probit model.

In order to show that the logit model has similar characteristics to the probit model, two demonstrations are made here. First it is demonstrated that the logit model, like the probit model, estimates an even split for transit and auto when the impedance difference (c_a – c_t,) is equal to zero. Secondly, it will be demonstrated that similar to the probit model, the inflection point of the logit model occurs when the impedance difference is equal to zero.

In order to demonstrate the first point, we set c_a = c_t in the logit formula. This results in:

$$\%\,\text{Transit}\,\Big|_{c_a=c_t} = \frac{1}{1+\exp(0)} = \frac{1}{1+1} = 0.5$$

because any number raised to the power of zero equals one. When the cost of transit and auto are equal, the impedance difference is zero and the modal split model predicts a 50 percent transit modal split.

The second demonstration is made using simple calculus. Whenever the second derivative of a function is zero at a point, then that point must either be a maximum, a minimum, or an inflection point. A maximum or minimum can be ruled out because of the sigmoid shape of the logit function. To find the inflection point of the logit function we must merely find the second derivative and set it to zero. For ease of notation we set $ID = c_a - c_t = x$ and % Transit = y :

$$y(x) = \frac{1}{1+\exp(-\mu x)}$$

$$\frac{dy(x)}{dx} = \frac{-\mu\exp(-\mu x)}{(1+\exp(-\mu x))^2}$$

$$\frac{d^2y(x)}{dx^2} = \frac{\mu^2 \exp(-\mu x)(1-\exp(-\mu x))}{(1+\exp(-\mu x))^3} = 0$$

The second derivative can only be equal to zero if exp(-μx) = 0 or exp(-μx) = 1; the former occurs when if x = ID = 0. Hence the inflection point of the logit function, like the probit function, occurs when ID = 0.

The conversion from the probit model to the logit model was relatively straight forward since the two models have nearly identical diversion curves. To facilitate the conversion, the logit model is rewritten as follows:

$$\%\ \text{Transit} = \frac{\exp(a'+b'(ID))}{1+\exp(a'+b'(ID))}$$

where:

- a',b' additive and multiplicative calibration constants for the logit model
- ID impedance difference, identical to that defined for the probit model

It should be noted that the definition of ID used in the above equation is transit minus auto impedance, while that used in the original logit model is auto costs minus transit costs. The next step is to reformulate the logit linear predictor $a'+b'(ID)$ as:

$$a'+b'(ID) = b'(ID+k')$$

where:

$$k' = \frac{a'}{b'}$$

The conversion from the probit to logit model for each of the 18 curves is accomplished by the following four steps:

Plot the graph of the probit curve and find the ID value *k* associated with the inflection point. This will be the location where there is a 50 percent transit modal split.

1. Set *k'* = -*k* and plot the associated logit diversion curve on top of the probit curve.
2. Adjust the value of *b'* so as to minimize the discrepancy between the plots of the logit and probit curves.
3. By inspection of the graphs iteratively fine tune the estimates of *k'* and *b'* to minimize the discrepancy between the two curves.

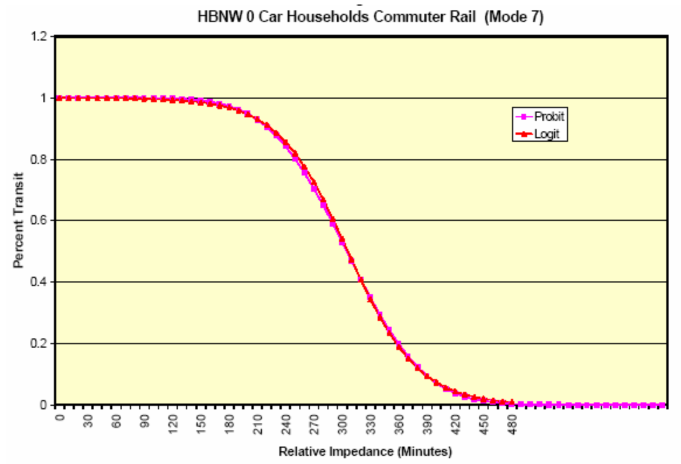
The diversion curves for each of the 18 probit modal split models were converted to logit formulations using the above procedures. The resulting calibration constants are shown in ***Table IX-3***. ***Figures IX-8 to IX-10*** compare the 3 probit and logit diversion curves for zero and 1+ car households for the commuter rail mode as an example. As can be seen in these figures the differences between the probit and logit modal split models are almost zero. Negligible differences between these two models are also found for the subway-elevated and surface transit modes.

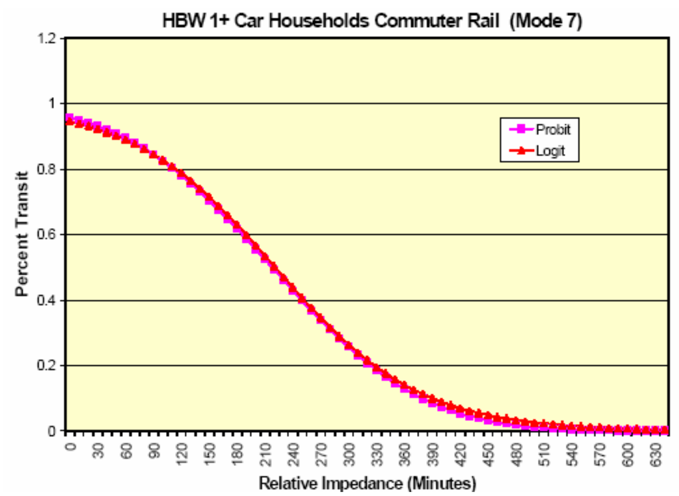
Table IX-4 presents the daily transit ridership by transit company and division for the 1997 model as estimated by both the probit and logit models. The largest percent differences are in those divisions with small ridership – the SEPTA Frontier division with a 12 percent difference and the NJT Mercer division with a 7 percent difference. Even these differences are not significant for most planning and forecasting purposes. These differences can easily be corrected in the model calibration of regional simulations and focused transit studies. Overall, the conversion from probit to logit changed the simulated daily ridership by about 0.2 percent.

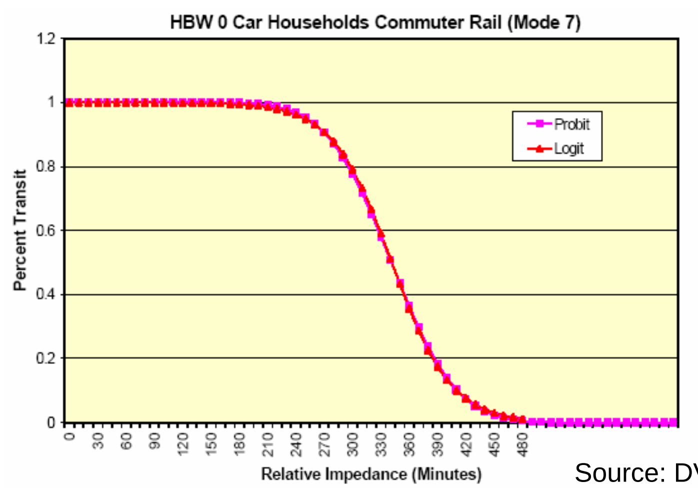
Table IX-3 Parameters for the 1997 Modal Split Model Converted to Logit Form

Transit Submode	Purpose	Autos Owned	k'	a'	b'
Commuter Rail	HBW	0	-341.5	10.93	-0.032
Commuter Rail	HBNW	0	-306.0	8.26	-0.027
Commuter Rail	NHB	0	-279.0	12.83	-0.046
Commuter Rail	HBW	1+	221.0	2.87	-0.013
Commuter Rail	HBNW	1+	-195.0	5.07	-0.026
Commuter Rail	NHB	1+	-105.0	1.21	-0.012
Subway-Elevated	HBW	0	-375.0	6.00	-0.16
Subway-Elevated	HBNW	0	-337.5	6.413	-0.019
Subway-Elevated	NHB	0	-277.0	7.76	-0.028
Subway-Elevated	HBW	1+	-246.6	5.43	-0.022
Subway-Elevated	HBNW	1+	-202.0	3.84	-0.019
Subway-Elevated	NHB	1+	-162.8	3.26	-0.020
Surface	HBW	0	-347.0	5.55	-0.016
Surface	HBNW	0	-287.0	4.16	-0.015
Surface	NHB	0	-239.0	5.40	-0.023
Surface	HBW	1+	-178.0	2.60	-0.015
Surface	HBNW	1+	-145.0	2.61	-0.018
Surface	NHB	1+	-105.0	2.21	-0.021

Source: DVRPC July 2008







Source: DVRPC July 2008

Figures IX-8, 9, & 10 Logit and Probit Diversion Curves for Zero Car Households for Commuter Rail

Table IX-4 1997 Transit Ridership as Estimated by Probit and Logit Modal Split Models

Company	Probit Model	Logit Model	Difference	Percent Difference
SEPTA CTD	838,016	835,042	-2,974	-0.4%
SEPTA Victory	42,223	44,105	1,882	4.5%
SEPTA Frontier	10,200	11,443	1,243	12.2%
SEPTA Regional Rail	87,886	88,391	505	0.6%
SEPTA Subtotal	**978,325**	**978,981**	**656**	**0.1%**
NJ TRANSIT Mercer	14,719	15,843	1,124	7.6%
NJ TRANSIT Southern	33,440	35,200	1,760	5.3%
NJT Subtotal	**48,159**	**51,043**	**2,884**	**6.0%**
PATCO	34,483	33,577	-906	-2.6%
Grand Total	**1,060,967**	**1,063,601**	**2,634**	**0.2%**

Source: DVRPC July 2008

C. 2000 and 2005 Modal Split Models

The 2000 and 2005 nested modal split models use a logit formulation. This section describes the 2000 and 2005 models. The nested modal split is described first; input data are described next, with an explanation of the adoption of the INET program. Model operation is described followed by a comparison of 1990, 2000, and 2005 model results.

1. DVRPC Nested Modal Split Model

The DVRPC nested modal split model is incorporated into the three time period Evans iterative model described previously. This model differs from the 1990 DVRPC model in that the model is now nested by mode of approach ***(see Figure IX-11)*** in addition to be transformed from probit to logit. Walk/bus approach transit trips are modeled separately from auto approach transit trips in the modal split/transit assignment models each using separate transit network configurations. Following the separate transit assignments, the transit volumes are merged together and summarized to reflect total transit riding.

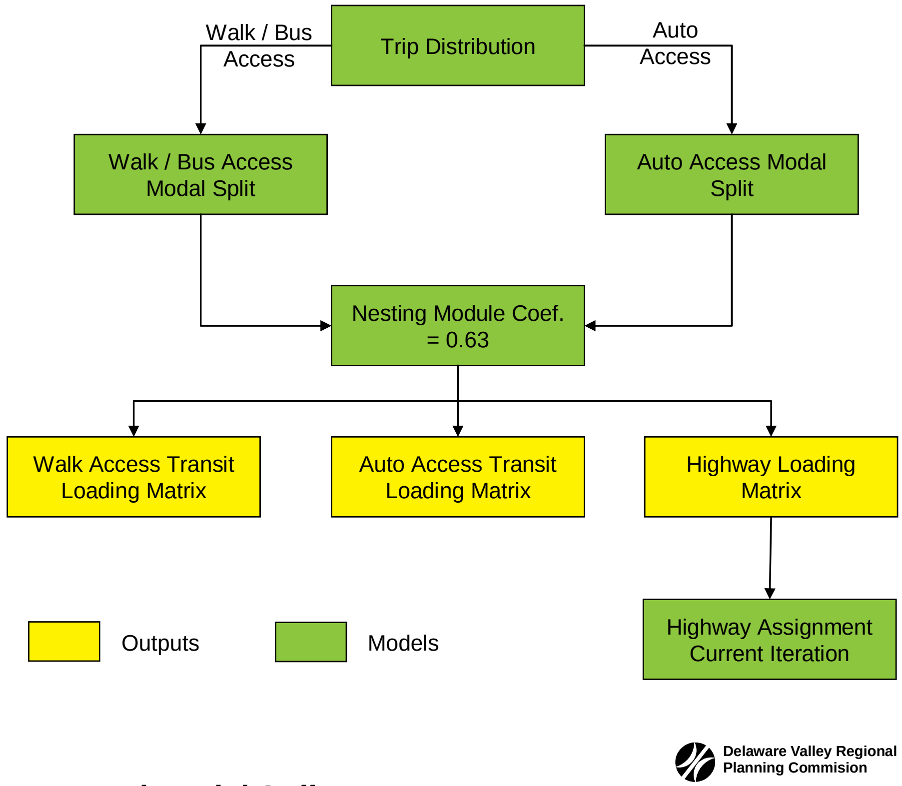


Figure IX-11 Nested Modal Split Process

This nested process is executed in a straight forward way within the Evans iterative execution job stream. The modal split portion of the control files are similar in scope to the 1990 DVRPC model except that the modal split/transit assignment control file is now more complex. External-internal transit trips are added to the walk/bus approach trip table prior to the walk/bus approach assignment step of the simulation process (omitted from ***Figure IX-11*** for simplicity).

The nested modal split process starts with a base transit network, coded to the DVRPC model specifications. The walk and auto approach sub-networks are specified parametrically by utilizing delete access and egress parameters in UPATH as follows:

- The walk approach transit network is generated by removing all the auto approach links *(mode #3, see* ***Table A-V-1***) for both access and egress.
- The auto approach network is also specified within UPATH. In this case, the walk links (mode #1) connecting transit facilities to centroids are made one-way from the transit lines with the delete egress parameter. This prevents walk access to the transit system on the home end of the trip, but allows walk egress at the non-home end. It is important to note that the network walk links connected to a given centroid are not altered. As with the walk

approach network, the time period network is build in DVFARE using the unaltered link, coordinate, and line files.

Modeling walk/bus and auto approach by using UPATH to turn certain links on and off is advantageous from an operational point of view in that the separation of mode of approach is achieved parametrically through enhanced path building rather than through the use of separate networks. This reduces the number of networks from six to three in order to run the three time period model. All of these steps are integrated into a single job stream that is run without human intervention.

2. 2000 Input Data Description

The modal split model takes as primary input the internal-internal person trip tables for the HBW, HBNW, and NHB trip purposes. These tables are further disaggregated into zero-vehicle and vehicle owning households. Tables of highway and transit impedances by TAZ pair (*i,j*) are obtained by building and skimming minimum impedance trees from the highway and transit networks, respectively. The impedance difference for each TAZ pair is then calculated and the modal split determined using the proper diversion curves.

The most significant difference between the 1997 logit model and the 2000 logit model is the use of INET for the transit network. Previously, completely separate networks had been maintained for the highway and transit networks. The program UNET was used for transit assignment and hence building minimum impedance trees. This arrangement had several disadvantages. The main disadvantage is that there was no way of updating transit travel times for future year simulations to account for changes in highway congestion. The base year simulations assume that current transit in-vehicle (running) times reflect current highway congestion levels for surface transit modes (bus, trolley). But if highway congestion improves or degrades in future years, then transit running times will either decrease or increase, respectively. These changes in run times will affect not only assignment, but modal split as well. Since the highway and transit networks were completely separate, there was no way of capturing this effect. Other disadvantages included matching cordon stations and the effort in maintaining separate networks.

The new coding procedure utilizes the highway network links for those modes that use highway links – bus and in-street light rail or trolley. Transit modes with independent rights of way use links independent from the highway system and are therefore not affected by highway congestion. For future year simulations the transit in-vehicle time is updated by a linear relationship to the change in highway congestion using the INET program in TRANPLAN.

The transit impedance calculated for modal split modeling for the 2000 model is reflective of the transit system in 2000. Impedance adjustment factors, listed in ***Table IX-2*** are used to account for land use.

Several economic and calibration inputs are required for calculating the impedance difference. The household income (Y) and consumer price index (P) are used to weight together the various elements of impedance. They are in ***Table IX-5*** for 2005, 2000, and 1990 as indexed to 1990 values. Also listed is the auto operating cost per mile.

Table IX-6 lists the impedance coefficients. These factors have remained constant from 1990 and were not changed for the 2000 or 2005 models. Also, the fare paid for service is an element of the impedance for travel by transit. The fares used for travel by transit for the 2000 and 2005 models are listed in ***Table IX-7*** by company.

Table IX-5 Economic Inputs to Impedance Model

Year	Average Income Index (Y)	Consumer Price Index (P)	Auto Operating Cost (cents/mile)
1990	100	100	34.3
2000	136	130	49.1
2005	158	150	52.2

Source: DVRPC July 2008

Table IX-6 Impedance Constants

Out of Vehicle Time (K1)	In Vehicle Time (K2)	Out of Pocket Costs (K3)	Transfer Penalty (K4)
2.5	1.67	1.00	16.0

Source: DVRPC July 2008

The impedance difference is calculated based on the input data. This is used by the calibrated logit model to determine transit and auto mode shares. The 2000 and 2005 models use the same *a'* and *b'* factors as the converted 1990 model. Similar to the probit model, the 2000 and 2005 models use transit and auto captivities. While the *a'* and *b'* factors did not change, slight adjustments were made to the auto and transit captivities from the 1990 model for the 2000/2005 models. These factors act as a maximum and minimum modal split regardless of the impedance difference. The transit and auto captivities for the 2000 and 2005 modal split model are listed in ***Table IX-8***.

Table IX-7 Transit Fare Data by Transit Submode for 2000 and 2005

Operating Company	2000 Base Fare (¢)	2000 Transfer Charge (¢)	2000 Zone Increment (¢)*
SEPTA			
City Division	132	26	-
Victory Division	143	38	20
Frontier Division	162	32	20
Regional High Speed Rail	205	205	Varies with distance
NJ TRANSIT			
Mercer division	110	45	20
Southern Division	110	45	20
NJT Rail	110	-	Varies with distance
PATCO	100	**	Varies with distance
Pottstown Urban Transit	150	35	Varies with distance

Operating Company	2005 Base Fare (¢)	2005 Transfer Charge (¢)	2005 Zone Increment (¢)*
SEPTA			
City Division	148	29	-
Victory Division	160	31	23
Frontier Division	181	36	23
Regional High Speed Rail	230	230	Varies with distance
NJ TRANSIT			
Mercer division	121	54	22
Southern Division	121	54	22
NJT Rail	121	-	Varies with distance
PATCO	153	**	Varies with distance
Pottstown Urban Transit	150	35	Varies with distance

* All coded fares are averaged over pass, token, and cash fare rates using relative usage.
** SEPTA City Division has special PATCO transfers.

Source: DVRPC July 2008

Table IX-8 Transit and Auto Captivities for 2000/2005 Modal Split Models

	Peak		Midday		Evening	
Transit Submode	**Auto**	**Transit**	**Auto**	**Transit**	**Auto**	**Transit**
Commuter Rail	0%	0%	40%	0%	45%	0%
Subway Elevated	0%	0%	0%	0%	40%	0%
Phila. City Bus	20%	0%	0%	10%	25%	10%
PA Suburban Bus	25%	0%	20%	1%	15%	0%
SEPTA Frontier	25%	1%	20%	1%	15%	2%
PATCO	0%	5%	20%	0%	30%	0%
S. Jersey Bus	30%	0%	30%	1%	30%	0%
Mercer Co. Bus	30%	0%	30%	1%	30%	0%

Source: DVRPC July 2008

Appendix IX-1 lists various other data needed to determine impedance and calculate impedance differences. Tolls for PA and NJ toll roads are listed. Also listed in this appendix are average daily weekday parking charges by TAZ.

3. FTA New Starts Modeling Modal Split Requirements

As discussed above different diversion curves are used for different transit submodes. This is permitted by the FTA as long as the differences can be substantiated by local data and conditions. This is the case for the DVRPC region, where mode choice characteristics are different for different transit submodes. Other special modeling requirements for FTA New Starts Analysis are discussed in **Chapter II**.

Modal split results are used by the FTA's SUMMIT model in order to evaluate New Starts transit projects. The SUMMIT model uses travel time and travel costs, modal splits, and access data in order to calculate user benefits. SUMMIT then compares user benefits for build scenarios against a No-build baseline. FTA uses SUMMIT to ensure that project benefits are calculated in a consistent manner for the competitive New Starts funding process.

4. Model Operation

The modal split model is run by calling the "Evans Modal Choice" TRANPLAN function. This function requires trip table inputs by trip purpose as well as highway and transit impedance skims. Zonal data is also required. The modal split model produces outputs of auto driver, total highway person, and transit person trip tables by trip purpose.

D. Modal Split Results

Table IX-9 displays the 2000 modal split results summarized by county, state, and region. The results are listed by HBW, HBNW, and NHB trip ends as well as total trip ends. This table has, for each county and trip purpose, the total number of person trips and the percent of transit trips. The data are also summarized by state and for the entire region. More detailed results by CPA are presented in **Appendix IX-2** and shown in ***Figure IX-12***. As can be expected, Philadelphia County has the highest percentage of transit trips with an overall transit mode share of 14.4 percent. The Philadelphia CBD has an even higher transit modal split of 47.3 percent. Transit usage varies significantly throughout the region, however. Chester, Montgomery, Bucks, Mercer, Burlington, and Gloucester counties all have overall transit mode shares of less than 1 percent. Home-based work trips have much higher mode shares than HBNW or NHB trips for all counties. Regionally HBNW trips have a higher transit mode share than NHB trips, but this pattern is reversed for some counties.

Table IX-10 displays 2005 results summarized by county, state, and region. The 2005 patterns are similar to the 2000 patterns. The total number of trips increased from 2000 to 2005 for all counties except Philadelphia, which showed a slight decrease in trips. Between 2000 and 2005 the percentage of motorized trips made by transit stayed nominally the same. The two exceptions to this were Burlington and Mercer counties which had slight increases in transit usage. The transit mode share for HBW trips nearly doubled for Burlington County from 2000 to 2005.

1. Comparison of 2005, 2000, and 1990 Modal Split Results

The 2005 results from the modal split model can be compared with previous results. ***Table IX-11*** compares 2000 and 2005 simulated results with 1990 simulated results. This data is aggregated for the entire region. The 2000 model has a slightly lower HBW transit mode split than the 1990 model. The 2000 modal split is lower for HBNW trips, but slightly higher for NHB trips. The 2005 transit modal splits are slightly lower for all trip purposes when compared to 2000. This is reflective of the continued pattern of disperse development in the region to areas not served by transit and the decline of older cities served by the existing transit system.

Table IX-9 2000 Modal Split Results by County and Trip Purpose

County	HBW		HNBW		NHB		Total	
	Person Trip Ends	% Transit	Person Trip Ends	% Transit	Person Trip Ends	% Transit	Person Trip Ends	% Transit
Phila. CBD	424,670	57.5%	340,212	48.8%	220,931	25.1%	985,813	47.3%
Philadelphia	1,983,913	29.2%	4,278,091	11.5%	2,236,755	6.7%	8,498,759	14.4%
Delaware	737,872	5.6%	2,057,298	0.5%	863,032	0.6%	3,658,202	1.6%
Chester	767,064	0.8%	2,103,396	0.1%	863,856	0.2%	3,734,316	0.2%
Montgomery	1,448,601	2.4%	3,748,023	0.3%	1,631,930	0.4%	6,828,554	0.8%
Bucks	981,599	1.3%	2,764,259	0.1%	1,098,789	0.1%	4,844,647	0.3%
Berks (portion)	21,562	0.0%	59,881	0.0%	23,958	0.0%	105,401	0.0%
Pennsylvania	**5,940,611**	**11.4%**	**15,010,948**	**3.5%**	**6,718,320**	**2.5%**	**27,669,879**	**4.9%**
Mercer	619,329	2.5%	1,477,982	0.5%	689,429	0.4%	2,786,740	0.9%
Burlington	707,346	0.8%	1,949,986	0.1%	792,221	0.2%	3,449,553	0.3%
Camden	769,909	5.6%	2,035,845	0.8%	851,256	0.7%	3,657,010	1.8%
Gloucester	394,993	1.2%	1,140,795	0.2%	442,830	0.2%	1,978,618	0.4%
New Jersey	**2,491,577**	**2.8%**	**6,604,608**	**0.4%**	**2,775,736**	**0.4%**	**11,871,921**	**0.9%**
Region	**8,432,188**	**8.8%**	**21,615,556**	**2.5%**	**9,494,056**	**1.9%**	**39,541,800**	**3.7%**

Source: DVRPC July, 2008

Figure IX-12 Transit Mode Share for 2000 by CPA

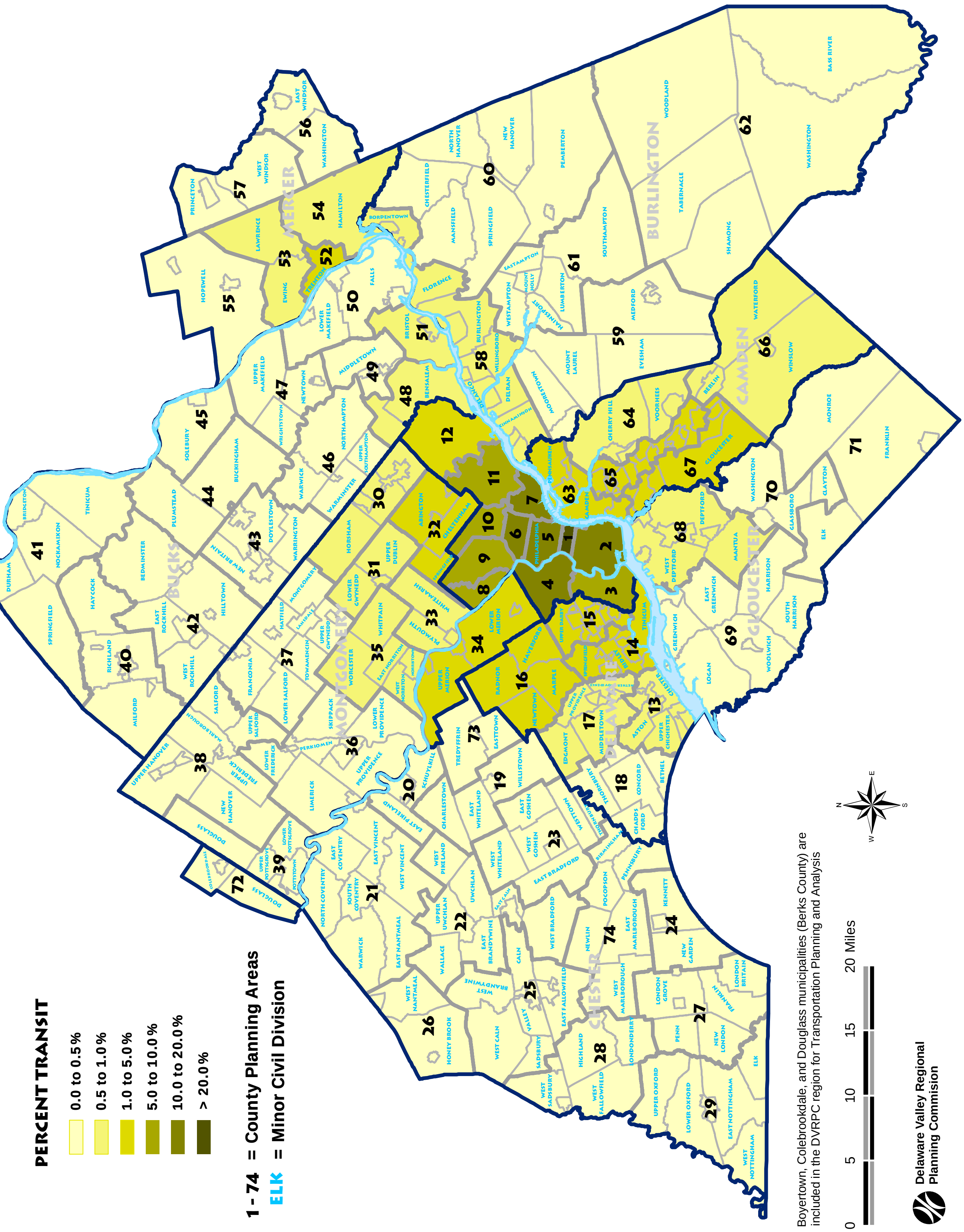


Table IX-10 2005 Modal Split Results by County and Trip Purpose

	HBW		HNBW		NHB		Total	
County	**Person Trip Ends**	**% Transit**	**Person Trip Ends**	**% Transit**	**Person Trip Ends**	**% Transit**	**Person Trip Ends**	**% Transit**
Phila. CBD	423,586	57.5%	340,212	48.8%	220,931	25.1%	985,813	47.3%
Philadelphia	1,945,188	29.6%	4,206,874	11.4%	2,199,584	6.8%	8,351,646	14.4%
Delaware	737,646	5.6%	2,076,518	0.5%	865,061	0.6%	3,679,225	1.5%
Chester	822,198	0.7%	2,302,519	0.1%	932,368	0.2%	4,057,085	0.2%
Montgomery	1,493,685	2.3%	3,926,521	0.3%	1,693,410	0.4%	7,113,616	0.8%
Bucks	1,019,104	1.3%	2,912,648	0.1%	1,148,899	0.2%	5,080,651	0.3%
Berks (portion)	22,316	0.0%	59,066	0.0%	22,428	0.0%	103,810	0.0%
Pennsylvania	**6,040,137**	**11.1%**	**15,484,146**	**3.3%**	**6,861,750**	**2.4%**	**28,386,033**	**4.7%**
Mercer	648,977	2.7%	1,548,027	0.5%	718,972	0.4%	2,915,976	1.0%
Burlington	750,942	1.5%	2,072,048	0.1%	842,662	0.2%	3,665,652	0.4%
Camden	786,069	5.5%	2,069,874	0.7%	868,571	0.7%	3,724,514	1.7%
Gloucester	427,907	1.3%	1,245,351	0.2%	480,637	0.3%	2,153,895	0.4%
New Jersey	**2,613,895**	**3.0%**	**6,935,300**	**0.4%**	**2,910,842**	**0.4%**	**12,460,037**	**0.9%**
Region	**8,654,032**	**8.6%**	**22,419,446**	**2.4%**	**9,772,592**	**1.8%**	**40,846,070**	**3.6%**

Source: DVRPC July, 2008

Table IX-11 Comparison of 1990, 2000, and 2005 Transit Mode Splits

	Percent of Total Person Trips		
Trip Purpose	**1990 Model**	**2000 Model**	**2005 Model**
HBW	12.4%	8.8%	8.6%
HBNW	3.2%	2.5%	2.4%
NHB	1.6%	1.9%	1.8%
Total	**5.1%**	**3.7%**	**3.6%**

Source: DVRPC July 2008

X. VEHICLE OCCUPANCY MODEL

The modal split model produces auto person trip tables disaggregated by trip purpose and vehicle availability. A secondary model, the vehicle occupancy model, is used to convert the highway person trip tables into highway vehicle trip tables for highway assignment. This is done by calculating a vehicle occupancy which is then applied to the highway person trip tables. The highway vehicle trip tables are added to external and through vehicle trips and used by the highway assignment model to produce link traffic volumes.

A. 1990 Vehicle Occupancy Model

Previous investigations found that the principal determinants of vehicle occupancy are trip length and trip purpose. The 1990 model continued using this approach. The 1990 DVRPC vehicle occupancy model was based on linear equations which related the number of occupants per vehicle to trip length. The linear equations developed in earlier studies were recalibrated for the 1990 study using 1987 Household Travel Survey and Census Transportation Planning Package (CTPP) data. Separate equations were used for HBW and HBNW trips, while NHB trips used a single value for all trip lengths. The average trip length from surveys and the previous and recalibrated 1990 model is shown in ***Table X-1***. The recalibrated model reproduced average vehicle occupancies.

Table X-1 Average Auto Occupancies from the Recalibration of the 1990 Auto Occupancy Model

Trip Purpose	1990 Census CTPP	1987 Household Travel Survey	Previous Model	Recalibrated 1990 Model
HBW	1.09	1.12	1.14	1.13
HBNW	-	1.54	1.68	1.53
NHB	-	1.41	1.26	1.41
Total	**-**	**1.38**	**1.43**	**1.39**

Source: DVRPC July 2008

B. 2000 and 2005 Vehicle Occupancy Models

The equations and procedures used in the 1990 model were generally used with new data in the 2000 and 2005 models. The main difference between the 1990 model and the 2000 and 2005 models is the use of separate equations for each of the different time periods. This was mainly done because of significant differences in vehicle occupancy for HBNW trips in the 2000 Household Travel Survey.

Three main data sources were available for estimating vehicle occupancy. The first is the 1999 DVRPC *Vehicle Occupancy Survey for the Delaware Valley Region*. This survey determined vehicle occupancy by observing and counting the number of people inside of vehicles at various locations throughout the Delaware Valley. The second source was data from the 2000 Census Journey to Work survey. The third data source was the 2000 Household Travel Survey. The three sources are shown below.

Source	Vehicle Occupancy
1999 Vehicle Occupancy Report	1.19
2000 Census Journey to Work	1.17
2000 Household Survey	1.35

Source: DVRPC July 2008

The data from Census 2000 applies only to HBW trips, while the others apply to all trip types. The values from the 2000 Household Travel Survey were judged to be the best and were used to update the vehicle occupancy equations.

Like the 1990 model, the 2000 and 2005 models use the following formula to calculate vehicle occupancy:

Vehicle occupancy = $a + b$*(HDT)   Maximum = c

where:

- HDT   highway driving time in minutes
- *a,b,c*   Time period and trip purpose dependant parameters

The parameters for each time period and trip purpose are shown in ***Table X-2***. The same equations are used for both the 2000 and 2005 models. In ***Table X-2*** b= 0.0 for all NHB trips for all time periods. This indicates that NHB trips all use a fixed vehicle occupancy value. Comparing the HBW and HBNW models, the HBNW models have higher sensitivities to trip length. The parameters for HBW and NHB trips are relatively consistent between time periods. The parameters for HBNW trips are significantly different in the midday time period than either the peak or evening time periods. This follows the results from the survey results.

The vehicle occupancy model under predicts vehicle occupancies for Center City Philadelphia trip attractions. CBD occupancies were increased by 10 percent for all trip purposes.

Table X-2 Vehicle Occupancy Model Parameters for 2000 and 2005 Models

Purpose/Period	a	b	c
HBW Peak	1.012	0.0019	-
HBNW Peak	1.539	0.00913	2.5
NHB Peak	1.224	0.000	-
HBW Midday	1.001	0.0019	-
HBNW Midday	1.232	0.0073	2.5
NHB Midday	1.212	0.000	-
HBW Evening	1.012	0.00192	-
HBNW Evening	1.539	0.0092	2.5
NHB Evening	1.244	0.000	-

Source: DVRPC July 2008

While vehicle occupancy is a separate model from modal split, the actual calculations for vehicle occupancy are performed by the same TRANPLAN program. The modal split model calculates vehicle occupancies based on highway trip time after the modal split model determines highway person trip tables for each trip purpose. The output from the vehicle occupancy model is separate highway vehicle trip tables for each trip purpose.

Although adequate in estimating the number of internal vehicle trips, the DVRPC vehicle occupancy model should be enhanced to include other variables such as vehicle operating cost, tolls, and other variables. Such variables may or may not improve the accuracy of the results.

C. 2000 and 2005 Auto Occupancy Results

The vehicle occupancies by time period for the 2000 Household Travel Survey and the 2000 and 2005 model are shown in ***Table X-3***. The 2000 model results show good agreement to the survey results. All the trip purpose/time period categories show a 1 percent of less difference, except for the NHB Evening time period which has a 4 percent different between survey and simulation vehicle occupancy. The 2000 and 2005 model results are very similar. The average vehicle occupancies by trip purpose for the 1990 model, 2000 survey, 2000 model, and 2005 model are shown in ***Table X-4*** and graphically in ***Figure X-1***. The 2000 model and surveyed vehicle occupancies are lower than the 1990 model vehicle occupancies. As is well known, HBW occupancies are lower than for the other trip purposes. Both HBW and NHB occupancies decreased from 1990 to 2000/2005, while HBNW vehicle occupancies increased.

Table X-3 Vehicle Occupancies by Time Period for 2000 and 2005

Purpose/Period	2000 Survey	2000 Model	2000 Survey vs. Model Diff.	% Diff	2005 Model
HBW Peak	1.080	1.091	-0.011	-1.064	1.091
HBNW Peak	1.696	1.687	0.009	0.541	1.685
NHB Peak	1.289	1.287	0.002	0.144	1.287
HBW Midday	1.078	1.088	-0.010	-0.958	1.088
HBNW Midday	1.358	1.347	0.011	0.829	1.346
NHB Midday	1.276	1.262	0.014	1.090	1.263
HBW Evening	1.092	1.097	-0.005	-0.415	1.097
HBNW Evening	1.594	1.597	-0.003	-0.210	1.595
NHB Evening	1.441	1.499	-0.058	-4.055	1.498

Source: DVRPC July 2008

Table X-4 Daily Vehicle Occupancy

Trip Purpose	1990 Model	2000 Surveyed	2000 Model	2005 Model
Home-Based Work	1.13	1.08	1.09	1.09
Home-Based Non-Work	1.53	1.53	1.54	1.56
Non-Home Based	1.41	1.30	1.30	1.30
Average	**1.39**	**1.35**	**1.36**	**1.36**

Source: DVRPC July 2008

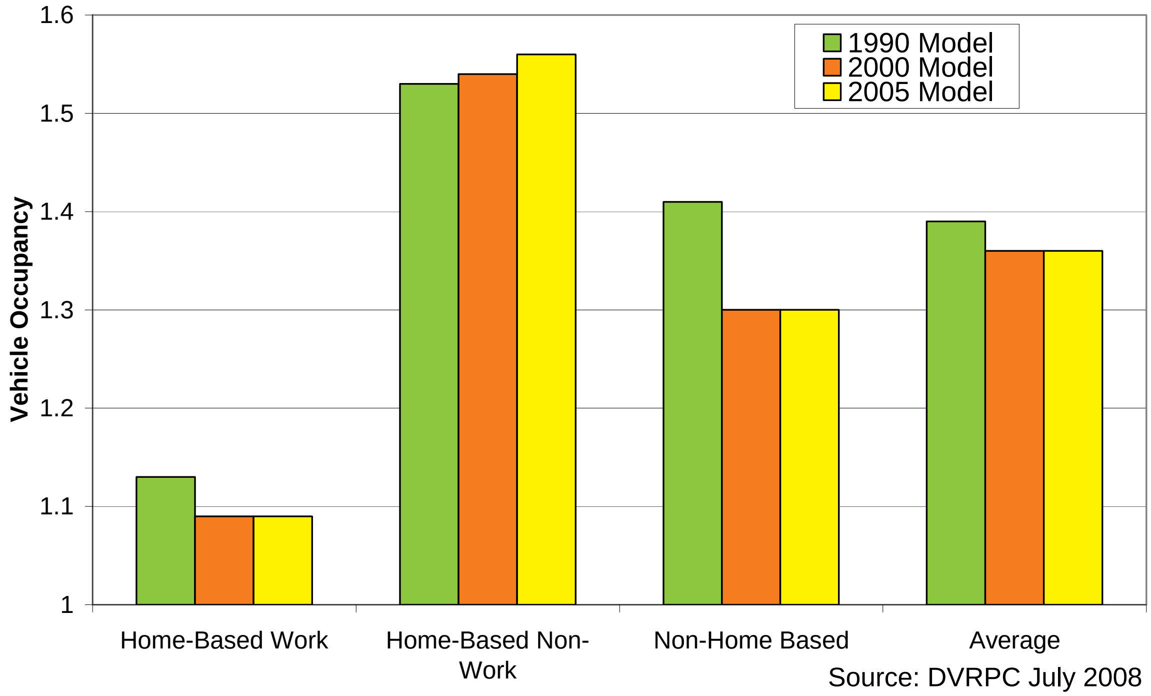


Figure X-1 1990 to 2005 Daily Vehicle Occupancy by Trip Purpose

Summary results by time period, trip purpose, and county are in presented in ***Table X-5*** for 2000 and ***Table X-6*** for 2005. Between 2000 and 2005 vehicle trips generally increased across purposes and time periods. Philadelphia is an exception with highway vehicle trips decreasing. Pennsylvania accounts for about two-thirds of highway vehicle trips from the three purposes, while New Jersey accounts for the remaining third. The peak period has the largest proportion of HBW work trips, while the midday period has the largest proportions of HBNW and NHB trips.

Table X-5 2000 Vehicle Occupancy Model Results by Time Period, Trip Purpose, and County – Highway Vehicle Trips (000s)

	2000 Peak			2000 Midday			2000 Evening			2000 Daily		
	HBW	HBNW	NHB	HBW	HBNW	NHB	HBW	HBNW	NHB	HBW	HBNW	NHB
Philadelphia	316	471	237	105	478	430	181	338	98	601	1,288	765
Delaware	180	239	99	59	245	182	94	170	42	333	654	323
Chester	195	250	104	63	255	190	96	179	47	354	684	340
Montgomery	327	414	192	107	424	352	164	294	83	597	1,133	627
Bucks	267	334	132	88	343	241	134	240	59	489	917	431
Berks (portion)	6	8	3	2	8	5	3	5	1	10	21	10
Pennsylvania	**1,290**	**1,716**	**767**	**424**	**1,754**	**1,399**	**671**	**1,226**	**330**	**2,384**	**4,696**	**2,496**
Mercer	144	177	83	47	181	152	72	127	38	263	485	273
Burlington	185	233	95	60	239	173	92	168	44	337	640	313
Camden	184	241	98	61	247	180	94	171	43	340	659	322
Gloucester	107	137	54	35	140	97	53	99	25	195	376	175
New Jersey	**620**	**788**	**330**	**203**	**807**	**602**	**312**	**565**	**150**	**1,135**	**2,161**	**1,083**
Region	**1,909**	**2,504**	**1,097**	**627**	**2,561**	**2,002**	**983**	**1,791**	**480**	**3,519**	**6,857**	**3,579**

Source: DVRPC July, 2008

Table X-6 2005 Vehicle Occupancy Model Results by Time Period, Trip Purpose, and County – Highway Vehicle Trips (000s)

	2005 Peak			2005 Midday			2005 Evening			2005 Daily		
	HBW	HBNW	NHB	HBW	HBNW	NHB	HBW	HBNW	NHB	HBW	HBNW	NHB
Philadelphia	308	465	233	103	473	421	176	334	96	587	1,272	750
Delaware	180	241	99	60	248	182	93	172	43	333	660	325
Chester	209	274	112	68	280	204	103	196	50	380	750	367
Montgomery	338	436	200	111	446	365	169	309	87	618	1,191	651
Bucks	278	353	138	91	362	252	139	253	62	507	968	451
Berks (portion)	6	8	3	2	8	5	3	6	1	11	21	9
Pennsylvania	**1,318**	**1,778**	**785**	**434**	**1,816**	**1,429**	**683**	**1,270**	**339**	**2,435**	**4,864**	**2,553**
Mercer	151	184	87	49	189	158	76	132	40	276	506	284
Burlington	193	247	100	63	253	183	96	177	46	352	677	329
Camden	188	245	100	62	252	184	96	175	44	347	672	328
Gloucester	115	149	58	38	152	105	58	108	27	210	409	190
New Jersey	**648**	**826**	**345**	**212**	**846**	**631**	**326**	**593**	**156**	**1,186**	**2,264**	**1,132**
Region	**1,966**	**2,603**	**1,130**	**646**	**2,662**	**2,060**	**1,009**	**1,862**	**495**	**3,621**	**7,128**	**3,685**

Source: DVRPC July, 2008

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XI. HIGHWAY ASSIGNMENT MODEL

The steps leading up to highway assignment are used to produce vehicle trip tables by trip purpose, such as home based work, light truck, and external-internal turnpike trips. The trip tables define the origin and destination locations for a trip and the fact that a trip will use the highway system. But they do not define the route or series of roadway facilities that a particular trip will use. This information is critically important in determining link volumes. Link volumes are the most important model output for highway design, traffic engineering, and transportation planning studies.

The highway assignment model assigns or loads the trip tables onto the highway network. Routes and hence link volumes are determined, along with congested travel times and speeds. Link volumes are important for planning and engineering studies and are also used along with congested travel speeds for air quality conformity analysis, traffic operation, energy analysis, economic evaluation of transportation plans and programs, and other studies.

This chapter discusses the theory behind the equilibrium highway assignment. The process and input data follow. The enhancement of the highway assignment model and its integration with the trip distribution and modal split models using the Evans algorithm is discussed next. Results of the 2000 and 2005 highway assignment models are given next. Finally, focused travel simulations for use in detailed highway and transit studies are discussed briefly and illustrated by an example of a traffic study completed by DVRPC.

A. Characteristics of the DVRPC Highway Assignment Model

The DVRPC highway assignment model has the following characteristics:

- Determines the path or route drivers take along the highway network to reach their destination.
- Is based on highway travel time and cost.
- Travel times between origin and destination are recalculated based on congestion levels.
- Trips are diverted to other facilities as travel time increases with congestion.
- Is solved by an iterative process constrained by highway capacity.

1. Equilibrium Highway Assignment Model

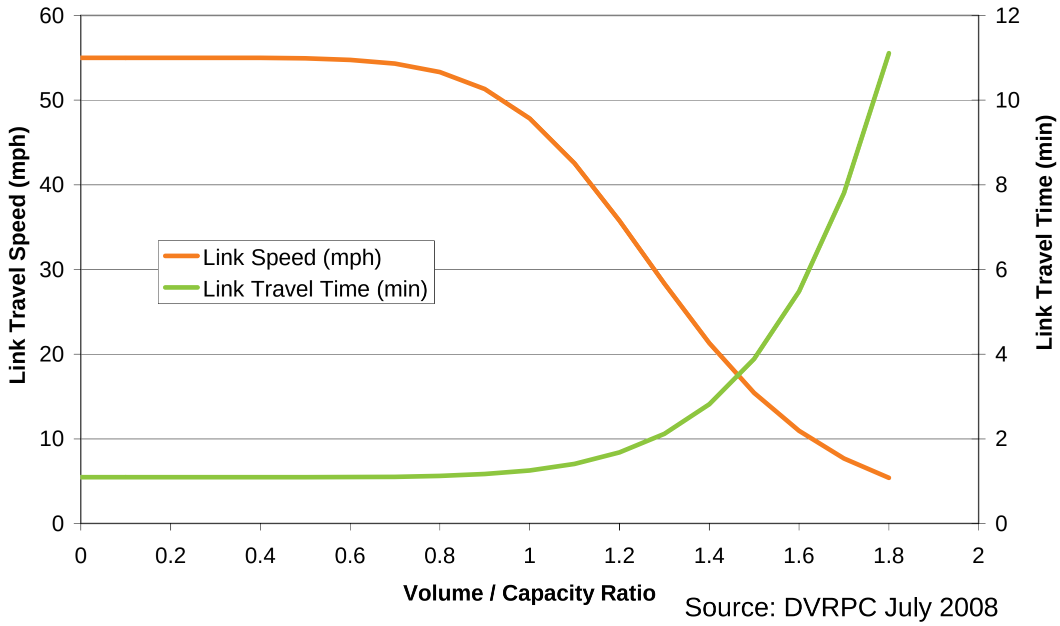
The highway assignment model, like the other models in travel forecasting, operate under the assumption that users make travel decisions so as to minimize their impedance (time/cost/disutility) of travel. In trip distribution, for example, a person will tend to choose a grocery store that is closer than farther. In mode choice modeling, travelers will tend to choose the lower cost mode. In highway assignment, which could also be referred to as route choice, drivers have many possible routes among which to choose to get from their origin to destination. By the above principal, they will choose routes that minimize their impedance of travel. This can be succinctly stated using Wardrop's law - *"The journey times on all routes actually used are equal, and less than those which would be experienced by a single vehicle on any unused route."* The goal, then, of highway assignment is to find the least impedance path (a sequence of links) for each TAZ pair (i,j) and assign all of the volume in the trip table to that path. This, however, is problematic, as the journey time for any particular link in the network depends of the volume of vehicles using that link due to congestion. Various mathematical equations have been used to represent this relationship. The volume-delay function used by DVRPC is adapted from an FHWA equation:

$$T = T_0\left(1.0 + 0.15\left(\frac{V}{C}\right)^7\right)$$

where:

- T Travel time on a link
- T_0 Free-flow (unloaded) travel time on a link
- V Volume assigned to link
- C Capacity of link

The quantity V/C is the volume to capacity ratio. Because the ratio is being raised to the seventh power, the travel time increases rapidly as the capacity is approached and then exceeded. Examine ***Figure XI-1***, which contains a graph of loaded link speed and travel time versus the volume to capacity ratio. This example uses an urban freeway segment one mile long with a free-flow speed of 55.0 mph. As the volume increases the travel time on the link increases slowly at first, then drastically.



Source: DVRPC July 2008

Figure XI-1 Volume/Capacity Ratio vs. Link Travel Time and Link Speed for an Urban Freeway Link

Because of the interdependent nature of the assigned highway link volumes and travel times, an iterative equilibrium assignment technique is used. This technique was developed in earlier travel simulation studies and was used for both the 1990 and 1997 models. The term "equilibrium" in this context means that the assigned volumes are in equilibrium with the link impedances, which in turn are dependant on the volumes. In terms of the above stated Wardrop's law, no vehicle traveling between *i* and *j* could change to a lower impedance route given the congested levels in the network. The equilibrium assignment procedures solve a non-linear constrained equilibrium optimization problem. This approach is differentiated from earlier heuristic methods which gave good but non-equilibrium (sub-optimal) solutions to the highway assignment problem.

The iterative technique proceeds as follows. For the first iteration all the volume for each trip interchange (*i* to *j*) is assigned to the minimum cost route using free-flow travel speeds. This solution is called the current solution (V_a). All link costs are then updated based on the network loading from the first iteration. For the second iteration all the volume for each trip interchange is again assigned to the minimum cost route, this time using the updated link travel times. This new solution is called the subproblem solution (W_a). A new current solution $V_a^{'}$ is calculated via a convex combination of V_a and W_a by using a weight λ selected by solving the following program:

$$\min_{\lambda} \sum_{a} \int_{0}^{V_a^{'}} c_a(x)dx$$

subject to:

$$0 \le \lambda < 1$$

and where:

$$V_a^{'} = (1-\lambda)V_a + \lambda W_a$$

where:

- V_a link volumes from current solution from previous iteration
- $V_a^{'}$ link volumes for updated current solution
- W_a link volumes from subproblem solution
- a a link
- $c_a(x)$ impedance function based on volume
- λ convex weighting factor

Since the above non-linear program has only one variable (λ), it can be solved using a line search technique, such as a bi-section search. For the third iteration $V_a \leftarrow V_a^{'}$ is set and the process is repeated. For the 2000 and 2005 models 15 iterations of highway assignment are conducted. The link volumes and impedances approach the equilibrium solution after 15 iterations.

2. Highway Assignment Process and Input Data

The highway assignment model has two primary inputs – the highway trip tables and the network representation. Before highway assignment begins the various vehicle trip tables, HBW, HBNW, NHB, light truck, heavy truck, the four external-internal categories, and taxi vehicle trip tables are combined into a single highway trip table. In this process the HBW and HBNW trip tables are converted from production-attraction format to origin-destination format. The tables are then squared to produce a symmetric trip table. This combined highway trip table is then assigned to the network. This differs from some other models which assign different vehicle classes separately. The trip table for 2000 is square (2068 x 2068) and contains a total of 11,950,571 vehicle trips that are assigned to the highway network. Similarly there are 12,712,987 vehicle trips assigned to the highway network in the 2005 model.

The highway network, which is described briefly below, is represented by a set of links and nodes. Between each pair of nodes there are at most two directional links. The nodes are located in space by X (a proxy for longitude) and Y (a proxy for latitude) coordinates. The links have properties of capacity, length, functional class, area type, and number of lanes.

The primary highway network information is stored in three parts within a single file, referred to as a "card" file for historical reasons. The first part of the highway cards file contains a speed and capacity reference table. This table gives daily capacities and free-flow speeds for all permutations of roadway functional class, area type, and number of lanes. In the second part, each node is given a unique identifying number. The node section also lists the X and Y coordinates as expressed in hundredths of a mile using the US Geological Survey's 1927 Universal Transverse Mercator, zone 18 projection with a "False Northing" of -2000 miles.

The third part of the highway cards file contains information about each link. The beginning and ending nodes are identified by node number. Each link in the highway cards file is not given a link number and is only identified by its beginning and ending nodes. The link part also contains area type, distance, direction codes, functional class, number of lanes, and DVRPC's county planning area codes for each link. Detailed information on highway coding can be found in **Chapter V** and **Appendix V-1**. A map of the highway network can be seen in ***Figure III-1*** (page 39).

Each iteration of traffic assignment consists of building a network description from the link data cards and building a set of minimum impedance trees through the network. There is one tree for each centroid in the network, including external centroids. Each tree determines the shortest (minimum impedance) route from a given centroid to every other centroid. For the 2000 and 2005 regional simulations, 2,068 trees are found during each iteration. After shortest routes are found the trip table is loaded onto the network as discussed in the previous section.

The relationship of the highway assignment problem to the other modeling steps is shown in ***Figure XI-2***. The vehicle trip tables are produced in the trip distribution step. The person trip tables are determined in the modal split model and fed to the vehicle occupancy model which transforms them into vehicle trip tables. These are then combined with the other vehicle trip tables to produce the total highway trip table. These are then input to the highway assignment model.

3. Description of the Highway System in the Delaware Valley

The Delaware Valley highway system is a network of limited access facilities, arterial highways, secondary collector roads, and local streets, reflecting the different uses and periods of highway construction and the programs that have supported the system. The major existing highway facilities are described below.

Limited access facilities are divided into toll and freeway facilities. These are listed below in ***Table XI-1***. These facilities provide the main means of moving people and freight in and through the region.

Table XI-1 Limited Access Facilities in the DVRPC Region

Facility	Description
• Pennsylvania Turnpike (I-76 and I-276)	Toll road running east-west across the state of Pennsylvania, which links the Ohio and New Jersey turnpikes and serves as a partial circumferential route extending around the northern section of Philadelphia.
• Schuylkill Expressway (I-76)	Parallels the Schuylkill River from the Pennsylvania Turnpike at Valley Forge (King of Prussia) to the approach of the Walt Whitman Bridge. In New Jersey, it connects with I-295 at the NJ 42 Freeway.
• Delaware Expressway (I-95)	Parallels the Delaware River and serves the corridor from Wilmington, Delaware to Trenton, NJ where it terminates at I-295.
• Mid-County Expressway (I-476)	Traverses a north-south route between I-95 north of Chester and I-276 in Plymouth Meeting, extending north to Scranton and the Pocono Mountains as a toll facility.
• Vine Expressway/ North-South Freeway (I-676)	In Philadelphia, connects I-76 with I-95 immediately providing access to the Ben Franklin Bridge. In New Jersey, it provides a limited access connection between the approaches of the Ben Franklin and Walt Whitman Bridges with intermediate access points serving the City of Camden.
• US 422 Expressway	Connects Pottstown with US 202 at King of Prussia and serves a growing development corridor in Montgomery County.
• PA 309 Expressway	Provides a bypass of the old Bethlehem Pike. It runs from Northwest Philadelphia to Montgomery and Bucks counties.
• US 202 Expressway	North-south limited access route between West Chester in Chester County and King of Prussia in Montgomery County.
• US 202/611 Bypass	Limited access facility which bypasses Doylestown Borough in Bucks County.
• US 30 Bypass	Limited access facility which bypasses the Coatesville/Downingtown area in Chester County.
• US 1 Freeway	North-south limited access facility in Bucks County between Philadelphia and Trenton.
• US 1 Media Bypass	Limited access facility to bypass the Media area between PA 352 and PA 320 in Delaware County.
• US 1	Limited access facility in Chester County south of PA Route 52 to the Pennsylvania/Maryland state line.
• New Jersey Turnpike	Toll facility traversing the region north-south, providing access from the Baltimore/Washington area.
• I-195	Connects I-295 in Hamilton Township, New Jersey with various shore points.
• I-295	Parallels the New Jersey Turnpike, serving the corridor from Wilmington to Trenton.

Source: DVRPC July 2008

Table XI-1 Limited Access Facilities in the DVRPC Region (continued)

Facility	Description
• Atlantic City Expressway	East-west toll facility connecting the North-South Freeway (NJ 42) with Atlantic City.
• NJ 42 Freeway	Provides a limited access connection between the I-76/I-295 interchange and the Atlantic City Expressway.
• NJ 55 Freeway	Connects NJ 42 in Deptford Township with the Vineland area in Cumberland County.
• NJ 90	Carries traffic between the Betsy Ross Bridge and NJ 73 in Cinnaminson.
• Trenton Freeway (US 1)	Limited access bypass of old US 1 through Trenton and a portion of Bucks County.

Source: DVRPC July 2008

An extensive network of major arterial facilities supplements the limited access highway network of the region. An arterial highway, characterized by its use and its design, is usually the main thoroughfare between the established centers of the region. Some of the arterial highways have been replaced by limited access highways along the same corridor because of heavy use. As a result, these roads now serve a more local function, often providing access to commercial and industrial areas. Examples include US 13, which is paralleled by I-95 along the Pennsylvania side of the Delaware River, and US 130, which is paralleled by I-295 in New Jersey.

Arterials provide added connections needed between limited access highways. Many of these routes, though congested, extend radially outward from the region's core of Philadelphia.

Collector roads provide the links between local streets and the arterial and limited access highways. These routes are generally unnumbered in Pennsylvania. In New Jersey, collectors usually carry secondary route numbers and are under the control of the counties. However, many of these secondary routes are more properly classified as arterials.

There are 18 bridges in the region spanning the Delaware River and connecting Pennsylvania with New Jersey, comprising a significant element of the highway network. North of the Trenton area, eight highway bridges connect roads in Bucks County to Mercer and Hunterdon counties in New Jersey. Most of the bridges are minor and are not generally intended for a high volume of commercial traffic. The major bridges in this section are the US 202 toll bridge just north of New Hope and the Scudder Falls (I-95) bridge, which has no toll. Two bridges link local streets at Trenton.

From Trenton to the Delaware border, there are eight major bridges linking Pennsylvania and New Jersey, all of which are toll facilities.

- US 1 Freeway
- Delaware River Turnpike Bridge (I-276)
- Burlington-Bristol (PA 413/County 541)
- Tacony-Palmyra (PA/NJ 73)
- Betsy Ross (NJ 90)
- Benjamin Franklin (I-676, US 30)
- Walt Whitman (I-76)
- Commodore Barry (US 322)

4. Determination of Hourly Time Period Capacities

The determination of daily capacities for each link type is discussed in **Chapter V**. These values, however, are too large to represent the capacity for a peak, midday, or evening time period. The daily capacity listed in the highway network description is converted to a time period hourly capacity in order to perform an accurate capacity restrained time period assignment. This is done through the CONFAC parameter. The CONFAC is included in the parameter set of the TRANPLAN equilibrium traffic assignment program. These values are determined by the output time period speeds and VMT resulting from the assignment, the hourly distribution of traffic within each time period, and the magnitude of time period traffic versus the daily total. The CONFAC parameter settings for each time period and the resulting VMT and speeds from the highway assignment are shown in ***Table XI-2***.

Another adjustment, in addition to the CONFAC parameter, is made to the daily capacities when determining the hourly capacity used for assignment. The hourly and daily capacities listed in **Chapter V** are based on level of service (LOS) E. The highway assignment algorithm, however, is based on LOS C. The capacities are multiplied by a factor of 0.75 before being used by the highway assignment algorithm.

The speeds given in the table resulted from the volume-delay function, which represents the cumulative travel time on each link rather than average travel time and cannot be directly interpreted in terms of observed travel behavior. These values approximate average speeds except for links with high V/C ratios, for which the simulated speeds are much lower than the actual average link speed. The 1997 travel time survey produced similar average speeds (weighted by volume) in the peak and midday periods.

Table XI-2 CONFAC Parameters, VMT, and Assigned Speeds

Time Period	CONFAC	Regional VMT	Average Assignment Speeds
Peak	2.439	42,040,860	27.67
Midday	2.439	38,496,492	31.13
Evening	1.538	32,464,036	33.03
Total	**-**	**113,001,318**	**30.38**

Source: DVRPC July 2008

B. Evans Algorithm Theory and Practice

The DVRPC highway assignment procedure discussed above is conducted for 15 iterations. After 15 iterations there is a reasonable loading on the highway network and the link flows and costs are beginning to come into equilibrium considering the fixed highway trip table. At this point, however, additional items need to be considered in order to obtain a true system equilibrium such as is needed to accurately predict traffic flows. The trip distribution and model split models use the highway network to determine the impedance between TAZ centroids. The impedance can not be accurately determined until after the highway assignment stage, yet the resulting level of congestion determined in highway assignment depends on the trip table produced by the trip distribution and modal split models. Hence the trip distribution, mode split, and highway assignment models are not strictly sequential as in the traditional four-step process, but interrelated.

The link costs that are used to determine trip patterns in the trip distribution model, mode choices in the modal split model, and the route choices in the assignment model must be in equilibrium with the trip table and link flows that result from these three models. In order to find this equilibrium solution trip table and link flows, a combined equilibrium formulation is used which combines the three models of trip distribution, modal split, and traffic assignment into a single mathematical formulation. This formulation is then solved by the Evans algorithm, discussed here.

The three combined models are formed into a single optimization program formulated below:

$$\min_{c_a, T_{ijm}} K_1 \frac{Y}{P} \sum_i \sum_j \left(T_{ijh} w_{ijh} + T_{ijt} w_{ijt} \right) + K_2 \frac{Y}{P} \left(Q \sum_a \int_0^{Va} c_a(x)dx + \sum_i \sum_j T_{ijt} c_{ijt} \right)$$
$$+ K_3 \frac{1}{P} \left(\sum_a \int_0^{Va} k_a(x)dx + \sum_i \sum_j T_{ijh} s_j + \sum_i \sum_j T_{ijt} k_{ijt} \right)$$

subject to:

$$\sum_{r \in R_{ijh}} h_r = \frac{T_{ij}}{Q} \qquad \forall i, j$$

$$T_{ijh} + T_{ijt} = T_{ij} \qquad \forall i, j$$

$$\sum_j T_{ij} = O_i \qquad \forall i$$

$$\sum_i T_{ij} = D_j \qquad \forall j$$

$$\sum_i \sum_j \sum_m T_{ijm} \ln T_{ijm} \geq -S_0$$

$$h_r \geq 0$$

$$T_{ijm} > 0 \qquad \forall i, j, \quad m = h, t$$

where:

$$V_a = \sum_i \sum_j \sum_{r \in R_{ijh}} h_r \delta^a_{ijrh}$$

$$L_a = \sum_i \sum_j \sum_{r \in R_{ijt}} h_r \delta^a_{ijrt}$$

where:

- $K_{1,2,3}$ — factors to convert to impedance
- Y — change in average household income in the region, expressed as an index with 1990 as the base year
- P — change in the consumer price index for the region, expressed as an index with 1990 as the base year
- Q — vehicle occupancy factor
- a — a link in the network
- V_a — highway flow on link *a*
- L_a — transit flow on link *a*
- c_a — in-vehicle time to travel on link *a*
- i,j — centroids
- t,h — transit and highway mode subscripts
- T_{ijm} — Flow from *i* to *j* using mode m
- T_{ij} — all trips from *i* to *j*
- c_{ijt} — cost to travel from *i* to *j* via transit
- R_{ijm} — set of all routes from *i* to *j* using mode m
- r — a route
- k_a — the vehicle operating cost for link *a*
- s_j — parking cost for zone *j*
- w_{ij} — out of vehicle travel time for *i* and *j*
- c_{ijt} — transit in-vehicle travel time between *i* and *j*
- k_{ijt} — transit cost, including fare, between *i* and *j*
- w_{ijt} — transit out of vehicle travel time for travel between *i* and *j*

- O_i trips originating in zone i
- D_j trips destined from zone j
- δ^a_{ijrm} equals 1 if link *a* is used by route *r* from *i* to *j* using mode *m*
- S_0 modal dispersion constraint constant for logit formulation

The first term in the objective function, modified by K_1, represents the impedance due to out-of-vehicle time, including waiting time for transit. The second term, modified by K_2, represents the in-vehicle time for highway and transit modes. The third term, modified by K_3, represents the out of pocket monetary expenses for travel, including parking for highway modes and fare for transit. Most of the constraints are for book keeping, such as making sure that the transit and auto OD flows add up to the total origin-destination flows. The fifth constraint, $\sum_i \sum_j \sum_m d_{ijm} \ln d_{ijm} = -S_0$, requires some explanation, however. This constraint ensures that travelers do not always choose the least cost modal alternative. It ensures that some dispersion is added to the modal split model consistent with the logit formulation, which was discussed in **Chapter IX**.

This optimization program is solved with the Evans algorithm (named after discoverer Dr. Susan Evans). The Evans algorithm is similar to the algorithm used for only highway assignment with the use of an iterative process that consists of weighting together the results from several steps. A diagram of the algorithm is shown ***Figure XI-2***.

After the initial 15 iterations of highway assignment, the updated link speeds given the current loading pattern is used to update the zone to zone impedances. This updated impedance data is used to restart the modeling chain at trip distribution. The trip distribution, modal split, vehicle occupancy, and highway assignment models are all rerun (this time the highway assignment only uses a single iteration instead of the opening 15). The second run through the trip chain produces new highway and transit trip tables and a new set of link loadings. These are the sub-problem solutions that are weighted together with the results from the original pass through the model chain. This is done by finding a weighting factor λ that minimizes the objective function, similar to the weighting method used in the highway assignment only iterations described in the pervious section.

Seven Evans iterations are performed where each time the modeling chain is repeated with updated highway network costs. The result from each iteration is weighted together in a convex combination with the results from the pervious iteration(s). The Evans iterations can be seen as the outer loop in ***Figure XI-2***. After 15 iterations of highway assignment and 7 iterations of the Evans algorithm the solution approaches the equilibrium solution with a precision corresponding to the rounding error present in the TRANPLAN program. The weighting factors (λ's) for

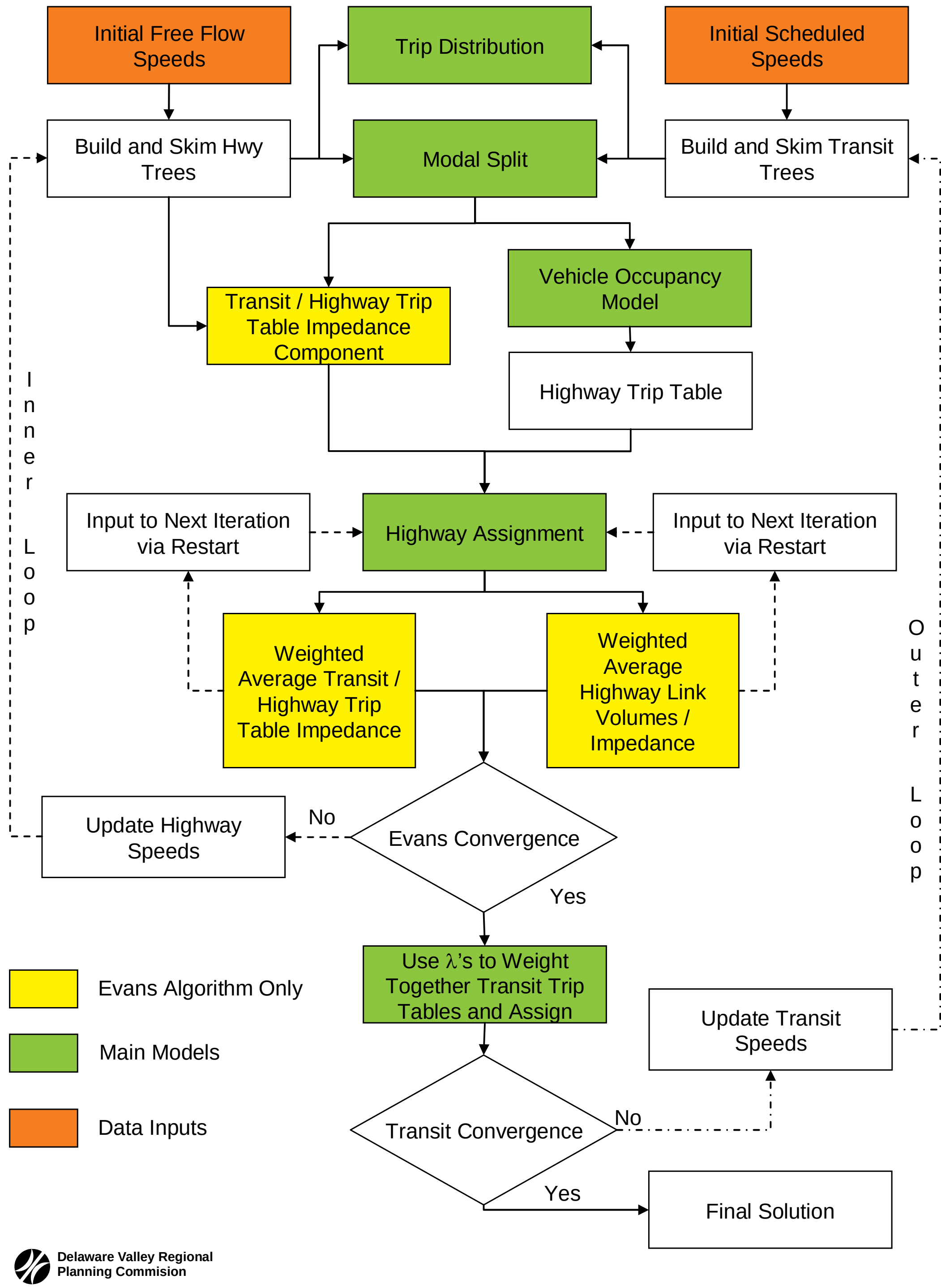


Figure XI-2 Highway and Transit Assignment Models in Evans Structure

the 15 initial highway assignment only iterations and for the first two Evans iterations are fixed. The weighted transit trip tables are assigned to the transit network after the highway results have sufficiently converged, as shown in the outer loop in ***Figure XI-2.*** Transit assignment is discussed in the next chapter. The Evans algorithm was first implemented on the 1997 network. It was then exclusively used for the 2000 and 2005 travel simulation models

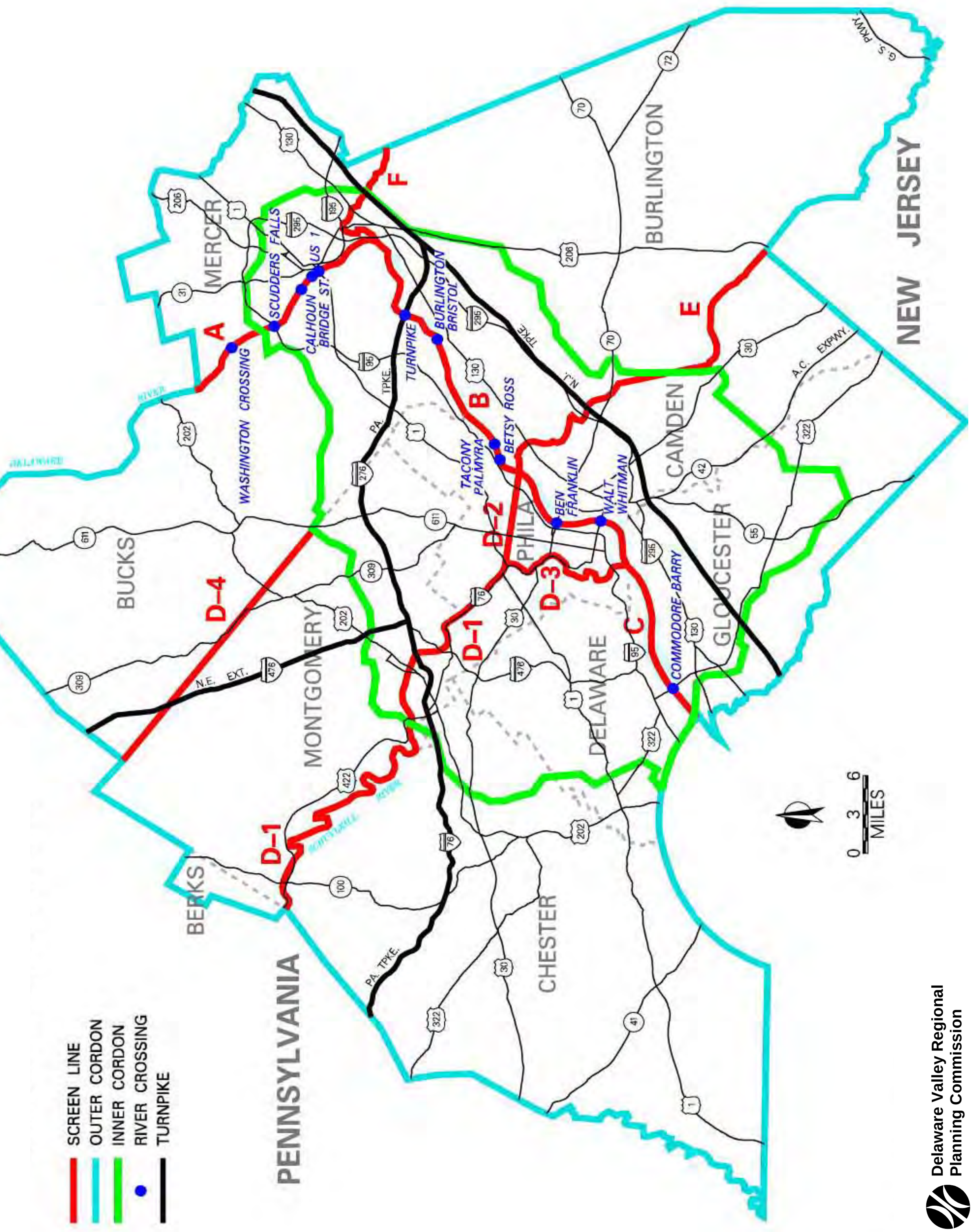
C. Highway Assignment Results

Link volumes are the output of highway assignment. These can be analyzed in several ways via post processing. The quality of the highway assignment is determined by evaluating the highway link volumes on the 10 screenlines that are described in and shown in ***Figure XI-3***. The simulated screenline counts are compared to actual screenline counts. The link volumes are used for highway design, traffic engineering, highway operating, and highway planning studies. The link volumes and the associated link speeds are used for air quality conformity modeling and energy analysis. The simulated VMT are usually compared to those prepared by the Pennsylvania and New Jersey Departments of Transportation for the Highway Performance Monitoring System (HPMS), which are based on actual traffic counts.

1. Link and Screenline Volumes

Table XI-3 contains selected assigned traffic volumes from the regional highway assignment for individual facilities. These links are all taken from the Schuylkill Crossing Traffic Study. The figures in the table are taken directly from the computer simulation without adjustment. While the error on the aggregated volumes for all nine facilities is small, 1.8 percent, the error on individual facilities is much higher. The error on some facilities is reasonable: 5.6 percent for the I-476 Bridge and -3.9 percent for Main Street. The error on other facilities is quite unreasonable; Belmont Avenue has an error of 61.1 percent, and US 202 has an error of 22.0 percent. Errors on individual links can go higher than these percentages in the regional simulation for local roads. Various parameters (capacity, speed, etc.) are adjusted in order to bring the simulated volumes closer to count volumes in cases where individual link volumes are important, such as for focused area simulations. Unreasonable computer numbers must be analyzed and adjusted, if needed, before using them in various studies. Such adjustments are made in the calibration phase of the focused traffic assignment.

Figure XI-3 DVRPC Screenlines and Cordons



Delaware Valley Regional Planning Commission

Table XI-3 2005 Regional Simulation Simulated Traffic vs. Traffic Counts for Selected Facilities from the Schuylkill River Crossing Traffic Study

Selected Highway Facilities	Counts 2005	Simulation 2005	Difference Absolute	Difference Percent
I-476 Schuylkill River Bridge	113,394	97,031	-16,363	-14.4%
Belmont Ave/Green Lane Schuylkill River Bridge	24,776	39,912	15,136	61.1%
US-1 (Roosevelt Expwy) Schuylkill River Bridge	117,189	103,928	-13,261	-11.3%
US 202 - Saulin Blvd to DeKalb St Ramps	36,353	44,357	8,004	22.0%
PA 23 - Anderson Rd to PA 23 Overpass	9,714	11,031	1,317	13.6%
I-76 EB Off-Ramp to Belmont Ave	7,069	8,097	1,028	14.5%
I-76 WB On-Ramp from Belmont Ave	7,716	8,147	431	5.6%
Main Street - Leverington Ave to Green Lane	17,442	16,766	-676	-3.9%
Green Lane - Main Street to Silverwood St	10,327	8,609	-1,718	-16.6%
All 9 Facilities	**343,980**	**337,878**	**-6,102**	**-1.8%**

Source: DVRPC July 2008

Table XI-4 presents results for the regional travel simulation. The table compares counted and simulated volumes on selected screenlines throughout the region. The screenline simulated volumes show reasonable agreement with the counted volumes. The inner cordon line is 5.9 percent less than counted volume, while the Center City Philadelphia cordon is 8.7 percent less than the counted volumes. The other screenlines show better agreement, with assigned volumes being within 2.0 percent of counted volumes. Overall, the simulated volumes are 3.2 percent less than the counted volumes. This indicates that the not only the highway assignment model, but the preceding models in the modeling chain are reasonable.

Table XI-4 2005 Simulated Traffic vs. Actual Traffic Counts (000s)

Selected Screenlines	Count	Assigned	Difference Absolute	Difference Percent
Inner Cordon	2,650.9	2,494.9	-156.0	-5.9%
Delaware River Screenline	611.1	602.5	-8.6	-1.4%
Bucks-Montgomery County Screenline	264.2	269.6	5.4	2.0%
Center City Cordon	1,090.8	995.6	-95.2	-8.7%
Crosswicks Creek Screenline	254.7	253.4	-1.2	-0.5%
Pennsauken Creek	576.6	569.7	-6.9	-1.2%
All Screenlines	**9,087.8**	**8,796.8**	**-291.0**	**-3.2%**

Source: DVRPC July 2008

2. Vehicle Miles of Travel and Average Speeds

Vehicle miles of travel (VMT) and link speeds are important model outputs, especially for conformity demonstration. The accuracy of the highway assignment model can be assessed by comparing the simulated VMT with that derived from DVRPC's traffic monitoring programs. Regional and county VMT is estimated through traffic counts as part of the Highway Performance Monitoring System (HPMS). HPMS is an FHWA mandated program for monitoring the performance of the nation's highway system. A subset of the region's highway facilities are counted at least once every three years on an on-going basis. Annual VMT for all facilities in the region is estimated from the HPMS sample.

Table XI-5 contains a comparison of VMT from the HPMS system versus that from the model. The model results were run through the DVRPC post-processor to estimate the VMT on local facilities that are not included in the network. Both the regional and state simulated VMT totals are within 1 percent of the HPMS totals. The county VMT results from the simulation are within several percent of the HPMS results, except for the outlier of Chester County. The region wide total in ***Table XI-2*** is the raw figure directly for the highway assignment model and hence slightly different from the more accurate post-processor derived figure in ***Table XI-5***. Overall, the figures in ***Table XI-5*** demonstrate that the highway assignment model replicates travel patterns well.

Table XI-5 Comparison of 2005 Daily VMT Estimates

County	HPMS	DVRPC Simulation	Difference Absolute	Difference Percent
Bucks	13,696.1	13,221.9	-474.2	-3.5%
Chester	11,832.0	13,865.5	2,033.5	17.2%
Delaware	10,180.6	10,061.7	-118.9	-1.2%
Montgomery	19,109.5	18,915.3	-194.2	-1.0%
Philadelphia	16,316.4	15,538.4	-778.0	-4.8%
Pennsylvania	**71,134.6**	**71,602.8**	**468.2**	**0.7%**
Burlington	13,365.5	12,825.5	-540.0	-4.0%
Camden	10,855.2	10,661.7	-193.5	-1.8%
Gloucester	7,430.7	7,716.7	286.0	3.8%
Mercer	9,488.2	9,590.2	102.0	1.1%
New Jersey	**41,139.6**	**40,794.1**	**-345.5**	**-0.8%**
Regional Total	**112,274.2**	**112,396.9**	**122.7**	**0.1%**

Source: DVRPC July 2008

D. Focused Travel Simulation

The regional travel simulation models, even with equilibrium assignment techniques, do not always give reasonable volume estimates on every link, particularly on local streets. In addition, local streets not included in the regional highway network are often of great interest to policy makers, particularly if they are impacted by a proposed new freeway or arterial improvement. In order to improve the accuracy of the assignment and to incorporate additional facilities, a special enhanced assignment technique, focused on a specific detailed study area, is used.

The focused simulation process has several characteristics which makes it desirable for use in these studies:

- It can provide link and turning volumes for nearly all streets and intersections within the detailed corridor or study area.
- It allows the use of DVRPC regional simulation models without recalibration, except the highway assignment program which must be recalibrated for the study area.
- It increases the accuracy of travel volume estimates within the detailed study area.

The first step in the preparation of the focused simulation process is to identify the streets and intersections for which traffic volume estimates are needed. All through streets and local roads of concern inside the detailed study area are included in the network. The estimation of fine-grained highway link and turning movements require that some traffic zones be subdivided into smaller zones within the study area. Generally, the grain of these zones should be the same as the highway network, so that the fine-grained traffic loadings necessary for accurate turning movements can be made.

The focused travel simulation model requires the following changes:

1. Inside the study areas, split the traffic zones into smaller areal units. Add in any missing streets. Recode the approaches to the highway and transit networks to reflect these smaller zones.

2. Split the traffic zone estimates of population, households, vehicle availability to households, employed residents and employment down to the finer zones. Also incorporate the travel resulting from special trip generators such as office buildings or shopping centers, if these developments influence traffic patterns and are not included in the base forecast of socio-demographic and employment variables.
3. Redefine the regional travel simulation model input data sets, control files etc. to reflect the new number of zones, cordon station centroid number series, and additional traffic zones within the detailed study area.

This socio-economic data disaggregation is accomplished by examining aerial photographs of the study area to determine the existing and likely distributions of development and open space therein. From this, an estimate of the percentage of demographic variables that effect travel is made and allocated to each split zone. These factors, which sum to one for any traffic zone, are then used to disaggregate the traffic zone level inputs to the trip generation model into the sub-zone portions.

The focused simulation process is then executed to prepare estimates of traffic volumes for the streets, ramps, freeways, and turning movements and transit lines. The process is then validated within the study area by comparing predicted with actual facility volumes and any required adjustments or corrections to the model are implemented.

Detailed information on focuses traffic simulation can be found in **Appendix XI-1**. This appendix contains excerpts from report on a focused simulation preformed for a section of US 202 is Montgomery and Bucks counties.

XII. TRANSIT ASSIGNMENT MODEL

The modal split model together with the Evans algorithm produces the transit person trip tables by trip purpose. The three internal person trip tables, HBW, HBNW, and NHB, are combined to form a single transit person trip table. This gives zone-to-zone transit volumes for each TAZ pair. The transit assignment model produces several important results. The transit trip table gives the total number of transit trips. However, some of these trips use multiple modes and vehicles. The model produces the number of unlinked trips which include the effect of transferring. Secondly, the unlinked transit trips are associated with specific transit facilities to produce line, link, and station volumes. These results are produced simultaneously with the TRANPLAN program TRLOAD, which assigns the transit trip matrix to the minimum impedance paths built from the transit network.

A. Transit Assignment Methodology

The transit assignment algorithm is similar to the highway assignment algorithm. The minimum impedance route for each O-D pair is found according to the following definition of impedance consistent with that used in the modal split model when calculating impedance difference:

$$\text{Transit Impedance} = K_1 \frac{Y}{P} w_{ijt} + K_2 \frac{Y}{P} c_{ijt} + K_3 \frac{1}{P} k_{ijt} + K_4 \left(TRFR_{ij} + 1 \right)$$

where the following variables were defined and used earlier:

- $K_{1,2,3,4}$ factors to convert to impedance
- Y change in average household income in the region, expressed as an index with 1990 as the base year
- P change in the consumer price index for the region, expressed as an index with 1990 as the base year
- c_{ijt} transit in-vehicle travel time between *i* and *j*
- k_{ijt} transit cost, including fare, between *i* and *j*
- w_{ijt} transit out-of-vehicle travel time for travel between *i* and *j*
- $TRFR_{ij}$ number of transfers in transit route from *i* to *j*

The total impedance and transit submode from these paths are also used as input to the modal split model. The allocation of trips by transit submode in the modal split model and transit assignment procedure is done by the construction of minimum paths. In the sequence of events, minimum impedance paths are constructed and the necessary information is passed to the mode choice models. One of the data items extracted from the paths for mode choice is the submode of travel, which the modal split model uses to select the appropriate diversion curve. The transit trip table for each sub-mode as determined from the modal split model is assigned to the correct minimum impedance path by the transit assignment model. For internal travel, six different trip tables (three time periods, auto approach and walk/bus approach) are assigned to six sets of minimum paths for the assignment of internal transit travel.

As discussed in **Chapter IX**, the modal split model is nested by mode of approach. Separate sets of minimum impedance paths through the peak, midday, and evening transit networks were calculated using the composite impedance values for both the auto and walk/bus modes of approach. The nested modal split process starts with a base transit network, coded to the DVRPC model specifications. The walk and auto approach sub-networks are specified parametrically by utilizing delete access and egress modes parameters in UPATH as follows:

- The walk approach transit network is generated by removing all the auto approach links for both access and egress.
- The auto approach network is also specified within UPATH. The walk links connecting transit facilities to centroids are made one-way away from the transit lines by using the delete egress parameter. This prevents walk access to the transit system on the home end of the trip, but allows walk egress at the non-home end. It is important to note that the network walk links connected to a given centroid are not altered. As with the walk approach network, the time period network is built in DVFARE using the unaltered link, coordinate, and line files.

After the nesting coefficient is applied, the nested modal split model produces separate transit loading matrices for auto and walk/bus approach. The transit assignment process shown in ***Figure XII-1*** is run separately for the peak, midday, and evening time periods.

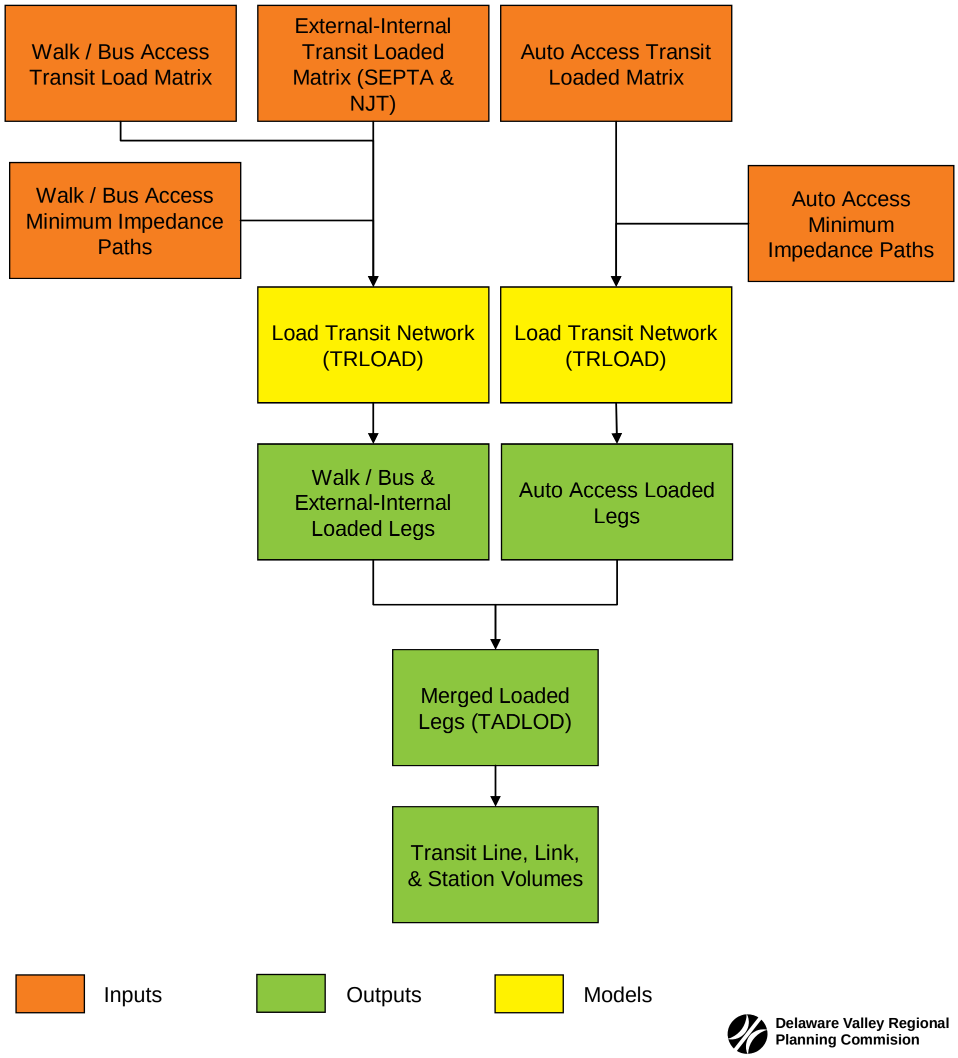


Figure XII-1 Nested Transit Assignment Process

Following the nested structure and TRANPLAN practice, the walk/bus approach trips, as augmented by the external-internal transit trips (discussed subsequently), are assigned to the corresponding walk approach paths to produce an intermediate TRANPLAN loaded legs file. The loaded legs file stores the facility level assignment results in a special compressed format. The auto approach transit trips are then assigned to the auto approach paths producing a second loaded legs file. In the final step, the two loaded legs files are merged and summarized together to produce the transit route, line, and station assignment summaries for that time periods. The loaded legs files for the peak, midday, and evening time periods cannot be merged together because the route service patterns are different by time period.

Unlike highway assignment, transit assignment is not capacity constrained. The highway network experiences significant roadway congestion so that a capacity constrained assignment procedure is required to obtain reasonable highway volumes. The same is not true for the transit system since the DVRPC region does not experience significant passenger crowding on most routes. For instance, passengers are typically able to board the first bus or train that serves their desired destination. As such, a constrained transit assignment algorithm is not needed. Instead, what is referred to as an "all-or-nothing" transit assignment is conduced on the minimum impedance path through the transit network. This method is especially suited for cases where one transit path has a significant advantage over other possible paths. In cases where two transit paths have equal or nearly equal impedances, however, assigned line and link volumes might deviate from actual passenger counts.

1. Transit Network

Transit service in the Delaware Valley is provided by various agencies and private carriers. The Southeastern Pennsylvania Transportation Authority (SEPTA) operates public transportation in the Pennsylvania counties, maintaining one of the most diverse transit systems in the nation. SEPTA bus and rail lines also extend into New Jersey (City of Trenton) and regional rail service is also provided to Delaware. SEPTA service is augmented in the Pottstown area with local bus service provided by Pottstown Urban Transit (PUT).

The New Jersey Transit Corporation (NJ TRANSIT) provides bus and rail services for Burlington, Camden, Gloucester and Mercer counties, with additional direct service to Philadelphia and various shore destinations. NJ TRANSIT also provides commuter rail services between Philadelphia and Atlantic City, and between Trenton, Princeton, and New York. Additional heavy rail transit service is provided between Center City Philadelphia and Lindenwold in Camden County by the Port Authority Transit Corporation (PATCO).

There are three operating divisions within SEPTA which offer different types of services in different areas of the region - City Transit Division, Regional Rail Division, and the Victory and Frontier Divisions

The City Transit division is the largest of the groups and provides numerous types of transit services. Two heavy rail transit lines, the Market-Frankford Subway/Elevated and the Broad Street Subway, serve as the foundation of this division's services. They are supplemented by five subway-surface light rail and 84 bus routes.

The Market-Frankford Line is the most heavily used line in the entire SEPTA system. The line follows an L-shaped route, running east along Market Street from 69th

Street in Upper Darby Township, Delaware County through Center City Philadelphia to the Delaware River waterfront. The line then turns northward to follow Front Street, Kensington Avenue and Frankford Avenue to its terminus at the Frankford Transportation Center.

The Broad Street Subway is a north-south line running underground between Fern Rock Station and Pattison Avenue via Philadelphia City Hall, where passengers may transfer for free to the east-west Market-Frankford Line.

Subway-Surface Light Rail Service is currently offered on five regularly scheduled routes, all in West Philadelphia. The lines operate on the street west of 40th or 36th Streets and underground east to 13th Street in Center City Philadelphia. SEPTA also operates another, surface only, streetcar route along Girard Ave. This line was recently restored from bus service using remanufactured PCC cars.

The City Transit Division also operates buses, which carry about 50 percent of the division's riders. Several routes go beyond the city limits into areas of Bucks, Montgomery, Chester, and Delaware counties. SEPTA also operates three trolleybus (electric bus service or "trackless trolley") lines in Northeast Philadelphia.

The following commuter lines are operated by SEPTA's Regional Rail Division:

- R1: Service between Glenside and Philadelphia International Airport via Center City Philadelphia.
- R2: Service between Delaware and Warminster via Center City Philadelphia.
- R3: Service between Elwyn and West Trenton via Center City Philadelphia.
- R5: Service between Thorndale and Doylestown via Center City Philadelphia.
- R6: Service between Norristown and Cynwyd via Center City Philadelphia.
- R7: Service between Trenton and Chestnut Hill East via Center City Philadelphia.
- R8: Service between Chestnut Hill West and Fox Chase via Center City Philadelphia.

The Victory and Frontier divisions provide transit service mainly in the suburban Pennsylvania counties. The Victory Division operates 25 bus routes, mostly out of its principal terminus at 69th Street in Upper Darby Township. Other bus routes focus on the Darby Terminal with its rail connections to West Philadelphia and Philadelphia City Hall, and the City of Chester.

There are also three rail lines operating out of 69th Street. Two of them are light rail lines (Sharon Hill and Media). The third rail route, the Route 100, possesses some rather unique characteristics and can be classified as “light-rail rapid transit.” The

Route 100, commonly referred to as the "Norristown High Speed Line," runs for almost 14 miles through suburbs to the Norristown Transportation Center.

The Frontier Division provides 21 bus routes to selected outlying portions of the region. Most of these routes extend SEPTA's service north and west from the Norristown Transportation Center. Additional routes connect King of Prussia with West Chester and Chestnut Hill with Lansdale. Other routes originate at the Oxford Valley Mall and serve lower Bucks County and the Trenton area.

Pottstown Urban Transit (PUT) serves the western portion of Montgomery County and northern Chester County. The current system consist of 5 bus routes and offers daily service to the Borough of Pottstown and its surrounding communities.

NJ TRANSIT provides bus service across the Delaware River between New Jersey and Philadelphia. NJ TRANSIT provides transit service to the four NJ counties of the region as well as to shore points and the New York region. Trips between Philadelphia and seashore points originate and terminate at the Greyhound Terminal located at Tenth and Filbert streets in Philadelphia.

NJ TRANSIT operates 47 bus routes, including regular bus routes within and between Trenton and Mercer County, with some service extending to Hunterdon County. Many of these routes originate in Philadelphia and provide service to New Jersey suburban communities. Also, NJ TRANSIT operates weekday rail trips and extra service on weekends between Atlantic City, Lindenwold, and 30th Street Station in Philadelphia. Within the region, intermediate stops are made at Garden State Park in Cherry Hill, the PATCO High Speed line Station in Lindenwold and the PATCO Station on NJ 73.

NJ TRANSIT rail carries passengers between Trenton, Princeton Junction, Newark Penn Station and New York Penn Station along the Northeast Corridor. In addition it operates the River Line (light rail) from Camden to Trenton. The line, which opened in 2004, uses diesel multiple unit (DMU) light rail cars.

The Port Authority Transit Corporation (PATCO) provides regularly scheduled heavy rail service to Camden County. The 14.2 mile line provides service between Lindenwold in New Jersey and 16th and Locust Streets in Philadelphia. There are seven stations in suburban Camden County, all of which are adjacent to park-and-ride lots. The line also has four subway stations in Center City Philadelphia.

AMTRAK operates intercity rail service from Philadelphia's 30th Street and North Philadelphia Stations as well as Princeton Junction and Trenton Stations in New Jersey. Frequent service is offered along the Northeast Corridor between Washington, DC and New York City. AMTRAK also schedules regular service between New York, Pittsburgh, and Chicago via the Harrisburg rail line with additional service provided between Philadelphia and Harrisburg.

2. Transit Network Preparation

The primary data inputs to the transit assignment process are the coded transit network and the transit person trip tables. The DVRPC transit network represents all transit operators and modes operating within the DVRPC nine-county region. The network models transit service completely internal to the region, service that has one end external to the region, and through service with both ends external to the region. For various reasons explained below, the transit network is divided into two separate networks for transit assignment – internal and shadow. The primary sources for the computer representation of the regional transit network are the schedules produced by the transit operating agencies. The schedules provide fare, route, and headway data inputs to the transit coding process.

The representation of the transit network is located in several files. The main file is a route file that describes each transit service pattern by the nodes that it uses. Often a single transit route as designated by the transit provider will have various service patterns that run throughout the day – some are short-turn services, others have small diversions, etc. Each of these is in effect stored as a separate transit route. The transit network utilizes the node-link structure contained in the highway network file as well as separate, transit only, nodes and links. A complete description of DVRPC's transit coding can be found in **Chapter V** with technical details located in **Appendix V-2**. Maps of the transit network can be seen in ***Figures V-4*** (page 93) ***Figure A-V-4,*** (page 350)***and A-V-5*** (page 351).

3. External Transit Assignment and the Shadow Network

In addition to assigning internal-internal transit person trips, the transit assignment algorithm also assigns external transit trips – AMTRAK and intercity bus routes. Transit external-local and through trip origins and destinations are obtained from transit operator ridership counts and on-board survey data. For future travel simulations, external-internal and through trips are forecasted by Frataring the base year values to projected cordon station totals, which are prepared by DVRPC staff.

The coding process described in **Chapter V** produces a composite transit network that includes all regularly scheduled common carriage service in the DVRPC region. AMTRAK and Greyhound/Martz provide services along the same alignment as corresponding SEPTA service. It is not possible to assign both the transit through and internal trips at the same time because of the minimum impedance path assignment procedure. The minimum path tends to be AMTRAK and Intercity bus because of express service and faster running times. The transit network is divided into two parts in order to properly assign internal and through trips – the internal network, excluding intercity operators, which assigns internal and some unambiguous external-local travel, and the shadow network for assigning transit through trips to intercity operators. The internal and shadow transit networks have a great deal of overlap because the internal transit system is used to provide access to Philadelphia 30th Street Station and the Trenton AMTRAK station. The shadow network has SEPTA R7 Trenton, R2 Wilmington, and R5 Main Line services removed as they fall on the same alignment as AMTRAK service. The regular network has AMTRAK and NJ TRANSIT NE Corridor lines and intercity bus lines removed. This ensures that internal transit person trips are assigned to the proper SEPTA, NJ TRANSIT bus, and PATCO lines. By convention, NJ TRANSIT seashore buses, Atlantic City rail, and SEPTA Wilmington R2 external-internal trips are assigned to the walk/bus approach internal transit network.

Table XII-1 lists the service patterns that are removed from the conventional network and placed in the shadow network. The DVFARELG computer program automatically deletes centroid walk and auto approach, transfer, and network operating links associated with the deleted service patterns (line cards). ***Table XII-2*** lists which external transit trips are assigned to the conventional network and which are assigned to the shadow network.

Table XII-1 Lines by Time Period Removed from the Conventional Network

Time Period	Mode	Line Card #s	Routes
Peak	9	All	Intercity Bus Routes
Peak	14	1-6	NJ TRANSIT NE Corridor
Peak	15	All	AMTRAK NE Corridor and Keystone Service
Midday	9	All	Intercity Bus Routes
Midday	14	1-3	NJ TRANSIT NE Corridor
Midday	15	All	AMTRAK NE Corridor and Keystone Service
Evening	9	All	Intercity Bus Routes
Evening	14	1-4	NJ TRANSIT NE Corridor
Evening	15	All	AMTRAK NE Corridor and Keystone Service

Source: DVRPC July 2008

Table XII-2 Allocation of Cordon Station External Trips to the Shadow and Internal Transit Networks

Cordon Station	Route	Shadow	Internal
1913	AMTRAK south	x	
1914	SEPTA WILMINGTON		x
1916	Intercity Bus	x	
1949	AMTRAK West	x	
1996	NJTransit Bus		x
2008	NJTransit Bus		x
2009	AMTRAK north	x	
2010	NJTransit Rail north	x	
2026	NJTransit Bus		x
2040	NJTransit Bus		x
2042	NJTransit Bus		x
2043	NJTransit Bus		x
2045	NJTransit Bus		x
2049	NJTransit Bus		x
2057	NJTransit Bus		x
2062	NJTransit Bus		x
2067	NJTransit Bus		x

Source: DVRPC July 2008

There is no rigorous way to combine the shadow transit assignment with the internal assignment at this time. This is because transit external-internal and through trips are not disaggregated into separate walk/bus and auto approach trip tables. By convention, the Wilmington and Atlantic City external-local matrices are assigned to the walk/bus approaches and the matrices associated with AMTRAK and intercity bus are assigned to minimum paths through the composite network. In practice, this causes some auto approach trips to be assigned to regular transit routes. Ridership assignments to specific AMTRAK, NJTransit, and intercity bus routes are accurate; but transit network approaches, especially to AMTRAK, stations may be overstated.

B. Transit and Highway Speed Determination and Post-Processor Speed Updates

Accurate highway speeds are needed for two purposes – air quality analysis and future transit speed updates. Transit in-vehicle times for in-street transit lines (right-of-way C) depend on prevailing levels of congestion. The transit in-vehicle link speeds for base year simulations are assumed to include the present level of highway congestion. The transit in-vehicle times for future year simulations are updated according to changes in the prevailing levels of highway congestion.

Estimating changes in future simulated transit in-vehicle times, therefore, requires an accurate estimation of highway speeds. This process, as discussed below, is shown as the outer loop in ***Figure XI-2*** in the previous chapter. As this process is slightly non-convex, only a single iteration of the outer-loop is conducted.

While the congestion delay functions (**Chapter XI.A.1**) provide a volume/speed relationship, these equations are calibrated to accurately represent the effects of congestion on user-path choice, and not congested speeds. DVRPC uses a post-processor to calculate highway speeds where added accuracy is needed, such as for air quality analysis and transit speed updates. The post-processor contains separate curves for freeways/expressways and other facilities. Freeway speeds are dependent upon volume and capacity per lane, free-flow speed, and operating speed at capacity (congested highway speeds). The curves for the surface-street facilities (parkway, arterial and collector, and local) are a function of volume and capacity per lane, free-flow speed, and the number of traffic signals per-mile. Inputs to both the freeway and surface street models vary by area type.

After the post-processor calculates highway speeds, a linear correction is used to bring the speeds closer to surveyed results. These speeds are used directly for air quality analysis, which is discussed in the next chapter. The post-processor speeds are not used directly, however, for updating future transit in-vehicle times. Instead, the ratio of future to current post-processor simulated highway speeds is used to update scheduled transit in-vehicle times. Details on this procedure are located in **Appendix V-2.D**.

The highway speed post-processor was originally developed for previous versions of the DVRPC model. The post-processor was updated for the 2000 model due to new survey data and new EPA MOBILE6.2 requirements. The recalibration effort is documented in the memo "Recalibration of DVRPC's Postprocessor Speed Curves with Current Survey Data."

As discussed in **Chapters II** and **IX**, DVRPC follows the FTA guidelines when calibrating and forecasting transit trips by sub-mode for News Starts Alternatives Analysis. This forces a different simulation process that affects the determination of both highway and transit speeds. The FTA requires that build-alternatives must use the No-build trip table and speeds. Each alternative is forced to have identical travel patterns. The effects of reduced highway congestion on increasing transit speeds are not considered since highway and transit link impedances are kept constant.

C. Transit Assignment Results

Table XII-3 contains output from the regional transit assignment model. Assigned boarding and alighting volumes at several SEPTA Regional Rail stations are compared with actual counts. The total simulated volumes for these nine stations differ from counted volumes by about 3 percent. The simulated volumes at individual stations, however, can differ significantly from counted volumes. The volumes at five of the nine stations in ***Table XII-3*** are more than 10 percent off from counted volumes, with the Carpenter Station volume being 22 percent greater.

Table XII-3 Weekday Boardings and Alightings from the 2005 Regional Simulation for Selected Stations

			Difference	
Selected Railroad Stations	**Counts**	**Simulation**	**Absolute**	**Percent**
Elkins Park	886	813	-73	-8.2%
Carpenter	556	679	123	22.1%
St. Davids	478	561	83	17.4%
Rosemont	615	543	-72	-11.7%
Meadowbrook	187	206	19	10.2%
Hatboro	810	790	-20	-2.5%
Glenside	1,922	1,670	-252	-13.1%
Fern Rock	75	79	4	5.3%
Eastwick	561	573	12	2.1%
All 9 Stations	**6,090**	**5,914**	**-176**	**-2.9%**

Source: DVRPC July 2008

Table XII-4 presents selected transit simulated and counted volumes from the 2005 regional simulation summarized by company and mode. The largest positive difference is with PATCO ridership (9.7 percent) and SEPTA City Division bus and trolley ridership (6.9 percent). The largest negative difference is SEPTA regional rail, where simulated volumes are 3.9 percent lower than counted volumes. Like the computer results from the highway traffic assignment, the transit computer results must be thoroughly evaluated by transportation planners before being used in various rail, subway, and bus studies. Calibration factors are essential for producing reasonable transit forecasts.

D. Focused Transit Assignment

The focused transit simulation is able to provide more accurate transit volumes than the regional simulation. This is important for transit studies as individual station and line volumes are used to evaluate alternatives and to plan facilities. For this reason the focused transit simulation process requires added levels of accuracy and precision in the study area versus the regional transit simulation.

Table XII-4 Comparison of 2005 Passenger Counts with Simulated Volumes

		2005 Volumes (000)		Difference	
Company/Division	**Mode**	**Simulated**	**Count**	**Absolute**	**Percent**
SEPTA City Transit	Subway-Elevated	301.0	293.5	7.4	2.5%
SEPTA City Transit	Bus & Trolley	604.9	565.7	39.2	6.9%
SEPTA Suburban	All Modes	61	62	-0.5	-0.8%
SEPTA Regional Rail	Commuter Rail	102.2	106.4	-4.2	-3.9%
NJ TRANSIT	All Modes	73.0	70.5	2.5	3.6%
PATCO	High Speed Rail	37.1	33.8	3.3	9.7%

Source: DVRPC July 2008

The steps used in the DVRPC focused transit simulation process are:

1. Define Study Area
2. Refine Traffic Zones
3. Prepare Demographic and Employment Inputs
    a. Current Calibration Year
    b. Forecast Years
4. Fine Tune Regional DVRPC Model Calibration for the Study Area
    a. Regional Transit Simulation
    b. Study Area Highway Screenlines
    c. Corridor Rail Stations and Bus Lines
    d. 2000 CTPP Work Trips
5. Prepare No-build Travel Forecasts
    a. Update Highway and Bus Congested Speeds for Future Conditions
    b. Transit Line and Station Ridership
    c. Highway Screenline Volumes
6. Build Alternative Forecasts
    a. Use No-build Person Trip Tables
    b. Use No-build Highway and Bus Congested Speeds
7. Prepare User Benefit Estimates from SUMMIT

TAZs are split in order to better estimate transit line access patterns. Model simulation parameters are modified in order to increase the accuracy of line and station volumes in the study area. Furthermore, additional data such as station parking requirements, are estimated in the focused simulation.

DVRPC's focused simulation process for FTA New Starts analysis is similar to the regional simulation process and the focused highway simulation process, but contains key differences due to FTA regulations. The travel models follow the traditional steps of trip generation, trip distribution, mode choice, and traffic assignment. A single iteration is sufficient to produce reasonable estimates of future highway congestion levels for purposes of estimating projected travel patterns.

For the build alternatives, the FTA currently requires that the No-build person trip table be utilized. This limits the feedback iterations to the modal split and transit/highway assignment model steps, resulting in separate iterative processes. Transit operator scheduled transit times and highway times taken from a travel time survey are used for model calibration. Both the No-build and Build alternative future iterative processes start with current scheduled transit and surveyed highway times.

This socioeconomic data disaggregation is accomplished by examining aerial photographs of the study area to determine the existing and likely distributions of development and open space therein. From this, an estimate of the percentage of demographic variables that effect travel is made and allocated to each split zone. These factors, which sum to one for any traffic zone, are then used to disaggregate the traffic zone level inputs to the trip generation model into the sub-zone portions.

The focused simulation process is then executed to prepare estimates of traffic volumes for rail transit lines, bus routes, stations, and stops. The process is then validated within the study area by comparing predicted with actual facility volumes and any required adjustments or corrections to the model are implemented.

Detailed information on focused transit simulation can be found in **Appendix XII-1**. This appendix contains excerpts from a report on a focused simulation performed to study alternatives for providing rail service to Quakertown, PA.

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XIII. MOBILE SOURCE EMISSIONS MODELING AND CONFORMITY DEMONSTRATION

The Clean Air Act (CAA), first enacted in 1963 and last amended in 1990, requires the US EPA to set national ambient air quality standards (NAAQS) for air pollutants that are considered harmful to public health and the environment. The CAA also requires the agency to periodically review the standards to ensure that they provide adequate health and environmental protection. These standards are set at the level required to provide an ample margin of safety to protect the public health.

A. Air Pollutants

US EPA has set NAAQS for several principal air pollutants, which are called "criteria" pollutants. These NAAQS criteria pollutants include:

- ozone, carbon monoxide (CO).
- coarse particulate matter (PM10).
- fine particulate matter (PM2.5).
- sulfur dioxide (SO2).
- lead (Pb).

Ozone is a photochemical oxidant and a major component of smog. Ozone is not emitted directly into the air, but is formed through complex chemical reactions between precursor emissions of volatile organic compounds (VOCs) and oxides of nitrogen (NOx) in the presence of sunlight. While ozone in the upper atmosphere shields and protects the earth from harmful radiation from the sun, high concentrations of ozone at ground level are a serious health and environmental concern. Ozone can damage lung tissue, reduce lung function, and sensitize the respiratory system to other irritants.

In 1990 the entire DVRPC region was designated as a severe non-attainment area for ozone. The region was required to attain the ozone standard by 2005. This standard was 0.12 parts per million (ppm) of ozone averaged over a 1-hour period. However, in 2004, this 1-hour standard was revoked and replaced with a more-stringent 8-hour standard of 0.08 ppm. At that time, the entire DVRPC region was reclassified as a Moderate Ozone Non-Attainment Area. Moderate non-attainment areas are required to reach the new ozone standard by 2010.

Carbon monoxide can reduce the delivery of oxygen to the body's organs and tissues. Health threats are most serious for those who suffer from cardiovascular disease. There are two NAAQS for CO: a 1-hour standard of 35 ppm and an 8-hour standard of 9 ppm. In 1990, portions of the DVRPC region were designated as non-attainment for CO because they did not meet the 8-hour standard. By 1996, however, the entire DVRPC region met both CO standards. Following this attainment status, portions of 4 counties in the region were designated as separate CO maintenance areas. These counties are Philadelphia, Burlington, Camden, and Mercer.

Particulate matter (PM) includes both solid particles and liquid droplets found in the air. These particles come in a wide range of sizes. The “coarse” particles less than 10 micrometers (µm) in diameter (PM10) pose a health concern, since they can be inhaled into and can accumulate in the respiratory system. The “fine” particles less than 2.5 µm in diameter (PM2.5) are believed to pose even greater health risks. PM2.5 can be emitted directly from combustion engines or be chemically formed in the atmosphere when certain gases are present. Direct PM2.5 emissions result from particles in exhaust fumes, from brake and tire wear, from road dust kicked up by vehicles, and from highway and transit construction. Indirect PM2.5 emissions can result from one or more of several exhaust components, including VOCs, NOx, sulfur oxides (SOx) and ammonia (NH3). The PM2.5 NAAQS include an annual average standard set at 15 $\mu g/m^3$ and an average daily standard of 65 $\mu g/m^3$.

US EPA designations under the PM2.5 standards became effective in 2005. Although split between two non-attainment areas, the entire DVRPC region is designated as a Non-Attainment area for PM2.5, based on the annual standard. The region is required to meet the NAAQS by 2010; however, a more stringent PM2.5 standard is expected to be in place by 2010.

B. Transportation Conformity

CAA section 176(c) (42 U.S.C. 7506(c)) requires that federally supported highway and transit project activities must “conform to” state air quality goals, which are documented in State Implementation Plans (SIPs). The process that preserves this consistency is called transportation conformity. This process ensures that transportation and air quality agencies are consulting with one another to look for strategies to relieve traffic congestion, improve air quality, and provide communities with a safe and efficient transportation system.

Transportation conformity is demonstrated when highway and transit activities that receive federal funds or approval are determined not to cause new air quality violations, worsen existing violations, or delay timely attainment of NAAQS. The Federal Highway Administration (FHWA) and Federal Transit Administration (FTA) jointly make conformity determinations within air quality non-attainment and maintenance areas to ensure that federal actions are consistent with the purpose of the corresponding SIPs. The United States Department of Transportation (US DOT) cannot fund, authorize, or approve federal actions to support programs or projects that are not found to conform to the CAA requirements governing the current NAAQS for transportation conformity. Such highway and transit projects must conform to the state implementation plans.

1. Pollutants in the Delaware Valley Region

MPOs, such as DVRPC, must demonstrate that their Transportation Improvement Programs (TIPs) and Long-range Plans conform to the applicable SIPs. Transportation conformity in the DVRPC region applies to the following pollutants and non-attainment areas:

- Volatile Organic Compounds (VOCs) meeting the 8-hour ozone NAAQS requirements in the DVRPC portion of the Philadelphia-Wilmington-Atlantic City Ozone Non-Attainment Area.
- Nitrogen Oxides (NOx) meeting the 8-hour ozone NAAQS requirements in the DVRPC portion of the Philadelphia-Wilmington-Atlantic City Ozone Non-Attainment Area.
- Fine Particulate Matter (PM2.5) meeting the PM2.5 NAAQS requirements in the DVRPC portion of the Philadelphia-Wilmington, PA-NJ-DE PM2.5 Non-Attainment Area; and the DVRPC portion of the New York-Northern New Jersey-Long Island, NY-NJ-CT PM2.5 Non-Attainment Area.

2. Conformity Rules

EPA's Final Conformity Rule (40 CFR 93) stipulates that regional emissions analysis conducted to demonstrate conformity of the TIP and/or Long-range Plan includes all "regionally significant, non-exempt" projects – that is, those which can impact regional air quality. The Rule defines a regionally significant project as one that is on a facility which serves regional transportation needs (such as access to and from the outside of the region; major activity centers in the region; major planned developments, such as new retail malls, sports complexes, etc. and transportation terminals; as well as most terminals themselves) and would normally be included in the modeling of a metropolitan area's transportation network, including at a minimum all principal arterial highways and all fixed guideway transit facilities that offer an alternative to regional highway travel. The Rule also requires that transportation-related emissions estimates used to support conformity determinations be made with a travel demand model which meets the following criteria:

- The model must be validated against observed counts (peak and off-peak, if possible) for a base year that is not more than 10 years prior to the date of the conformity determination. Model forecasts must be analyzed for reasonableness and compared to historical trends and other factors, and the results must be documented.
- Land use, population, employment, and other network-based travel model assumptions must be documented and based on the best available information.
- Scenarios of land development and use must be consistent with the future transportation system alternatives for which emissions are being estimated. The distribution of employment and residences for different transportation options must be reasonable.
- A capacity-sensitive assignment methodology must be used, and emissions estimates must be based on a methodology which differentiates between peak and off-peak link volumes and speeds and uses speeds based on final assigned volumes.
- Zone-to-zone travel impedances used to distribute trips between origin and destination pairs must be in reasonable agreement with the travel times that are estimated from final assigned traffic volumes. Where use of transit currently is anticipated to be a significant factor in satisfying transportation demand, these times should also be used for modeling mode splits.
- Network-based travel models must be reasonably sensitive to changes in the time(s), cost(s), and other factors affecting travel choices.

The Final Rule stipulates that the emission analysis of transportation plans and programs must model all regionally significant and non-exempt projects. Each categorized project is classified by the first year it is included in the analysis, commonly referred to as the “analysis year.” Certain projects that cannot be analyzed within the travel demand model are categorized as “off-network,” and are evaluated using trip estimate techniques outside the DVRPC travel demand model. The Pennsylvania Air Quality Off-Network Estimator (PAQ-ONE) and the New Jersey Air Quality Off-Network Estimator (NJAQ-ONE) are a set of travel impact and emissions analysis methodologies developed for the Pennsylvania and New Jersey State Departments of Transportation (state DOTs) used for off-network analyses in their respective states.

3. Conformity of Transportation Plans and Programs

For areas with an implemented SIP, the motor vehicle emissions budget (MVEB) prescribed in the SIP sets a regional emissions amount that functions as a threshold against which conformity is tested. This process is commonly known as the "budget" test. The Final Rule stipulates that each SIP is sovereign and that, for a multi-state MPO, such as DVRPC, conformity applies separately to individual state portions of its planning area under respective SIPs. In the absence of an implemented SIP, areas must perform what is known as the "interim" emissions test. Only certain interim test types and methodologies are allowed in a given non-attainment area, and they must be applied uniformly throughout the area. The US DOT determination on transportation conformity must be on the entire non-attainment area. The Final Rule further requires that all affected MPOs in the non-attainment area must work together to demonstrate conformity jointly until respective SIPs are implemented.

Within the DVRPC region, the NAAQS requirements for ozone and PM2.5 must be met. As of 2007, conformity of CO emissions is no longer required anywhere in the DVRPC region. In the nine-county DVRPC planning area, governing SIPs are in place for ozone in the Pennsylvania and New Jersey sub-regions. For the ozone precursors, VOC and NOx, DVRPC utilizes the budget test to demonstrate conformity using applicable SIP MVEBs. In 2006, New Jersey implemented a PM2.5 SIP for selected portions of the state. Those areas in New Jersey with effective SIP PM2.5 MVEBs include only Mercer County within the DVRPC planning area. Therefore, in Mercer County, the budget test is also employed to demonstrate PM2.5 conformity.

Otherwise, for the DVRPC portion within the Philadelphia-Wilmington, PA-NJ-DE PM2.5 Non-Attainment Area, DVRPC coordinates its conformity efforts with the Wilmington Area Planning Council (WILMAPCO), and the two MPOs demonstrate conformity collectively for the entire non-attainment area. DVRPC and WILMAPCO jointly decided to use the "no-greater than-2002-baseline" interim test.

Currently, the mobile source ozone emissions analysis years for VOC and NOx are 2010 (8-hour ozone standard attainment year), 2020 (the interim year selected to keep all analysis years no more than ten years apart), and 2030 (the horizon year of the Plan). VOCs and NOx, which are heat-sensitive ozone precursors, are estimated for a July day. The current ozone MVEB year governing the DVRPC region is 2005, in both Pennsylvania and New Jersey. All emissions estimates are tested against these budgets.

In the PM2.5 demonstration, analysis years vary due to the different emissions tests being applied by area. The current analysis years in the Philadelphia-Wilmington, PA-NJ-DE PM2.5 Non-attainment Area are 2010, 2020, and 2030. These years are a required part of the interim test and will be used until applicable PM2.5 SIPs are implemented in the non-attainment area. For the New York-Northern New Jersey-Long Island, NY-NJ-CT PM2.5 Non-Attainment Area, the year 2009 is analyzed instead. 2009 is a PM2.5 MVEB budget year for Mercer County. To demonstrate conformity, projected PM2.5 emissions in all analysis years must not exceed 1) the 2002 baseline emissions results in the Philadelphia-Wilmington, PA-NJ-DE PM2.5 Non-Attainment Area; and 2) the 2009 budgeted emissions in the New York-Northern New Jersey-Long Island, NY-NJ-CT PM2.5 Non-Attainment Area. The following analysis illustrates the demonstration of transportation conformity of the DVRPC 2030 Long-range Plan and the FY 2007 Pennsylvania and New Jersey Transportation Improvement Programs (TIPs) with the respective SIPs and NAAQs requirements under the CAA.

C. DVRPC Emissions Estimation Model

Regional emissions analyses begin with the regional travel simulation model. The 2005 validation of the DVRPC travel simulation model is used to demonstrate conformity. The calculated travel impact changes from the travel simulation process are passed to a post-processor and are prepared for an emissions estimate model. In demonstrating conformity, use of the newest version of the MOBILE emissions estimate model is required under the Final Rule. MOBILE6.2 is the latest version of the family of mobile source emissions models developed by US EPA and reflects many cumulative technological enhancements, emissions control updates and trend shifts introduced since 1996. These changes include expanded vehicle type categories and state inspection and maintenance program specification options; more detailed vehicle activity information and fuel program definition; and revised base emissions rates.

Taking advantage of these updated changes, the input parameters to the MOBILE6.2 model specify best available local data to accurately reflect the local conditions. Local temperature and humidity data are particularly important, because MOBILE6.2 relies on these values to estimate automobile air conditioning usage. Other settings accept the US EPA’s default values, which represent “the worst-case conditions.” Collectively, these local and default settings generate dependable regional emissions estimates suitable for demonstrating transportation conformity in the DVRPC region.

The regional travel simulation model and the associated planning assumptions used as inputs are described briefly in this section. Detailed descriptions can be found in the other chapters of this report. This is followed by a description of the emissions post-processor, the MOBILE6.2 inputs and the use of off-network calculations. Emissions results demonstrating conformity are then detailed.

1. DVRPC Travel Simulation Models

The DVRPC travel simulation model is a classic four-step travel demand modeling application that operates within an iterative (Evans algorithm) structure with respect to highway travel time, and is disaggregated into separate peak, midday, and evening time periods. In the four-step modeling process, trip generation is based on constant trip rates. Trip distribution uses a doubly constrained gravity model, stratified into three person (home-based work, home-based non-work, and non home-based) and seven vehicle trip purposes. Modal split employs a binary logit formulation stratified by trip purpose, transit submode, and auto ownership. The highway assignment component is based on the equilibrium method using minimum travel-impedance path. Free-flow highway speeds are stratified by functional class and density of development. The Evans algorithm iterates the trip distribution, modal split, and highway assignment models.

This process is based on updated speeds after each iteration of the highway assignment and determines a weight value upon each performed iteration. This weight is then used to prepare a convex combination of the link volumes and trip tables for the current iteration and a running weighted average of the previous iterations. This algorithm converges rapidly to an equilibrium solution on highway travel speeds and congestion levels. When equilibrium is attained, the model assigns the weighted average transit trip tables to the transit networks and produces link and route passenger volumes. Transit assignment is unrestrained and uses minimum paths based on the modal split model definition of impedance. The iterative DVRPC travel demand simulation process has been reviewed and approved by the Transportation Conformity Interagency Consultation Group (TCICG).

2. Planning Assumptions

All planning assumptions utilized in this demonstration are the latest and most current as of March 26, 2007, which is the start date of the DVRPC conformity analysis. The DVRPC TCICG has reviewed and concurred on all of the latest planning assumptions utilized. DVRPC uses a multi-step, multi-source methodology to produce long-range population and employment estimates at the county-level. These estimates, in turn, become the control totals for municipal-level and traffic analysis zone (TAZ) level estimates.

Population forecasting at the regional level involves review and analysis of six major components: births, deaths, domestic in-migration, domestic out-migration, international immigration, and changes in group-quarter populations (e.g. dormitories, military barracks, prisons, and nursing homes). DVRPC uses both the cohort survival concept and a modified Markov transition probability model, based on the US Census 2000 and the Current Population Survey research, to age individuals and determine the flow of people. DVRPC also relies on member counties to provide information on any known, expected and/or forecasted changes in group-quarter populations. Current and future population estimates for the DVRPC planning area were adopted by the DVRPC Board in February 2005.

Regional employment is influenced by several socioeconomic factors at local, national, and global levels. The Bureau of Economic Analysis (BEA) provides the most complete and consistent time-series data on county sectoral employment and is DVRPC's primary data source for employment forecasts. The US Census Bureau and the Census Transportation Planning Package (CTPP) also provide basic data on employment. Such data are reviewed by DVRPC and its member governments and adjusted to be consistent with local data. As in the population forecasts, county level totals are used as control totals for municipal and TAZ-level sector distribution forecasts.

These forecasts incorporate various supplemental data from public and private sectors including data from the BEA, Dun & Bradstreet, Bureau of Labor Statistics, Occupational Privilege Tax database, Woods & Poole Economics Complete Economic and Demographic Data Source, and other public and private sector statistics. These are also reviewed by member counties for final adjustments based on local knowledge. Current and future employment estimates were adopted by the DVRPC Board in February 2005.

As part of the latest planning assumptions, current transit operations policies and other road toll structures are also considered. All fares entering the transit network are "blended" by operating entity. For each operator, different existing fare types (e.g. cash, token, transfer charge, daily, weekly, and monthly passes) are blended into a single fare policy based on the percentage of each fare type and use in the 2000 fare structure. Then, the future fare for each operator is held constant in current dollars. All current operating plans, ridership and service levels of transit systems are built into the transit network and are incorporated into the future year networks as well. Future year transit networks are also augmented with any new services identified in the corresponding DVRPC TIPs and the Plan. Other transportation related costs such as automobile operating costs, gasoline costs, parking costs, and road/bridge tolls are also based on current and available data and are held constant in current dollars into the future analysis years.

3. Emissions Estimation Procedure

A post-processor program is employed to combine the appropriate emission factors with the travel on each simulated model highway link on an hour-by-hour basis. A comprehensive, region-wide travel time and speed survey was used to develop a methodology to convert the estimated speeds output from the travel simulation model to real world conditions, thus improving the accuracy of the emission calculation.

The post-processor creates separate VMT summary input files for each county in the region to allow more precise emissions estimates to be calculated. These VMT summary files contain simulated VMT distributions by functional class, hour, and speed range. Both network and non-network VMT are included in the calculation of emissions. ***Figure XIII-1*** contains a flowchart that displays the mobile source emissions calculation procedures with MOBILE6.2, including the necessary input data, such as seasonal and hourly traffic variations. The programs, INVENTM6 and POSTPRM6 and the subroutine CALSPR were written specifically for use with MOBILE6.2. The formatted output files are used to override the MOBILE6.2 default data files FVMT.DEF, HVMT.DEF, and SVMT.DEF. Separate files are prepared for each county for a given analysis year and season or month.

In addition to travel demand model outputs, the post-processor utilizes seasonal factors to adjust average daily traffic volumes to summer or winter conditions, hourly distributions of traffic by functional class and area type, and embedded speed curves.

DVRPC's post-processor for air quality calculates hourly speeds for each link in the simulation highway network, given the assigned volume, functional class, and area type. Separate methodologies are used for freeways and arterials. In addition to volume per lane, other inputs to the freeway equations include the free-flow speed, the capacity per lane, and the congested highway speed. Arterial inputs include the speed limit, the number of traffic signals per mile, and the capacity per lane.

4. MOBILE6.2 Files

DVRPC utilizes the best available data for applicable input settings in MOBILE6.2 to accurately reflect the local conditions. These settings include, among other parameters, MIN/MAX TEMP, ABSOULTE HUMIDITY, REG DISTRIBUTION (vehicle age distribution by vehicle type), DIESEL FRACTIONS, VMT FRACTIONS, VMT BY FACILITY, VMT BY HOUR, SPEED VMT, FUEL RVP (Reid vapor pressure), ALTITUDE, and state vehicle Inspection and Maintenance (I/M) program information. Local temperature and humidity data are particularly important, because MOBILE6.2 relies on these values to estimate air conditioner usage. As for specific parameter values, inputs for individual pollutants can differ.

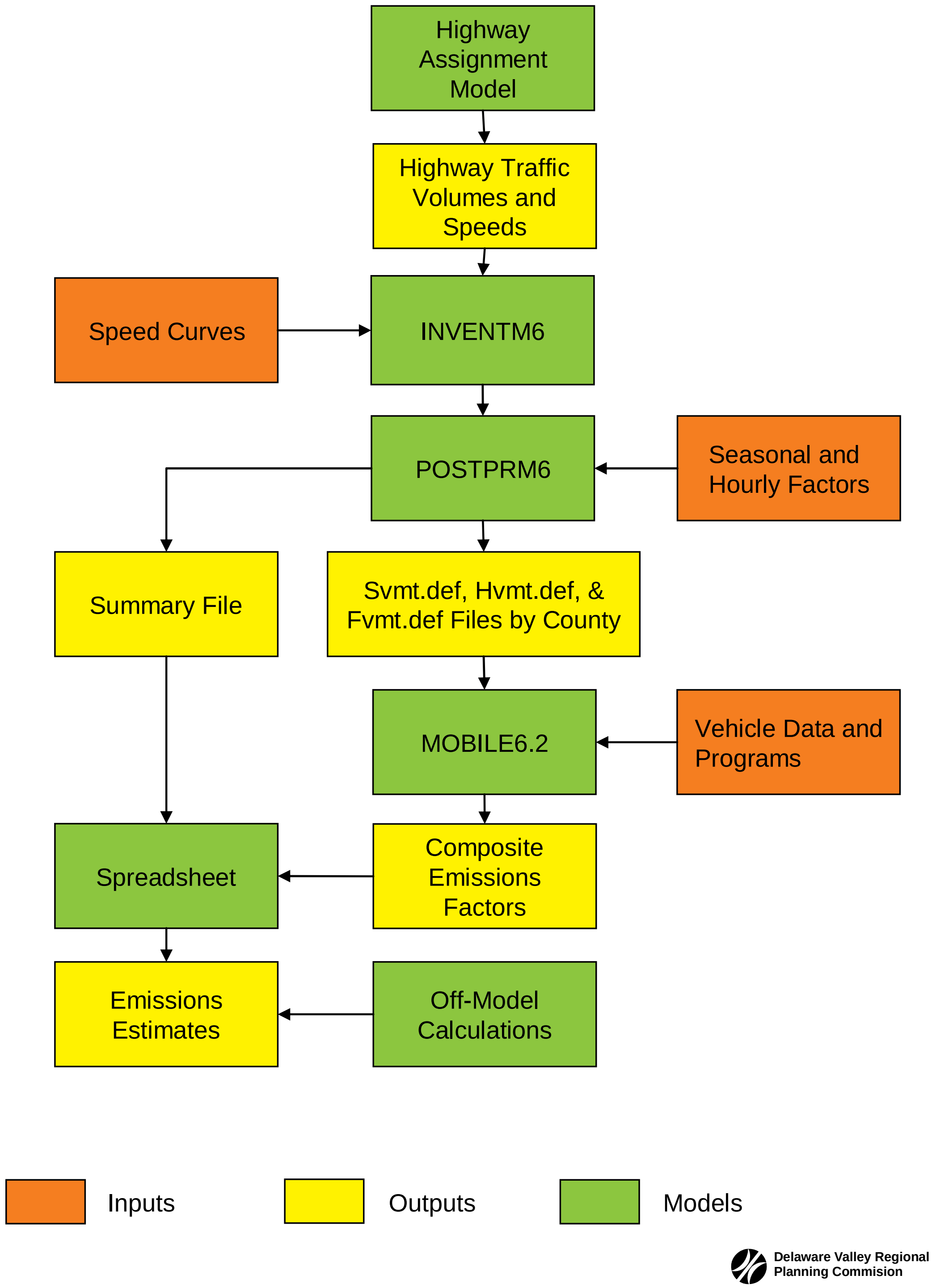


Figure XIII-1 Mobile Source Emissions Modeling Procedure

Using ozone settings as an example, MOBILE6.2 takes the minimum/maximum daily temperatures and humidity values that are based on conditions from the ten days with the highest ozone concentrations during a three-year period. These settings facilitate the model output to cater to real-life driving patterns including air conditioner usage, various state and local emissions control provisions, and changing meteorological conditions. Applicable I/M program settings are also part of the MOBILE6.2 inputs. All gasoline fueled cars and trucks in both Pennsylvania and New Jersey are subject to emissions tests.

Depending on the vehicle type and age, each vehicle is subject to an on-board diagnostics test, a dynamometer test, or an idle test under the respective state emissions requirements and I/M programs. These services are fundamentally similar in nature and are performed in a largely decentralized fashion where private garages both conduct the emissions test and make necessary vehicle repairs. However, New Jersey has some centralized test-only locations in addition to the private garages. The emissions tests include a check of the vehicle's evaporative control system and the integrity of the vehicle's emissions control equipment. They are performed annually in Pennsylvania and biennially in New Jersey. MOBILE6.2 also utilizes vehicle registration data to generate emissions estimates.

In 2004, the New Jersey Legislature enacted a law requiring the NJ DEP to promulgate rules adopting the California Low Emission Vehicle Program (CA LEV II). Subsequently, the New Jersey Low Emission Vehicle (NJ LEV) program and the DVRPC emissions estimates reflected this change.

Additionally, the Pennsylvania Clean Vehicles Program, adopted in 1998, incorporated the CA LEV II by reference. However, it also allowed automakers to comply with the National Low Emission Vehicle (NLEV) program as an alternative to the Pennsylvania program until a later model year (MY). The Pennsylvania Clean Vehicles Program had initially targeted MY 2006 for implementation, but PA DEP has recently passed a regulation that postpones compliance with the Pennsylvania program until MY 2008. Also, the Pennsylvania program was analyzed using US EPA's recommended analysis approach, and the methodology and data files therein were revised to phase in CA LEV II after MY 2008 as well.

Other MOBILE6.2 parameter settings, including CLOUD COVER, PEAK SUN, SUNRISE/SUNSET, STARTS PER DAY, START DIST, SOAK DISTRIBUTION, HOT SOAK ACTIVITY and DIURN SOAK ACTIVITY parameters currently accept the US EPA's default values, which represent "the worst-case conditions." ***Table XIII-1*** provides a summary of the major MOBILE6.2 parameter settings used in ozone air quality analysis. Collectively, these local and default settings generate dependable regional emissions estimates suitable for demonstrating transportation conformity in the DVRPC region.

In the PM2.5 analysis, MOBILE6.2 input settings vary slightly from those in the ozone analysis The conformity determination for the Philadelphia-Wilmington, PA-NJ-DE PM2.5 Non-Attainment Area is based on the four-season annual inventory methodology, requiring four sets of seasonal input conditions, one for each of the four seasons. Since MOBILE6.2 has only two input options for evaluation month (i.e. January for winter and July for summer), July input parameters are entered for a spring inventory and January of the following year issued for a fall inventory. Fuel parameters and VMT inputs are seasonally apportioned as well. The total annual PM2.5 inventory for the DVRPC portion of the non-attainment area is the sum of these four seasonal inventories.

For the New York-Northern New Jersey-Long Island, NY-NJ-CT PM2.5 Non-Attainment Area, MOBILE6.2 must be configured to produce a monthly run, because the governing PM2.5 SIP is developed using a 12-month inventory methodology. Therefore, the input settings such as temperature and humidity data are adjusted for each month accordingly. The sum of these monthly inventories is then tested against the SIP budget in Mercer County to determine conformity.

5. Off-Network Data

Due to the project scale, scope, or governing characteristics, some non-exempt, regionally significant projects, such as park-and-ride facilities or bikeway improvements, cannot be properly represented and evaluated by the travel demand model. As previously noted, therefore, travel impacts and emissions analyses of such projects are performed using PAQ-ONE and NJAQ-ONE. These off-network analysis tools are a set of travel impact and emissions analysis methodologies and are configured for summer conditions only. These methodologies were initially developed for state DOTs to assist in the analysis and ranking of congestion mitigation/air quality (CMAQ) funded projects.

Table XIII-1 MOBILE6.2 Parameter Settings for Ozone Precursors

MOBILE6.2 Parameter	Pennsylvania	New Jersey
Minimum/Maximum Temperature	70.7 F/93.4 F	73.2 F/96.1 F
Absolute Humidity	72.6 grains/lb	72.6 grains/lb
Cloud Cover	0.0 (default)	0.0 (default)
Peak Sun	10 am to 4 pm (default)	10 am to 4 pm (default)
Sunrise/Sunset	6 am and 9 pm (default)	6 am and 9 pm (default)
Fuel Reid Vapor Pressure	6.80 psi	6.80 psi
Engine Starts Per Day		
Cars (weekday/weekend)	7.28/5.41 (default)	7.28/5.41 (default)
Trucks (weekday/weekend)	8.06/5.68 (default)	8.06/5.68 (default)
Daily Distribution of Starts	Default Values	Default Values
Trip Length Distribution	Default Values	Default Values
Diesel Fractions	2002 Data	2003 Data
Altitude	Low	Low
Stage II Refueling	N/A	Applied
Fuel Program	RFG, Northern Region	RFG, Northern Region
Low Emissions Vehicle Program	PA LEV Program	NJ LEV Program
Vehicle Registration Base Year	2002	2005
I/M Program		
Program Length	Annual	Biennial
Centralized/Decentralized	100% Decentralized	70% Centralized/30% Decentralized
Credit for Decentralized Program	100%	80%
On-Board Diagnostics	1996 Model Year or Later	1996 Model Year or Later
ASM5015	1981 to 1995 Model Years	1981 to 1995 Model Years
Anti-Tapering Program	Light-Duty Vehicles Only	Light- and Heavy-Duty Vehicles
Gas Cap Evaporative Check	1975 Model Year or Later	1970 Model Year or Later
OBD Evaporative Check	1996 Model Year or Later	1996 Model Year or Later
Pre-1981 Model Year Stringency	20%	30%
Waiver Rate	3%	3%
Compliance Rate	96%	98%

Source: DVRPC July 2008

There are currently 33 PAQ-ONE and NJAQ-ONE travel impact methodologies available, all of which have three steps in common: 1) data collection; 2) calculation of changes in travel characteristics; and 3) computation of the emissions impacts associated with the changes in travel characteristics. In steps 1) and 2), each of the off-network methodologies calculates the estimated travel impacts of individual projects based on a combination of project-level, county-level, and national data, and then assesses the resulting changes on the transportation system. Outputs are typically measured in the change in vehicle-miles-traveled (VMT), in vehicle trips, in total vehicle time spent in idling, and in speed. In step 3), the travel changes are fed into an emission estimate module to produce the air quality impacts.

Both PAQ-ONE and NJAQ-ONE contain independent MOBILE6.2 modules to determine emissions estimates. Once the characteristic changes in travel are calculated, the transportation results are fed to the emissions module to create emissions factors based on the county-level data and local assumptions. The input parameters for the MOBILE6.2 component, prepared by the travel impact module of the off-network methodologies, vary by each off network project's own scope, scale and characteristics, but include the average speed and VMT mixes broken down for each county by area type, facility type, time of day, and/or inspection and maintenance programs implemented. Final off-network emissions estimate outputs show the changes in VOCs, NOx, and PM2.5 in both kg/day and tons/day for individual projects.

6. Emissions Results

Mobile source emissions estimates are obtained by using MOBILE6.2 emission factors to convert link-level VMT and speed from the traffic assignments. The regional emissions analysis must meet all conformity tests in the Final Rule. Specifically, emissions of VOCs, NOx, and PM2.5 in Mercer County must be less than the MVEBs established by the states. Having no budgets, PM2.5 emissions levels in the Philadelphia-Wilmington, PA-NJ-DE PM2.5 Non-attainment Area must meet the “no-greater-than-the-2002-baseline” interim test.

The conformity demonstration for ozone precursors is performed using the established 1-hour ozone SIP MVEBs. These budgets will be in force until the 8-hour ozone SIPs are established. Analysis years for ozone are 2010, 2020, and 2030. These results are compared with the budgets to demonstrate conformity.

DVRPC must make conformity determination for PM2.5 in two different non-attainment areas with two different emissions tests In the DVRPC portion of the New York-Northern New Jersey-Long Island, NY-NJ-CT PM2.5 Non-attainment Area, a governing SIP MVEB exists and PM2.5 conformity is demonstrated against this budget, which is established for 2009. All applicable direct PM2.5 sources and precursors are tested for the 2010, 2020, and 2030 PM2.5 emissions estimates.

In the Philadelphia-Wilmington, PA-NJ-DE PM2.5 Non-Attainment Area, there are no PM2.5 SIPs, and DVRPC and WILMAPCO have opted to utilize the “no-greater-than-2002-baseline” interim emissions test. All analysis results are considered against the 2002 baseline for the interim test. Collectively, these tables show that the estimated emissions of VOCs, NOx, and PM2.5 do not exceed the respective MVEBs included in the SIPs established by the corresponding states or the appropriate baseline established for the interim emissions test.

The emissions results for DVRPC's Fiscal Year 2007 TIP and 2030 Plan are presented in ***Tables XIII-2 thru XIII-4***. ***Tables XIII-2 and XIII-3*** display the emission analysis results for ozone precursors of VOC and NOx, respectively. In the Pennsylvania counties, the VOC budget is 79.69 tons per day and the NOx budget is 144.37 tons per day. In 2010, the emissions associated with mobile sources are expected to be 58.29 tons per day of VOC and 88.07 tons per day of NOx. By 2030, these values will decrease to 23.90 tons per day of VOC and 16.52 tons per day of NOx. That is, VOC emissions will be reduced by 60.3 percent and NOx emissions by 81.2 percent between 2010 and 2030.

Similarly, in New Jersey, the VOC budget is 42.99 tons per day and the NOx budget is 63.44 tons per day. In 2010 mobile source emissions will be 21.41 tons per day of VOC and 44.91 tons per day of NOx. By 2030 these values will decrease to 11.16 tons per day of VOC and 8.37 tons per day of NOx, reductions of 47.9 percent and 81.3 percent, respectively, between 2010 and 2030. These emissions results for the Pennsylvania and New Jersey counties in the Delaware Valley region are shown graphically for VOC and NOx in ***Figures XIII-2 and XIII-3***, respectively.

Table XIII-2 Emission Results for VOC (Tons/July Day)

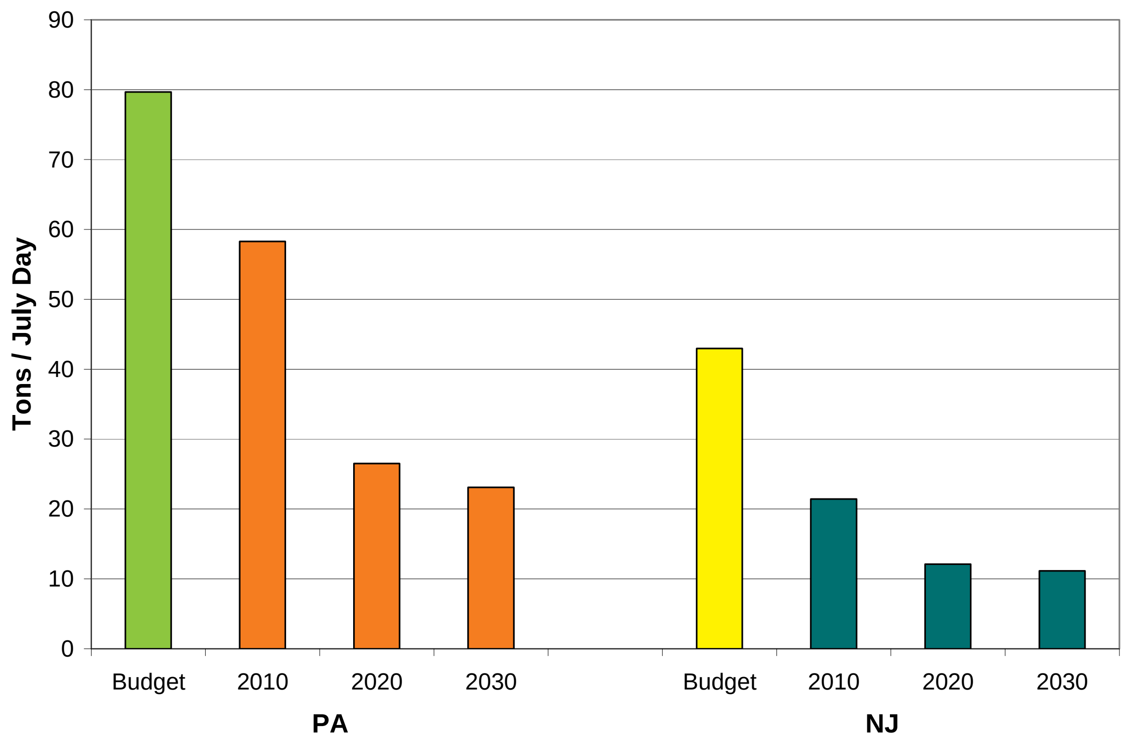
		2005 SIP MVEB[1]	2010 Emissions	2020 Emissions	2030 Emissions
PA	Emissions from MOBILE6.2		58.29	26.53	23.11
	Off-Network Project Adjustments[2]		0.00	0.00	0.02
	Estimated Total Emissions	**79.69**	**58.29**	**26.53**	**23.09**
NJ	Emissions from MOBILE6.2		21.41	12.11	11.16
	Off-Network Project Adjustments[2]		0.00	0.00	0.00
	Estimated Total Emissions	**42.99**	**21.41**	**12.11**	**11.16**

Source: DVRPC July 2008

Table XIII-3 Emission Results for NOx (Tons/July Day)

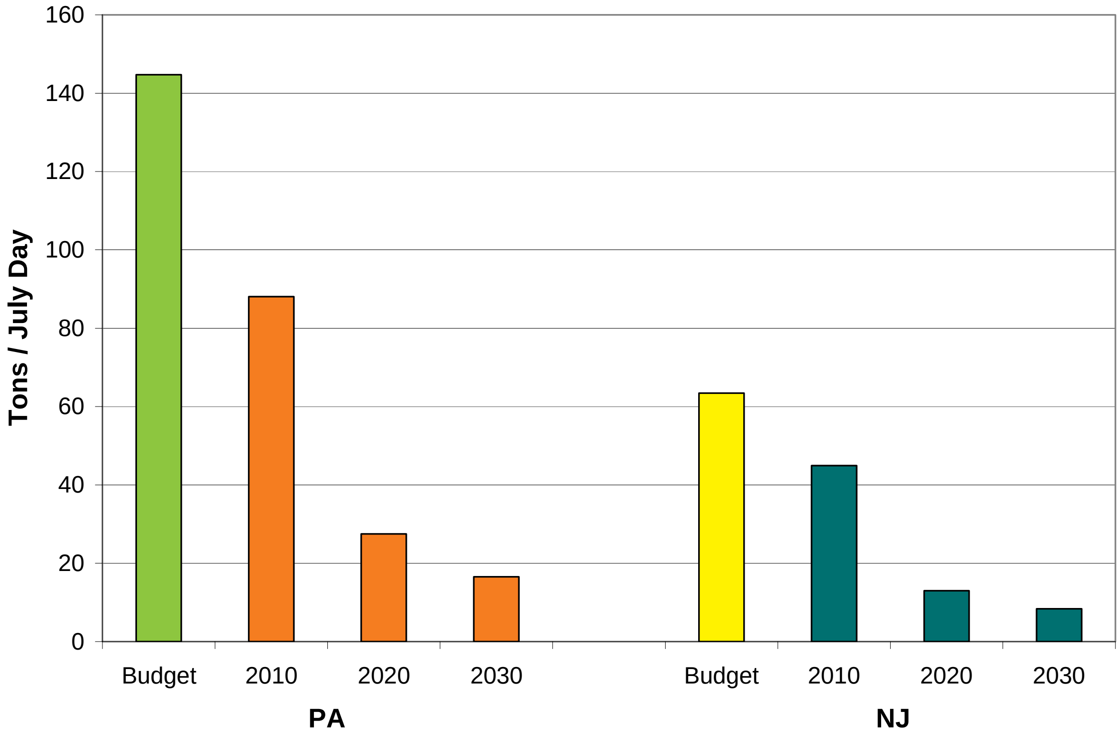
		2005 SIP MVEB[1]	2010 Emissions	2020 Emissions	2030 Emissions
PA	Emissions from MOBILE6.2		88.07	27.90	16.80
	Off-Network Project Adjustments[2]		0.00	0.44	0.28
	Estimated Total Emissions	**144.73**	**88.07**	**27.46**	**16.52**
NJ	Emissions from MOBILE6.2		44.91	12.97	8.37
	Off-Network Project Adjustments[2]		0.00	0.00	0.00
	Estimated Total Emissions	**63.44**	**44.91**	**12.97**	**8.37**

Source: DVRPC July 2008



Source: DVRPC July 2008

Figure XIII-2 VOC Emissions Results



Source: DVRPC July 2008

Figure XIII-3 NOx Emissions Results

Table XIII-4 displays the emission results associated with fine particulates. The table includes annual values for both direct PM2.5 emissions and also for the NOx. Between 2010 and 2030, Direct PM2.5 emissions will be reduced by 33.3 percent in the Pennsylvania counties; 34.3 percent in Burlington, Camden, and Gloucester counties; and by 35.0 percent in Mercer County. Annual NOx emissions will be reduced by 81.4 percent in the Pennsylvania counties; 81.2 percent in Burlington, Camden, and Gloucester counties; and by 81.4 percent in Mercer County. ***Figures XIII-4 and XIII-5*** also display the results associated with direct particulate emissions and their NOx precursor, respectively. The emission results for the Pennsylvania and New Jersey counties of the Delaware Valley region are shown in these figures. Mercer County emissions are shown separately for Direct PM2.5 for meeting the conformity requirements.

Table XIII-4 Emission Results for Direct PM2.5 and NOx (Tons/Year)

		2002 Baseline[1]	2009 MVEB[1]	2009 Emissions	2010 Emissions	2020 Emissions	2030 Emissions
Direct PM2.5	5 Pennsylvania Counties	998.2	n/a	n/a	608.5	420.4	405.7
	Burlington, Camden, Gloucester Cos.	486.7	n/a	n/a	264.4	183.2	173.7
	Mercer County	n/a	89	86	80	55	52
NOx	5 Pennsylvania Counties	59,346.0	n/a	n/a	31,169.7	9,730.8	5,774.0
	Burlington, Camden, Gloucester Cos.	30,499.9	n/a	n/a	12,079.7	3,487.8	2,264.0
	Mercer County	n/a	4,328	4,051	3,664	1,041	681

[1]Associated 2002 Baseline or 2009 MVEB applies to all future analysis years. All emissions are rounded to the nearest tenth except for Mercer County, which are rounded to the nearest integer in accordance with the SIP
n/a = not applicable

Source: DVRPC July, 2008

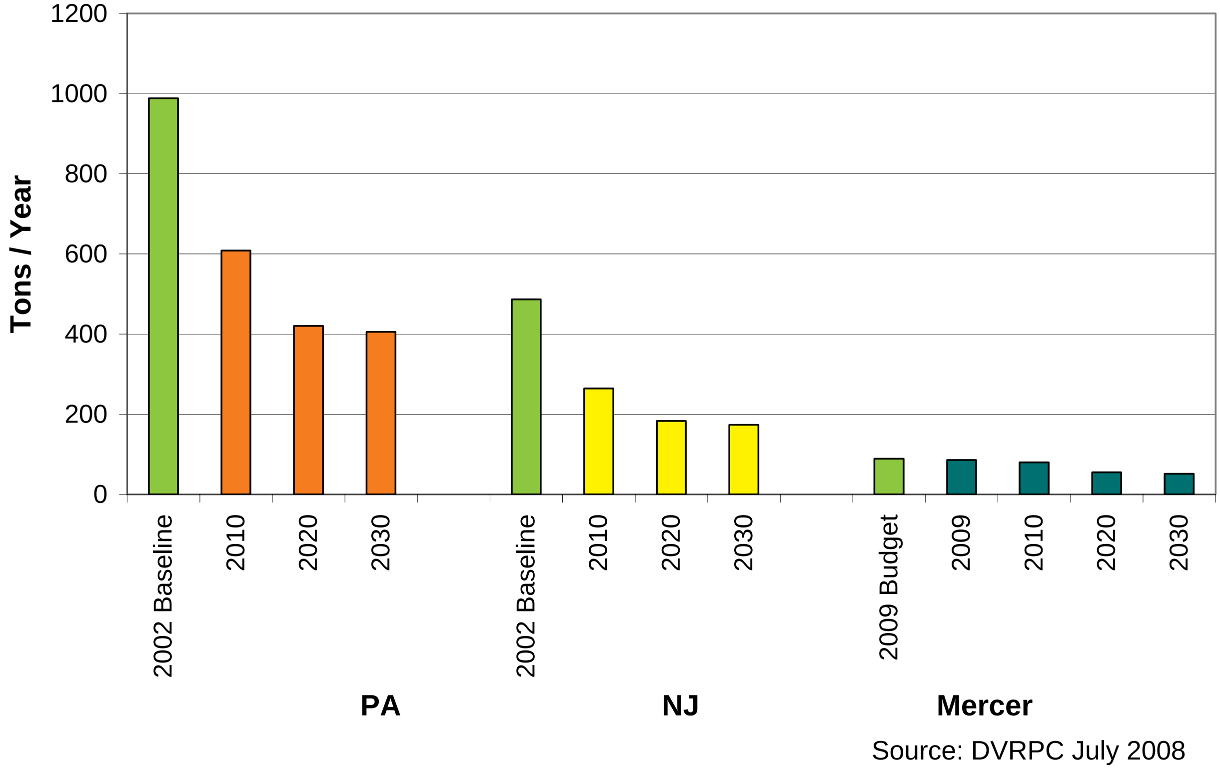


Figure XIII-4 Direct PM2.5 Emissions Results

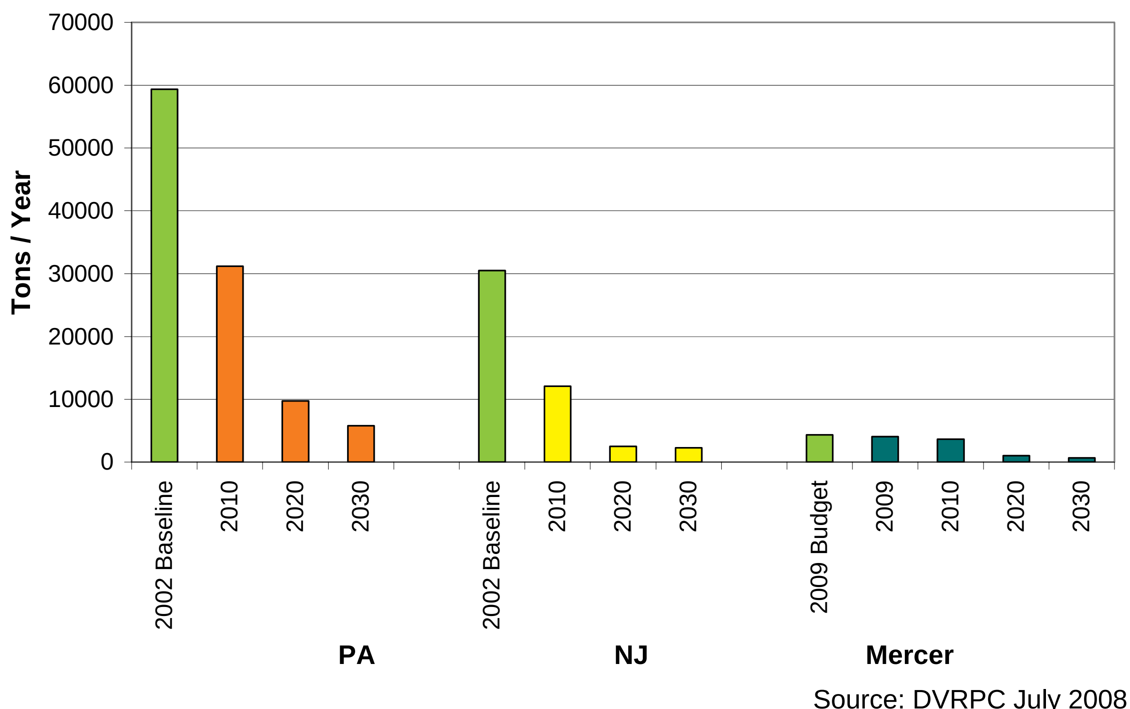


Figure XIII-5 PM2.5 NOx Precursor Emissions Results

D. Conformity Demonstration

The forecasted emissions levels of VOCs, NOx, and PM2.5 do not exceed the respective budgets and baseline established by state departments of environmental protection in accordance with the Final Rule under the current NAAQS governing applicable pollutants. The transportation conformity analysis meets all applicable conformity criteria including, but not limited to, the following:

- That the Plan and the TIPs are fiscally constrained [40 CFR 93.108];
- That this determination is based on the latest planning assumptions [40 CFR 93.110];
- That this determination is based on the latest emissions estimation model available [40 CFR 93.111];
- That DVRPC has made the determination according to the applicable consultation procedures [40 CFR 93.112];
- That the Plan and the TIPs do not interfere with the timely implementation of TCMs (Transportation Control Measures) [40 CFR 93.113]; and
- That the Plan and the TIPs are consistent with the motor vehicle emissions budgets in the applicable implementation plans [40 CFR 93.118].

It is clear from this analysis that DVRPC's Pennsylvania and New Jersey TIPs and its Long-range Plan conform with the current Pennsylvania and New Jersey SIPs and their established motor vehicle emissions budgets. The Plan and TIPs meet all requirements under the CAA for all analysis years and meet all the applicable criteria for non-attainment areas.

XIV. VALIDATION OF TRAVEL SIMULATION MODELS

The validation of the travel demand models is an integral part of the travel simulation process. The travel demand models must be able to predict system behavior with sufficient accuracy. Travel simulation model validation is meant to ensure that the model outputs are sufficiently close to reality that they can be used as a proxy for the actual system. The validation demonstrates to transportation decision makers and the general public that travel simulation models can be used in making major infrastructure and policy decisions.

The first section of this chapter discusses errors in modeling. Errors of various kinds are present in the simulation process. Knowledge of the various types and sources of errors are important to minimizing total error so that the model results are reasonable. The second section presents the methodology used to validate the model to 2000 and 2005 conditions. DVRPC uses a multi-step iterative calibration and validation process. The third section presents results for the 2000 and 2005 validation. Some validation data has already been presented for each of the major models in the DVRPC modeling chain in **Chapters VII-XII**. The most important outputs of the travel simulation models are from the highway and transit assignment models. Any errors in previous models will be reflected in the results from these assignment models. As such, additional validation data is presented for the highway and transit assignment models for 2000 and 2005. The validation statistics are then compared to the 1990 model. The final section discusses the changes made to the travel simulation models during the past 15 years. Problems with the current modeling software are also discussed, as are the changes that are likely in the near future for DVRPC's travel simulation models.

A. Regional Travel Simulation Errors

Various types of errors are present in the models. These errors degrade the accuracy of the output results – link volumes, modal splits, etc. A small amount of error in the model results is acceptable and anticipated. Large errors in travel forecasting threaten the usability of the model and are unacceptable. This section discusses three types of errors – input data errors, model errors, and computational errors.

1. Input Data Errors

Travel demand forecasting requires an immense amount of data. The trip generation model requires socioeconomic data from the census and other sources and trip rates from various surveys. The trip distribution model requires estimates of average trip length by trip purpose from the household travel surveys. The modal split model requires estimates of transit and highway mode shares. The highway and transit assignment models require estimates of facility usage. The errors for each of these data sources can be divided into sampling and non-sampling errors.

A complete count of the data is rarely conducted for most of the example data sources listed above. The data is instead sampled. The household travel survey counted 4,217 households. This represents 1 in 466 households in the Delaware Valley. Highway traffic volumes are not typically counted continuously and then averaged over the entire year, but are derived from 48 hour counts combined with a seasonal correction factor. Population and employment data from the census is derived from a complete count, but the journey-to-work and mode choice responses only come from 1 in 6 households.

The lack of a complete count in these data sources results in sampling error. The households/individuals/days that are sampled may not be representative of the entire population. Sampling errors are inversely proportional to the square root of the number of samples in the survey. The sample size needs to be quadrupled in order to half the sampling error. Sampling errors are thus very expensive to reduce. The size of the household travel survey, for example, was the result of a careful balance between minimizing sampling error and minimizing survey cost.

Another type of input data error is non-sampling or bias error. This error can arise by survey questions not being constructed properly. An example can be found in the Census journey to work survey. The survey asks for typical mode taken to work. Many individuals, however, may drive to work 3 or 4 days out of the week, but take transit for the remainder. This question, therefore, underestimates transit ridership due to the occasional use phenomenon.

Other errors can be present in input data. Data might be incorrectly coded or entered into digital form when processed. This type of error can be minimized by careful data collection and checking procedures.

2. Modeling Errors

In addition to data input errors, modeling errors also exist. One type of modeling error is specification error. This refers to the wrong type of mathematical model being chosen to represent a certain phenomenon. This can occur when variables of importance for a certain decision, such as mode choice, are not considered. The inclusion of an irrelevant variable can also introduce specification errors in non-linear models. Another type of specification error is the use of the wrong functional form, such as the use of a linear model for the prediction of a non-linear phenomenon.

Modeling errors can also be introduced due to miscalibration. Various parameters are estimated from survey data, such as the travel propensity curves in **Figures VIII-5,7,9**, and **13** (page 175 & ff.) for the gravity model. While the calibration process is designed to find the correct parameter values to use in the model, some small amount of calibration error is always present.

3. Computational Errors

Errors in model output can also be introduced by the computational process. Computational errors take two forms – rounding and convergence. Travel simulations require millions of calculations. Each calculation involves some small amount of rounding. These errors can accumulate in the final results. The degree of rounding error depends on the degree of precision used in the calculations.

Convergence errors result from the iterative algorithms used to solve the travel demand models. Both the highway assignment and combined equilibrium (Evans) model formulations are solved by iterative algorithms. These algorithms are designed to converge to an equilibrium solution that is "correct." However, the algorithm approaches but never actually reaches the equilibrium solution. For reasons of efficiency, the algorithm is terminated when it reaches a point sufficiently close to the true equilibrium solution to the model. This introduces some small amount of error into the model. The current DVRPC practice is to run 15 iterations of highway only assignment followed by 7 Evans algorithm iterations. This procedure was chosen so that the convergence error is roughly equal to the rounding error associated with use of the TRANPLAN modeling software package.

4. Overall Simulation Error

The errors in the final simulation results are due to a combination of all the types of errors discussed above – input data errors, model errors, and computational errors. These errors all accumulate throughout the modeling process. Theoretically, these various types of errors could add one on top of the other. Fortunately, the errors are rarely additive in practice. Some errors are positive, while others are negative; when combined, errors can cancel one another out. The overall error is considered and evaluated in the DVRPC model validation process.

B. Model Calibration and Validation Methodology

DVRPC uses a comprehensive validation methodology that accounts for all types of errors present in the modeling process. This methodology ensures that the travel simulation models are able to accurately reproduce travel patterns in the Delaware Valley, both now and in the future. This section discusses the methodology used to perform the 2000 and 2005 model validations and the validation guidelines.

1. Validation Methodology

The methodology used to validate DVRPC's models can be seen in ***Figure XIV-1***. Briefly, the models are validated for 2000 based on past experience and current data. This model is then used with and checked against 2005 data.

The first step is to collect, review, and correct 2000 and 2005 input data. The data must be carefully checked and reviewed for errors before being used for model calibration and validation. The trip generation model is calibrated first using 2000 data. Past experience from the 1997 and 1990 model calibrations are also used. The trip distribution model is calibrated next using inputs from the 1997 calibration, 2000 data, and the results from the calibrated 2000 trip generation model.

The modal split and vehicle occupancy models are calibrated next using the 1997 calibration, 2000 data, and the 2000 calibrated trip distribution results. Following this, the highway assignment model is calibrated based on the input data and the highway vehicle trip table from the 2000 modal split and vehicle occupancy models. Finally, the 2000 transit assignment model is calibrated based on the trip table from the calibrated 2000 modal split model. Both the highway and transit assignment model results are checked against facility traffic counts.

The process is then repeated in an iterative fashion and parameters are adjusted. Feedback from the transit and highway assignment models is used to refine the calibrations for the trip generation, trip distribution, and modal split models. The calibration error for each model is calculated. Some reasonably small amount of error is allowed to remain in each model. The process ceases once the errors fall to a reasonable level, < 10 percent. The models are rerun with updated input data in order to validate them for the 2005 model year. The results from the highway and transit assignment are checked against survey data in order to validate the models for the new modeling year.

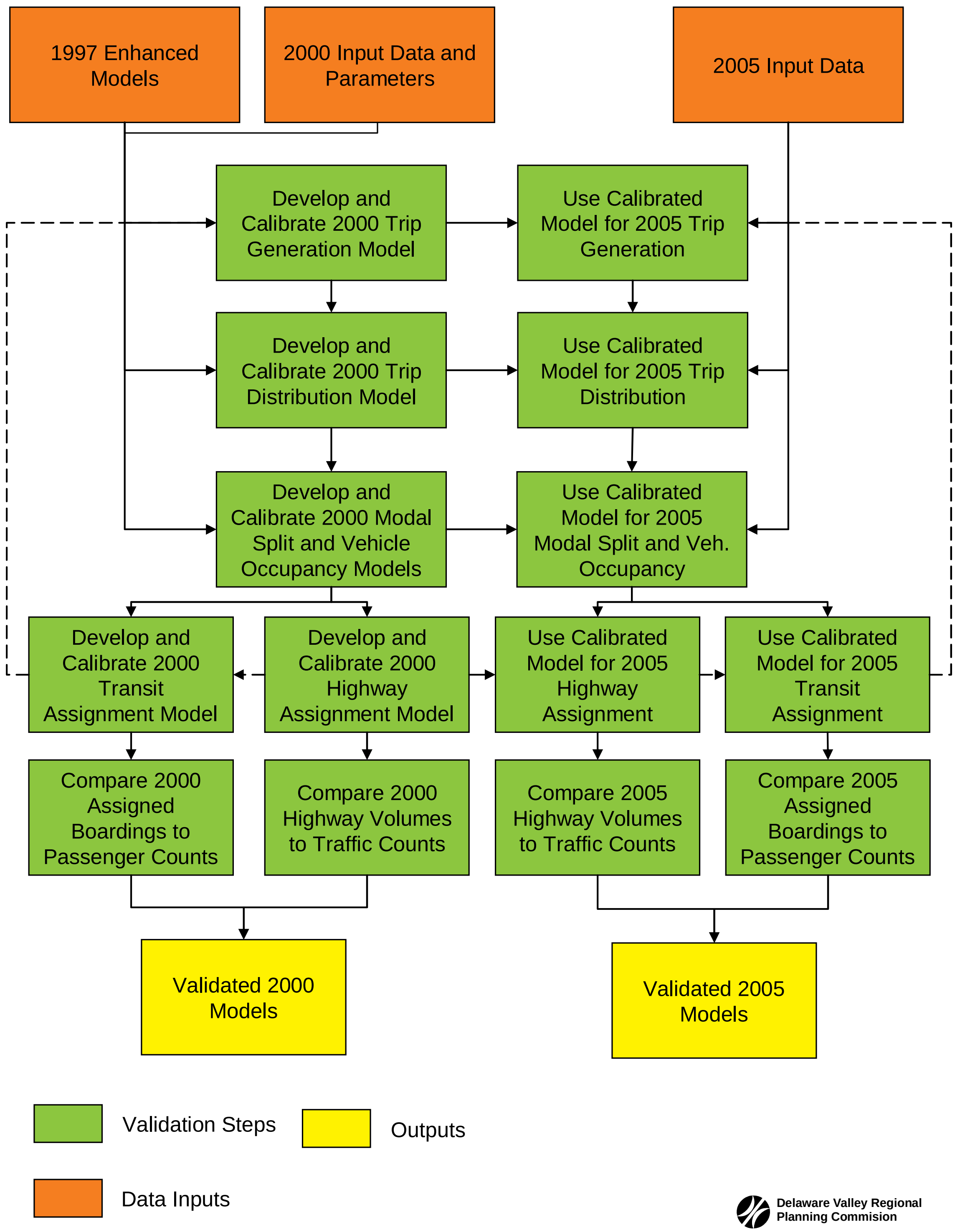


Figure XIV-1 Validation of the DVRPC Travel Simulation Models

2. Validation Guidelines

The overall error in the DVRPC models is consistent with FHWA, EPA, and FTA practice of < 10 percent based on counts versus simulated values. Each model is checked separately. Trip generation rates are checked to make sure that the overall number of trips matches surveyed results. The gravity model inputs are checked to see that trip length patterns are replicated. The modal split model is checked to make sure that the correct proportion of transit trips is created in each CPA and county. The overall results of the model are also checked using traffic counts and transit counts. Additional levels of aggregation typically produce more accurate results, as small errors will tend to cancel one another out. This corresponds with the Law of Large Numbers in statistics. As such, the errors on high volume facilities, such as freeways, are typically much lower in percentage terms than the errors on low volume facilities, such as local streets.

C. 2000 and 2005 Simulation Results and Model Validation

Data validating the trip generation, trip distribution, and modal split models have been represented in their respective chapters. This section describes the validation of the non-motorized trip generation model, the highway assignment model, and the transit assignment model for 2000 and 2005. Simulated data is compared for each model against census data, traffic counts, and transit boardings, respectively.

1. Validation of the Non-Motorized Travel Model

The non-motorized travel model was new for the 2000 model. **Chapter VII** contains some validation data. ***Table VII-15*** (page 151) compares model simulated trips for the three trip purposes to results from the Household Travel Survey. The simulated results are within 4 percent of surveyed results.

The home-based work portion of the non-motorized trip generation model can also be validated using census data. The model generated 128,786 non-motorized home-based work productions. This compares to 121,300 work trips from the Census journey to work data for bike and walk modes combined. This is a 5 percent difference and is well within the validation limits.

Table VII-5 (page 129) contains a comparison of 2000 and 2005 non-motorized results. There are no reliable survey results for non-motorized travel in 2005. The 2005 results, therefore, need to be compared against 2000 for reasonableness. The changes between 2000 and 2005 are small, 1.5 percent or less. The changes from 2000 to 2005 are reasonable and match changes in the underlying demographic variables.

2. Validation of the Highway Assignment Model

Screenline traffic counts are used to validate both the highway assignment model and the entire motorized modeling chain. The screenlines and cordons are discussed in **Chapter VI**. ***Table XIV-1*** contains a comparison of 2000 simulated versus counted screenline traffic volumes for the screenlines shown in ***Figure XI-3***. (page 234) These comparisons fall in two categories – the inner cordon and the screenlines. For the inner cordon, the simulated values are all within 10 percent of counted traffic volumes. The deviation ranges from -9.9 percent for the Mercer County inner cordon to -0.3 percent for the Gloucester County inner cordon. The inner cordon assigned total is -3.4 percent lower than counted volumes.

The screenlines all fall within 5 percent of traffic counts. The deviation ranges from 5.0 percent for the Delaware River Screenline to 0.4 percent for the Bucks-Montgomery County screenline. The total for all the screenline volumes is -0.1 percent difference from counted traffic volumes. Summing inner and outer cordon line volumes and the seven screenlines produces a simulated volume 1.4 percent less than traffic counts for the 2000 model.

Table XIV-2 contains validation data for the 2005 highway assignment. The inner cordon simulated volumes for 2005 were all within about 10 percent of counted volumes. The differences ranged from a maximum of 10.6 percent for the Delaware County inner cordon to a minimum of -3.2 percent for the Chester County inner cordon. The total simulated volume crossing the inner cordon was 5.9 percent lower than counted volumes for 2005.

The 2005 screenline simulated volumes were all within 10 percent of counted volumes. The deviation ranged from a maximum of -8.7 percent for the Center City screenline to a minimum of -0.5 percent for the Crosswicks Creeks screenline. The total simulated volume crossing all screenlines was 3.4 percent less than the counted volumes. For the inner and outer cordons and the screenlines, the total 2005 simulated volume was 3.2 percent less than the counted volumes.

Table XIV-1 2000 Screenline Simulated Traffic vs. Traffic Counts

			Difference	
Screenline or Cordon Name	**Count**	**Assigned**	**Absolute**	**Percent**
Bucks County Inner Cordon	275,938	257,185	-18,753	-6.8%
Montgomery County Inner Cordon	512,370	488,525	-23,845	-4.7%
Chester County Inner Cordon	236,398	240,663	4,265	1.8%
Delaware County Inner Cordon	246,138	265,660	19,522	7.9%
Mercer County Inner Cordon	449,011	404,591	-44,420	-9.9%
Burlington County Inner Cordon	344,543	335,830	-8,713	-2.5%
Camden County Inner Cordon	172,294	159,851	-12,443	-7.2%
Gloucester County Inner Cordon	258,170	257,271	-899	-0.3%
Subtotal Inner Cordon	**2,494,862**	**2,409,576**	**-85,286**	**-3.4%**
Delaware River Screenline	571,582	600,208	28,626	5.0%
Schuylkill River Screenline	1,367,451	1,356,172	-11,279	-0.8%
Bucks-Montgomery County Screenline	255,537	256,445	908	0.4%
Center City Cordon	994,175	963,419	-30,756	-3.1%
North Philadelphia Screenline	515,080	493,930	-21,150	-4.1%
Crosswicks Creek Screenline	232,812	243,110	10,298	4.4%
Pennsauken Creek	554,160	571,085	16,925	3.1%
Subtotal Other Screenlines	**4,490,797**	**4,484,369**	**-6,428**	**-0.1%**
9 County Cordon	**1,640,485**	**1,611,351**	**-29,134**	**-1.8%**
Grand TOTAL	**8,626,144**	**8,505,296**	**-120,848**	**-1.4%**

Source: DVRPC July 2008

Table XIV-2 2005 Screenline Simulated Traffic vs. Traffic Counts

			Difference	
Screenline or Cordon Name	**Count**	**Assigned**	**Absolute**	**Percent**
Bucks County Inner Cordon	296,243	267,589	-28,654	-9.7%
Montgomery County Inner Cordon	555,991	509,863	-46,128	-8.3%
Chester County Inner Cordon	265,506	257,106	-8,400	-3.2%
Delaware County Inner Cordon	251,158	277,795	26,637	10.6%
Mercer County Inner Cordon	459,013	425,873	-33,140	-7.2%
Burlington County Inner Cordon	385,220	347,539	-37,681	-9.8%
Camden County Inner Cordon	169,734	155,133	-14,601	-8.6%
Gloucester County Inner Cordon	268,044	254,034	-14,010	-5.2%
Subtotal Inner Cordon	**2,650,909**	**2,494,932**	**-155,977**	**-5.9%**
Delaware River Screenline	611,134	602,531	-8,603	-1.4%
Schuylkill River Screenline	1,470,424	1,443,276	-27,148	-1.8%
Bucks-Montgomery County Screenline	264,182	269,586	5,404	2.0%
Center City Cordon	1,090,805	995,589	-95,216	-8.7%
North Philadelphia Screenline	523,359	494,927	-28,432	-5.4%
Crosswicks Creek Screenline	254,672	253,448	-1,224	-0.5%
Pennsauken Creek	576,615	569,714	-6,901	-1.2%
Subtotal Other Screenlines	**4,791,191**	**4,629,071**	**-162,120**	**-3.4%**
9 County Cordon	**1,645,667**	**1,672,804**	**27,137**	**1.6%**
Grand TOTAL	**9,087,767**	**8,796,807**	**-290,960**	**-3.2%**

Source: DVRPC July 2008

Figure XIV-2 shows a comparison of counted versus assigned traffic volumes for all the individual facilities that comprise the screenlines and the inner-cordon line for 2000. These are daily volumes. Ideally, all the points should fall on the 45º line, indicating that the assigned volumes match the counted volumes. However, both the assigned volumes and the counted volumes contain errors. The points in the figure show a reasonable scatter around the 45º line.

The plot in ***Figure XIV-2*** is one method of validating the quality of the highway assignment. Various statistics can also be used to judge the agreement between the counted and assigned volumes. ***Table XIV-3*** presents validation statistics for the 2000 highway assignment. These statistics come from the same facilities used to construct ***Figure XIV-2***. There are 416 individual facilities used to construct the screenlines and inner cordon. The mean counted traffic volume is 16,792, while the mean assigned volume is 16,572. This is a difference of 220, or 1.31 percent of the mean counted value.

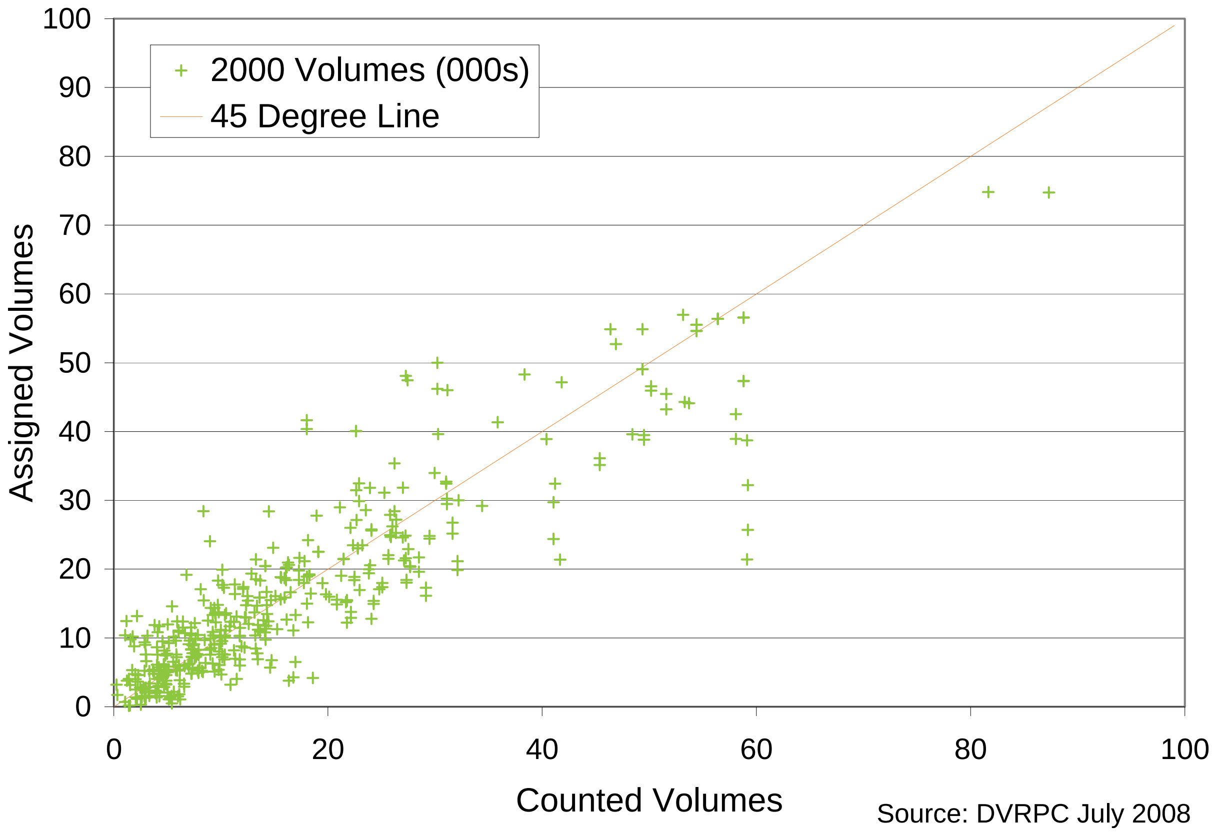


Figure XIV-2 Comparison of 2000 Highway Counted and Assigned Volumes (000s) from Screenline and Inner Cordon Facilities

Table XIV-3 Validation Statistics for the 2000 Highway Assignment

Measure	Value
# of Observations	416
Average Counted Volume	16,792
Average Assigned Volume	16,572
Difference Between Means	220
Percent Difference Between Means	1.31%
Root Mean Squared Error (RMSE)	6,696.8
RMSE as Percentage of Mean	39.9%
Coefficient of Correlation (R)	0.893
Coefficient of Determination (R^2)	0.798
Theil's Inequality Coefficient (U)	0.1524
Theil's Bias Coefficient (U^M)	0.0011
Theil's Variance Coefficient (U^S)	0.0252
Theil's Covariance Coefficient (U^C)	0.9762

Source: DVRPC July 2008

Comparing the means can overstate the accuracy of the assignment, however, as positive and negative errors will cancel one another out. The root mean squared error (RMSE) statistic considers the difference between counted and assigned volumes for each facility regardless of whether it is positive or negative. The RMSE is defined as:

$$RMSE = \sqrt{\frac{\sum_{n=1}^{N}\left(V_n^c - V_n^a\right)^2}{N}}$$

where:

- V_n^c Counted volume for facility *n*
- V_n^a Assigned volume for facility *n*
- N Number of Observations

The RMSE for the 2000 volumes for the screenline and inner cordon line facilities is 6697. This is 40 percent of the mean counted value. Caution should be taken with the RMSE as it tends to give a large amount of weight to the largest deviations. That is, a few large errors can greatly increase the RMSE, even in a large population. For example, removing six outliers among the population of 416 observations reduces the RMSE to 5,893. Additionally, most of the error appears in the lower volume facilities. The assigned volumes on the higher volume facilities agree much better with the counted volumes, as seen in ***Table XIV-4***. In this table the links have been sorted according to their counted volumes into eight different categories. For each category or group, the RMSE is calculated and then shown as a percentage of the mean for that group. As can be seen, the errors on low volume roads are quite high – 60 percent for links with volumes between 5,000 and 10,000, 70 percent for links with volumes between 3,000 and 5,000, and over 200 percent for links with volumes under 3,000. The RMSE error as a percentage of the mean is quite reasonable for higher volume facilities – 30 percent or less for the three link volume groups with volumes over 20,000.

Table XIV-4 Highway RMSE as a Percentage of the Mean by Volume Group

Link Volume Group	# Observations	RMSE as % of Mean
< 3,000	33	229.2%
3,000 - 5,000	47	70.5%
5,000 - 10,000	96	60.4%
10,000 - 15,000	73	36.9%
15,000 - 20,000	39	42.7%
20,000 - 30,000	71	30.1%
30,000 - 50,000	32	25.0%
> 50,000	25	24.6%
Total	**416**	**39.9%**

Source: DVRPC July 2008

There are two reasons why the assigned and counted volumes are closer as a percentage of the total volume on higher volume roads than on lower volume roads. The flows on higher volume facilities are the result of the aggregation of flows from many lower volume facilities. Thus because of the Law of Large Numbers, the many errors on these contributing flows will tend to cancel one another out. Furthermore, many of the low volume facilities are loaded directly by centroids; in reality these loadings would be spread over many local facilities. These results, especially the poor loading of lower volume facilities, demonstrate the need for the focused simulation process for project level simulations.

The coefficient of correlation, R, is 0.893 while the coefficient of determination, R^2, is 0.798. R is a measure of how well the assigned volumes are correlated or dependant of the counted volumes. R^2 is a measure of the amount of variation in the counted volumes that can be explained by the simulation model results. The values for both indicate that the model does a good job of predicting facility level flows.

Theil statistics are also given in ***Table XIV-3***. The Theil statistics measure the goodness of fit between observed and simulated data. They are described and discussed in **Appendix XIV-1**.

The results shown in ***Figure XIV-2 , Table XIV-3***, and ***Table XIV-4*** validate the results of the highway assignment model. The DVRPC regional travel simulation does a good job of replicating travel patterns and choices in the Delaware Valley. Care should be taken, however, in using the results for local facilities without additional calibration.

3. Validation of the Transit Assignment Model

The methods used to validate the transit assignment model are similar to those used to validate the highway assignment model. Assigned volumes summarized by operating company and mode are compared to counts. Model results are also compared to counts on a line-by-line basis using plots and summary statistics.

Table XIV-5 contains 2000 transit results by transit sub-mode. These data have been calculated by aggregating the line ridership for all the lines in each mode. The assigned results for each sub-mode are close to passenger counts. The assigned volume for the commuter rail mode is only 0.4 percent less than the counted volume. The surface and subway/elevated mode assigned volumes are both within about 5 percent of counted volumes for 2000. The total assigned volume is 4.5 percent higher than the counted volume.

Table XIV-6 contains counted and assigned transit volumes by mode for 2005. The commuter rail assigned volumes are 3.9 percent less than counted volumes. The subway/elevated assigned volumes are 3.0 percent greater than counted volumes. The surface mode assigned volumes are 6.4 percent higher than counted volumes. The total assigned transit volumes for 2005 are 4.4 percent higher than the counted volumes. Both the 2000 and 2005 results are reasonable and validated when compared by mode.

Table XIV-7 compares the transit assignment results by operating company for 2000. The assigned volumes for all operating companies are within 6 percent of counted volumes. The total SEPTA assigned volume is 4.8 percent higher than the counted volume. The total New Jersey Transit (NJT) assigned volume is 1 percent higher than the counted volume. The PATCO (DRPA) assigned volume is almost identical to the counted volume for 2000.

Table XIV-5 2000 Transit Validation Results by Sub-mode

Mode	Assigned Results	Passenger Counts	Difference	% Difference
Commuter Rail	103,824	104,200	-376	-0.4%
Subway-Elevated	347,092	331,400	15,692	4.7%
Bus and Trolley	728,002	692,667	35,335	5.1%
Total	**1,178,918**	**1,128,267**	**50,651**	**4.5%**

Source: DVRPC July 2008

Table XIV-6 2005 Transit Validation Results by Sub-mode

Mode	Assigned Results	Passenger Counts	Difference	% Difference
Commuter Rail	102,223	106,400	-4,177	-3.9%
Subway-Elevated	344,385	334,437	9,948	3.0%
Bus and Trolley	732,850	688,810	44,040	6.4%
Total	**1,179,458**	**1,129,647**	**49,811**	**4.4%**

Source: DVRPC July 2008

Table XIV-7 2000 Transit Validation Results by Operating Company

Company/Division	Submode	Assigned Results	Passenger Counts	% Difference
SEPTA City Transit	Subway-Elevated	302,435	286,500	5.6%
SEPTA City Transit	Bus & Trolley	616,122	583,193	5.7%
SEPTA Victory Division	Subway-Elevated	7,252	7,600	-4.6%
SEPTA Victory Division	Bus & Light Rail	39,222	37,200	5.4%
SEPTA Frontier Division	Bus	15,426	15,600	-1.1%
SEPTA Regional Rail	Commuter Rail	103,824	104,200	-0.4%
SEPTA Total	**All**	**1,084,281**	**1,034,293**	**4.8%**
NJT Southern Division	Bus	41,597	41,874	-0.7%
NJT Mercer Division	Bus	15,635	14,800	5.6%
Total NJ TRANSIT	**Bus**	**57,232**	**56,674**	**1.0%**
DRPA	Subway-Elevated	37,405	37,300	0.3%
Grand Total	**All**	**1,178,918**	**1,128,267**	**4.5%**

Source: DVRPC July 2008

The 2005 results by operating company are in ***Table XIV-8***. Similar to the 2000 transit assignment results, the 2005 assigned volumes show good agreement to counted passenger volumes. SEPTA assigned volumes are 4.3 percent higher than counted volumes. NJT assigned volumes are 3.6 percent higher than counted volumes. The total assigned transit volume is 4.5 percent higher than the counted volume.

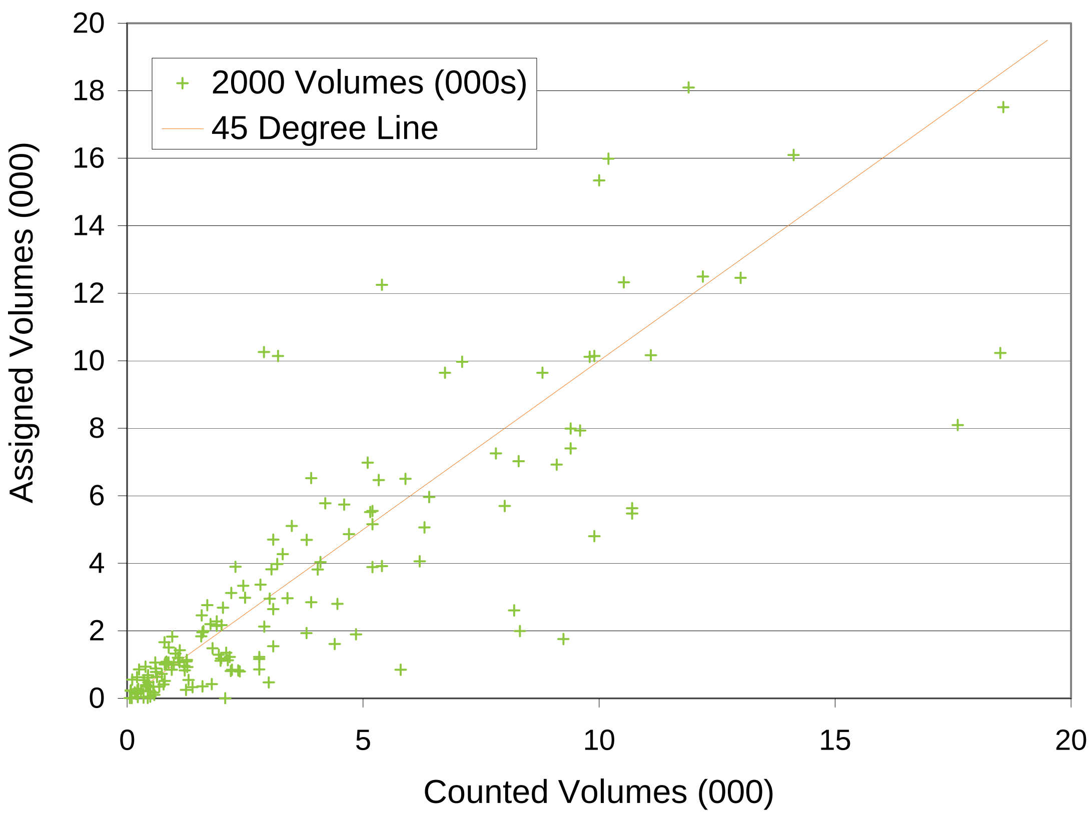
Similar to the highway assignment, it is important to look at the transit assignment results on a line-by-line basis and not just in aggregate***.*** ***Figure XIV-3*** compares assigned to total volumes on a line-by-line basis. Each point represents a separate line. If the DVRPC models were perfect, each point would fall on the 45º line, indicating that the assigned and counted volumes are identical. ***Figure XIV-3*** shows that while there is scatter in the comparison of counted versus assigned volumes, the points are clustered around the 45º line.

Table XIV-9 contains summary statistics for the transit assignment. There were 177 different transit lines used to calculate the summary statistics. The average counted volume was 6,254 while the average assigned volume was 6,596. The difference between the averages is 342, which is 5.5 percent of the average counted volume.

Table XIV-8 2005 Transit Validation Results by Operating Company

Company/Division	Submode	Assigned Results	Passenger Counts	% Difference
SEPTA City Transit	Subway-Elevated	300,958	293,531	2.5%
SEPTA City Transit	Bus & Trolley	604,897	565,724	6.9%
SEPTA Victory Division	Subway-Elevated	6,369	7,123	-10.6%
SEPTA Victory Division	Bus & Light Rail	38,786	38,885	-0.3%
SEPTA Frontier Division	Bus	16,120	13,681	17.8%
SEPTA Regional Rail	Commuter Rail	102,223	106,400	-3.9%
SEPTA Total	**All**	**1,069,353**	**1,025,344**	**4.3%**
NJT Southern Division	Bus	55,324	55,020	0.6%
NJT Mercer Division	Bus	17,723	15,500	14.3%
Total NJ TRANSIT	**Bus**	**73,047**	**70,520**	**3.6%**
DRPA	Subway-Elevated	37,058	33,783	9.7%
Grand Total	**All**	**1,179,458**	**1,129,647**	**4.4%**

Source: DVRPC July 2008



Source: DVRPC July 2008

Figure XIV-3 Comparison of 2000 Transit Line Assigned and Counted Volumes

Table XIV-9 Validation Statistics for the 2000 Transit Assignment

Measure	Value
# of Observations	177
Average Counted Volume	6,254
Average Assigned Volume	6,596
Difference Between Means	342
Percent Difference Between Means	5.5%
Root Mean Squared Error (RMSE)	4,086
RMSE as Percentage of Mean	65.3%
Coefficient of Correlation (R)	0.9743
Coefficient of Determination (R^2)	0.9492
Theil's Inequality Coefficient (U)	0.1130
Theil's Bias Coefficient (U^M)	0.0070
Theil's Variance Coefficient (U^S)	0.1154
Theil's Covariance Coefficient (U^C)	0.8833

Source: DVRPC July 2008

The same statistics that were used to validate the highway assignment are used to validate the transit assignment. The RMSE is 4,086. This is 65.3 percent of the mean value. The correlation coefficient (R) is 0.974 while the coefficient of determination (R^2) is 0.949. Both of these are quite high and indicate that the transit assignment and the other models in the DVRPC modeling chain do a good job predicting transit ridership. The Theil statistics for the transit assignment are discussed in **Appendix XIV-1**.

There was a strong correlation between error and link volume in the highway assignment results. The same relationship is not as strong for the transit assignment. ***Table XIV-10*** shows RMSE by volume group. While the smallest volume group (vol.< 500) has the largest error (86 percent) as a percent of the mean and the largest volume group (vol. > 25,000) has the smallest error (12 percent), there is not a clear relationship through the remaining volume groups. The 1,500-3,000 group has a smaller error than the 500-1,500 group.

Table XIV-10 Transit RMSE as a Percentage of the Mean by Volume Group

Volume Group	# of Observations	RMSE as % of Mean
< 500	29	86%
500 - 1,500	33	48%
1,500 - 3,000	35	77%
3,000 - 7,500	37	51%
7,500 - 25,000	39	63%
> 25,000	4	12%

Source: DVRPC July 2008

D. Summary of 2000 and 2005 Model Validation

The data, plots, and statistics cited in the previous section indicate a well validated model. The validation of the 2000 and 2005 models compares well with that of previous models. A number of statistics were computed and published during earlier modeling studies and can be used to compare the quality of the present simulation models. The statistics computed for the 2000 and 2005 validations compare favorably to those from previous model validations.

The errors present within the regional simulation are demonstrated with the above cited statistics to be reasonable. The level of accuracy of the regional travel simulation models meets FHWA, EPA, and FTA guidelines. As discussed earlier, a focused simulation process is used for project level work where volumes on local low volume facilities are important. Zones are split, additional coding is added to the highway and transit networks, and the calibration parameters are refined in the focused simulation process. All of this produces a more accurate final highway and/or transit assignment. ***Table XIV-11*** presents a comparison of highway volumes from the regional simulation and from a focused simulation. While the aggregate error is not decreased, the maximum error is drastically reduced. Of the facilities listed in ***Table XIV-11***, the maximum error in the regional simulation is 61 percent for the Belmont Ave/Green Lane Schuylkill River Bridge. In the focused simulation this facility has an error of 20.3 percent. Also, in the regional simulation only two facilities have errors of under 10 percent, while five facilities in the focused simulation have errors of less than 10 percent.

Table XIV-12 presents validation statistics comparing the quality of the assignment for the 43 facilities in the focused assignment to the same facilities in the regional simulation. The 43 facilities used for the calculations in ***Table XIV-12*** are a subset of the 416 facilities used to calculate the highway validation statistics in ***Table XIV-3***. The statistics show that the focused assignment is significantly better than the regional simulation. The RMSE for the focused simulation is less than half that of the regional simulation. The R and R^2 values are both dramatically improved as well.

Table XIV-11 Comparison of Link Volumes for Regional and Focused Highway Simulations

Selected Highway Facilities	Counts 2005	Regional Simulation Results: Simulation 2005	Regional Difference: Absolute	Regional Difference: Percent	Focused Simulation Results: Simulation 2005	Focused Difference: Absolute	Focused Difference: Percent
I-476 Schuylkill River Bridge	113,394	97,031	-16,363	-14.4%	111,628	-1,766	-1.6%
Belmont Ave/Green Lane Schuylkill River Bridge	24,776	39,912	15,136	61.1%	29,808	5,032	20.3%
US-1 (Roosevelt Expwy) Schuylkill River Bridge	117,189	103,928	-13,261	-11.3%	116,945	-244	-0.2%
US 202 - Saulin Blvd to DeKalb St Ramps	36,353	44,357	8,004	22.0%	39,131	2,778	7.6%
PA 23 - Anderson Rd to PA 23 Overpass	9,714	11,031	1,317	13.6%	10,586	872	9.0%
I-76 EB Off-Ramp to Belmont Ave	7,069	8,097	1,028	14.5%	7,821	752	10.6%
I-76 WB On-Ramp from Belmont Ave	7,716	8,147	431	5.6%	8,078	362	4.7%
Main Street - Leverington Ave to Green Lane	17,442	16,766	-676	-3.9%	14,619	-2,823	-16.2%
Green Lane - Main Street to Silverwood St	10,327	8,609	-1,718	-16.6%	11,390	1,063	10.3%
All 9 Facilities	**343,980**	**337,878**	**-6,102**	**-1.8%**	**350,006**	**6,026**	**1.8%**
All Highway Facilities in the Study Area	**1,373,896**	**1,343,949**	**-29,947**	**-2.2%**	**1,322,979**	**-34,188**	**-2.8%**

Source: DVRPC July, 2008

Table XIV-12 Validation Statistics for Regional and Focused Highway Assignments

Measure	Regional Simulation	Focused Simulation
# of Observations	43	43
Average Counted Volume	31,951	31,951
Average Assigned Volume	31,255	30,767
Difference Between Means	696	1,184
Percent Difference Between Means	2.18%	3.71%
Root Mean Squared Error (RMSE)	16,420	7,330
RMSE as Percentage of Mean	51.4%	22.9%
Coefficient of Correlation (R)	0.892	0.982
Coefficient of Determination (R^2)	0.795	0.963
Theil's Inequality Coefficient (U)	0.1830	0.0795
Theil's Bias Coefficient (U^M)	0.0018	0.0261
Theil's Variance Coefficient (U^S)	0.2033	0.1948
Theil's Covariance Coefficient (U^C)	0.8186	0.8023

Source: DVRPC July 2008

Table XIV-13 compares the results from the regional simulation to a focused simulation for a transit study. The aggregate error for station volumes is reduced from 16.5 percent to 4.9 percent. In the regional simulation there are five stations with errors higher than 20 percent, and two (Colmar and North Wales) have errors of over 50 percent. In the focused simulation there is only one station with an error of over 10 percent, Colmar, which has an error of 12.8 percent. These examples show that the errors in focused simulations are small.

Table XIV-14 contains validation statistics based on the focused transit simulation for the station in ***Table XIV-13***. The RMSE as a percentage of the mean decreases from 43.7 to 5.0 percent between the regional and focused simulation. Both the R and R^2 values are dramatically better in the focused simulation than in the regional simulation.

It is clear from the analysis of both highway and transit simulated volumes that neither the regional simulation nor focused travel simulation will produce reasonable simulated volumes for every highway link or transit line in a study area. For example, the Colmar Station volumes in ***Table XIV-13*** are 12.8 percent greater than the counted volume in the focused simulation. Adjustments must be made before using simulated numbers for planning, design, or operational studies.

Table XIV-13 Comparison of Station Volumes for Regional and Focused Transit Simulations

		Regional Simulation Results			Focused Simulation Results		
			Difference			Difference	
Study Area R5 Stations	**Counts**	**Simulation**	**Absolute**	**Percent**	**Simulation**	**Absolute**	**Percent**
Link Belt	144	111	-33	-22.9%	137	-7	-4.9%
Colmar	532	243	-289	-54.3%	600	68	12.8%
Fortuna	134	126	-8	-6.0%	147	13	9.7%
Lansdale	2,106	2,322	216	10.3%	2,145	39	1.9%
Pennbrook	826	520	-306	-37.0%	834	8	1.0%
North Wales	1,411	687	-724	-51.3%	1,416	5	0.4%
Doylestown	643	995	352	54.7%	666	23	3.6%
Delaware Valley	107	92	-15	-14.0%	108	1	0.9%
Chalfont	267	221	-46	-17.2%	268	1	0.4%
Gwynedd	567	438	-129	-22.8%	504	-63	-11.1%
North Hills	333	321	-12	-3.6%	360	27	8.1%
Melrose	423	475	52	12.3%	414	-9	-2.1%
All 12 Stations	**7,493**	**6,551**	**-942**	**-12.6%**	**7,599**	**106**	**1.4%**
All R5 Doylestown Stations	**16,645**	**13,900**	**-2,745**	**-16.5%**	**15,831**	**-814**	**-4.9%**

Source: DVRPC July, 2008

Table XIV-14 Validation Statistics for Regional and Focused Transit Assignments

Measure	Regional Simulation	Focused Simulation
# of Observations	12	12
Average Counted Volume	624	624
Average Assigned Volume	546	633
Difference Between Means	-79	-9
Percent Difference Between Means	-12.6%	-1.4%
Root Mean Squared Error (RMSE)	273.1	31.31
RMSE as Percentage of Mean	43.7%	5.0%
Coefficient of Correlation (R)	0.899	0.999
Coefficient of Determination (R^2)	0.808	0.997
Theil's Inequality Coefficient (U)	0.1656	0.0184
Theil's Bias Coefficient (U^M)	0.0826	0.0796
Theil's Variance Coefficient (U^S)	0.0095	0.0758
Theil's Covariance Coefficient (U^C)	0.9913	0.9283

Source: DVRPC July 2008

Several adjustments are made to the simulation model in order to improve results. Proper loading of trips onto the highway and transit networks is important. Additional TAZs are added based on land use locations and patterns in order to properly load the network. Additionally, local roads are added to the highway network and more connections are added to the transit network in order to facilitate better loading. The model by default uses a general speed lookup table based on area type and facility classification. Speeds and other parameters are sometimes adjusted to local conditions as part of the refinement process.

The simulation might still produce unreasonable results for some facilities even after all of these adjustments. It is necessary in these cases to use adjustment factors as part of the calibration process. These adjustment factors are typically based on several types of analysis:

- Screenline/cut-line analysis, especially in corridor analysis.
- Traffic flow theory.
- Comparisons with previous studies.
- Comparisons with the theoretical and operational capacity of facilities.

All of these adjustments are made through the calibration process, which produces reasonable numbers for all highway links, transit lines, and transit stations being studied. Several iterations of the calibration process are performed to obtain the most reasonable simulated highway and transit volumes.

E. Current Software Issues and Future Model Improvements

Travel demand forecasting is performed by the use of mathematical models that are implemented with computer software. The software used has a strong impact on the quality of the implementation of these models. It also impacts the efficiency of travel demand forecasting. This section discusses the current DVRPC model software, including several limitations. Also, a brief description is given of model improvements that have been made over the past 15 years. DVRPC's plan for the next round of model update is also discussed, along with plans to update the software that implements the travel demand models.

1. TRANPLAN Modeling Software

DVRPC uses the TRANPLAN modeling software package for travel simulation, as discussed throughout this report. TRANPLAN has been updated several times by DVRPC staff. This includes both the construction of custom made programs and the modification of existing programs at the FORTRAN source-code level. While TRANPLAN has served DVRPC's modeling needs to date, several problems exist. The owner of TRANPLAN, CitiLabs, does not currently support it. This means that TRANPLAN has not been updated to take advantage of recent advances, such as new GIS technologies. Any modifications needed must be made by DVRPC staff. Also, many output and evaluation measures are not readily provided. Some common measures and summaries, such as the validation statistics used in this chapter, must be laboriously computed using Excel or other computing software. Other evaluation measures or techniques, such as select link analysis, must be set-up before running the model. Additional analysis can only be performed by rerunning the model. In addition, TRANPLAN performs calculations to a limited degree of precision. This introduces rounding errors that can be significant. Because of all these shortcomings, DVRPC plans to reconsider the use of TRANPLAN in the near future.

2. Recent Model Improvements

In the mid 1990s DVRPC undertook a major model update. Each sub-model in the travel simulation was examined against regulatory requirements, the state of the practice, and the state of the art. This effort was done by DVRPC in conjunction with consultants from *Cambridge Systematics, Inc*. As a result of this review, several changes were made to the DVRPC model. The biggest change was the introduction of feedback from the highway assignment model to the trip distribution and modal split models. This was accomplished through the introduction of the Evans algorithm to iterate the model. This allowed not only the underlying mathematical programs to be solved more accurately and precisely, but to meet regulatory requirements to use feedback. The highway assignment speeds, capacities, and restraint curves were updated based on new data. A non-motorized model was added to trip generation to capture the increasingly important modes of walk and bicycle. The modal split model was updated from Probit to Logit and nested by mode of approach (auto or walk). The model was changed from daily assignment to three time periods – peak, midday, and evening. Numerous other changes were made as well, as discussed in **Chapter II**.

3. Future Model Improvements

The changes made as a result of the model update study in the 1990s were crucial to maintaining the integrity of the DVRPC model. However, it has been 15 years since the model update study was initiated. In the past 15 years there have been numerous advances in both the theory and practice of transportation demand modeling. Examples include the introduction of activity/tour based models and the proliferation of GIS tools and technologies. Modeling software has also advanced dramatically. Many tasks that are time consuming and error prone in TRANPLAN, such as network coding and updating, can now be performed easily and quickly with new modeling software such as CUBE, TRANSCAD, and VISUM. As such, DVRPC plans a new model update. This task will encompass updates to the model theory and structure, and to the software used to implement the model.

DVRPC plans to hire a consultant to assist in this effort. The consultant will evaluate recent advances in modeling practice and theory and recommend changes that are prudent to keep the DVRPC model up to date both now and in the future. The consultant will also evaluate the various software packages that are commercially available and recommend one that is consistent with the model update recommendations and that will take advantage of recently developed technologies. DVRPC will evaluate the consultant's recommendations and implement those that are prudent and consistent with the goals and budget of the commission. DVRPC plans to import the existing DVRPC modeling chain into the new modeling package as far as is possible. DVRPC also plans to work collaboratively with the consultant and software vendor in-order to implement new models and changes to the existing models to update DVRPC's travel simulation process consistent with the state of the practice.

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XVI. GLOSSARY

AAA – American Automobile Association

AADT – Average Annual Daily Traffic

ACS – American Community Survey

ADT – Average Daily Traffic

Air quality conformity demonstration – The process whereby the MPO shows that the emissions from mobile sources do not exceed the budget provided by the State Implementation Plan (SIP)

AMTRAK – National Railroad Passenger Corporation

APTA – American Public Transportation Association

Area type – Classification system used to group traffic analysis zones by their level of activity. DVRPC uses area types ranging from CBD to Open Rural.

AASHTO - American Association of State Highway and Transportation Officials

Assignment – The process of assigning highway or transit trips to individual links.

Attractions – The non-home trip end of a home based trip

BEA – Bureau of Economic Analysis

BLS – Bureau of Labor Statistics

Build Alternative(s) – The design alternative(s) in an alternatives analysis where improvements to the transportation system are tested and evaluated.

CAA – Clean Air Act

CAA – Clean Air Act Amendments

Calibration – Process of adjusting model parameters in order to improve the quality of the travel simulation model

CB – Census Bureau

CBD – Central Business District; similar to Center City for the City of Philadelphia

CDF – Cumulative Distribution Function

Centroid – Point that is considered the “middle” of a TAZ from which all travel is modeled as either originating or terminating

CMAQ – Congestion management and air quality

CO – Carbon Monoxide

Coding – Process of representing the actual network in a computer format for travel simulation modeling

CONFAC – Conversion factor to convert daily capacities to time period capacities

Cordon – Line that surrounds a particular area and is used for traffic counting and model validation purposes

CPA – County planning area

CTPP – Census Transportation Planning Package

Destinations – Terminating trip end

DMU – Diesel Multiple Unit

DOTs – Departments of Transportation

DRPA – Delaware River Port Authority

DVRPC – Delaware Valley Regional Planning Commission

EPA – Environmental Protection Agency

Equilibrium – State in a transportation system model where travelers can not alter their destination, mode of travel, or route in order to reduce their impedance of travel

ES-202 – Source of employment data

ETC – Electronic toll collection

ETRP – Employee trip reduction program

Evans – An algorithm designed to solve the trip distribution, mode split, and highway assignment models simultaneously

Evening time period– 6 PM – 7 AM

External Trip – A trip with at least one end outside of the DVRPC region

FHWA – Federal Highway Administration

Fratar – A process named after Mr. Fratar for updating Origin-Destination matrices with growth factors

Free-flow – Condition on a highway when no congestion exist

FTA – Federal Transit Administration

Functional Classification (FC) – System used to classify highway facilities

GIS – Geographical Information Systems

Group quarters – Census Bureau classification system for those individuals not living in regular housing

“K” factors – Factors used to combine various elements of impedance

HCM – Highway Capacity Manual

Home-based non-work (HBNW) – Trips with one end at home and the other end at a non-work location

Home-based work (HBW) – Trips with one end at home and the other end at work

HPMS – Highway performance monitoring system

ID – Impedance difference; difference between highway and transit impedance

IF – Impedance factor; used to incorporate effects of land use on transit modal split

Impedance – The various travel factors, including cost and time, which travelers face and seek to minimize when making a trip. Also referred to as disutility.

INET – Integrated Network – a coding system for jointly coding the highway and transit networks

Internal Trip – Trips with both ends inside of the DVRPC region

Intrazonal Trip – Trips that begin and end within a single TAZ

ISTEA – Intermodal Surface Transportation Efficiency Act

ITS – Intelligent transportation systems

Land Use – The purpose (residential, commercial, industrial) and intensity of use of land.

LEV – Low emission vehicle

LOS – Level of highway service

LRT – Light rail transit

MCD – Minor civil division

Midday time period – 9AM – 3 PM

MOBILE – EPA computer program used to calculate emissions

Modal split – Model which splits trips between auto and transit

Motorized trips – Trips made by either auto or transit

MPO – Metropolitan planning organization

MVEB – Motor vehicle emissions budget

MY – Model year

NAAQS – National ambient air quality standards

NAICS – North American Industry Classification System

New Starts – Competitive FTA program for major transit infrastructure projects involving fixed guideway systems

NJDOT – New Jersey Department of Transportation

NJT – New Jersey Transit

NLEV – National Low Emission Vehicle

No-build Alternative – "Do-nothing" baseline against which to test the build alternatives in an alternatives analysis.

Non-Attainment – Condition when a region exceeds the NAAQS for one or more criteria pollutants

Non-home based (NHB) – a trip where neither end occurs at the home

Non-motorized trips – trips made by either walking or bicycling

Origin – Beginning end of a trip

PATCO – Port Authority Transit Corporation

Pb – Lead

Peak time period – 7 AM – 9 AM and 3 PM – 6 PM

PENNDOT – Pennsylvania Department of Transportation

PHL – Philadelphia International Airport

PM10 – Particulate matter under 10 microns

PM2.5 – Particulate matter under 2.5 microns

Post-processor – A computer program used for conformity analysis and speed updates that refines certain simulation outputs such as highway link speeds

Production – Home end of a home-based trip.

PTR – Pneumatic traffic recorder

RMSE – Root mean squared error

Screenline/cutline – A line drawn through an area and crossing several transportation facilities. Used for traffic counting and model validation purposes

SEPTA – Southeastern Pennsylvania Transit Authority

SIC – Standard Industrial Classification

SIP – State Implementation Plan

SJTPO – South Jersey Transportation Planning Organization

SO2 – Sulfur Dioxide

SUMMIT – Computer program used by FTA to calculate user benefits from proposed transit improvements for New Starts

SUVs – Sports Utility Vehicle

TAQ – Transportation Air Quality

TAZ – Traffic Analysis Zone

TCICG – Transportation Conformity Interagency Consultation Group

Through Trips – A trip with both ends outside of the DVRPC region, but which passes though the DVRPC region

Time Period – One of three periods (peak, midday, and evening) into which the day is divided in order to model changing daily transportation patterns

TIP – Transportation Improvement Plan

TMA – Transportation Management Association

TRANPLAN – A set of computer programs containing all the major travel simulation models and used by DVRPC for travel simulation modeling

Travel demand modeling – a model that predicts travel behavior based on the supply and cost of transportation services and the socioeconomic characteristics of travelers in an area

TRB – Transportation Research Board

Trip distribution – Process of matching trip productions to trip attractions, or origins to destinations

Trip end – one end of a trip; either a production, attraction, origin, or destination, depending on the trip type

Trip generation – Process of simulating trip ends based on socioeconomic variables and trip rates

Validation – Process whereby travel simulation model outputs are verified to represent actual transportation system patterns

VMT – Vehicle miles of travel

VOCs – Volatile organic compounds

WILMAPCO – Wilmington Area Planning Council

2KD – Factor to convert from hourly to daily capacity for highway links

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CHAPTER III APPENDICES

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APPENDIX III-1 1990 AND 2000 TAZS AND CPAS FOR THE DVRPC REGION

County	County Planning Area (CPA)*	Number of TAZs 1990	Number of TAZs 2000	1990 and 2000 TAZs**	2000 External Cordon Stations
PENNSYLVANIA					
PHILADELPHIA (101)		427	529		
1	Center City Philadelphia			1-54, ***1396-1430***	
2	South Philadelphia			55-101, ***1431-1440***	
3	Southwest Philadelphia			102-126, ***1441-1442***	
4	West Philadelphia			127-175, ***1443-1452***	
5	Lower North Philadelphia			176-195, 198-211, 217-224, ***1453-1460***	
6	Upper North Philadelphia			225-231, 253-264, ***1461-1463, 1466-1468***	
7	**Bridesburg - Kensington - Richmond**			196-197, 212-216, 232-252, ***1464-1465***	
8	Roxborough - Manayunk			268-281	
9	Germantown - Chestnut Hill			265-267, 282-316	
10	Olney - Oak Lane			317-349, ***1469-1475***	
11	Near Northeast Philadelphia			350-390, 392-405, ***1476-1482***	
12	Far Northeast Philadelphia			391, 406-427, ***1483-1497***	
DELAWARE (45)		162	209		1913 - 1924
13	Chester			493-530, 1337, ***1510-1515, 1543***	
14	South Central			473-492, 543-549, ***1504-1509, 1521-1522***	
15	South Eastern			428-472, 1336, ***1498-1503***	
16	**North Eastern**			553-579, 1338, ***1525-1536***	
17	North Central			532-542, 550-552, 580, ***1516-1520, 1523-1524, 1537***	
18	**North Western**			531, 581-585, 1339, ***1538-1542, 1544***	
CHESTER (29)		110	178		1925 - 1965
19	**Great Valley**			593-596, 614-616, ***1550-1553, 1564-1568***	
73	**Tredyffrin - Easttown**			586-592, 1340, ***1545-1549, 1608-1609***	
20	Phoenixville			597-602, 684, ***1554-1556***	
21	**Owen J. Roberts**			603-612, ***1557-1562***	
22	Downingtown			613,637,639-641, 644-647, 686, 1271, 1345, ***1563, 1587-1589, 1607, 1611***	
23	West Chester			617-628, 638, 1269-1270, 1341-1343, ***1569-1579, 1584, 1606, 1610***	
74	**Unionville - Chadds Ford**			629-630, 634-636, 662, 1344, ***1580, 1582-1583, 1595***	
24	Kennett			631-633, 666, ***1581, 1597***	
25	Coatesville			642-643, 652-661, 674, 685, ***1585-1586, 1592-1594***	
26	**Twin Valley**			648-651, ***1590-1591***	
27	Avon - Grove			663-665, 667-668, 670-671, ***1596, 1598***	
28	Octorara			672-673, 675-678, ***1600-1601, 1912***	
29	Oxford			669, 679-683, ***1599, 1602-1605***	

Source: DVRPC July, 2008

County	County Planning Area (CPA)*	Number of TAZs 1990	Number of TAZs 2000	1990 and 2000 TAZs**	2000 External Cordon Stations
PENNSYLVANIA (Continued)					
MONTGOMERY (91)		202	267		1972 - 1976
30	Upper Eastern			687-705,1272, ***1612-1615, 1673-1675***	
31	Ambler Area			721-730, 1276-1277, ***1622-1626***	
32	Lower Eastern			731-756, 868-872, 1278, ***1627-1630***	
33	Conshohocken Area			757-761, 780-787, 1280, ***1631-1632, 1639-1640***	
34	Merions			788-814, 1281-1282, ***1641-1649***	
35	Norristown Area			762-779, 830, 1279, ***1633-1638, 1655-1656***	
36	Lower Perkiomen			815-829, 852-854, 1283-1284, 1346, ***1650-1654, 1665-1667***	
37	North Penn			706-720, 831-839, 1273-1275, 1285, 1347, ***1616-1621, 1657-1660, 1676***	
38	Upper Perkiomen			840-847, 850-851, ***1661-1662, 1664***	
39	Pottstown Area			848-849, 855-867, ***1663, 1668-1672***	
BUCKS (17)		126	190		1977 - 1995
40	Quakertown			928-937, ***1704-1705***	
41	Palisades			938-943, ***1706-1708***	
42	Pennridge			920-927, 944-945, ***1700-1703, 1709***	
43	Central Bucks West			915-919, 951-956, 1292-1294, 1348, ***1714-1716, 1732-1733***	
44	Central Bucks East			946, 949-950, ***1710, 1712-1713***	
45	New Hope			947-948, ***1711***	
46	Centennial			906-914, 957-959, 1289-1291, 1295-1298, 1349, ***1697-1699, 1717, 1730-1731, 1734-1737***	
47	Newtown			960-963, 1299, 1350, ***1718, 1738-1739***	
48	Bensalem			873-878, 903-905, 1286-1288, ***1677-1682, 1695-1696, 1727-1729***	
49	Middletown			892-902, ***1689-1694***	
50	Pennsbury			964-977, 1300-1302, 1351, ***1719-1726, 1740***	
51	Bristol			879-891, ***1683-1688***	
BERKS (11)		3	7		1966 - 1971
72	Boyertown Area			1393-1395, ***1908-1911***	
	Pennsylvania TAZs	**1030**	**1380**		

Source: DVRPC July, 2008

County	County Planning Area (CPA)*	Number of TAZs 1990	Number of TAZs 2000	1990 and 2000 TAZs**	2000 External Cordon Stations
NEW JERSEY					
MERCER (21)		63	107		1996 - 2021
52	Trenton			978-1001, ***1741-1748***	
53	Ewing & Lawrence Twps.			1015-1023, ***1759-1767***	
54	Hamilton Twp.			1002-1014, 1352, ***1749-1758***	
55	Hopewell Twp. & Pennington Boro			1024-1027, ***1768-1770***	
56	Hightstown, East Windsor & Washington Twps.			1034-1037, 1303, ***1778-1783***	
57	Princeton & West Windsor Twps.			1028-1033, 1353, ***1771-1777, 1784***	
BURLINGTON (5)		111	162		2022 - 2037
58	**River Front**			1038-1045, 1055-1073, 1075-1078, 1304-1305, 1307-1309, ***1095-1105, 1785, 1790-1793, 1796, 1822***	
59	**South Central**			1046-1054, 1106-1107, 1116-1119, 1306, 1317-1318, 1322-1330, 1354-1355, ***1786-1789, 1807-1808, 1818-1821, 1827-1829, 1831-1835***	
60	North Central			1074, 1079-1088, 1310-1316, ***1794-1795, 1797-1803, 1823-1826***	
61	Mount Holly			1089-1094, 1108-1110, 1319-1321, ***1804-1806, 1809-1812, 1830***	
62	Pine Barrens			1111-1115, ***1813-1817***	
CAMDEN (7)		131	172		2038 - 2044
63	River District			1120-1158, 1185-1188, 1239-1241, ***1836-1844, 1873***	
64	Cooper Valley District			1159-1172, 1198-1201, 1214-1215, 1356-1358, ***1845-1855, 1874***	
65	White Horse District			1173-1184, 1192-1197, 1202-1204, 1211-1213, 1216-1221, 1230, ***1856-1857***	
66	Lower County District			1231-1238, 1331, 1361-1363, ***1867-1872, 1875-1876***	
67	Freeway District			1189-1191, 1205-1210, 1222-1229, 1359-1360, ***1858-1866***	
GLOUCESTER (15)		60	91		2045 - 2067
68	Deptford			1242-1245, 1250-1254, 1332-1334, 1364-1374, ***1880, 1892-1897***	
69	Greenwich			1246-1249, 1264-1268, ***1877-1879, 1888-1891***	
70	Mantua & Harrison			1255-1258, 1335, 1375-1386, ***1881-1884, 1898-1900***	
71	Glassboro-Clayton			1259-1263, 1387-1392, ***1885-1887, 1901-1907***	
	New Jersey TAZs	**365**	**532**		
	Regional TOTAL	**1395**	**1912**		

***** 2000 CPA name or boundary change are shown in bold.
****** 1990 TAZs are not shown in bold.

Source: DVRPC July, 2008

APPENDIX III-2 2000 TAZ MAPS FOR THE DVRPC REGION

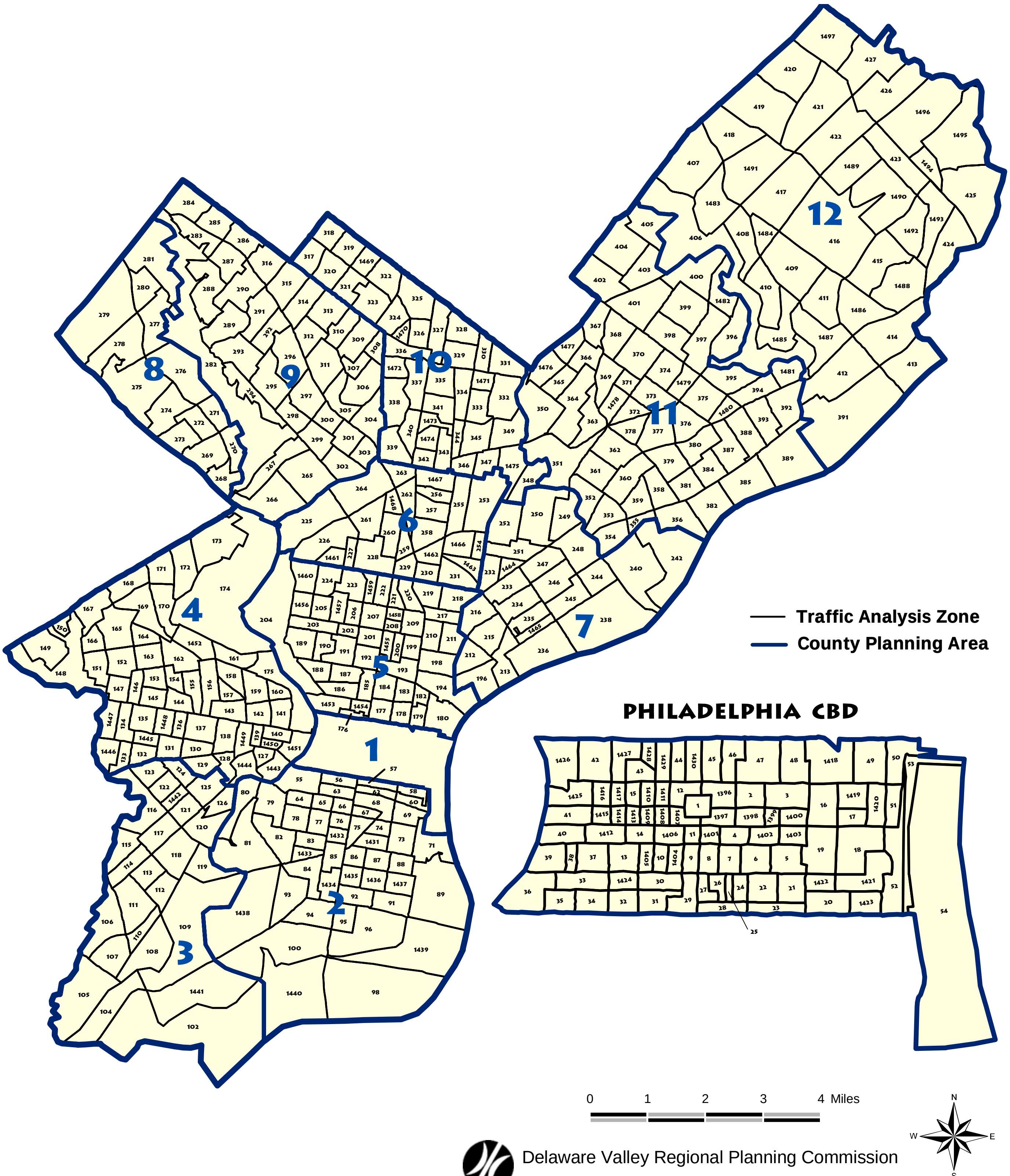

Figure A-III-1 2000 TAZs for the City of Philadelphia

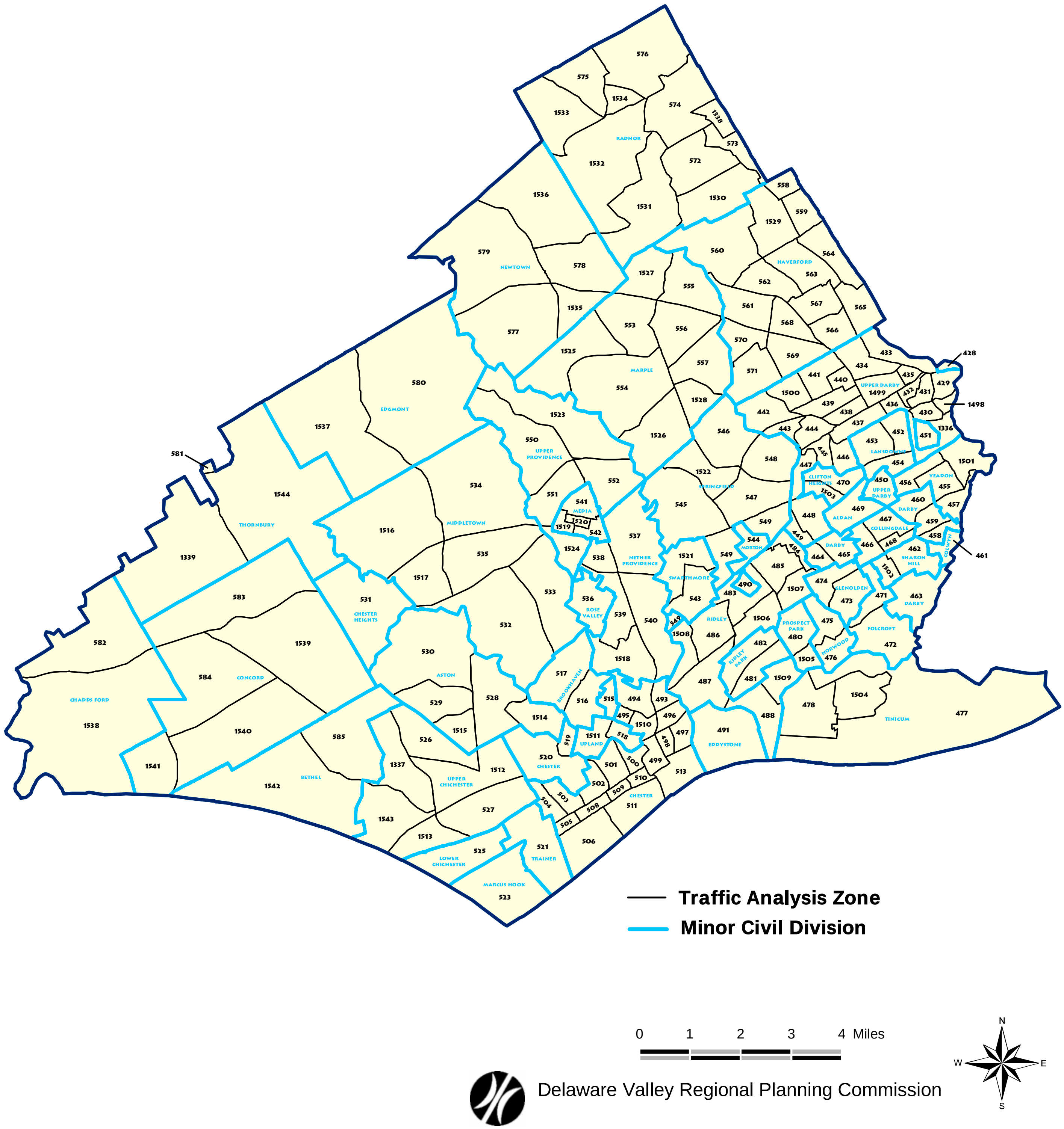

Figure A-III-2 2000 TAZs for Delaware County

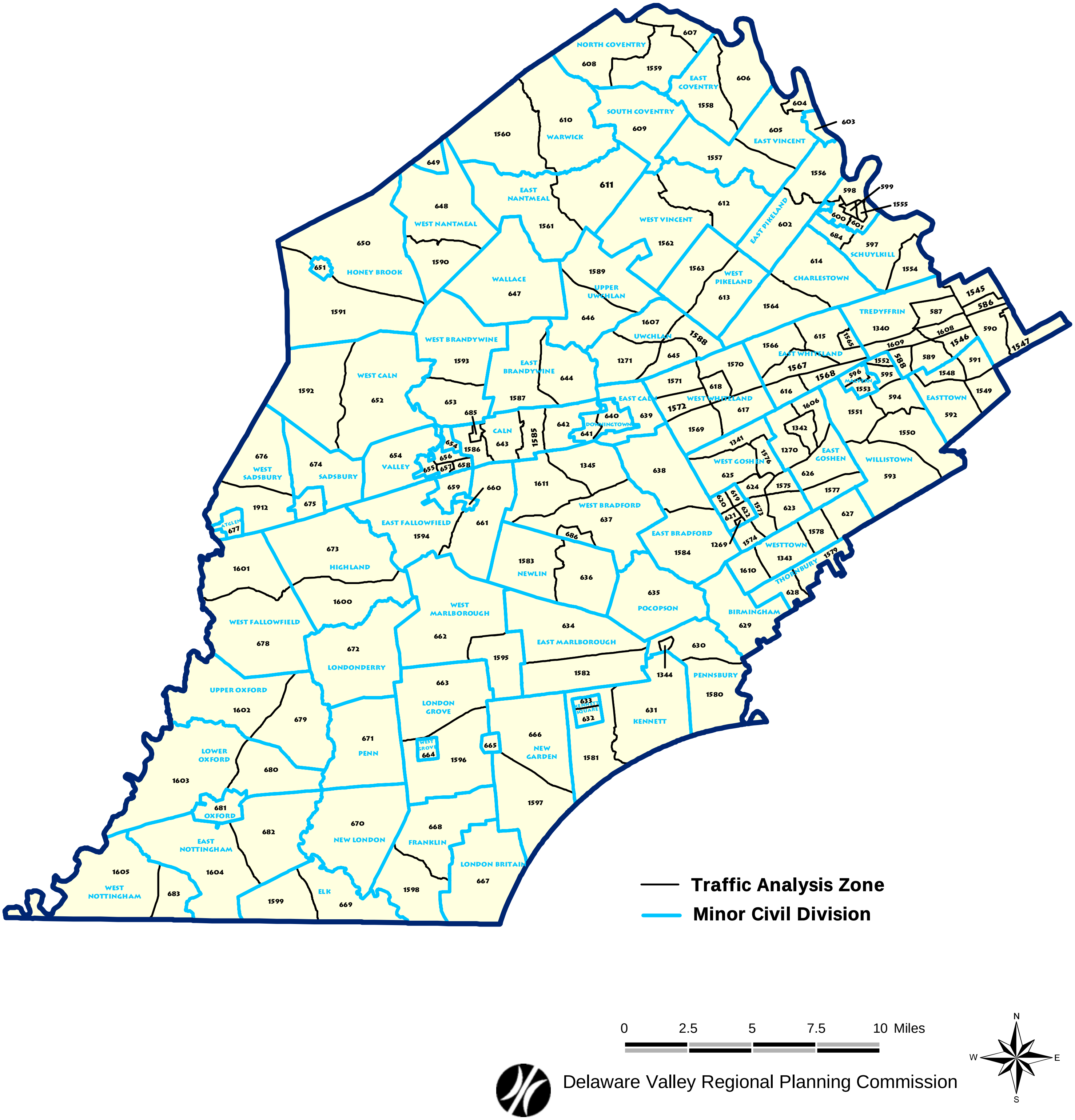

Figure A-III-3 2000 TAZs for Chester County

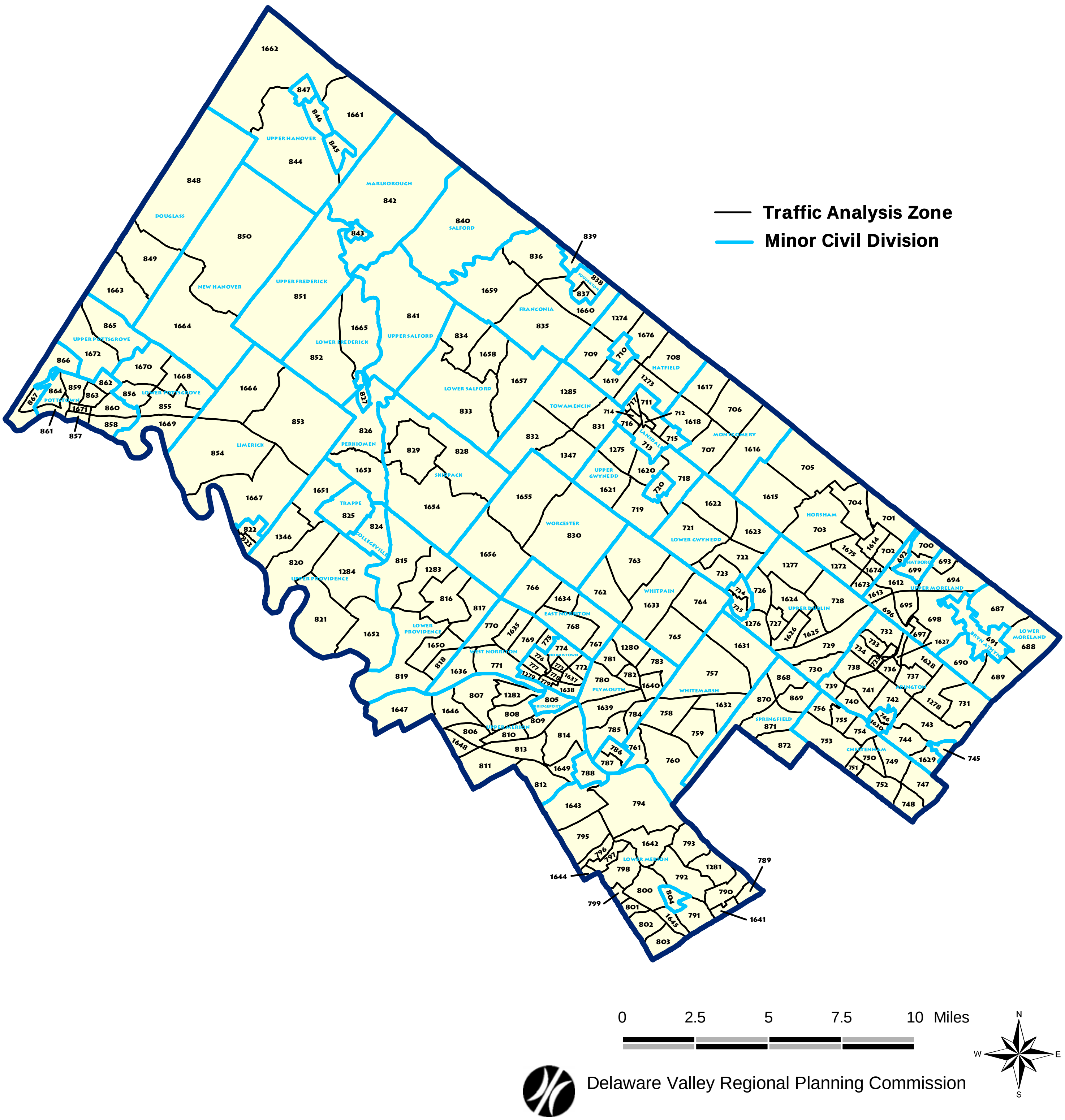

Figure A-III-4 2000 TAZs for Montgomery County

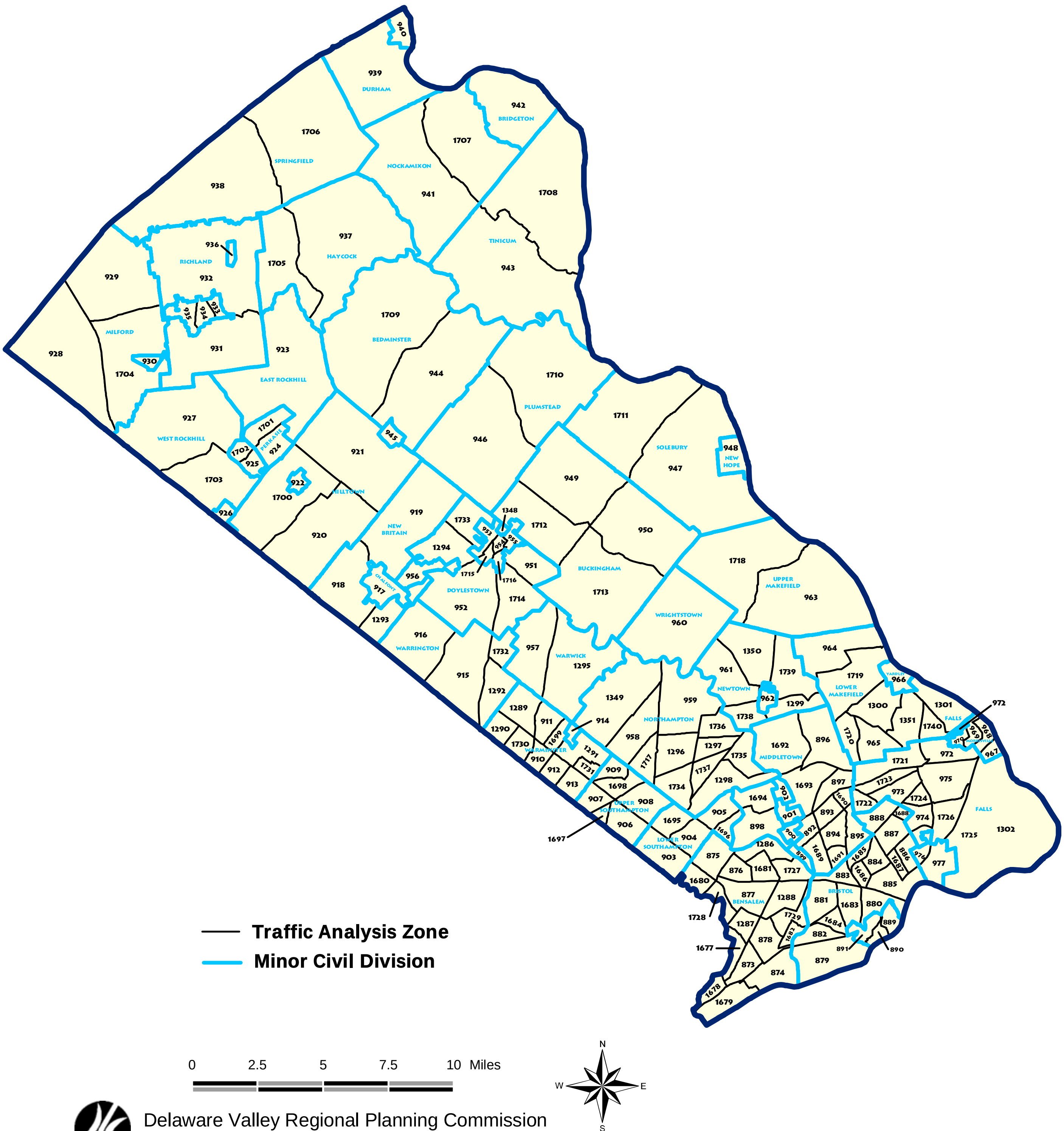

Figure A-III-5 2000 TAZs for Bucks County

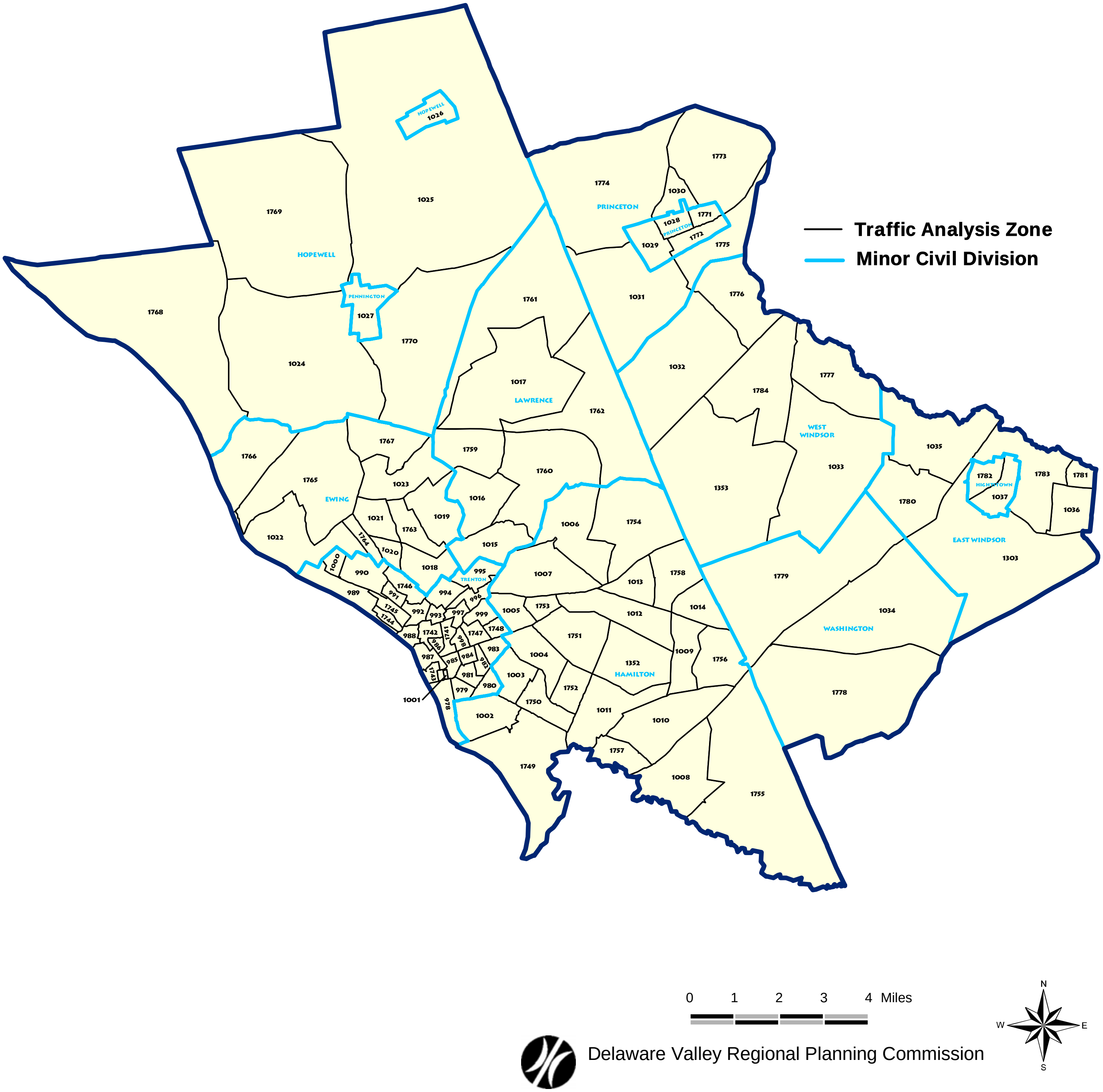

Figure A-III-6 2000 TAZs for Mercer County

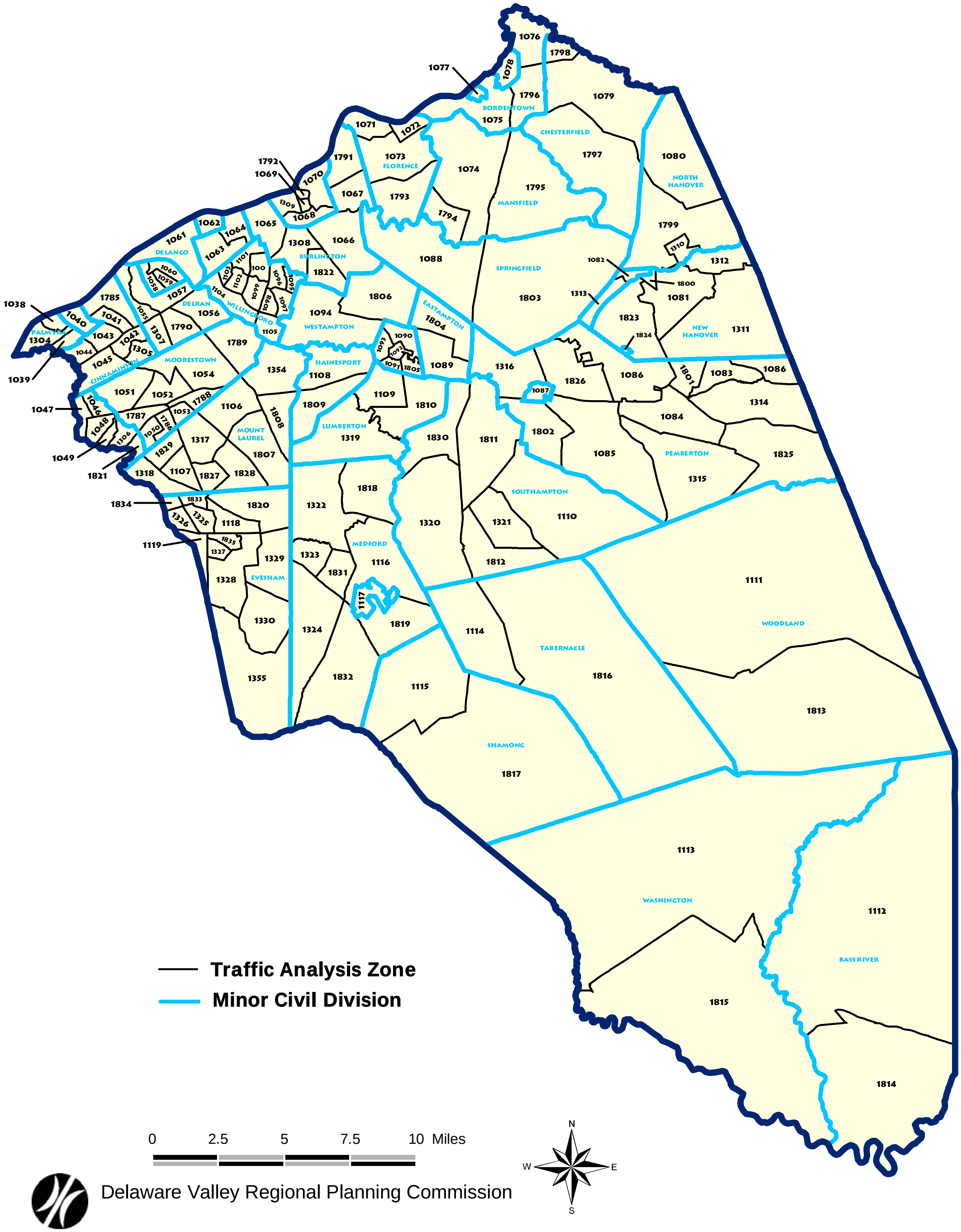

Figure A-III-7 2000 TAZs for Burlington County

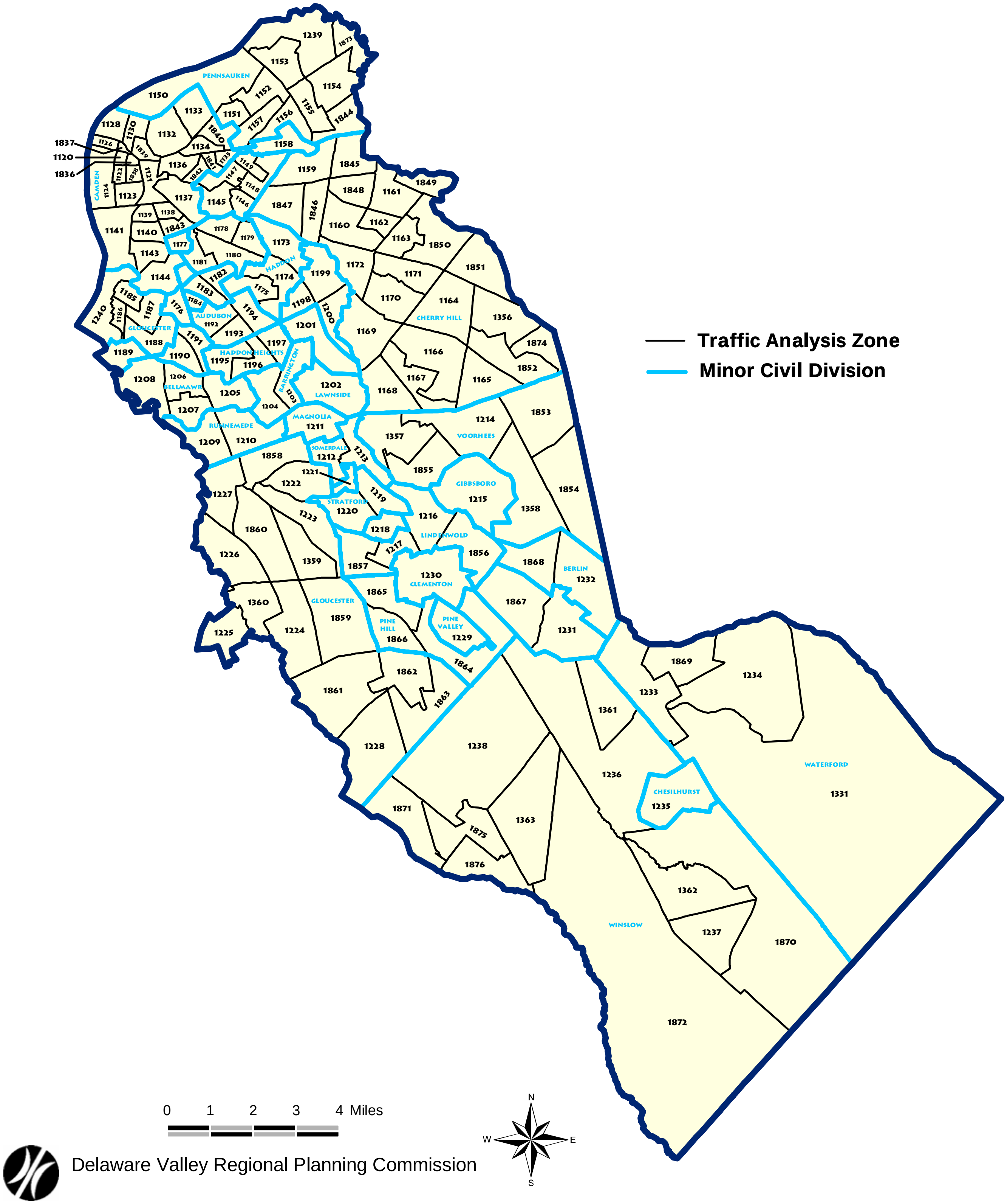

Figure A-III-8 2000 TAZs for Camden County

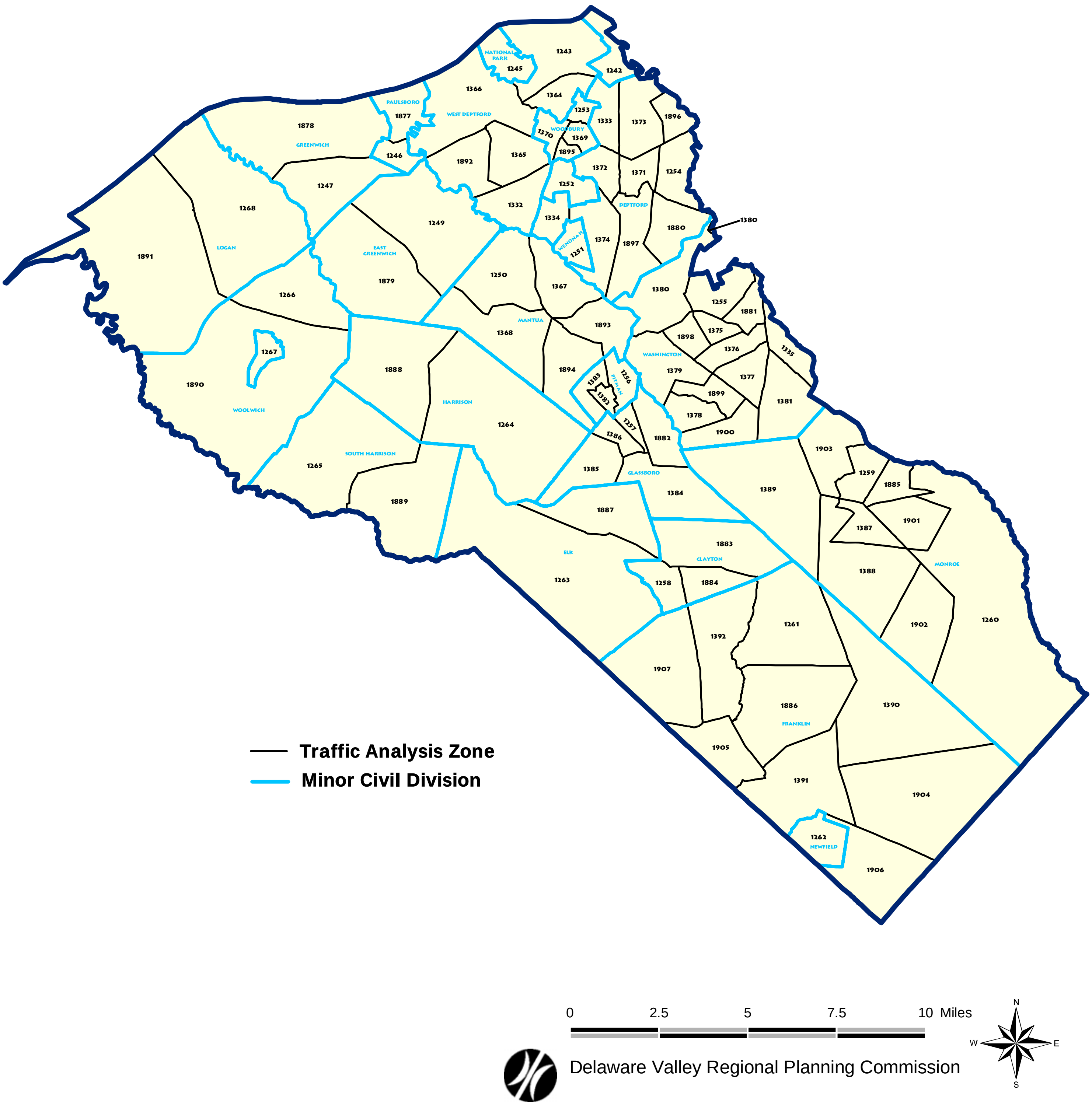

Figure A-III-9 2000 TAZs for Gloucester County

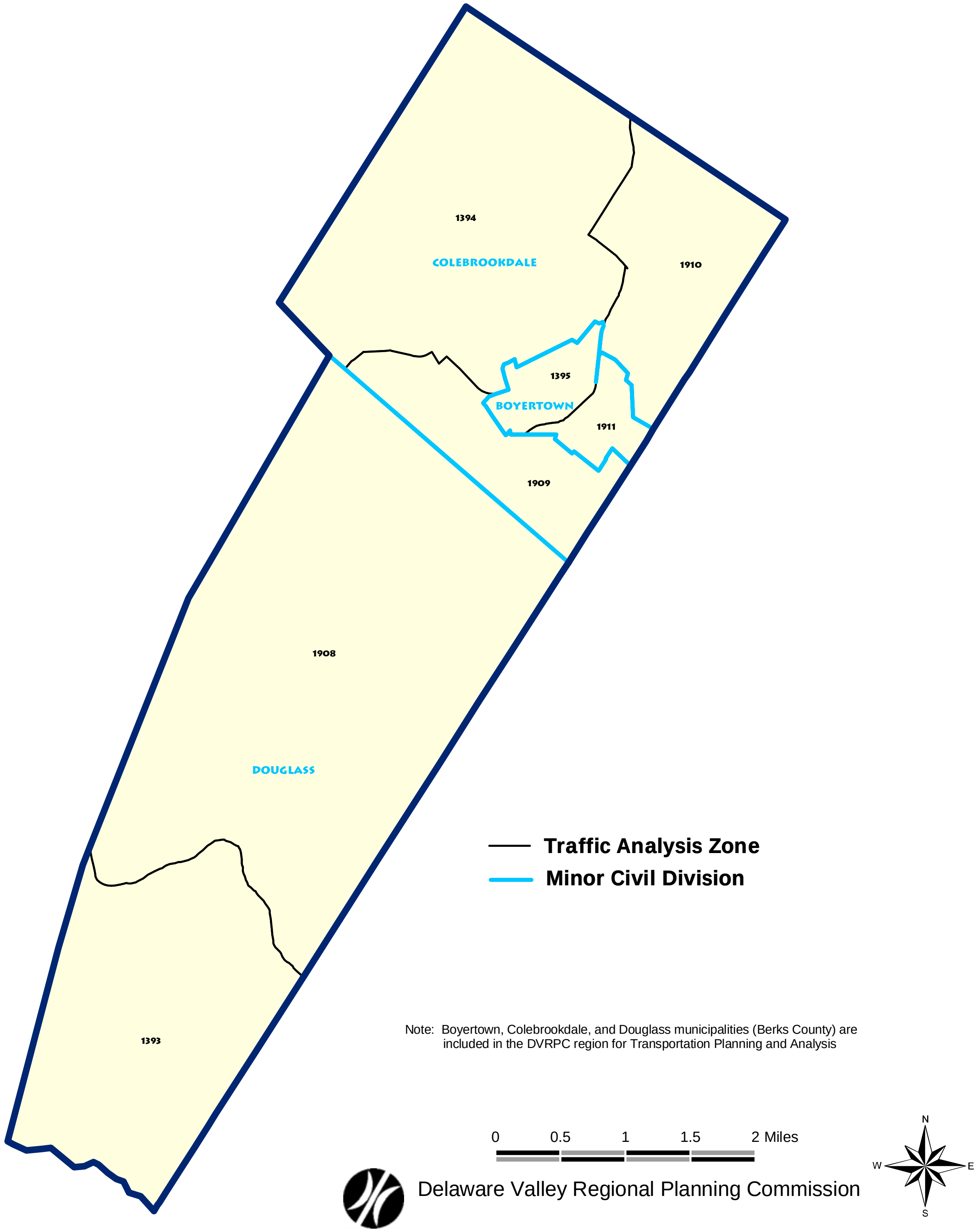

Figure A-III-10 2000 TAZs for the Portion of Berks County in the DVPRC Travel Demand Model

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CHAPTER V APPENDICES

Appendix V-1 Highway Network Coding Procedures and Information

Appendix V-2 Detailed Transit coding Procedures

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APPENDIX V-1 HIGHWAY NETWORK CODING PROCEDURES AND INFORMATION

This appendix contains various details for coding the highway network. File formats are documented, as is the procedure for building the highway network. This section is meant to be a quick reference to some of the most important files used in the highway coding process. Refer to the TRANPLAN documentation for more complete details.

A. File Formats

This section contains file format data for the highway cards file (*.cds), the toll data file (TOLDATAP.CDS), and the toll macro update file (MACROUPD.IN).

1. Highway Cards File Format

The highway cards file (HWY**BAS.CDS) contains data in four sections – header data, speed and capacity data, node data, and link data. The header contains basic information on the file. A sample of the speed/capacity lookup tables is:

```
LG1 = 1,  AG = 1, LG2 = 1, LG3 = 1-99, SPD1 =  5500, CAP1 = 23110,END
LG1 = 1,  AG = 1, LG2 = 2, LG3 = 1-99, SPD1 =  5500, CAP1 = 46220,END
LG1 = 1,  AG = 1, LG2 = 3, LG3 = 1-99, SPD1 =  5500, CAP1 = 72210,END
```

The various parts are defined as follows:

- LG1 – Link Group 1 – DVRPC functional classification (FC) (listed below)
- AG – Assignment Group – DVRPC area types
- LG2 – Number of lanes
- LG3 – County Planning Area
- SPD1 – Free-flow speed in hundredths of a mile per hour
- CAP1 – Capacity in veh/day

The node section contains the nodes listed sequentially and has the following appearance and format:

```
N    5       30243      74752
N    6       30227      74755
N    7       30211      74759
```

- Column 1 – an "N"
- Columns 2 – 6 – Node number
- Columns 13 – 17 – X coordinate
- Columns 24 – 28 – Y coordinate

The X and Y coordinates are expressed in hundredths of miles and are taken from the USGS "Quads" using the 1927 UTM scale. The X coordinate is miles*100; the Y coordinate is in (miles-2000)*100.

The link section of the cards file appears as:

```
6 42991  12T  40    1 7 0 1    0                                2  0  1
6 43001  12T  40    2 7 0 1    0                                2  0  1
6 43011  12T  40    3 7 0 1    0                                2  0  1
```

and has the following format:

- Columns 1 - 5 A-Node
- Columns 6 -10 B-Node
- Column 11 Area Type:
  - 1 – CBD
  - 2 – CBD Fringe
  - 3 – Urban
  - 4 – Suburban
  - 5 - Rural and Open Rural
- Columns 12-15 Distance, in hundredths of miles
- Column 16 "S" or "T" (for speed or time)
- Columns 17-20 Hardcoded speed (or time) to override speed/capacity lookup table value.
- Column 24 Not used
- Column 26 Direction Code:
  - 1 - Northbound
  - 2 - Eastbound
  - 3 - Southbound
  - 4 - Westbound
- Columns 27- 28 Functional Class
  - 11 - High Freeway/Expressway
  - 1 - Medium Freeway/Expressway
  - 21 - Low Freeway/Expressway
  - 12 - High Parkway
  - 2 - Medium Parkway
  - 22 - Low Parkway
  - 13 - High Major Arterial
  - 3 - Medium Major Arterial
  - 23 - Low Major Arterial
  - 14 - High Minor Arterial

  - 4 - Medium Minor Arterial
  - 24 - Low Minor Arterial
  - 16 - High Collector/Local
  - 6 - Medium Collector/Local
  - 26 - Low Collector/Local
  - 7 - Centroid Connector
  - 18 - High Ramp
  - 8 - Medium Ramp
  - 28 - Low Ramp
  - 38 - Turnpike Ramp
  - 9 - Dummy or Toll Link
- Column 30 Number of lanes (centroid connectors have 0 lanes)
- Columns 31-32 County Planning Area identifier
- Columns 33-38 Hard Coded Capacity (to override lookup value; centroid connectors and dummy links have 0 capacity)
- Column 58 One or two-way link (all DVRPC links are one-way, with separate link records for each direction).

2. MACROUPD.IN File Format and MASTERP0.IN File

The MACROUPD.IN file is used to insert actual toll values on toll facilities. By placing the toll values in the separate MACROUPD.IN file, toll values can be more easily updated than by placing them in the highway cards file. The header contains information about the input file (the built highway network), and the output file. A sample of the body of the MACROUPD.IN file appears below:

```
ANODE = 19998, BNODE = 19997, CHANGE, COST = R 12
ANODE = 9202,  BNODE = 9201,  CHANGE, COST = R 12
ANODE = 19984, BNODE = 19983, CHANGE, COST = R 6
```

Each line identifies a separate link in the transit network where a cost value is to be modified by the MACROUPD.IN file. Each link is uniquely identified by it's A and B nodes. The keywords "`CHANGE, COST`" indicate that the cost field should be changed. The "`= R 12`" in the first line above indicates that the cost field should have the current value replaced with toll code 12. The toll values corresponding to the toll codes are located under the field "TOLLS" in the MASTER*0.IN file.

The MASTER**.IN files contain the modeling chain where each model is called in the Evans process. There are seven separate MASTER**.IN files for each iteration. For example, MASTERP0.IN calls the various TRANPLAN programs for the peak ("P") zero iteration, while MASTERP7.IN performs the same function for the seventh peak iteration. The MASTER**.IN file also contains the relative weighting factors for time, distance, and tolls (ctime, cdist, and ctoll) respectively used in determining the generalized cost or impedance measure used in highway assignment:

Impedance = ctime*(link travel times + toll queuing times) + cdist*(link distances) + ctoll * (toll amount)

3. TOLDATAP.CDS File

The TOLDATAP.CDS file contains the data inputs for the toll booth queuing model. The header contains a value for “ctoll”; however, this value is superseded by the 2nd “ctoll” value in the MASTER*0.IN file. The body of the TOLDATAP.CDS file appears as:

```
1 4 14316  2313 PA TPKE DOWNINGTOWN OUT   6      0:12 1 1     0.09 0.25
1 4  2314 14317 PA TPKE VALLEY FRGE IN    5      0:06 1 1     0.10 0.26
1 4 14317  2314 PA TPKE VALLEY FRGE OUT   9      0:12 1 1     0.09 0.26
```

and has the following formats:

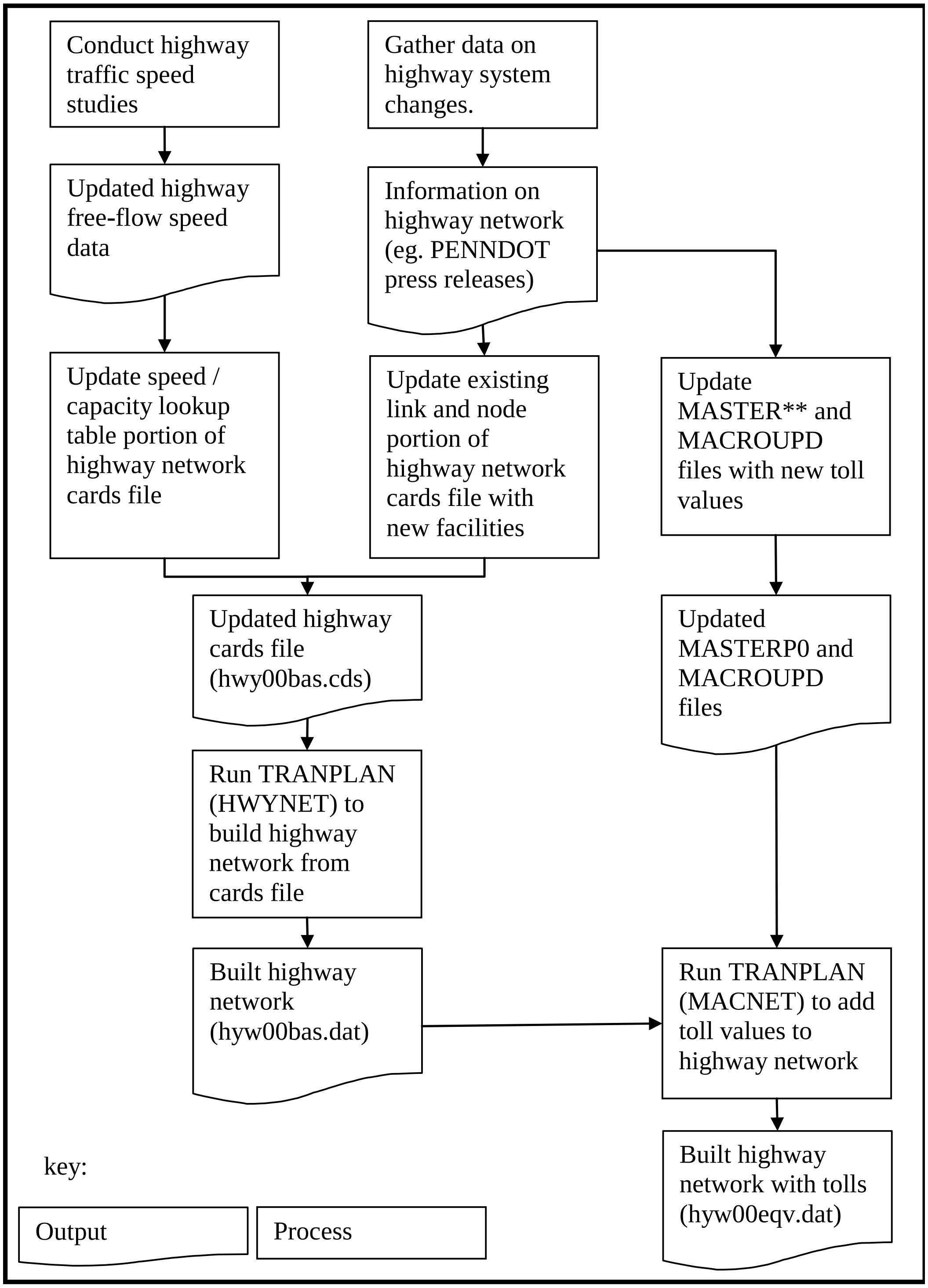
- Columns 1-3 Not used
- Column 4 A “4” is used for expressway tollbooths, and a 3 for bridge tollbooths
- Columns 6 – 10 A node
- Columns 12 – 16 B node
- Columns 18-42 Description
- Columns 44 – 45 Number of modeled lanes/tollbooths
- Columns 51 – 54 Tolls for the facility – not used (Inserted by MACROUPD.IN file)
- Columns 56-59 Average service time per vehicle in min. and sec.
- Column 61 Turns on deceleration modeling
- Column 63 Turns on acceleration modeling
- Columns 71 – 74 Percent of heavy trucks
- Columns 76 – 79 “K” factor – percent of period flow that occurs in the peak hour

Other coding conventions include:

- Turnpike acceleration and deceleration ramps get a functional class (FC) of 38.
- Toll booth links and mid-interchange links for accessing turnpike tolls should be given a FC of 9.
- As per the TRANPLAN documentation, acceleration or deceleration links must have a dummy link separating them from the outside network.

B. Process for Updating, Coding, and Building the Highway Network

Various steps are needed in order to code and build the highway network. They are listed below in ***Figure V-1-1***. The first steps are to gather data in order update and existing network. Highway free-flow speeds are gathered as discussed in **Chapter V**. Information on changes to the highway system is gathered on a continual basis from various sources including DOT press releases, the TIP, and newspaper articles. This data is then used to update the highway network as represented in the highway cards file and the toll files. The highway cards file (a text file) is then "built" into a data file (a binary file). After the highway network is built, it is modified by calling TRANPLAN again and adding the toll data. This final file (eq. HWY00EQV.DAT) is then ready for simulation.



Source: DVRPC July 2008

Figure A-V-1 Process for Updating, Coding, and Building the Highway Network

APPENDIX V-2 DETAILED TRANSIT CODING PROCEDURES

This appendix contains detailed information in three related areas – transit network coding, transit network processing, and the transit-highway network interface. Transit coding is the process of forming an abstract representation of the transit network. Transit network processing consists of the steps and programs used to convert the computer-text based representation of the transit network produced in by the transit coding process into a binary representation readable by TRANPLAN. The highway – transit network interface is used to modify transit running speeds due to changes in highway congestion levels.

A. Transit Network Coding Procedures

The 2000 enhanced integrated transit network is the most comprehensive and accurate transit network ever coded by DVRPC. It is a representation of the transit network that is completely coordinated with the 2000 highway in terms of link geometry and digitization. It represents an ambitious undertaking that required new, GIS-enhanced network coding procedures. Software was either enhanced or upgraded in order to edit and maintain the network and to incorporate it into the DVRPC TRANPLAN model chain. The region's transit system is categorized into 15 transit modes operated by a total of 13 companies. The transit modes are listed in ***Table A-V-1*** and the transit companies in ***Table A-V-2***. Pennsylvania standard bus is divided into two operating modes because of the TRANPLAN limitation of 200 separate service patterns per mode. Pennsylvania bus is separated from NJ Bus because of the need to include different fare policies. Other mode distinctions are used in the modal split and transit assignment models to stratify transit service into homogeneous categories of bus and rail services in terms of rider response. Transit operating company designations include all of the operators in the region, with SEPTA and NJ TRANSIT subdivided into internal divisions. Company codes are used to tabulate summaries of simulated transit riding for model validation and other purposes.

The starting point for transit network coding is the current transit schedule as published by the transit operators. The transit schedule provides detailed information on route service patterns, travel times between published control points, and vehicle headways. The service patterns are used to geographically define the transit routes in terms of underlying streets, stops, stations, rail, and other fixed guideway facilities. The scheduled travel times are allocated to the intervening highway and transit network nodes based on distance and other factors. Vehicle headways are used in the path building, modal split, and transit assignment models to calculate waiting times to board transit.

Table A-V-1 Enhanced DVRPC Integrated Transit Network Modes

Mode #	Mode
1	Walk
2	Auto Penalty
3	Auto Approach
4	Pennsylvania Standard Bus (Part 1)
5	Pennsylvania Standard Bus (Part 2)
6	New Jersey Standard Bus
7	Pennsylvania Express Bus
8	New Jersey Express Bus
9	Inter-City Bus
10	Subway/Surface Car (Light Rail)
11	Subway/Elevated (Heavy Rail)
12	Regional Commuter Rail (SEPTA)
13	PATCO Speed Line
14	Regional Commuter Rail (NJ TRANSIT)
15	AMTRAK

Source: DVRPC July 2008

Table A-V-2 Enhanced DVRPC Integrated Transit Network Companies

Company #	Company
1	SEPTA City Transit Division
2	SEPTA Suburban Frontier Division
3	SEPTA Suburban Victory Division
4	NJ TRANSIT Southern
5	Pottstown Urban Transit
6	Krapf's Coaches
7	NJ TRANSIT Rail
8	Delaware River Port Authority
9	SEPTA Regional Rail Division
10	Inter-City Bus
11	AMTRAK
12	NJ TRANSIT Mercer
13	TMA special Routes

Source: DVRPC July 2008

1. Separate Networks for Each Time Period

Different transit networks are needed for each of the three time periods because the provision of transit service is substantially different between the peak, midday, and evening time periods. Differences between the networks include the routes and service patterns represented as well as the headways on each line. The headways are determined by the number of runs of each line as presented in the schedule. The AM peak period network represents the transit network in the peak period, when service is the densest and frequency of service the greatest (the PM peak period does not need to be represented separately as it is roughly the inverse of the service present in the AM peak period network). To qualify as AM peak period service, the majority of the run must occur between the hours of 7:00 AM and 9:00 AM

The midday period network represents service in the balance of the non-peak period day. To qualify as midday period service, the majority of the run must occur between the hours of 11:00 AM and 1:00 PM

The evening period network represents service in the evening portion of the day. Generally, this service varies from either the peak or midday service and is therefore of interest when presenting simulation of the entire weekday service. To qualify as evening service, the majority of the run must occur between the hours of 8:00 PM and 10:00 PM

2. Service Pattern Diagramming and Coding

Each service pattern for each route in each time period is noted from the published schedule, together with the frequency that each pattern occurs. This is done separately by direction. Service patterns that are similar but have minor variations are combined to control the number of variations. Separate route directions are combined into a two-way service pattern vs. the standard one-way service pattern whenever they have similar frequencies and where the route does not utilize one-way streets.

Each service pattern is rigorously and comprehensively diagramed in the network coding process. This allows a pictorial representation of the node to node progression of the service pattern, the loading locations for travel (whether by walk or drive access), intermediate route variation termini, intersecting routes, transfer links, and directional routing where the service pattern utilizes one-way streets.

Windows of the highway network are printed out traversing the entire length of the transit route. On these plots all of the information mentioned above is noted. In addition, this allows the marking of which nodes may be "turned off" to simplify the algorithm ("turned off" refers to a node not being utilized as a trip loading point, a transfer opportunity to another route, or the end of a transfer link). The headway for each resulting service pattern is then determined by the formula (120 minutes/# occurrences of that service pattern = x minutes).

The TROUTE file is the location for information regarding each service pattern. This includes the company, mode, line card, headway, whether or not the service pattern is one- or two-way, a written description of the pattern, and a node to node progression along the alignment of the service pattern. Separate TROUTE files were prepared for each time period, which closely reflect the route service patterns and headways provided by transit operators in that time period. The TROUTE file follows the standard format utilized by the TRANPLAN INET and VIPER programs. The correspondence between TROUTE line number and company route designation/service pattern is given in the comment cards embedded in the TROUTE file.

3. Node and Link Coding

Highway network nodes referenced in the TROUTE file will automatically be included in the processing routines. An additional node file is needed for non-highway nodes used by the transit network. The transit node file contains coordinate data on supplementary nodes which include all nodes along routes which do not run on the highway network (railroad, subway-elevated, busway). In addition, all centroid companion nodes (necessary for auto approach links) appear here (for the 2000 base network, the centroid companion node was the TAZ number +22000). Terminals, such as intercity bus terminals or the NJ TRANSIT terminal at 10th & Filbert, which generally had large numbers of auto access link connections, are another example of a node whose descriptive data would be located in this file. Only a single non-highway node file is required as the digitized transit node locations were coordinated in all three time period networks. The standard TRANPLAN highway network large format coordinate format (see TRANPLAN documentation) is also used for the transit network. The highway grid coordinate format is used at this point in the process to maintain compatibility with the VIPER network display and update program. See **Appendix V-1** for details.

4. Transit Access Link Coding

The enhanced integrated format transit network utilizes links included in the highway network as much as possible. These include roadway alignment links utilized by bus/trolley service and highway network centroid access links wherever available. However, situations exist where links needed to support the transit network do not exist in the highway network. These supplemental transit links represent exclusive right-of-way transit facilities including commuter rail, subway-elevated, light rail transit facilities, access links, and walk transfer links within and between stations of grade separated transit lines. These supplemental transit links are specified in the TRANPLAN two-digit mode transit network coding format (see TRANPLAN documentation).

The transit access link file includes all relevant highway network walk access links as well as additional walk access links not currently available in the highway network, auto penalty links, and auto access links. Also included are links around the boundary of the region which facilitate the loading of external-external and external-internal trips. This file is build from component files described below.

There are three categories of centroid access links in the transit network - walk access, auto penalty links, and auto access links. DVRPC transit network coding procedures dictate that a zone should always be connected to at least one facility for each mode that is in or near the zone to provide reasonable service. A bus line must be within 1/4 mile of a zone, a subway-elevated facility within ½ mile, and a commuter rail or PATCO type facility within 5 miles via auto approach for non-terminal stations or within 10 miles of a zone for terminal stations for service to be provided. Exceptions in low density areas exist to compensate for large traffic zones.

Walk links represent walking to the transit route from centroids close enough to be reached by foot. The speed on all walk links is assumed to be 4 mph. The general rule for walk approach links is to code 0.2 miles and 3.0 minutes for CBD walk approach links, 0.3 miles and 5.0 minutes on urban and some suburban walk approach links, and greater than 5 minutes for other suburban and rural areas. By convention, auto approaches are coded from centroids too far away to reach the transit facility by walking. A given centroid to route connection will be made by walk or auto approach, never both. The intent of walk and auto approaches is to prepare separate transit paths representative of walk/bus and auto approach access for modal split nesting. Maximum transit walk airline centroid to route distances are 1/4 mile to bus/trolley lines and ½ mile to exclusive guideway (rail) transit facilities.

Auto approach links were used whenever the average distance to the transit facility was judged to be greater than 1/3 mile. Auto penalty links are by convention, coded with 0.1 miles and 10 minutes to represent vehicle terminal times and may also include any station parking charges if applicable (coded as ½ in each direction). Auto approach links are coded with a distance representative of the over-the-road distance to the station with travel times representative of prevailing speeds in the area.

5. Transit Alignment Links

There are two categories of alignment links, street running transit links determined by adding together underlying links in the highway network and exclusive right of way transit alignment links which are not affected by highway congestion levels. All transit link travel times, both street running and exclusive access, are extracted from the current transit schedules. Future travel times for street running links are updated to reflect future highway congestion levels using procedures described in the transit-highway network interface section below.

Street running transit links are determined from the TROUTE line cards by adding up the distances for highway network links in between negative node numbers on the TROUTE line cards. A positive node number indicates a shape node that is used only for defining the shape of a service pattern, and is not needed to interface with another portion of the transit network, such as intersecting routes or access links. Positive node numbers are dropped from the transit network and the node string including the deleted nodes is saved in a file for congestion related travel time updates.

One of the main benefits of having an integrated highway and transit network is that changes in travel time on the highway network are reflected in the transit service. As a beginning point, however, it is necessary to have a method to place the current transit travel times in the network. Transit operating times are slower than the corresponding highway time because of stop related deceleration, dwell, and acceleration times associated with revenue operation. For the 2000 model validation and calibration purposes, scheduled bus and trolley running times between retained transit nodes were averaged and apportioned from the scheduled times between check points.

Spreadsheets are created detailing each time point from the schedule, as well as the links which appear between each time point. The average travel time for each time period (AM Peak, Midday, Evening) between each time point is apportioned to the intervening links based on the percentage of the distance between the time points.

For each time period, a master file of all link occurrences with their apportioned time is created. These are sorted on A-Node, then B-Node. An average is calculated since a given link can be used by several service patterns. In this way, only one time per link per time period is read into the program. These averaged transit link times are stored in a separate file for each time period for insertion into the transit links by the network processing software.

Exclusive alignment transit links are the links that do not use the highway network. These include railroad, subway-elevated, and busway links. Also included are links between the highway network and terminals such as the NJ TRANSIT and intercity bus terminals. Scheduled travel times for each time period for these exclusive access facilities are for the most part allocated by the Elapsed Time computer function in INET (see INET documentation) through "EL" codes on the TROUTE line cards; in some instances, averaged times are calculated using the same methodology as for street running links. These times are stored in a separate file for each time period. Since exclusive alignment links are not associated with the highway network, distances are provided by this file, regardless of whether elapsed time allocations or average travel times are used. For convenience in network processing, the travel times and/or distances associated with street running and exclusive alignment links are provided to the network processing software in a merged file for each time period.

6. Transfer Links

Transfer links allow transfer between different transit services, usually involving different modes where there is a need to code a time penalty or a fare increment. There is a single transfer link file that is applicable to all three time periods.

7. Fare Boundary Links

The fare boundary link file, while not technically links, act as a repository where fare increments are stored. This data is added to the network in the network building process. Transit fares representing base fares and certain inter-company transfer charges are inserted parametrically by the program DVFARELG. However, distance related zonal fare increments are associated with links where the fare boundary occurs. These data are specified in a data file containing A-node, B-node, and fare increment in tenths of a cent in an I5, I6, I6 integer format (see TRANPLAN documentation).

B. Transit Network Processing

The initial Barton Aschman/Cambridge Systematics transit/highway network interface was based on the INET network methodology and computer programs included in the TRANPLAN package. Significant problems were encountered in this initial effort due to excessive network size and estimation of accurate simulated congested transit speeds. Later, as DVRPC staff implemented the overall Evans equilibrium process, it became clear that significant highway/transit interface issues also existed with respect to convergence to and the uniqueness of the equilibrium solution.

As part of the 1996 model enhancement project, TRANPLAN Version 8.0 was extended to accommodate the new enhanced integrated format transit network. TRANPLAN versions 9.1 and 9.2 were also extended to process the enhanced DVRPC transit network. Although attempts were made to extend program capacity, INET continued to have difficulties processing these very large networks because of software bugs and computer storage problems. Furthermore, the highway/transit speed curve methodology included in INET was unable to produce accurate transit link running speeds partly because of inaccurate simulated highway speeds. For these reasons, DVRPC staff prepared new network processing programs to utilize travel times taken from the current schedules and implement new transit/highway speed adjustment procedures. These procedures are described in detail here and in the highway-transit network interface section.

Although new network processing routines have been substituted for the UTPS/TRANPLAN program INET, the overall objectives of transit network processing remain unchanged:

1) Convert the TROUTE and related transit network data files from VIPER format to TRANPLAN HUDNET program two-digit mode card format.
2) Calculate the transit composite impedance variable so that the transit network can be processed into the binary format used by the remainder of the modeling chain.
3) Recalculate street running transit operating speeds based on simulated changes in highway congestion.

Three computer programs run in sequence are required to accomplish transit network processing:

1) INETLINE/ALLOETIM
2) DVFARELG
3) HUDNET

The processed used is explained below and is diagrammed in ***Figure A-V-2***.

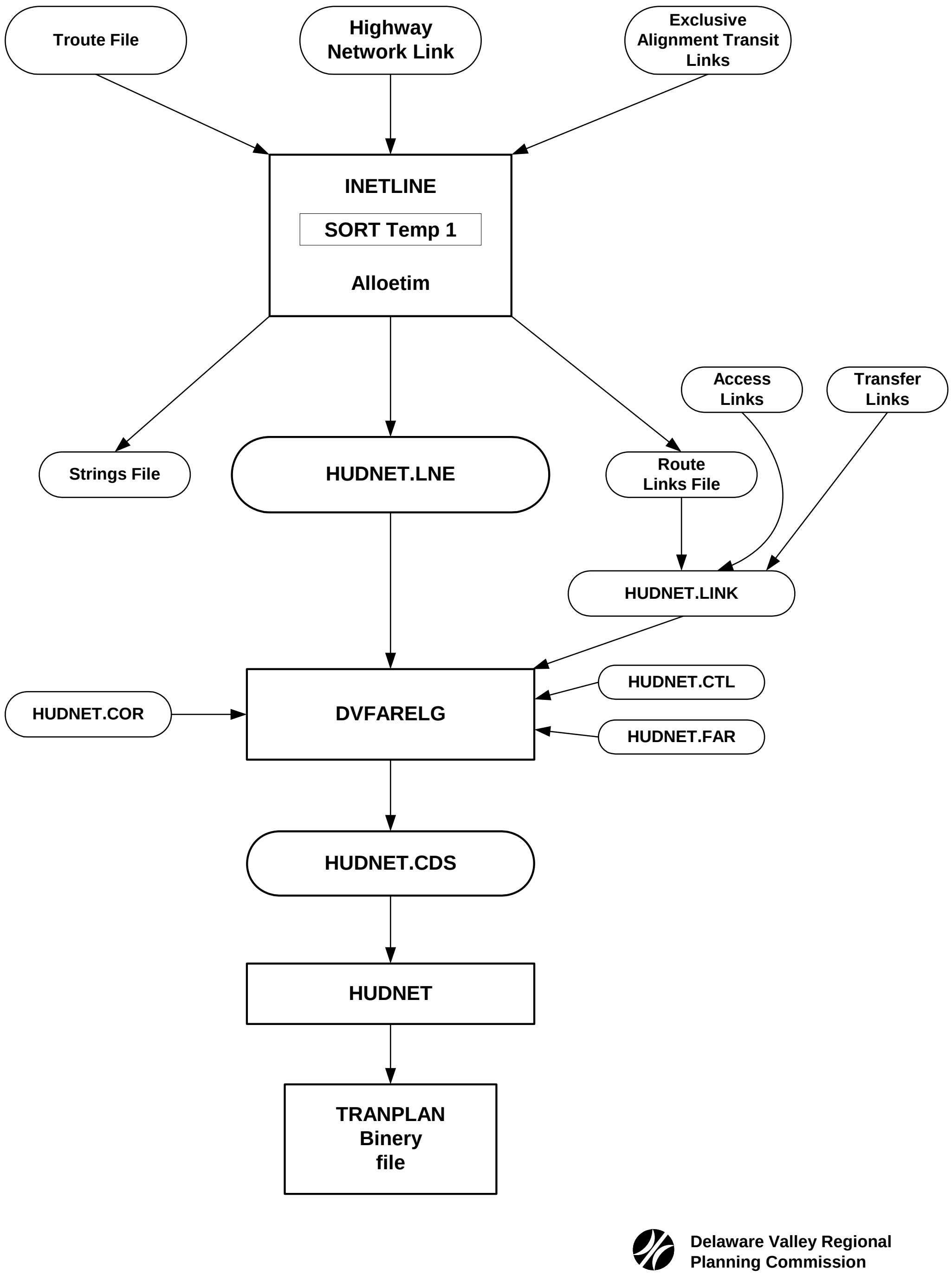


Figure A-V-2 Diagram of Transit Network Processing

1. INETLINE/ALLOETIM

The first programs in the sequence are INETLINE and ALLOETIM. These two programs read the TROUTE cards (VIPER format), Highway Network link cards (HNET/VIPER format), and EXCLUSIVE ALIGNMENT transit link cards (HUDNET 2-byte mode format). They output the transit/highway network interface STRINGS file (for use in the congested highway speed update procedure), the TROUTE line file converted to HUDNET format (HUDNET.LNE) and HUDNET format transit ROUTE link cards as described by the revenue service node strings on the TROUTE cards. This process is run separately for each time period. Detailed operating procedures are given in the following section.

Initially, INETLINE and ALLOETIM were intended to be written as a single routine. However, the transit maximum node numbers proved to be too large to be sorted by the internal TRANPLAN sort routines in use and they were separated to allow an intervening external sort. The temp1 file should be sorted down by ANODE, BNODE, and MODE (columns 1 through 14) prior to executing ALLOETIM. For the same reason, the Exclusive Alignment Transit Link File should be sorted down (cols 1 through 16) prior to executing INETLINE.

The next step is to assemble the HUDNET.LNK input file by merging the transit ROUTE link file with the ACCESS and TRANSFER link file described above. All of these link files are in HUDNET 2-byte mode TRANPLAN format.

2. DVFARELG

DVFARELG is a current adaptation of a long-standing DVRPC process. The program has three basic functions, 1) insert, parametrically specify, and/or factor the transit fares included in the transit network, 2) transform the transit network to include equivalent link impedances and route headways using user supplied equivalent monetary values of out-of-vehicle time, in-vehicle time, and monetary cost, 3) assemble, and reformat as required, all of the network components into a complete input data stream ready to run through HUDNET. In additionally, DVFARELG can renumber the transit network node number series as specified in an optional correspondence file.

The transit impedance is discussed in **Chapter XII**, including the “K” factors used for weighting together the various impedance components. The parameters used to represent the K factors are displayed in ***Table A-V-3***. All the factors have an implicit scale factor of 4.0 to keep the impedance values from exceeding the capacity of the HUDNET input data fields. F(1), F(2), and H represent transit out-of-vehicle time (walk, auto connector and waiting time). These fields are given a 2000 value of

0.913 = 3.652/4.0. F(3) through F(15) represent auto connector and transit modes 4 through14 in-vehicle time and receive and value of 0.609; calculated as 2.436/4.0. OPCOST represents auto operating cost in 1960 dollars over the distance coded for auto approach links. The 7.380 cents/mile for the 2000 simulation represents American Automobile Association 2000 estimate of 49.1 cents per mile deflated to 1960 dollars – 49.1/5.68. In this case only, the scale factor of 4 is input by the WTAC parameter 0.25. Since current (2000) transit fares are inserted into the transit networks, the 0.044 weight for transit fares is calculated as 0.25 (1.00/5.68) = 0.044.

Table A-V-3 DVFARE (HUDNET.FAR) INPUT PARAMETERS

Variable	Contents	Location	2000 Value
F(1)	Weight for Mode 1	6-10	0.913
F(2)	Weight for Mode 2	11-15	0.913
F(3)	Weight for Mode 3	16-20	0.609
F(4)	Weight for Mode 4	21-25	0.609
F(5)	Weight for Mode 5	26-30	0.609
F(6)	Weight for Mode 6	31-35	0.609
F(7)	Weight for Mode 7	36-40	0.609
F(8)	Weight for Mode 8	41-45	0.609
F(9)	Weight for Mode 9	46-50	0.609
F(10)	Weight for Mode 10	51-55	0.609
F(11)	Weight for Mode 11	56-60	0.609
F(12)	Weight for Mode 12	51-65	0.609
F(13)	Weight for Mode 13	66-70	0.609
F(14)	Weight for Mode 14	71-75	0.609
F(15)	Weight for Mode 15	76-80	0.609
H	Headway Factor	81-85	0.913
OPCOST	Operating Cost for Auto (1960 Cents)	86-90	7.380
TRANS	Weight for Transfer Part of the Fare	91-95	0.044
WTFR	Weight for Base Fare and Zonal Increment	96-100	0.044
WTAC	Weight for Auto Approach Cost	101-105	0.25

Source: DVRPC July 2008

Transit fares are parametrically inserted into the transit network using the company codes given in ***Table A-V-2*** (page 332). The update is accomplished by a linear equation which updates and inserts transit fares on the HUDNET.LNK cards and updates the values included on the HUDNET.FAR inputs described above.

$$F' = B + A*F$$

where:

- F' = updated fare
- F = input fare (HUDNET.FAR only)
- A and B are parameters

Fare values recorded on the input HUDNET.LNK cards are ignored. For information purposes, the updated fares values in tenths of a cent are stored in cols. 66-71 of the link card images in the HUDNET.CDS file. These values cannot be recycled back through the DVFARE program. Fares must be specified through the HUDNET.FAR file and DVFARE parameter cards. For fare update purposes only, walk, auto connection, and auto approach links (HUDNET modes 1, 2, and 3) are company codes 23, 24,and 25, respectively.

The HUDNET.CTL parameter cards that correspond to the transit fares in ***Table IX-8*** (page 207) are listed in ***Table A-V-4***. The first entry is decoded as follows: companies 23 to 1 represent walk to SEPTA city transit division. The slope (A) inserted into equation 1 is 0.00 which zeros out any values that may be present in the HUDNET.FAR file. The constant (B) valued at 530.0 is inserted as the base transit fare in the HUDNET.CDS file. The value 530.0 is determined from ***Table IX-8*** as follows: (1320/2 - 260/2) or ½ the base fare minus ½ the transfer charge as noted above. Zonal increment charges are usually factored using the "A" parameter. For instance, company 9 to company 9 (SEPTA Commuter Rail) is increased by 52 percent by the1.52 value specified in ***Table IX-9*** (page 209) Please note that TrailPass transfer usage has already been factored into weighted fare values specified in ***Table IX-9***.

Table A-V-4 2000 Transit Network DVFARE Fare Update Parameter Cards

From Company	To Company	A	B	From Company	To Company	A	B
23	1	0.00	530	23	8	0.00	500
1	23	0.00	530	8	23	0.00	500
25	1	0.00	530	25	8	0.00	500
1	25	0.00	530	8	25	0.00	500
1	1	1.00	0	8	8	1.65	0
23	3	0.00	575	8	4	0.00	835
3	23	0.00	575	4	8	0.00	835
25	3	0.00	575	8	1	0.00	1030
3	25	0.00	575	1	8	0.00	1030
3	3	1.27	0	23	12	0.00	325
23	2	0.00	650	12	23	0.00	325
2	23	0.00	650	25	12	0.00	325
25	2	0.00	650	12	25	0.00	325
2	25	0.00	650	12	12	1.21	0
2	2	0.75	0	23	4	0.00	325
1	3	0.00	270	4	23	0.00	325
3	1	0.00	270	25	4	0.00	325
1	2	0.00	290	4	25	0.00	325
2	1	0.00	290	12	4	1.21	0
2	3	0.00	300	4	12	0.00	450
3	2	0.00	300	12	4	0.00	450
23	9	0.00	1005	23	7	0.00	1000
9	23	0.00	1005	7	23	0.00	1000
25	9	0.00	1005	25	7	0.00	1000
9	25	0.00	1005	7	25	0.00	1000
9	9	1.52	0	7	7	1.00	0
9	1	0.00	1535	12	7	0.00	1325
1	9	0.00	1535	7	4	0.00	1325
3	9	0.00	1580	4	7	0.00	1325
9	3	0.00	1580	7	12	0.00	1325
2	9	0.00	1655	7	9	0.00	1530
9	2	0.00	1655	9	7	0.00	1530

Source: DVRPC July 2008

C. Detailed Computer Operating Procedures for Coding and Processing

This section provides detailed operating instructions for updating the transit network using the procedures described in Section B. The VIPER/INETLINE/ALLOETIM transit network update can be run in a variety of ways depending on the nature and extent of the update being performed. Although it is possible to read all of the TROUTE cards at once into VIPER (assuming that the associated rail links are input in highway network binary format), VIPER does not preserve the route identification comments inserted into the TROUTE card stream that are essential for documenting the network. Also, there is limited capability to insert, evaluate, edit, and create transit approach links and transfer links within VIPER. For these reasons, it is recommended that VIPER be applied only to editing street running transit routes on an individual as needed route basis. Exclusive right-of-way service may be modified by manually updating the TROUTE, EXCLUSIVE ALIGNMENT LINKS, HUDNET.COR, and HUDNET.FAR card files outside of VIPER. The updated or new TROUTE cards from VIPER and the manual update process should then be run through the INETLINE process and the output HUDNET line, link, coordinate, and fare cards manually inserted into the DVFARELG input files prior to processing the updated transit network. Details of this recommended process are described and documented in this section.

1. Computer Assisted Coding of VIPER Format Bus TROUTE Cards

Editing the TROUTE file is a very time consuming task because the bus line card must follow the highway network links, which tend to be short and very numerous (interchange ramps, small cross roads, etc.). The VIPER Visual Planning Environment software includes transit line coding functionality that largely automates the bus line card coding. The highway network is graphically displayed and the analyst sequentially uses the mouse pointer to select nodes to be included in the bus line card. It is not necessary to point to every highway node, only enough nodes to define the bus route are needed. VIPER automatically fills in the intervening nodes using minimum distance paths. The result is a very large reduction on the man-hours needed to code the bus line cards.

2. INETLINE Computer Generation of Transit Network Bus Link Cards

Figure A-V-3 presents an overview of the network generation process. Transit link cards corresponding to the VIPER line cards are generated by computer from the highway network. The bus route link cards are prepared by INETLINE from VIPER TROUTE cards and the underlying highway network link data. As described in Section B above, existing transit route running times should be taken from the schedule, future/congested running times for existing routes should be prepared by the update procedure described in Section D. For new transit routes, current running times should be estimated from other routes running on the same highway links or the scheduled or congested running speeds of similar existing routes.

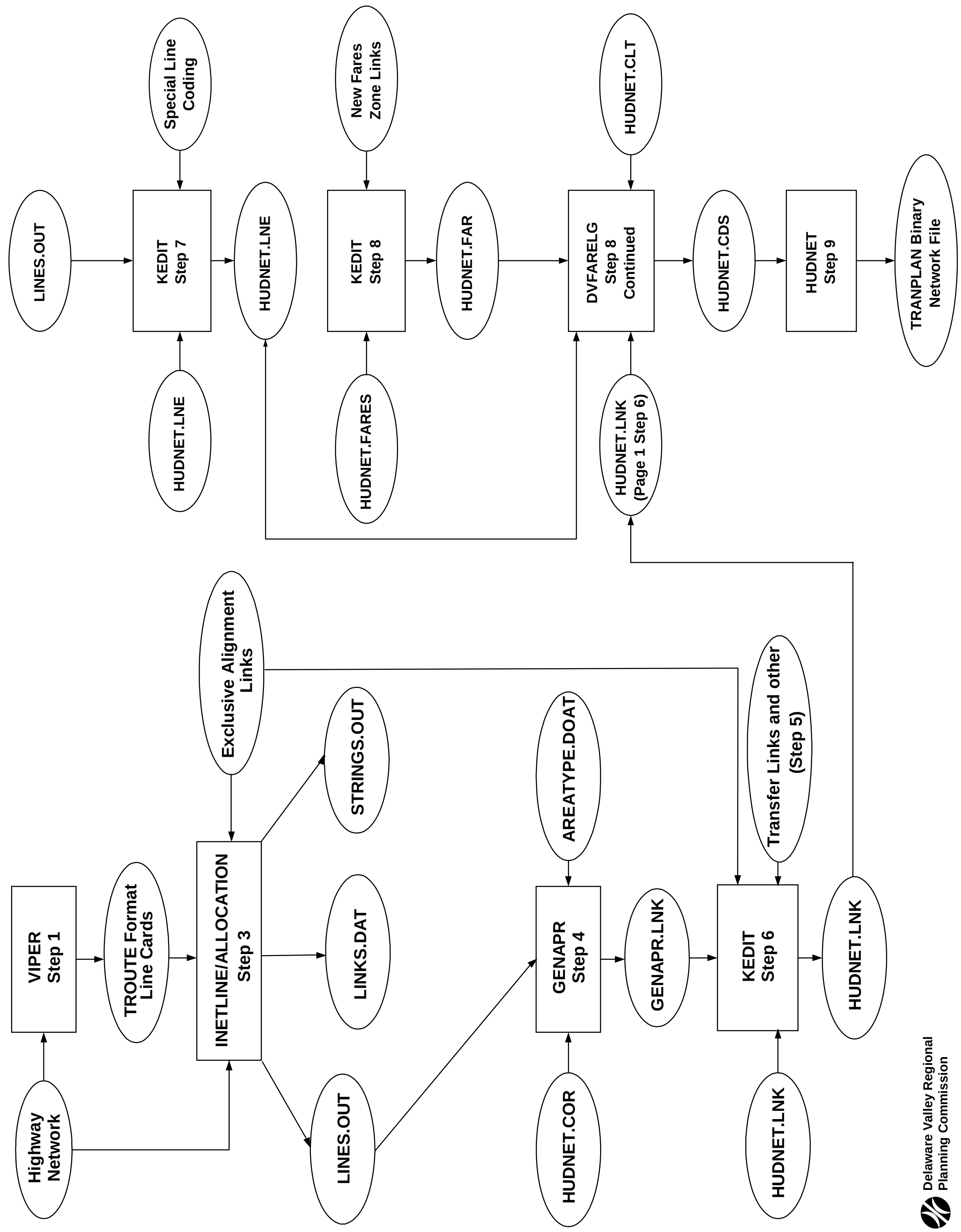
3. Exclusive Right-of-Way Transit Service

For entirely new bus, Bus Rapid Transit, Heavy Rail, or Commuter Rail service running times may be estimated from an engineering analysis of the proposed service. Running times should be input via the Exclusive Alignment Link file or through the elapsed time function of the TROUTE card and transferred to the output transit link file by the INETLINE/ALLOETIM process. In many cases, the VIPER transit/highway interface will not be helpful for this coding exercise.

4. Generation of Walk Approach Links to the Bus and Rail Stops in the VIPER Line Cards

DVRPC staff has written computer software that prepares the walk links corresponding to the new VIPER coded transit line cards in HUDNET format as output by INETLINE. This program is parameter driven, using centroid distance, route connectivity, and maximum-number-of-links criteria by area type. This program also produces large labor savings compared to coding the walk approach links by hand. Taken together these automated features should significantly reduce the labor costs required to prepare transit networks reflective of the updated service patterns or proposed transit alternatives.

Figure A-V-3 DVRPC Computer Assisted Transit Coding Flow Chart



5. Procedures for Transit Network Coding

Detailed step-by-step instructions to operate the DVRPC automated transit network coding procedures follow (see flow chart in ***Figure A-V-3***). This process must be executed separately for the peak, midday, and night time period transit networks. It is convenient to keep the time period networks in separate sub-directories.

1. Code the new bus line cards in VIPER using standard VIPER procedures. These new lines should be saved in a VIPER TROUTE format ASCII computer file. This file should contain only the new line cards. The base No-build alternative line cards are already in the HUDNET format network.

2. Rename the VIPER output line card file to "TROUTE.TEM." INETLINE/ALLOETIM uses user specified data set names stored in the INETLINE.CTL and ALLOETIM.CTL files. The analyst can rename the control file names as appropriate (see also ***Figure A-V-3***).

3. Execute INETLINE by typing "INETLINE" at the command prompt of a computer with the TRANPLAN software installed. Review the "PRINTER.OUT" file to make sure that INETLINE found all of the links in the highway network. Sort down the TEMP1 file by cols 1-20 and execute ALLOETIM as described in Section B above. Separate the link and line cards using a text editor into appropriate HUDNET format computer files. It is not necessary to save the coordinate cards for street running transit line updates, because all transit node coordinates are already in the existing coordinate file (HUDNET.COR). For exclusive alignment routes, the appropriate link, coordinate, and line cards must be generated, either by INETLINE/ALLOETIM or coded by hand.

4. Use the GENAPR program to generate the walk links from the new/updated line cards output from INETLINE. Review the link generation parameters in the "PARM.TAB" file before executing GENAPR. The default values are given below. Execute GENAPR by typing "GENAPR" at the command prompt. Follow the instruction that appear on the screen. You will be asked to specify an output file name, the area type file, the INETLINE generated line card file, and finally, the transit network grid coordinate file (HUDNET.COR). GENAPR runs for a few minutes.

GENAPR Default Parameters

Area Type	Max. Bus Link Dist. (miles)	Max Rail Link Dist. (miles)	Max. Links Out
1	2.5	5.0	5
2	2.5	5.0	5
3	5.0	5.0	5
4	10.0	10.5	5
5	10.0	10.0	5
6	10.0	10.0	5

Source: DVRPC July 2008

5. Manually code any required transit facility transfer links, auto approaches, grade separated transit facilities, and any special coding to model non-standard situations. For the most part these will be link data.

6. Append the link cards generated by GENAPR and coded manually (auto approaches etc.) to the end of the “HUDNET.LNK” file using a text editor. Again, this file must be named “HUDNET.LNK.” There is no sort requirement on this file.

7. Insert the new/updated transit lines to the No-build network line card file (HUDNET.LNE) using a text editor. HUDNET requires that all transit line cards be sorted by mode, line number, and line card sequence number.

8. The HUDNET.FAR file may require editing prior to executing DVFARELG. This file contains fare zone increments assigned to transit links crossing fare boundaries. Any zonal fares required by the undated transit coding must be added to this file (anode, bnode, and fare in tenths of a cent). Both directions of 2-way links must be included separately.

9. Assemble the transit network for input to TRANPLAN by executing DVFARELG. Type “DVFARELG” at the command prompt of a computer with the installed software. As described in Section B, standardized names are given to the DVFARELG input and output files. The input link cards are contained in HUDNET.LNK, the input line cards in HUDNET.LNE, the input coordinate cards in HUDNET.COR, and the TRANPLAN network control cards in HUDNET.CTL. The output is put in a file named “HUDNET.CDS.” All other required fare information is inserted parametrically by DVFARELG.

10. Finally, convert HUDNET.CDS to TRANPLAN binary format by typing “TRANPLAN HUDNET.CDS” at the command prompt of a computer with the TRANPLAN software installed. This executes the TRANPLAN HUDNET program. The TRANPLAN binary output file is given the name specified in the “HUDNET.CTL” file. The TRNPLN.OUT file from HUDNET and the display of the

binary TRANPLAN network in TNIS should be reviewed for errors. Review the TRNPLN.OUT printout file to insure that all coding is done correctly and there are no tunnels or missing links or line cards. The alternative network is ready to be tested by copying the transit DAT files into the appropriate NETS sub-directory and changing the "NETWORKS" file in the SIMXXPK, SIMXXMID, and SIMXXNIT as appropriate to reflect the alternative transit network data set names.

Figure V-4 (page 93) displays the regional AM peak transit network. ***Figures A-V-4 and A-V-5*** displays the regional midday and evening transit networks, respectively. The route alignments shown in the peak and midday networks are very similar. Differences between these networks primarily involve service frequencies and detailed service patterns (express service and turnbacks). There is a large difference between the day time and evening networks, because many routes cease operations during evening hours.

D. Methodology for Updating Highway and Transit Speeds for FHWA/EPA Modeling

The majority of transit lines in the Delaware Valley operate in mixed traffic conditions. Changes in future highway speeds will result in changes in future transit operating speeds. This section discusses the determination of future highway and hence transit speeds.

Federal travel simulation model requirements promulgated by FHWA/EPA and FTA have diverged to the point that a single model chain can no longer satisfy all of the requirements. The FHWA/EPA requires iterative processes that converge to equilibrium highway speeds – such as the Evans process. This emphasis on equilibrium highway speed comes from the need to calculate speed dependent mobile source emissions for future scenarios with large increases in congestion.

The FTA stipulates a much simpler more traditional four step modeling process that is closely registered to scheduled/surveyed transit and highway speeds. Future speeds are updated only for the No-build alternative and these No-build speeds are held constant throughout the simulation of the build alternatives. The FTA objective in their process is to be able to closely study and evaluate the model runs and thereby minimize the possibility of forecasting abuse, and to obtain reasonable results from the SUMMIT user benefit calculation model.

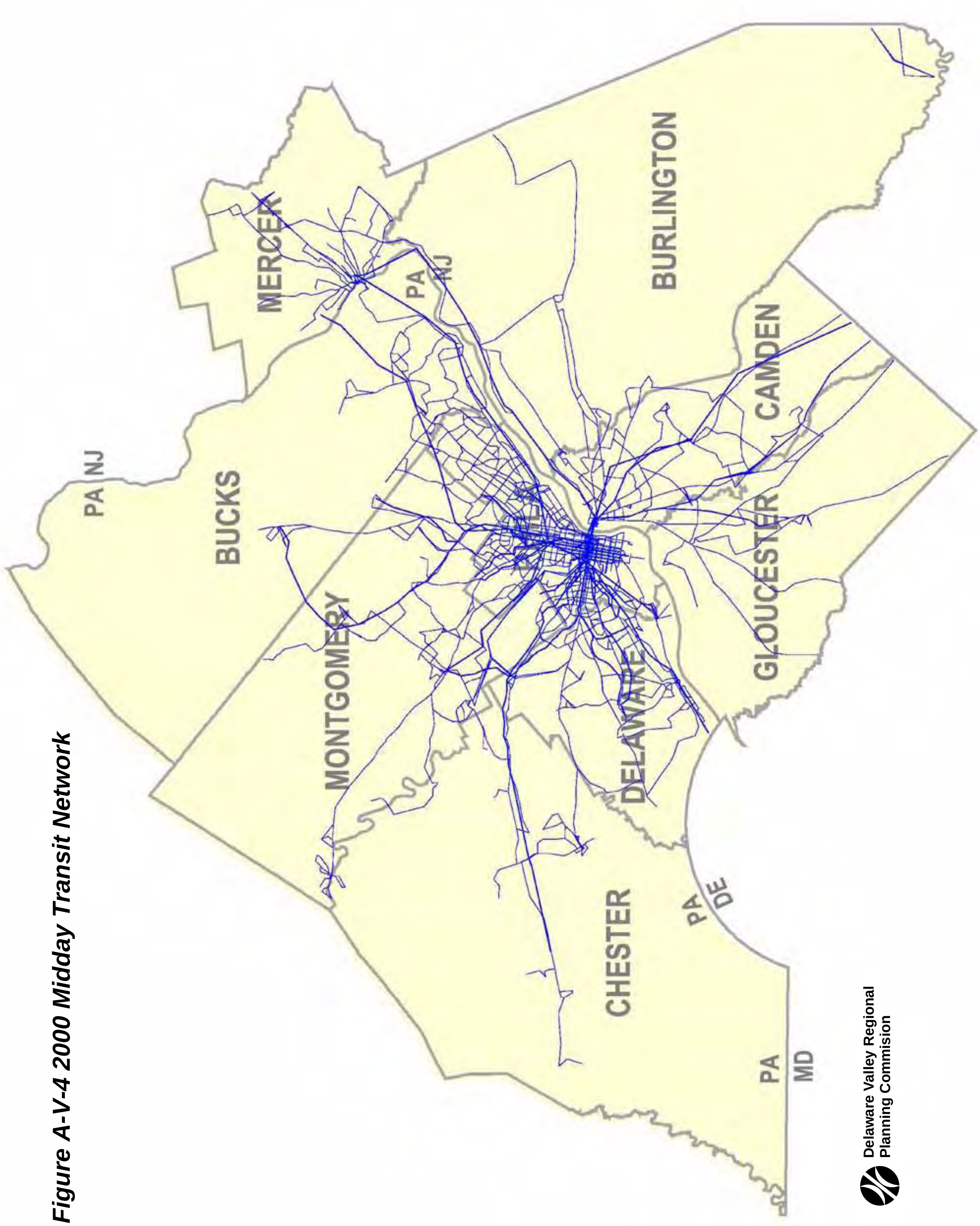
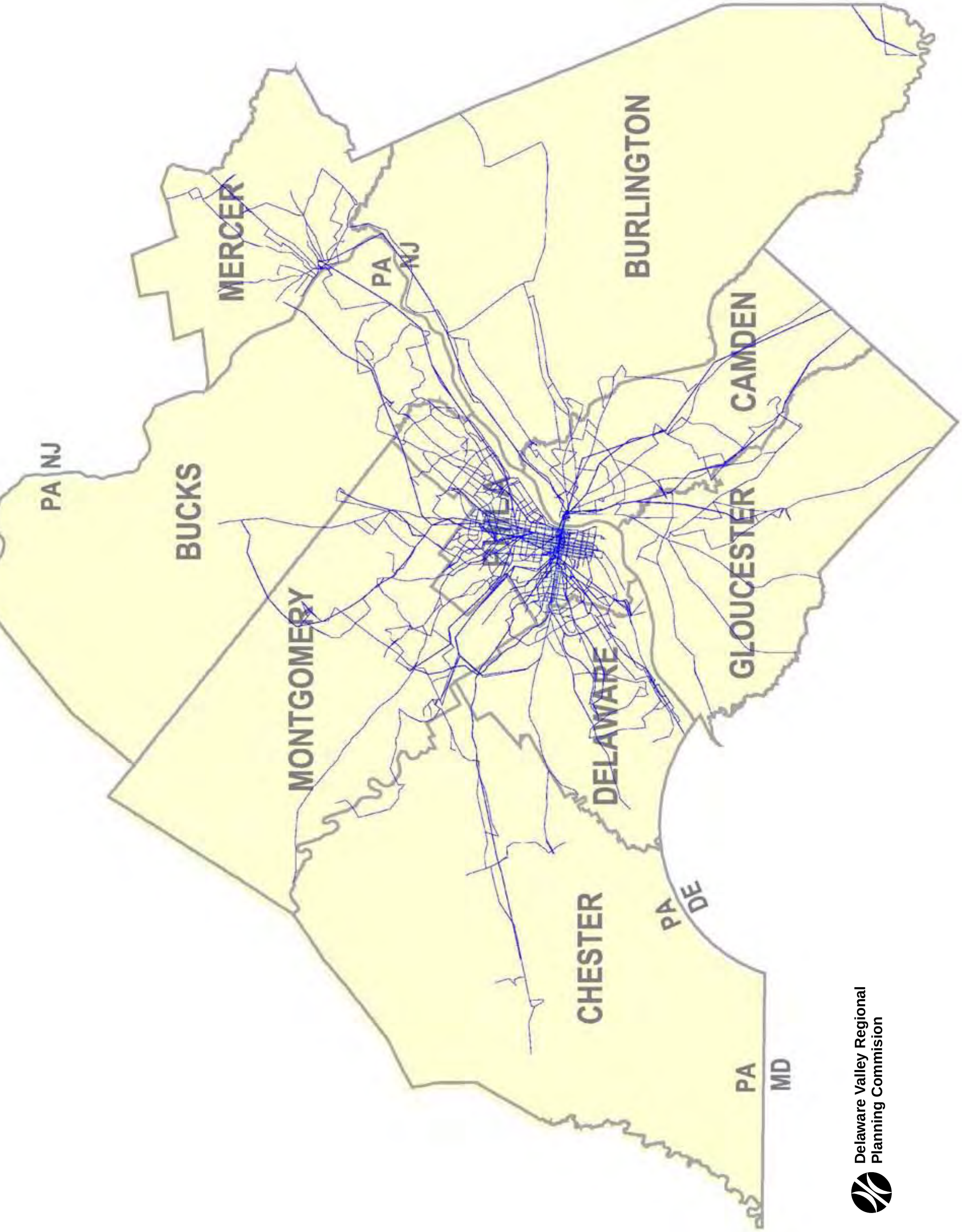


Figure A-V-4 2000 Midday Transit Network

Figure A-V-5 2000 Evening Transit Network



Updating highway and transit speeds for future year simulations for FHWA and EPA related modeling is discussed in this section. FTA compliant modeling is discussed in the following section. In order to update transit speeds three steps are needed:

1. Determination of future highway link speeds.
2. Determination of future transit link speed changes based on highway link speed changes.
3. Compensation for dropped nodes in the transit network.

Methods for each step are discussed below.

1. Determination of Congested Highway Speeds

Several methods are possible to determine congested highway speeds for future year simulations. The capacity restraint equations produce highway speeds for each link in the highway network (see **Chapter XI.A**). These capacity restraint equations are designed to represent the effects of congestion on driver behavior, but do not necessarily produce speeds that match well with surveyed results. More accurate highway speeds can be found using post processing techniques (see **Chapter XII.C.3**). The same post-processing techniques used for transportation air quality (TAQ) are used for determining highway speeds for the purpose of estimating future transit speeds. The post processor speed curves were calibrated with the 1997 DVRPC highway travel time survey. The highway speeds are based on equilibrium assignment highway link volumes after iteration 15 of the calibration run, using hourly volume factors representative of 7:00 to 8:00 AM for the peak congestion and 11:00 to 12:00 noon for midday congestion. The post-processor employs different equations for freeways and arterials, includes a minimum speed for highly congested conditions, and includes additive parameters such as traffic signal density. The post-processor speeds are not used directly, however. They are used in a ratio to update scheduled transit speeds as detailed in the following section.

2. Estimation of Street Running Congested Transit Speeds

Integrated network (INET) speed curves may be determined by comparing current scheduled travel speeds with simulated highway speeds from the 2000 validation run of the highway assignment. Although the post-processor highway speed curves produce better results than the capacity restraint function, unacceptable levels of scatter still occur. This scatter in part results from lack of information about the details of highway link and intersection designs in the highway simulation network, and in part from the unstable nature of highway speeds which are inherently difficult to model. The current transit speeds inserted into the 2000 transit network are taken directly from the operator's route schedules. These speeds are enforced by route supervisors, who monitor transit on-time performance on an ongoing basis. These scheduled speeds provide an accurate starting point for estimating future congested transit speeds. It is reasonable to assume that errors in highway speed estimating will be similar in current and future network assignments. Therefore, the best way to estimate future mixed traffic transit speeds is to factor the current scheduled speed by the simulated growth in the highway congestion for the corresponding highway links using the following equation:

$$T_f = T_s \frac{H_f}{H_c}$$

where:

T_f - Future or build alt. congested transit speed.
T_s - Scheduled or base alt. transit speed.
H_f - Simulated future or build alt. congested highway speed.
H_c - Simulated current or base alt. highway speed.

This process can be run in two ways: 1) to estimate future transit speeds based on simulated current vs. future highway congestion, or 2) to estimate build alternative transit speeds based on simulated build vs. base alternative simulated highway speeds. In either case there are two steps to the process – calculate updated post-processor highway speeds and use the current/base and future/build highway speed ratios to update street running route transit operating speeds.

This process is somewhat more complicated than traditional capacity constraint function/INET transit speed updates because highway post-processor speed estimates must be prepared for both the current/base and future/build simulations outside of the normal highway assignment/capacity restraint process. But the results are much more reasonable and not subject to the severe underestimation of highway speeds that can sometimes occur under highly congested conditions.

3. Transit-Highway Interface

The recalculation of operating speeds for transit operating in mixed traffic is based on simulated changes in highway congestion. It involves specifying and maintaining a correspondence between the transit and highway networks after unneeded (positive in TROUTE line Cards) highway nodes are squeezed from the transit network by aggregation. This is accomplished by using the same node numbers for the same locations in the transit and highway network and by generating the "STRINGS" file during TROUTE file processing. The STRINGS file contains the correspondence between the transit and highway network in cases where unneeded highway nodes are squeezed out of the transit network to reduce the number of nodes needed to describe a transit service pattern. This reduction is primarily required to keep the number of nodes on a given line card below the TRANPLAN maximum. Processes and special computer software have been developed to accomplish this task and are listed in the following section.

E. Detailed Computer Operating Procedures for Updating Transit Speeds

The process listed below is run for each time period by changing the file names (peak, midday, or evening) as appropriate. This process is somewhat ad hoc and rough from a computer operations perspective and it may be enhanced in the future to integrate it into TRANPLAN in a more streamlined and simplified way. However, the following procedure gives detailed operating instructions for the process as it now exists.

Download Loaded Highway Network to Cards

1. For each time period (simxxpk, simxxmid, simxxnit) , run NETCARD to output combined lodhist to cards. Enter prompted responses as follows:

Response	Comment (DO NOT ENTER)
lodhxxe0.d15	Input combined lodhist file
lodhxxe0.peak.cds	Output lodhist file as cards (also lodhxxe0.midday.cds lodhxxe0.evening.cds as appropriate)
y	
1	
n	
1	
0	
n	
y	
y	

Highway Link Speed Update

1. Copy lodhhist cards file to appropriate time period hwyspeed sub-directory

2. Run SUMVMLK to calculate post-processor speeds and put output in *.spd file. Enter prompted responses as follows:

Response	Comment (DO NOT ENTER)
lodhxxe0.peak.cds	Input cds file.
lodhxxe0.peak.prt	Output print file
lodhxxe0.peak.spd	Output link file.

3. Run HYNETUPD to update hwy speeds based on future/build peak highway speeds

Edit the *.spd and *.cds files above to remove control cards and grid coordinates HYNETUPD needs just links in these files.
Enter prompted responses or use <filenames option

Response	Comment (DO NOT ENTER)
1.041	Default speed adjustment factor
lodh00e0.peak.spd	2000 or Future No-build peak speed cards
lodhxxe0.peak.spd	Future No-build or Future Build Alt. peak speed cards
lodhxxe0.peak.cds	Future No-build or Build Alt. table lookup link cards
lodhxxe0.peak.cd4	Future No-build or Build Alt. Updated Speed Cards
hynetupd.prt	

4. Update lodhxxe0.peak.cd4 to put in TRANPLAN Header and end function card

    a. Edit lodhxxe0.peak.cd4
    b. Insert header.peak.hwy at front of file
    c. Insert $end tP function at end of file

5. Execute TRANPLAN to Build updated highway network.

    Type "TRANPLAN lodhxxe0.peak.cd4"

6. Insert EQUILB toll codes as follows:

    a. Edit Macroupd.in as needed to update filenames
    b. Type "TRANPLAN macroupd.in" hit enter.

7. Copy the output highway network (hy3xxplpk.evq or new name) up one level to Peak_net

Transit Link Speed Update

1. Copy lodhxxe0.peak.spd cards from hwyspeed to trnetupd sub-directories

2. Run TRNETUPD as follows:

Enter prompted responses or use <filenames option

Response	Comment (DO NOT ENTER)
1.037	Default speed adjustment factor
stringf.test7	Transit/highway link correspondence cards
lodh00e0.peak.spd	2000 or future No-build peak highway speed cards
lodhxxe0.peak.spd	Future No-build or Build Alt. peak highway speed cards
links	Future Build or No-build Scheduled speed transit links
hudnet.lnk	Output transit links with updated speeds
trnetupd.prt	Output printed summaries

3. Run DVFARELG as follows:

    Type “DVFARELG” and hit enter
    Output file is hudnet.cds

4. Build Transit Network into Binary Format as follows:

    Type “TRANPLAN hudent.cds” and hit enter

5. Copy the output transit network (trxxpk.dat or new name) up one level to Peak_net

6. Perform the same process for the Midday and Evening networks.

F. Methodology for Updating Highway and Transit Speeds for FTA Compliance

FTA guidelines require that the forecasted person trip table and highway and transit speeds be held constant at No-build alternative estimates, for all future build alternatives. These No-build data sets are based on one or two simple model iterations over simulated highway and transit speeds ***(Figure II-2 top)*** (page 22). The build alternatives are then simulated with person trips and transit and highway speeds held constant at No-build values ***(Figure II-2 bottom)*** (page 22).

The FTA process starts with calibration year surveyed highway speeds and scheduled transit times and is updated for future No-build alternative highway speeds when preparing forecasts. By FTA mandate, build alternative highway and transit congestion relief cannot be considered in patronage forecasts or in the calculation of user benefits. One iteration of speed update is performed to complete the No-build forecasts. Future iteration 0 speed adjustments for both highway and transit are calculated based on base year highway and transit speeds. This is similar to the process and equation for updating future transit running speeds used in the Evans process. The updated speeds based on iteration 0 volumes are fed back into simulation model and the simulation model is rerun to produce the final No-build travel forecasts.

G. Transit Network Company , Station, and Route Coding

The transit network is modeled by a system of links and nodes. In addition, the transit network contains routes or service patterns. Each service pattern runs over a sequence of links. ***Table A-V-5*** is a complete list of all public transit routes included in the network along with the mode, company and line card designations. This table allows the user to quickly identify the transit route (in the TROUTE.CDS file) that corresponds to a real-world transit service, such as a bus route. A summary of the transit company codes were listed previously in ***Table A-V-2*** (page 332) and modes in ***Table A-V-1*** (page 332)***.*** Finally, ***Table A-V-6*** shows the station node number correspondence for the rail stations in the region, including SEPTA's regional rail and subway-elevated systems, NJTransit's RiverLine, and PATCO's Hi-Speedline. This table can be used, along with the travel model outputs, to determine the number of boardings and alightings at individual rail stations within the transit network.

Table A-V-5 Transit Route Coding

Company No. 1 - SEPTA City Transit Division

Route	Reg or Exp	Mode	Company	Peak	Line Cards Midday	Night
1	R	4	1	1-2	1-2	
2	R	4	1	3-5	3-4	1-2
3	R	4	1	6-8	5-6	3-4
5	R	4	1	9-10	7-8	5-6
6	R	4	1	11	9	7
7	R	4	1	12-15	10-11	8-9
8	R	4	1	16-17		
9	R	4	1	18-20	12-14	10-11
12	R	4	1	21-23	15-16	12-13
14	R	4	1	24-32	17-20	14-21
15	R	4	1	33-35	21-22	22-23
17	R	4	1	36-40	23-26	24-26
18	R	4	1	41-44	27	27-30
19	R	4	1	45-47	28-29	
20	R	4	1	48-49	30	31
21	R	4	1	50-55	31-34	32-35
22	R	4	1	56-59	35-38	36-39
23	R	4	1	60-68	39-41	40-41
24	R	4	1	69-74	42-46	42
25	R	4	1	75-81	47-48	43-44
26	R	4	1	82-88	49-52	45-48
27	R	4	1	89-95	53-57	49-52
28	R	4	1	96-97	58	53-54
29	R	4	1	98-99	59-60	55-56
30	R	4	1	100-103	61-62	57-58
31	R	4	1	104-106	63-65	59-60
32	R	4	1	107-112	66-67	61-62
33	R	4	1	113-114	68-69	63-64
35	R	4	1	115-116	70-71	65-66
37	R	4	1	117-120, 237-238	72-73	67-68
38	R	4	1	121-123	74-75	69-70
39	R	4	1	124-125	76-77	71-72
40	R	4	1	126-127	78-79	73-74
42	R	4	1	128-133	80-83	75-78
43	R	4	1	134-137	84-85	79-80
44	R	4	1	138-143	86-89	81-83
46	R	4	1	144	90-91	84-85
47	R	4	1	145-147	92-93	86-87
47	m	4	1	148	94-95	
48	R	4	1	149-152	96-97	88-89

				Line Cards		
Route	Reg or Exp	Mode	Company	Peak	Route	Reg or Exp
52	R	4	1	153-159	98	90-91
53	R	4	1	160-161	99	92-93
54	R	4	1	162	100	94-95
55	R	4	1	163-168	101-103	96-98
56	R	4	1	169-170	104	99-100
57	R	4	1	171-175	105-108	101-102
58	R	4	1	176-182	109-113	103-105
59	R	4	1	183	114	106-107
60	R	4	1	184-185	115	108-109
61	R	4	1	186-193	116-119	110-111
64	R	4	1	194-195	120-121	112-113
65	R	4	1	196-197	122-123	114-115
66	R	4	1	198-203	124-126	116-117
67	R	4	1	204-210	127-128	118
68	R	4	1	211-212	129-130	119-120
70	R	4	1	213-216	131-134	121-123
71	R	4	1	217-218	135-136	
73	R	4	1	219	137	124
75	R	4	1	220-221	138-139	125-126
77	R	4	1	222-223	140-141	
79	R	4	1	224	142	127
84	R	4	1	225-227	143-144	128-129
88	R	4	1	228-230	145-147	130-132
89	R	4	1	231-232	148-149	133-134
121	R	4	1	233-236		135
C	R	5	1	1-6	1-4	1-4
G	R	5	1	7-11	5-8	5-7
H	R	5	1	12-13	9-10	8
J	R	5	1	14-16	11-12	9-10
K	R	5	1	17-18	13-14	11-12
L	R	5	1	19-26	15-18	13-16
R	R	5	1	27-32	19-22	17-20
XH	R	5	1	33-34	23	21-22
LUCY	R	5	1	35-36	24-25	
1	EXP	7	1	1		
18	EXP	7	1	2-3		
20	EXP	7	1	4-6		
22	EXP	7	1	7-9		
58	EXP	7	1	10-11		
61	EXP	7	1	12		
68	EXP	7	1			1
80	EXP	7	1	13	1	
H	EXP	7	1	14		
L	EXP	7	1	15		
XH	EXP	7	1	16		
10	R	10	1	1-2	1-2	1

				Line Cards		
Route	**Reg or Exp**	**Mode**	**Company**	**Peak**	**Route**	**Reg or Exp**
11	R	10	1	3-4	3	2-3
13	R	10	1	5-9	4-6	4-6
34	R	10	1	10-11	7	7
36	R	10	1	12-15	8	8
Market-Frankford	R	11	1	1-2	1	1-2
Broad St Subway	R	11	1	3-4	2-3	3-4
Broad St Spur	R	11	1	5	4	5-6

<u>Company No. 2 - SEPTA Suburban Frontier Division</u>

					Line Cards	
Route	**Reg or Exp**	**Mode**	**Company**	**Peak**	**Midday**	**Night**
92	R	5	2	37-38	26-27	23-24
93	R	5	2	39-40	28-29	25-26
94	R	5	2	41-42	30-31	27-28
95	R	5	2	43-48	32-33	29-30
96	R	5	2	49-52	34-35	31-32
97	R	5	2	53-54	36-37	33-34
98	R	5	2	55-61	38-39	35-37
99	R	5	2	62-66	40-43	38-41
118	R	5	2	67-69	44-45	
124	R	5	2	70-73	46-47	42-43
125	R	5	2	74-76	48-50	44-46
127	R	5	2	77-78	51-52	47-48
128	R	5	2	79	53	
129	R	5	2	80-81	54-55	49-50
130	R	5	2	82-83	56-57	51-52
131	R	5	2	84-85	58-59	
133	R	5	2	86-87	60-61	53-54
201	R	5	2	88	62	55
206	R	5	2	89-90	63-64	
304	R	5	2	91	66	
310	R	5	2	92-94	67-68	56-57
94	EXP	7	2	17-18		
NHSL	R	11	2	6-12	5	7

Company No. 3 - SEPTA Victory Division

Route	Reg or Exp	Mode	Company	Line Cards Peak	Midday	Night
103	R	5	3	95-96	69-70	58-59
104	R	5	3	97-102	71-72	60-63
105	R	5	3	103-108	73-76	
106	R	5	3	109-112	77	
107	R	5	3	113-114	78-79	64
108	R	5	3	115-121	80-84	65-69
109	R	5	3	122-123	85-86	70-71
110	R	5	3	124-128	87-89	72-73
111	R	5	3	129-132	90-93	74-76
112	R	5	3	133-136	94-96	
113	R	5	3	137-140	97-99	77-79
114	R	5	3	141-144	100-103	80-81
115	R	5	3	145-146	104	82-83
117	R	5	3	147-150	108-108	84-86
119	R	5	3	151-153	109-110	87-88
120	R	5	3	154-155	111-112	89-90
122	R	5	3	156-158	113	
123	R	5	3	159-160	114-115	91-92
204	R	5	3	161	116-117	93-94
305	R	5	3	162-163	118-119	95-96
314	R	5	3	164-165	120-121	
Blue Loop (314)	R	5	3		122	
Green Loop (314)	R	5	3		123	
104	EXP	7	3	19-20		
111	EXP	7	3	21		2
112	EXP	7	3	22		
120	EXP	7	3	23		
204	EXP	7	3	24		
101	R	10	3	16-18	9	9
102	R	10	3	19-21	10	10

Company No. 4 - NJ TRANSIT Southern Division

Route	Reg or Exp	Mode	Company	Line Cards Peak	Midday	Night
313	R	6	4	1-2	1-2	1-2
315	R	6	4		3-4	
317	R	6	4	3-5	5-6	3-4
319	R	6	4	121-122	90-91	69-70
400	R	6	4	6-12	7-12	5-8
401	R	6	4	13-14	13-14	9-10
402	R	6	4	15		11-12
403	R	6	4	16-20, 123-124	15-18	13-14
404	R	6	4	21-25	19-20	15-16
405	R	6	4	26-28	21-22	17-18
406	R	6	4	29-33	23-26	19-20
407	R	6	4	34-39	27-28	21-22
408	R	6	4	40-43	29-30	23-24
409	R	6	4	44-48	31-34	25-27
410	R	6	4	49-50	35-37	28-29
412	R	6	4	51-52	38-39	30-31
413	R	6	4	53-58	40-43	32-33
419	R	6	4	59-60	44-45	34-35
450	R	6	4	61-63	46-47	36-37
451	R	6	4	64-66	48-49	
452	R	6	4	67-68	50-51	38-39
453	R	6	4	69-70	52-53	
455	R	6	4	71-73	54-55	40-42
457	R	6	4	74-75	56-57	43-44
459	R	6	4	76	58	45
463	R	6	4	77	59	46
554	R	6	4	78-79	60	47
400	EXP	8	4	1		
402	EXP	8	4	2-3		
406	EXP	8	4	4		
408	EXP	8	4	5		
409	EXP	8	4	6		
410	EXP	8	4	7		
412	EXP	8	4	8		
419	EXP	8	4	9		
551	EXP	8	4	10-11	1-2	1-2
559	EXP	8	4	12-13	3-4	3-4
River Line	R	14	4	9	5	7-8

Company No. 5 - Pottstown Urban Transit

Route	Reg or Exp	Mode	Company	Line Cards Peak	Midday	Night
High	R	5	5	166-167	124-125	
N. End Loop	R	5	5	168-169	126-127	
Beech	R	5	5	170-171	128-129	
Center	R	5	5	172-173	130-131	
Coventry	R	5	5	174-175	132-133	

Company No. 6 - Krapf's Coaches

Route	Reg or Exp	Mode	Company	Peak	Line Cards Midday	Night
A	R	5	6	176-177	134-135	97-98
Coatesville Link	R	5	6	178-179	136-139	99-101

Company No. 7 - NJ TRANSIT Rail

Route	Reg or Exp	Mode	Company	Peak	Line Cards Midday	Night
N.E. Corridor	R	14	7	1-4	1	1-2
Princeton Junction	R	14	7	4-6	2-3	3-4
AC Line	R	14	7	7-8	4	5-6

Company No. 8 - Delaware River Port Authority (DRPA)

Route	Reg or Exp	Mode	Company	Peak	Line Cards Midday	Night
Local	R	13	8	1-2	1	1
Lindenwold	EXP	13	8	3		
Woodcrest	R	13	8	4-5		

Company No. 9 - SEPTA Regional Rail

Route	Reg or Exp	Mode	Company	Peak	Line Cards Midday	Night
R1	R	12	9	1-4	1-2	1-2
R2	R	12	9	5-11	3-4	3
R3	R	12	9	12-19	5	4-5
R5	R	12	9	20-29	6-7	6-7
R6	R	12	9	30-34	8-9	8-9
R7	R	12	9	35-38	10	10-13
R8	R	12	9	39-42	11	14-17

Company No. 10 - Inter-City Bus

Route	Reg or Exp	Mode	Company	Line Cards Peak	Midday	Night
I-95	R	9	10	1-2	1-4	1-2
PA 340	R	9	10	3	5	
I-76	R	9	10	4-7	6-11	3-10
US 422	R	9	10		12-13	11-14
I-476	R	9	10		14-15	
PA 309	R	9	10	8-9	16-17	15-16
PA 611	R	9	10		18-19	
US 202	R	9	10	10-11	20-21	
NJ Turnpike	R	9	10	12-15	22-27	17-22
AC Expressway	R	9	10	16-17	28-29	23-24

Company No. 11 - AMTRAK

Route	Reg or Exp	Mode	Company	Line Cards Peak	Midday	Night
N.E. Corridor	R	15	11	1-4	1-2	1-3
Harrisburg	R	15	11	5-7	3-5	4-6

Company No. 12 - NJ TRANSIT Mercer County Bus

Route	Reg or Exp	Mode	Company	Line Cards Peak	Midday	Night
600	R	6	12	80-81	61-62	48
601	R	6	12	82-86	63-66	49-51
602	R	6	12	87-88	67-68	52-53
603	R	6	12	89-95	69-72	54-55
604	R	6	12	96-99	73-74	
605	R	6	12	100-101	75-76	56-57
606	R	6	12	102-107	77-78	58-60
607	R	6	12	108-109	79-80	61-62
608	R	6	12	110-114	81-82	63-64
609	R	6	12	115-119	83-87	65-68
611	R	6	12	120	88-89	

Company No. 13 - TMA Special Routes

Route	Reg or Exp	Mode	Company	Line Cards Peak	Midday	Night
Warminster Rush	R	5	13	180-182		
Street Rd Rush E Loop	R	5	13	183-184	140-141	
Street Rd Rush W Loop	R	5	13	185-186	142-143	
Doylestown DART	R	5	13	187-189	144	
Warminster Rush	EXP	7	13	25-26		
Doylestown DART	EXP	7	13	27-28	2	

Table A-V-6 Rail Station Coding

SEPTA Regional Rail Division

Node No.	Station	Node No.	Station
Trunk Lines			
22252	North Philadelphia	22135	Temple university
22132	30th Street	22136	North Broad
22133	Suburban	22137	Wayne Junction
22134	Market East	22138	Fern Rock T.C.
		22139	Melrose Park
		22140	Elkins park
		22141	Jenkintown/Wyncote
		22142	Glenside
R1 - Airport Line			
22129	Airport Terminals	22131	University City
22130	Eastwick		
R2 - Wilmington Line			
22150	Marcus Hook	22157	Prospect Park
22151	Highland Ave	22158	Norwood
22152	Lamokin	22159	Glenolden
22153	Chester T.C.	22160	Folcroft
22154	Eddystone	22161	Sharon Hill
22155	Crum Lynne	22162	Curtis Park
22156	Ridley Park	22163	Darby
R2 - Warminster Line			
22148	Warminster	22145	Crestmont
22147	Hatboro	22144	Roslyn
22146	Willow Grove	22143	Ardsley

Node No.	Station	Node No.	Station
R3 - Media Line			
22175	Elwyn	22182	Primos
22176	Media	22183	Clifton - Aldan
22177	Moylan - Rose valley	22184	Gladstone
22178	Wallingford	22185	Lansdowne
22179	Swarthmore	22186	Fernwood - Yeadon
22180	Morton	22187	Angora
22181	Secane	22188	49th St
R3 - West Trenton Line			
22201	West Trenton	22194	Forest Hill
22200	Yardley	22193	Philmont
22199	Woodbourne	22192	Bethayres
22198	Langhorne	22191	Meadowbrook
22197	Neshaminy Falls	22190	Rydal
22196	Trevose	22189	Noble
22195	Somerton		
R5 - Parkesburg - Paoli Line			
22202	Thorndale	22214	Radnor
22203	Downingtown	22215	Villanova
22204	Whitford	22216	Rosemont
22205	Exton	22217	Bryn Mawr
22206	Malvern	22218	Haverford
22207	Paoli	22219	Ardmore
22208	Daylesford	22220	Wynnewood
22209	Berwyn	22221	Narberth
22210	Devon	22222	Merion
22211	Strafford	22223	Overbrook
22212	Wayne		
22213	St. Davids		
R5 - Lansdale - Doylestown Line			
22239	Doylestown	22231	Pennbrook
22238	Delaware Valley College	22230	North Wales
22237	New Britain	22229	Gwynedd valley
22236	Chalfont	22228	Penllyn
22235	Link Belt	22227	Ambler
22234	Colmar	22226	Fort Washington
22233	Fortuna	22225	Oreland
22232	Lansdale	22224	North Hills

Node No.	Station	Node No.	Station
R6 - Norristown Line			
22174	Elm St	22168	Ivy Ridge
22173	Main St	22167	Manayunk
22172	Norristown T.C.	22166	Wissahickon T.C.
22171	Conshohocken	22165	East Falls
22170	Spring Mill	22164	Allegheny
22169	Miquon		
R6 - Cynwyd Line			
22242	Cynwyd	22240	Wynnefield
22241	Bala		
R7 - Trenton Line			
22263	Trenton	22257	Torresdale
22262	Levittown	22256	Holmesburg Junction
22261	Bristol	22255	Tacony
22260	Croydon	22254	Wissinoming
22259	Eddington	22253	Bridesburg
22258	Cornwells Heights		
R7 - Chestnut Hill East Line			
22243	Chestnut Hill East	22247	Sedgewick
22244	Gravers	22248	Stenton
22245	Wyndmoor	22249	Washington Lane
22246	Mount Airy	22250	Germantown
R8 - Fox Chase Line			
23411	Fox Chase	23409	Cheltenham
23410	Ryers	23408	Lawndale
R8 - Chestnut Hill West Line			
22264	Chestnut Hill West	23403	Upsal
22265	Highland	23404	Tulpehocken
23400	St. Martins	23405	Chelten Ave
23401	Allen lane	23406	Queen Lane
23402	Carpenter		

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APPENDIX VI-1 SURVEY FORMS

A. 2000 Household Travel Survey Recruitment Interview

Section 1: Introductory Script

A "Hello, this is [NAME] and I'm calling for the [LAST NAME] household on behalf of the [Delaware Valley Regional Planning Commission]/[South Jersey Transportation Planning Organization]. Last week we spoke with [First name] about an important transportation study in your area.

IF RESPONDENT NOT AT HOME, ASK FOR ANYONE 18 OR OLDER WHO LIVES IN THE HOUSEHOLD, OTHERWISE SCHEDULE CALLBACK.

1 YES, CONTINUE
REFUSAL
2 HARD REFUSAL ⇒ **THANK AND TERMINATE**
3 SOFT REFUSAL ⇒ **TERMINATE**, **AUTOMATIC CALLBACK SCHEDULED**
4 SPECIFIC CALLBACK TIME ARRANGED ⇒ **FILL OUT CALLBACK APPT SCREEN**
5 LANGUAGE BARRIER ⇒ **CALLED BACK BY SPECIAL LANGUAGE INTERVIEWER**

B A few days ago we sent a letter to your home to tell you about this very important project. It is sponsored by [DVRPC/SJTPO] which is the agency responsible for planning and improving transportation in the region. Did you receive the letter?

1 YES
2 NO
8 DON'T KNOW
9 REFUSED

C As the letter (would have - *if answer to Q.B is anything other than 1*) indicated, we are doing a survey about people's travel patterns and needs. This type of study is done only once every 15 or 20 years; the information I am gathering to make decisions about how to improve the highway and transit systems over the next 20 years.

I'd like to ask you a few questions. Your answers will remain completely confidential. This will take about 10 minutes. All households that participate in this study have an opportunity to win a pair of airline tickets to any continental U.S. destination. These tickets, contributed by a private company, are offered as a token of our appreciation for your time.

1 OK, CONTINUE
REFUSAL:
2 HARD REFUSAL ⇒ **THANK AND TERMINATE**
3 SOFT REFUSAL ⇒ **TERMINATE**, **AUTOMATIC CALLBACK SCHEDULED**
4 SPECIFIC CALLBACK TIME ARRANGED ⇒ **FILL OUT CALLBACK APPT SCREEN**
5 LANGUAGE BARRIER ⇒ **CALLED BACK BY SPECIFIC INTERVIEWER**

V1 Including all cars, trucks, vans, motorcycles and recreational vehicles, whether owned or leased or provided by an employer, how many vehicles are presently available to the members of your household?

00 ZERO ⇒ **SKIP TO Q1**
01 ONE
02 TWO
03 THREE
04 FOUR

05 FIVE
06 SIX
07 SEVEN
08 EIGHT
09 NINE OR MORE, SPECIFY (_____________)
98 DON'T KNOW ⇒ **THANK AND TERMINATE**
99 REFUSED ⇒ **THANK AND TERMINATE**

Now I need to get some information about your vehicle(s).

V2 What's the year of your vehicle? IF TWO OR MORE: "What's the year of vehicle number one, that is, the one used the most," "vehicle number two" and so on.
ENTER YEAR OF VEHICLE: _______
9998DON'T KNOW
9999REFUSED

V3 And what make and model is that? (List of 40 makes in alphabetical order)

V4 Model: ____________________-

V5 What's the body type?
01 AUTO SEDAN
02 AUTO 2-SEAT
03 VAN
04 SPORT UTILITY VEHICLE
05 UTILITY VEHICLE (i.e., WORK VAN OR TRUCK)
06 STATION WAGON
07 PICKUP TRUCK
08 MOTORCYCLE
09 MOPED
10 OTHER (SPECIFY ____________)
98 DON'T KNOW
99 REFUSED

V6 Is it owned or leased by a household member, an employer, or is it a rental car?
1 HOUSEHOLD OWNED/LEASED
2 EMPLOYER PROVIDED
3 RENTAL CAR
4 BORROWED FROM FRIEND OR RELATIVE
5 OTHER (SPECIFY ____________)
8 DON'T KNOW
9 REFUSED

V2 to V6 to be repeated for each vehicle, up to eight vehicles

V7 How many bikes does your household have that are presently available for travel or recreation?
NUMBER: __________
00 ZERO
01 ONE
02 TWO
03 THREE
04 FOUR

05 FIVE
06 SIX
07 SEVEN
08 EIGHT
09 NINE OR MORE, SPECIFY. (_____________)
98 DON'T KNOW
99 REFUSED

Q1 What kind of home do you live in? (IF RESPONSE = 6, TERMINATE)
1 SINGLE-FAMILY HOUSE – DETACHED
2 SINGLE-FAMILY HOUSE ATTACHED TO ONE OR MORE HOUSES (TOWNHOUSE)
3 BUILDING WITH AT LEAST 2 APARTMENTS (SPECIFY HOW MANY UNITS ARE IN THE BUILDING __________)
4 HOTEL/MOTEL
5 MOBILE HOME OR TRAILER
6 DORMITORY/GROUP QUARTERS/BARRACKS
97 OTHER (SPECIFY) ______________
98 DON'T KNOW
99 REFUSED

Q2 When did you move into this home?
1 WITHIN THE PAST YEAR
2 1 TO 5 YEARS AGO
3 MORE THAN 5 YEARS AGO
8 DON'T KNOW
9 REFUSED

Q3 Do you own or rent your home?
1 RENT
2 OWN/BUYING (PAYING OFF MORTGAGE)
3 OTHER (SPECIFY) ___________
8 DON'T KNOW
9 REFUSED

Q4 For this household travel survey, we need everyone in your household to write down what they do and where they go for a 24-hour period. We'll send a diary for each person. After the assigned recording time, we'll call again to collect the information.

Q4a To send the diaries, I need to verify your address {*Computer shows the address*}. I have it as:
{St. Number}
{St. Direction}
{St. Name}
{St. Type}

{Apt. Number}
{Municipality/City}
{State}
{County}
{Zip}

Q4b Is this correct?
1 YES
2 NO ⇒ **GO BACK TO Q4a**

Q4c Where would you like to receive your diaries?
1 AT HOME ⇒ **SKIP TO Q5**
2 P.O. BOX
3 ANOTHER ADDRESS ⇒ **SKIP TO Q4e**
8 DON'T KNOW ⇒ **THANK AND TERMINATE**
9 REFUSED ⇒ **THANK AND TERMINATE**

Q4d P.O. Box Number _______________
Municipality/City ____________________
State ___________________
Zip _____________________ ⇒ **SKIP TO Q5**

Q4e ST. NUMBER _______________
ST. DIRECTION _______________
ST. NAME _________________
ST. SUFFIX _________________
APT. NUMBER ______________
MUNICIPALITY/CITY _____________________
STATE ____________________
ZIP _____________________

Q5 Is there anyone in your household who does not understand English?
1 YES
2 NO ⇒ **SKIP TO Q9**
8 DON'T KNOW ⇒ **SKIP TO Q9**
9 REFUSED ⇒ **SKIP TO Q9**

Q6 What is the language they understand?
01 SPANISH
02 FRENCH
03 GERMAN
04 CHINESE
05 ITALIAN
06 TAGALOG
07 POLISH
08 KOREAN
09 INDIC
10 VIETNAMESE
11 OTHER (SPECIFY _________________)
98 DON'T KNOW
99 REFUSED

Q7 Will you or anyone else in your household be able to help them fill out the diaries?
1 YES ⇒ **SKIP TO Q9**
2 NO
8 DON'T KNOW
9 REFUSED

Q8 Is there anyone else, a friend or a neighbor, who can help this person fill out the diary?
1 YES
2 NO ⇒ **THANK AND TERMINATE IF Q6 <> 1**
8 DON'T KNOW ⇒ **THANK AND TERMINATE IF Q6 <> 1**
9 REFUSED ⇒ **THANK AND TERMINATE IF Q6 <> 1**

Q9 How many household members, including yourself, all infants and live-in domestic help live in your household?
ENTER THE NUMBER OF MEMBERS: _______
98 DON'T KNOW ⇒ **THANK AND TERMINATE**
99 REFUSED ⇒ **THANK AND TERMINATE**

Q10 We need some information about each person in your household, so we can prepare individual diaries. Again, I want to assure you that this information is for research purposes only and will be kept strictly confidential. Earlier, you indicated there were { # } persons in your household.

What is your first name? _______________________
IF TWO PERSONS LIVING IN HOUSEHOLD, ASK:
What is the first name of the other person living in your home? ______________________
IF 3 OR MORE PERSONS IN HOUSEHOLD, ASK:
Excluding yourself, what is the first name of youngest person in the household?
THEN ASK: What's the first name of the next person in your home, from oldest to youngest?
REPEAT THIS QUESTION UNTIL YOU HAVE NAMES FOR ALL THE OTHER HOUSEHOLD MEMBERS.

Q10A. What is [your/their] last name? [ASKED ONLY IF NAME NOT KNOWN]
ENTER THE LAST NAME:___________

Q11 to Q65 are asked for each household member. Respondent's information is retrieved first.

Q11 And what is {NAME }'s gender? ASK THIS QUESTION ONLY FOR OTHER HOUSEHOLD MEMBERS
1 MALE
2 FEMALE
8 DON'T KNOW
9 REFUSED

Q12 What is {his/her/your} age in years?
ENTER AGE: __________
97 97+ (specify)
98 DON'T KNOW
99 REFUSED

Q13 {Does/Do} {he/she/you} have a valid driver's license? ASK ONLY IF Q12>15
1 YES
2 NO
8 DON'T KNOW
9 REFUSED

Q14 What is {his/her} relationship to you? SKIP FOR RESPONDENT
01 SELF
02 SPOUSE/PARTNER
03 SON/DAUGHTER

04 FATHER/MOTHER
05 BROTHER/SISTER
06 GRANDPARENT
07 GRANDCHILD
08 LIVE-IN HELP
09 ROOM MATE/OTHER NON-RELATED
10 OTHER RELATED
99 DON'T KNOW/REFUSED

Q15 {Does/Do} {he/she/you} have a disability that limits the type of transportation {he/she/you} can use?
1 YES
2 NO ⇒ **SKIP TO Q17**
8 DON'T KNOW ⇒ **SKIP TO Q17**
9 REFUSED ⇒ **SKIP TO Q17**

Q16 What type of disability? MAXIMUM OF THREE RESPONSES ALLOWED
1 BLIND/VISUAL IMPAIRED
2 HEARING IMPAIRED OR DEAF
3 CANE OR WALKER
4 WHEELCHAIR NON-TRANSFERABLE
5 WHEELCHAIR TRANSFERABLE
6 COGNITIVELY CHALLENGED
7 OTHER (SPECIFY _____________)
98 DON'T KNOW
99 REFUSED

Q16A [IF V7>0 AND Q12>5 AND Q15=2] How many days a week does [NAME] typically ride a bike, for any reason?
00 ZERO
01 ONE
02 TWO
03 THREE
04 FOUR
05 FIVE
06 SIX
07 SEVEN
98 DON'T KNOW
99 REFUSED

Q16B [IF Q16A>0] What is the most common reason for bike riding?
1 Work
2 School
3 Shopping
4 Social/Recreational
5 Exercise
7 OTHER (SPECIFY _____________)
8 DON'T KNOW
9 REFUSED

Q17 {Is/Are} {he/she/you} enrolled in any level of school {or daycare}? ASK "OR DAYCARE" ONLY IF AGE<6.
1 YES
2 NO ⇒ **SKIP TO Q24 IF AGE >15 ELSE TO NEXT HHLD MEMBER**

8 DON'T KNOW ⇒ **SKIP TO Q24 IF AGE >15 ELSE TO NEXT HHLD MEMBER**
9 REFUSED ⇒ **SKIP TO Q24 IF AGE >15 ELSE TO NEXT HHLD MEMBER**

Q18 What type of school {is/are} {he/she/you} enrolled in?
1 DAYCARE
2 PRE-SCHOOL
3 KINDERGARTEN TO ELEMENTARY (GRADES K-6)
4 SECONDARY SCHOOL (GRADES 7-12)
5 VOCATIONAL/TECHNICAL SCHOOL
6 COLLEGE OR UNIVERSITY
7 ADULT SCHOOL
8 DON'T KNOW
9 REFUSED

Q19 What is the name of the school {he/she/you} {is/are} enrolled in?
1 ENTER RESPONSE: ___________________________
98 DON'T KNOW
99 REFUSED

Q20 Do {he/she/you} go to school at home or somewhere else?
1 HOME
2 ADDRESS KNOWN/GIVEN
9 DON'T KNOW/REFUSED

If complete address:	*If cross streets*
ST NUMBER	ST#1 DIRECTION
ST DIRECTION	ST#1 NAME
ST NAME	ST#1 TYPE
ST TYPE	ST#2 DIRECTION
APT/STE	ST#2 NAME
CITY, MUNICIPALITY, STATE, ZIP	ST#2 TYPE
STATE	CITY, MUNICIPALITY, STATE, ZIP

Q21 How many days a week {does/do} {he/she/you} go to school?
1 1
2 2
3 3
4 4
5 5
6 6
7 7
8 DON'T KNOW
9 REFUSED

Q22 On one typical day how {does/do} {he/she/you} go to school? MULTIPLE RESPONSES (UP TO FIVE) ALLOWED BUT NOT EXPLICITLY REQUESTED
11 WALK
12 WHEELCHAIR
14 BICYCLE
21 AUTO/VAN/PICKUP/SUV DRIVER
22 AUTO/VAN/PICKUP/SUV PASSENGER
23 MOTORCYCLE/MOPED
31 SHARED RIDE (CARPOOL, VANPOOL, ETC.)
41 BUS (SEPTA, NJ TRANSIT)
42 SCHOOL BUS

43 COMMUTER VAN/SHUTTLE BUS: FROM EMPLOYER OR GROUP CONTRACT
44 PARATRANSIT/DEMAND RESPONSIVE/ELDERLY/HANDICAPPED
45 INTERCITY BUS (GREYHOUND, TRAILWAYS, BIEBER, ETC.)
46 CHARTER BUS, JITNEY, ETC
47 TROLLEY/TROLLEY BUS
51 SUBWAY/ELEVATED (MARKET-FRANKFORD, BROAD ST., PATCO)
52 COMMUTER RAILROAD (SEPTA, NJ TRANSIT
53 AMTRAK OR OTHER RAILROAD
54 TAXI/LIMOUSINE
55 BOAT/FERRY
56 AIRPLANE/HELICOPTER
97 OTHER
98 DON'T KNOW
99 REFUSED

Q23 How much does it cost to park at or near the school?
ENTER THE AMOUNT AND THEN THE UNIT OF PAYMENT. ENTER $0.00 IF FREE
AMOUNT:
$ ___ ___ . ___ ____
999998 Don't know
999999 Refused

SELECT UNIT OF PAYMENT: [SKIP IF PAYMENT WAS ZERO]
0 FREE
1 PER HOUR
2 PER DAY
3 PER WEEK
4 PER MONTH
5 PER QUARTER
6 PER SEMESTER
7 PER SCHOOL YEAR
8 DON'T KNOW
9 REFUSED

If age is 15 or under SKIP TO NEXT HHLD MEMBER

Q24 {Is/Are} {he/she/you} employed?
1 YES - FULL-TIME (40 HRS +) ⇒ **SKIP TO Q26**
2 YES - PART-TIME (LESS THAN 40 HRS) ⇒ **SKIP TO Q26**
3 NO
8 DON'T KNOW
9 REFUSED

Q25 What is {his/her/your} current situation? Are you...
1 RETIRED ⇒ **SKIP TO NEXT HOUSEHOLD MEMBER**
2 HOMEMAKER ⇒ **SKIP TO NEXT HOUSEHOLD MEMBER**
3 UNEMPLOYED BUT LOOKING FOR WORK ⇒ **SKIP TO NEXT HOUSEHOLD MEMBER**
4 UNEMPLOYED AND NOT SEEKING EMPLOYMENT ⇒ **SKIP TO NEXT HOUSEHOLD MEMBER**
5 STUDENT (PART TIME OR FULL TIME) ⇒ **SKIP TO NEXT HOUSEHOLD MEMBER**
8 DON'T KNOW ⇒ **SKIP TO NEXT HOUSEHOLD MEMBER**
9 REFUSED ⇒ **SKIP TO NEXT HOUSEHOLD MEMBER**

Q26 {Does/Do} {he/she/you} have more than one job?
1 YES
2 NO
8 DON'T KNOW
9 REFUSED

Q27 Is {his/her/your} employer a . . .
1 PRIVATE COMPANY
2 GOVERNMENT
3 SELF-EMPLOYED
4 INSTITUTION & NON-PROFIT ORGANIZATIONS
97 OR, SOMETHING ELSE (SPECIFY ___________)
98 DON'T KNOW
99 REFUSED

Q28 What activity best describes {his/her/your} job?
11 AGRICULTURE, FORESTRY, FISHERIES
21 MINING
22 UTILITIES
23 CONSTRUCTION
31 MANUFACTURING - NONDURABLE GOODS
32 MANUFACTURING - DURABLE GOODS
42 WHOLESALE TRADE
44 RETAIL TRADE
48 TRANSPORTATION AND WAREHOUSING
51 INFORMATION
52 FINANCE AND INSURANCE
53 REAL ESTATE
54 PROFESSIONAL, SCIENTIFIC, AND TECHNICAL SERVICES
55 MANAGEMENT OF COMPANIES AND ENTERPRISES
56 ADMINISTRATIVE AND SUPPORT SERVICES
61 EDUCATIONAL SERVICES
62 HEALTH CARE AND SOCIAL ASSISTANCE
71 ARTS, ENTERTAINMENT, AND RECREATION
72 ACCOMMODATION AND FOOD SERVICES
81 OTHER SERVICES (EXCL. PUBLIC ADMINISTRATION)
92 PUBLIC ADMINISTRATION
97 OTHER (SPECIFY __________________)
98 DON'T KNOW
99 REFUSED

Q29 How would you describe {his/her/your} occupation?
01 EXECUTIVE, ADMINISTRATIVE, OR MANAGERIAL
02 PROFESSIONAL SPECIALTY
03 TECHNICIAN AND RELATED SUPPORT
04 SALES
05 ADMINISTRATIVE SUPPORT, CLERICAL
06 PRIVATE HOUSEHOLD
07 PROTECTIVE SERVICE
08 SERVICE, EXCEPT PROTECTIVE AND HOUSEHOLD
09 FARMING, FORESTRY, OR FISHING
10 PRECISION, PRODUCTION, CRAFT, OR REPAIR
11 MACHINE OPERATOR, ASSEMBLER, OR INSPECTOR
12 TRANSPORTATION, OR MATERIAL MOVING

13 HANDLER, EQUIPMENT CLEANER, HELPER, OR LABORER
97 OTHER (SPECIFY __________)
98 DON'T KNOW
99 REFUSED

Q30 How long {has/have} {he/she/you} been working at {his/her/your} current workplace?
1 LESS THAN A YEAR
2 1 TO 5 YEARS
3 MORE THAN 5 YEARS
8 DON'T KNOW
9 REFUSED

Q31 On average, how many weekdays{does/do}{he/she/you} work at {his/her/your} job, regardless of location?
0 NONE
1-5
8 DON'T KNOW
9 REFUSED

Q32 On average, how many weekend days {does/do} {he/she/you} work at {his/her/your} job, regardless of location?
0 NONE
1-2
8 DON'T KNOW
9 REFUSED

IF Q32=1 OR 2, ASK Q33. ELSE SKIP TO Q34

Q33 When in the weekend {does/do} {he/she/you} work? MULTIPLE RESPONSES ALLOWED
1 SATURDAY AM
2 SATURDAY PM
3 SUNDAY AM
4 SUNDAY PM
7 OTHER (SPECIFY ____________)
8 DON'T KNOW
9 REFUSED

Q34 On average, how many days per week {does/do} {he/she/you} work at home for {his/her/your} job instead of going to {his/her/your} workplace? Sometimes this is called telecommuting.
00 NONE/NEVER
1-7
97 Other (specify)
98 DON'T KNOW
99 REFUSED

COMPUTER SUMS NUMBER OF DAYS WORKED AS ANSWERED TO Q31, Q32, AND Q34. IF Q24=1 AND SUM<5, ASK Q35 AND Q36. ELSE SKIP TO Q37

Q35 Does {his/her/your} work have a compressed workweek, such as 80 hours in 9 days, or 40 hours in 4 days?
1 YES
2 NO ⇒ **SKIP TO Q36**
8 DON'T KNOW ⇒ **SKIP TO Q36**
9 REFUSED ⇒ **SKIP TO Q36**

Q36 {Does/Do} {he/she/you} work four days per week (4/40) or nine days per two weeks (9/80)?

1 9/80
2 4/40
7 OTHER (SPECIFY ________________)
8 DON'T KNOW
9 REFUSED

Q37 What is the name of {his/her/your} employer?

1 MAIN JOB NAME: _________________________
98 DON'T KNOW
99 REFUSED

Q38 {Does/Do} you work from home or somewhere else?

1 HOME ⇒ **SKIP TO Q40**
2 SOMEWHERE ELSE
9 DON'T KNOW/REFUSED

If complete address:

ST NUMBER
ST DIRECTION
ST NAME
ST TYPE
APT/STE
MUNCIPALITY/CITY
STATE
COUNTY
ZIP

If cross streets:

ST#1 DIRECTION
ST#1 NAME
ST#1 TYPE
ST#2 DIRECTION
ST#2 NAME
ST#2 TYPE
MUNICIPALITY/CITY
STATE
ZIP

Q39 What modes of transportation {does/do} {he/she/you} use most often to get to work?
MULTIPLE RESPONSES (UP TO FIVE) ALLOWED BUT NOT EXPLICITLY REQUESTED

11 WALK
12 WHEELCHAIR
14 BICYCLE
21 AUTO/VAN/PICKUP/SUV DRIVER
22 AUTO/VAN/PICKUP/SUV PASSENGER
23 MOTORCYCLE/MOPED
31 SHARED RIDE (CARPOOL, VANPOOL, ETC.)
41 BUS (SEPTA, NJ TRANSIT)
42 SCHOOL BUS
43 COMMUTER VAN/SHUTTLE BUS: FROM EMPLOYER OR GROUP CONTRACT
44 PARATRANSIT/DEMAND RESPONSIVE/ELDERLY/HANDICAPPED
45 INTERCITY BUS (GREYHOUND, TRAILWAYS, BIEBER, ETC.)
46 CHARTER BUS, JITNEY, ETC
47 TROLLEY/TROLLEY BUS
51 SUBWAY/ELEVATED (MARKET-FRANKFORD, BROAD ST., PATCO)
52 COMMUTER RAILROAD (SEPTA, NJ TRANSIT
53 AMTRAK OR OTHER RAILROAD
54 TAXI/LIMOUSINE
55 BOAT/FERRY
56 AIRPLANE/HELICOPTER
97 OTHER
98 DON'T KNOW
99 REFUSED

Q40 {Does/Do} {he/she/you} usually need a vehicle at work for business purposes? (For example, sales calls or client meetings)

1 YES
2 NO
8 DON'T KNOW
9 REFUSED

Q41 [IF Q38=1, SKIP] How much does it cost to park at work? If {he/she/you} {doesn't/don't} drive, please estimate how much parking would cost.
ENTER THE AMOUNT AND THEN THE UNIT OF PAYMENT. ENTER $0.00 IF FREE
ENTER AMOUNT:
$ ___ ___ . ___ ____
999998 DON'T KNOW
999999 REFUSED

SELECT UNIT OF PAYMENT: [SKIP IF PAYMENT WAS ZERO]

0 FREE
1 PER HOUR
2 PER DAY
3 PER WEEK
4 PER MONTH
5 PER QUARTER
6 PER SEMESTER
7 PER SCHOOL YEAR
8 DON'T KNOW
9 REFUSED

Q42 [SKIP IF Q27 = 3 OR Q38=1] Does {his/her/your} employer offer to pay for all or part of the cost of parking at work?

1 YES
2 NO
8 DON'T KNOW
9 REFUSED

Q44 [SKIP IF Q38=1] What kind of parking {does/do} {he/she/you} use at work? If {he/she/you} {doesn't/don't} drive, what kind of parking would {he/she/you} use if {he/she/you} did drive regularly?

1 IN A PARKING LOT OR GARAGE AT WORK
2 IN A PARKING LOT OR GARAGE OFF-SITE
3 ON THE STREET
4 OTHER (SPECIFY)
8 DON'T KNOW
9 REFUSED

Q45 [SKIP IF Q38=1] Approximately how long (in minutes) is the walk from this parking area to {his/her/your} work?
ENTER THE MINUTES: __________
98 REFUSED
99 DON'T KNOW

Q46 Does {his/her/your} employer offer to pay for all or part of the cost of using transit?
1 YES, ALL OR PART
2 NO ⇒ **SKIP TO Q48**
8 DON'T KNOW⇒ **SKIP TO Q48**
9 REFUSED⇒ **SKIP TO Q48**

Q47 {Does/Do} {he/she/you} take advantage of it?
1 YES
2 NO
8 DON'T KNOW
9 REFUSED

Q48 Approximately how much does it (or would it) personally cost {him/her/you} to buy a bus/rail pass? ENTER THE AMOUNT AND THEN SELECT THE UNIT. [ENTER $0.00 IF FREE]
ENTER THE AMOUNT:
$ ___ ___ . ___ ____
999998 DON'T KNOW
999999 REFUSED

SELECT THE UNIT OF PAYMENT: [SKIP IF PAYMENT WAS ZERO]
0 FREE
1 PER DAY
2 PER WEEK
3 PER MONTH
4 PER YEAR
5 OTHER (SPECIFY ____________)
8 DON'T KNOW
9 REFUSED

Q49 At {his/her/your} regular job, does {he/she/you} work a schedule or shift that changes on a regular basis?
1 YES
2 NO ⇒ **SKIP TO Q52**
8 DON'T KNOW ⇒ **SKIP TO Q52**
9 REFUSED ⇒ **SKIP TO Q52**

Q50 What time does {he/she/you} typically start work at {his/her/your} job?
___ ___ : ___ ___ [ENTER THE TIME]

Is this AM or PM?
1 AM
2 PM
98 DON'T KNOW
99 REFUSED

Q51 What time does {he/she/you} typically end work at {his/her/your} job?
___ ___ : ___ ___ [ENTER THE TIME]

Is this AM or PM?
1 AM
2 PM
98 DON'T KNOW
99 REFUSED

Q52 Are {his/her/your} start and end times at this job about the same every day?
- 1 YES ⇒ **SKIP TO Q55**
- 2 NO
- 8 DON'T KNOW ⇒ **SKIP TO Q55**
- 9 REFUSED ⇒ **SKIP TO Q55**

Q53 How much can {his/her/your} job's start times vary from the usual start time?
- 1 START TIME CANNOT VARY
- 2 WITHIN 15 MINUTES OR LESS
- 3 16 TO 30 MINUTES
- 4 31 TO 60 MINUTES
- 5 MORE THAN 1 HOUR
- 6 OR, SOMETHING ELSE (SPECIFY ______________)
- 8 DON'T KNOW
- 9 REFUSED

Q54 How much can {his/her/your} job's end times vary from the usual end time?
- 1 END TIME CANNOT VARY
- 2 WITHIN 15 MINUTES OR LESS
- 3 16 TO 30 MINUTES
- 4 31 TO 60 MINUTES
- 5 MORE THAN 1 HOUR
- 6 OR, SOMETHING ELSE (SPECIFY ______________)
- 8 DON'T KNOW
- 9 REFUSED

The following questions are asked only if Q26=1. Otherwise next household member.

Q55 What is the name of {his/her/your} second employer?
- 1 SECOND JOB NAME: _______________
- 98 DON'T KNOW
- 99 REFUSED

Q56 Is {his/her/your} second employer ...
- 1 A PRIVATE COMPANY
- 2 GOVERNMENT
- 3 HIMSELF/HERSELF (SELF-EMPLOYED)
- 7 OR, SOMETHING ELSE (SPECIFY ___________)
- 98 DON'T KNOW
- 99 REFUSED

Q57 Do {you/he/she} work from home or somewhere else?
- 1 HOME
- 2 ADDRESS KNOWN/GIVEN
- 9 DON'T KNOW/REFUSED

IF COMPLETE ADDRESS:
- ST NUMBER
- ST DIRECTION
- ST NAME
- ST TYPE
- APT/STE
- MUNICIPALITY/CITY
- COUNTY
- STATE
- ZIP

IF CROSS STREETS:
- ST#1 DIRECTION
- ST#1 NAME
- ST#1 TYPE
- ST#2 DIRECTION
- ST#2 NAME
- ST#2 TYPE
- MUNICIPALITY/CITY
- STATE
- ZIP

Q58 What activity best describes {his/her/your} second job?

11 AGRICULTURE, FORESTRY, FISHERIES
23 MINING
24 UTILITIES
23 CONSTRUCTION
31 MANUFACTURING - NONDURABLE GOODS
32 MANUFACTURING - DURABLE GOODS
42 WHOLESALE TRADE
44 RETAIL TRADE
48 TRANSPORTATION AND WAREHOUSING
51 INFORMATION
52 FINANCE AND INSURANCE
53 REAL ESTATE
54 PROFESSIONAL, SCIENTIFIC, AND TECHNICAL SERVICES
55 MANAGEMENT OF COMPANIES AND ENTERPRISES
56 ADMINISTRATIVE AND SUPPORT SERVICES
61 EDUCATIONAL SERVICES
62 HEALTH CARE AND SOCIAL ASSISTANCE
71 ARTS, ENTERTAINMENT, AND RECREATION
72 ACCOMMODATION AND FOOD SERVICES
81 OTHER SERVICES (EXC. PUBLIC ADMINISTRATION)
92 PUBLIC ADMINISTRATION
97 OTHER (SPECIFY ___________________)
98 DON'T KNOW
99 REFUSED

Q59 How would you describe {his/her/your} occupation at {his/her/your} second job?

01 EXECUTIVE, ADMINISTRATIVE, OR MANAGERIAL
02 PROFESSIONAL SPECIALTY
03 TECHNICIAN AND RELATED SUPPORT
04 SALES
05 ADMINISTRATIVE SUPPORT, CLERICAL
06 PRIVATE HOUSEHOLD
07 PROTECTIVE SERVICE
08 SERVICE, EXCEPT PROTECTIVE AND HOUSEHOLD
09 FARMING, FORESTRY, OR FISHING
10 PRECISION, PRODUCTION, CRAFT, OR REPAIR
11 MACHINE OPERATOR, ASSEMBLER, OR INSPECTOR
12 TRANSPORTATION, OR MATERIAL MOVING
13 HANDLER, EQUIPMENT CLEANER, HELPER, OR LABORER
14 OTHER (SPECIFY __________)
98 DON'T KNOW
99 REFUSED

Q60 On average, how many days per week does {he/she/you} work at {his/her/your} second job?

1-7
8 DON'T KNOW
9 REFUSED

Q61 On average, how many days per week {does/do} {he/she/you} work at home for {his/her/your} second job instead of going to {his/her/your} workplace? Sometimes this is called telecommuting.
00 NONE/NEVER
1-7
97 OTHER (SPECIFY _____________) (THIS INCLUDES ONCE A MONTH)
98 DON'T KNOW
99 REFUSED

Q62 What time does {he/she/you} typically start work at {his/her/your} second job?
___ ___ : ___ ___ [ENTER THE TIME]

Is this AM or PM?
1 AM
2 PM
8 DON'T KNOW
9 REFUSED

Q63 What time does {he/she/you} typically end work at {his/her/your} second job?
___ ___ : ___ ___ [ENTER THE TIME]

Is this AM or PM?
1 AM
2 PM
8 DON'T KNOW
9 REFUSED

Once demographics are collected for all household members, interview continues.

As I said earlier, we'll send you a diary for each household member to complete. Now I just have a few more questions about your household.

Q64 How many separate telephone numbers are there to your current home? This would exclude any cellular or wireless phone numbers
____________________ (IF 1⇒ **SKIP TO Q66**)
98 DON'T KNOW
99 REFUSED

Q65 How many of these telephone numbers, if any, are used exclusively for a FAX machine or modem?
____
98 DON'T KNOW
99 REFUSED

Q66 In the past 12 months, have there been times, even for a few days, when you did not have phone service at your home?
1 YES
2 NO
8 DON'T KNOW
9 REFUSED

Q67 How long were you without a phone service?
1 LESS THAN 2 WEEKS
2 AT LEAST 2 WEEKS BUT LESS THAN 1 MONTH
1 AT LEAST 1 MONTH BUT LESS THAN 3 MONTHS
2 AT LEAST 3 MONTHS BUT LESS THAN 6 MONTHS
3 AT LEAST 6 MONTHS BUT LESS THAN 1 YEAR
8 DON'T KNOW
9 REFUSED

Q68 Does your household share a phone line with another household?
1 YES
2 NO ⇒ **SKIP TO Q70**
98 DON'T KNOW ⇒ **SKIP TO Q70**
99 REFUSED ⇒ **SKIP TO Q70**

Q69 How many households share a phone line with your household?
ENTER THE NUMBER OF HOUSEHOLDS: ____________________
98 DON'T KNOW
99 REFUSED

Q70 Do you own or share ownership in a second home or condo that your family uses as a residence at least one week per year? That includes beach or mountain homes, condos, etc. but not rental properties.
1 YES
2 NO ⇒ **SKIP TO Q73**
9 REFUSED

Q71 In what city and the state is that home located?
ENTER CITY AND THEN STATE ______________________________________

Q72 How many weeks out of the year do you stay at that second residence?
ENTER 1-52 FOR NUMBER OF WEEKS AND THEN SELECT THE UNIT OF TIME.
ENTER THE UNIT OF TIME:

____
8 DON'T KNOW
9 REFUSED

SELECT THE UNIT OF TIME:
1 WEEKS
2 MONTHS

Q73 Which of the following best describes your ethnicity?
01 BLACK/AFRICAN AMERICAN, NON-HISPANIC
02 WHITE, NON-HISPANIC
03 ASIAN/PACIFIC ISLANDER
04 AMERICAN INDIAN
05 HISPANIC
97 OTHER (SPECIFY ______________________)
98 DON'T KNOW
99 REFUSED

Q74 ASK ONLY IF INCOME WAS NOT OBTAINED DURING ADVANCE CALL. What was your total annual household income last year from all sources before taxes, for all members of your household? PAUSE. IF NO REPLY, CONTINUE. Is it above or below $50,000?

I don't need an exact amount, just a range. This is for statistical use only. I will read you a series of income ranges. Please stop me when I read the range that is closest to your household's. IF DON'T KNOW OF REFUSED, REMIND THE RESONDENT OF THE IMPORTANCE OF THE SURVEY AND THE IMPORTANCE OF THE INFORMATION TO MAKE SURE WE INCLUDE ALL TYPES OF HOUSEHOLDS.

BELOW		ABOVE	
		06	$50,000 to less than $75,000
02	less than $15,000	07	$75,000 to less than $100,000
03	$15,000 to less than $25,000	08	$100,000 to less than $125,000
04	$25,000 to less than $35,000	09	$125,000 to less than $150,000
05	$35,000 to less than $50,000	10	$150,000 or more

98 DON'T KNOW
99 REFUSED

Q75 ASK ONLY IF INCOME IS LESS THAN $25,000 OR REFUSED. In the past 12 months, have you or any household member received income from any of the following sources?

01 Welfare
02 Other Government Sources/benefits
03 None of the above
98 Don't Know
99 Refused

TRAVEL DAY DETERMINATION.

D1 Now let me give you the day on which we would like for everyone in your household to keep track of their activities.
IF NO ONE REPORTED USING TRANSIT FOR WORK OR SCHOOL:
The day is "[DAY OF THE WEEK AND DATE]." Is this day OK?

IF SOMEONE REPORTED USING TRANSIT FOR WORK OR SCHOOL
Since you told us that someone in your household uses transit for a work or school trip, we'd like to schedule you for a day where transit is being used. What day would that be?
Enter Assignment Number __________

D2 Will there be any overnight, out-of-town guests staying at your home on that date?
1 YES
2 NO
8 DON'T KNOW
9 REFUSED

D2A How many guests will you have?
ENTER THE NUMBER OF VISITORS: _______

D2B If yes, can I get their names so we can prepare diaries for them?
1 YES
2 NO ⇒ **GO TO ALTERNATE TRAVEL DATE (D1)**

D2C [FOR EACH VISITOR] What is the name of the [first] visitor?
ENTER NAME

D2D And what is {NAME }'s gender?
1 MALE
2 FEMALE
8 DON'T KNOW
9 REFUSED

D2E And how old is {he/she}?
ENTER AGE: __________
97 97+ (specify)
98 DON'T KNOW
99 REFUSED
REPEAT FOR ALL VISITORS

D3 I'd like to verify that I reached you at {PHONE NUMBER}. Is this correct?
1 NUMBER IS CORRECT
2 NUMBER IS INCORRECT (TYPE CORRECT NUMBER _____________)

D4 I'll call to collect your activity information the day following your travel day. Will DATE/TIME be a good time to reach you?

D5 Is there a different phone number where you or another member of your household would prefer to be called when we collect your information?
1 YES
2 NONE ⇒ **SKIP TO D7**
8 DON'T KNOW ⇒ **SKIP TO D7**
9 REFUSED ⇒ **SKIP TO D7**

D6 What is that phone number?
ENTER THE PHONE NUMBER: __________________

D7 Do you have an email account that you use daily and that you would like us to use to communicate with you?
1 YES
2 NONE ⇒ **SKIP TO D9**
8 DON'T KNOW ⇒ **SKIP TO D9**
9 REFUSED ⇒ **SKIP TO D9**

D8 What is that account?
ENTER ACCOUNT INFO CAREFULLY – READ BACK TO CONFIRM – BE CAREFUL OF UPPER/LOWER CASE REQUIREMENTS

D9 As a token of our appreciation, your household will be entered into a drawing. If you win, would you rather have a transit check voucher or a gas coupon? [AMOUNTS ARE RANDOMLY MIXED, E.G. $20 TRANSIT VOUCHER OR $25 GAS COUPON; $25 TRANSIT VOUCHER OR $30 GAS COUPON]

D10 IF NOT QUALIFIED AND NEED TO TERMINATE INTERVIEW: Although you are not qualified to continue with our survey today, we appreciate your time. Thank you and goodbye.

D11 Thank you very much for helping us. We'll call you on the evening before [DAY] to make sure you received your diaries and to answer any questions. We also want you to know that by writing down complete and accurate answers in the diaries -- including full addresses for each place you visit during the diary day -- you'll help to make the transportation system better. If you have any questions or comments about the study, you contact me at 1-888-687-8287, ext. 4055

B. 2000 Household Travel Survey Retrieval Interview

Introduction

Hi – my name is _______ and I'm calling on behalf of [DVRPC/SJTPO] about the survey your household recently completed. May I please speak with ______?

I'm calling to collect your travel information. First, I need to verify that the information we show for your household is correct.

I'd like to start by verifying the address where you live. Is it…
[IF PO BOX IS LISTED, BE SURE TO VERIFY PHYSICAL ADDRESS]

Our records show that there are [HHSIZE] people living in your household. Is this correct?

Okay – now I need to confirm the name, age, and gender we have for each household member:

	Name	Age	Gender	Employed?	Student?	Habitual Address
1						
2						
3						
4						

In terms of vehicles available to your household, we show that you have [HHVEHICLES] available:

	Year	Make	Model
1			
2			
3			
4			

Great, now I'd like to collect the trip information your household recorded for
Your TRAVEL DAY.

Let's begin with your information. Do you have the diary handy?

COLLECT EACH TRIP FOR EACH PERSON IN THE HOUSEHOLD.

Proxy Reporting Information

A1 WAS THIS DATA REPORTED IN PERSON? (Y/N). IF NO, NAME AND # REPORTING
A2 Did you/they use the diary to record your travel? (Y/N)
A3 How many total places did you visit over the course of the travel day? _____

Place 1

P1. Okay – where were you at 3 am on your travel day?

LOCATION – HOME/WORK/SCHOOL/OTHER
IF OTHER, PLACE NAME
ADDRESS/MUNICIPALITY OR CITY/STATE/ZIP
LANDMARK

P2-P7 And what did you do there?
1 Drop off/pickup someone
2 Visit friends/relatives
3 Eat Meals
4 Social/recreation/entertainment
5 Shopping via Internet
6 All other shopping
7 Doctor/dentist/other professional
8 Other family or personal business
9 Religious or civic
10 Work at home (job-related)
11 Work at regular job site
12 Work activity at another place
13 School at regular place
14 School activity at another place
15 Sleep
16 Other activities at home
97 Other (specify)

P8 Did you go anywhere else that day? Yes No
If Yes – P9
If No – P9 = 2:59 AM then skip to P10

P9 What time did you leave that place and go somewhere else?
__ __:__ __ AM/PM

P10 If did not travel,
So, you made no trips, including for work or school?
Why Not? (COMMENT FIELD)

P11 If out of area on travel day, collect city and state where stayed.

P12 Duration - computer calculates activity duration as P9 - 3 AM

All other places

Repeat Places 2 through x until end of day. At end of day 1, have CATI automatically enter 2:59 am.

Q1. Where did you go next? [PAUSE]

Did you make any stops along the way for any reason, such as to drop someone off or to change travel modes? Remember to tell me about trips or parts of trips you made by bike or walking.

LOCATION – HOME/WORK/SCHOOL/OTHER - if home, work, or school – CATI displays address information for interviewer to confirm. If totally new information, enter address below.

IF OTHER, PLACE NAME
ADDRESS
CITY
STATE
ZIP
MUNICIPALITY
LANDMARK

Q2 What time did you get there?
__ __:__ __ AM/PM

Q3 Trip Duration - computer calculates trip duration as Q2 – P9 (for Place 2)
Trip Duration (all other places) calculated as Q2 (next place)– Q15 (last place)

Q4-Q9 What did you do there? (multiple response allowed)
1 Drop off/pickup someone
2 Visit friends/relatives
3 Eat Meals
4 Social/recreation/entertainment
5 Shopping via Internet
6 All other shopping
7 Doctor/dentist/other professional
8 Other family or personal business
9 Religious or civic
10 Work at home (job-related)
11 Work at regular job site
12 Work activity at another place
13 School at regular place
14 School activity at another place
15 Sleep
16 Other activities at home
17 Change travel modes
97 Other (specify)

Q10 How did you get here? Please tell me in the order of use.
11 WALK
12 WHEELCHAIR
14 BICYCLE
21 AUTO/VAN/PICKUP/SUV DRIVER
22 AUTO/VAN/PICKUP/SUV PASSENGER
23 MOTORCYCLE/MOPED

31 SHARED RIDE (CARPOOL, VANPOOL, ETC.)
41 BUS (SEPTA, NJ TRANSIT)
42 SCHOOL BUS
43 COMMUTER VAN/SHUTTLE BUS: FROM EMPLOYER OR GROUP CONTRACT
44 PARATRANSIT/DEMAND RESPONSIVE/ELDERLY/HANDICAPPED
45 INTERCITY BUS (GREYHOUND, TRAILWAYS, BIEBER, ETC.)
46 CHARTER BUS, JITNEY, ETC
47 TROLLEY/TROLLEY BUS
51 SUBWAY/ELEVATED (MARKET-FRANKFORD, BROAD ST., PATCO)
52 COMMUTER RAILROAD (SEPTA, NJ TRANSIT)
53 AMTRAK OR OTHER RAILROAD
54 TAXI/LIMOUSINE
55 BOAT/FERRY
56 AIRPLANE/HELICOPTER
97 OTHER
98 DON'T KNOW
99 REFUSED

Q11 How many others traveled with you?
___ total

Q12 Of those, how many were household members?
____ household
Person #s of household members traveling with

Q13 CALCULATE # non-household from QA2 – QA3

IF (Q10=21, 22, or 23) GO TO M1 – do series of questions, then return
IF (Q10=41, 43, 44, 45, 46, 47, 51, 52, 53) GO TO N1 – do series then return

Q14 Did you go any place else that day? Are there any walk or bike trips you might have forgotten to tell me about?

Yes
No – END for that person day – enter time as 2:59 am

Q15 What time did you leave for the next place?
__ __:__ __ AM/PM

Q16 Place Duration - computer calculates activity duration as Q15 – Q2

ASK AS FINAL QUESTION (ONCE ALL TRAVEL FOR ALL HOUSEHOLD MEMBERS COLLECTED

I1 [IF INCOME REFUSED DURING RECRUITMENT] What was your total annual household income last year from all sources before taxes, for all members of your household? PAUSE. IF NO REPLY, CONTINUE. Is it above or below $50,000?

BELOW
02 less than $15,000
03 $15,000 to less than $25,000
04 $25,000 to less than $35,000

ABOVE
06 $50,000 to less than $75,000
07 $75,000 to less than $100,000
08 $100,000 to less than $125,000
09 $125,000 to less than $150,000

05 $35,000 to less than $50,000
98 DON'T KNOW
99 REFUSED
10 $150,000 or more

Mode Specific Questions

IF MODE=AUTO (IF Q10=21, 22 or 23)

M1 Did you use any of your household vehicles to get there?
1 Yes
2 No (SKIP TO M3 - ENTER 99 IN M2)

M2 Which household vehicle?
____ HH vehicle number

M3 Were you the driver or passenger?
1 Driver
2 Passenger ➔ SKIP TO M12

M4 Where did you park?
1 Street
2 Garage
3 Parking Lot
4 Driveway ➔ SKIP TO M7
5 Drop off or drive through (no park) ➔ SKIP TO M7
6 Other (specify) ➔ SKIP TO M7

M5 What did it cost to park?
Enter amount (0 for free, 999999 if unknown)

M6 Was that per …
1 hour
2 day
3 week
4 month
5 other (specify)

M7 Did you pay any tolls?
1 Yes
2 No ➔ SKIP TO M9

M8 How much in total did you pay to make this trip?
Enter amount (999.99 if unknown)

M9 Did you drop off or pick up anyone?
1 Yes
2 No ➔ SKIP TO M12

M10 Was it a household member?
1 Yes
2 No ➔ SKIP TO M12

M11 Which household member was it?
Enter person number(s)

M12 [END OF LOOP IF DRIVER] Were you dropped off or picked up?
1 Yes
2 No ➔ END OF LOOP FOR PASSENGER

M13 Was it a household member?
3 Yes
4 No ➔ END OF LOOP FOR PASSENGER

M14 Which household member was it?
Enter person number(s)

IF MODE=TRANSIT =41, 43, 44, 45, 46, 47, 51, 52, 53– do series then return

N1 Where did you board?
STATION NAME OR BUS STOP LOCATION (CROSS STREETS)
LINE OR ROUTE #

N2 How did you get to the bus/rail stop?
1-walk
2-drove and parked
3-was dropped off
4-rode bike
5-other (specify)

N3 How much did you pay?
$_____

N4 How did you pay?
1-cash
2-pass
3-transfer
7-OTHER (SPECIFY)

N5 – How many times did you transfer?
0 ➔ SKIP TO N15
1-2
3 3+

N6 What was the station or bus stop where you first transferred?

N7 What was the line # or route description to which you first transferred?

N8 – How much did you pay for that portion of your trip
$_____

N9 How did you pay?
1-cash
2-pass
3-transfer

N10 What was the station or bus stop where you transferred second?

N11 What was the line # or route description to which you transferred second?

N12 – How much did you pay for that portion of your trip?
$_____

N13 How did you pay?
1-cash
2-pass
3-transfer

N14 ENTER ANY ADDITIONAL TRANSFER INFORMATION HERE

N15 – Where did you get off the bus/light rail?
LOCATION – LANDMARK/ADDRESS/CITY /
STATION NAME OR BUS STOP LOCATION (CROSS STREETS)

N16 – How did you get from the bus/rail stop to your destination?
1-walk
2-got into parked car and drove
3-was picked up
4-rode bike
5-other (specify)

C. Cordon Line Survey Questionnaire

Delaware Valley Regional Planning Commission
EXTERNAL AND THROUGH TRIP SURVEY **Time :** : 1[ ] AM 2[ ] PM

Nº 10000

1. Where did you start this trip? (Origin) **2. Is this home?** 1[ ] Yes 2[ ] No

Street address or nearest intersection

Town or City County State Zip Code

3. Where will this trip end? (Destination) **4. Is this home?** 1[ ] Yes 2[ ] No

Street address or nearest intersection

Town or City County State Zip Code

5. Will you stop before arriving at your destination? **6. Is this home?** 1[ ] Yes 2[ ] No

1[ ] No 2[ ] Yes, If yes, where?

Street address or nearest intersection

Town or City County State Zip Code

7. Why do you use this road? (check one or more)
1[ ] Saves Time 3[ ] Less Congestion 5[ ] No Traffic Lights
2[ ] Saves Money 4[ ] Better Road Condition 6[ ] Other____________________

8. What is/are the major road(s) that you will take to reach the destination after this road?

1st Highway________________________ 2nd Highway ________________________

9. What type of vehicle is used for the trip?

Passenger Vehicles	**Light Trucks**	**Heavy Trucks (3 axles or more)**
1[ ] Auto	5[ ] Pickup	9[ ] Tractor-Trailer
2[ ] Van, Sta. Wagon	6[ ] Panel	10[ ] Double Trailer
3[ ] SUV	7[ ] Single Unit	11[ ] Other _____
4[ ] Other _____	8[ ] Other _____	

10. What is the purpose of this trip? (Passenger Vehicles Only)
1[ ] Work 3[ ] Eat Meal 5[ ] Social/Recreation 7[ ] Visitor/Tourist
2[ ] School 4[ ] Shopping 6[ ] Medical 8[ ] Other _____

11. How many people are in the vehicle? (Passenger Vehicles Only)
1[ ] One 2[ ] Two 3[ ] Three 4[ ] Four 5[ ] Five 6[ ] More than Five

12. Where is this truck garaged or parked when not in service? (Trucks Only)
1[ ] Bucks County 4[ ] Montgomery County 7[ ] Burlington County 10[ ] Mercer County
2[ ] Chester County 5[ ] Philadelphia County 8[ ] Camden County 11[ ] Other NJ County
3[ ] Delaware County 6[ ] Other PA County 9[ ] Gloucester County 12[ ] Other State

13. What type of commodities are you carrying? (Trucks Only)
1[ ] Empty 4[ ] Agricultural Products 7[ ] Retail Store Merchandise
2[ ] Manufactured Products 5[ ] Building Materials 8[ ] Parcels
3[ ] Petroleum Products 6[ ] Refrigerated Products 9[ ] Other ____________

D. Transit On-Board Survey Forms

PATCO PASSENGER SURVEY

The Delaware Valley Regional Planning Commission, in cooperation with PATCO and NJ TRANSIT, is conducting this survey to assess your transportation needs and to help us improve service. Please fill out this survey and mail the completed form. NO POSTAGE NECESSARY. Thank you for your cooperation.

1. **What time was it when you received this survey?** __:__ am / pm

2. **Where did you START this trip?** (where trip began, not the station)

   ____
   [Street address or nearest intersection]

   ____________ [City or Town] ____ [State] ____ [Zip Code]

3. **At which station did you BOARD this train?** ____________ Station

4. **How did you get to this station?** (Check one)

   1[ ] Walked
   2[ ] Was dropped off
   3[ ] Drove auto & parked
   4[ ] Rode in a carpool
   5[ ] Transferred from NJ TRANSIT route #____
   6[ ] Transferred from SEPTA subway line ____
   7[ ] Transferred from SEPTA bus route #____
   8[ ] Other ____________

5. **Why do you use this station?** (Check one)

   1[ ] Closest to home
   2[ ] Parking available
   3[ ] Lower PATCO fare
   4[ ] Bus service available
   5[ ] Convenient highway access
   6[ ] Other ____________

6. **How long did it take you to get from your START location to this station?** _____ minutes.

7. **How far is your START location from this station?** (Check one)

   1[ ] ¼ mile
   2[ ] ½ mile
   3[ ] 1 mile
   4[ ] 1-2 miles
   5[ ] 2-3 miles
   6[ ] 3-5 miles
   7[ ] 5-7 miles
   8[ ] 7-10 miles
   9[ ] 10-15 miles
   10[ ] 15-20 miles
   11[ ] 20-30 miles
   12[ ] 30 or more miles

8. **What type of fare did you pay for this trip?** (Check one)

   1[ ] One-Way Ticket
   2[ ] 2 Ride Ticket
   3[ ] 10 Ride Ticket
   4[ ] Senior Citizen Fare
   5[ ] Handicapped Fare
   6[ ] Other ____________

9. **At which station will you get off this train?** ____________ Station

10. **After getting off this train, how will you get to your FINAL destination?** (Check only one)

    1[ ] Walk only
    2[ ] Will be picked up
    3[ ] Drive auto I parked
    4[ ] Ride in carpool
    5[ ] Transfer to NJT bus route #____
    6[ ] Transfer to SEPTA subway ____
    7[ ] Transfer to SEPTA bus route #____
    8[ ] Other ____________

11. **Where is your FINAL destination?** (where trip ends, not the station)

    ____
    [Street address or nearest intersection]

    ____________ [City or Town] ____ [State] ____ [Zip Code]

12. **How long does it take you to travel from your START location to your FINAL destination?** ______ minutes.

13. **What is the main purpose of this trip?** (Check one)

    1[ ] Going to Work
    2[ ] Returning from Work
    3[ ] School
    4[ ] Company business
    5[ ] Shopping
    6[ ] Medical/Personal
    7[ ] Recreation/Social
    8[ ] Going out to eat
    9[ ] Other ____________

14. **Please enter the NUMBER of times you boarded a PATCO train on <u>each</u> of the last seven days?** (ie, If you used one train to get to work and one train to return home, that counts as 2 trains on that day.)

    1____ Monday
    2____ Tuesday
    3____ Wednesday
    4____ Thursday
    5____ Friday
    6____ Saturday
    7____ Sunday

15. **Why do you use PATCO?** (Check the most important reasons)

    1[ ] Saves time
    2[ ] Frequent service
    3[ ] Avoid driving
    4[ ] Saves money
    5[ ] Convenient schedule
    6[ ] Comfortable ride
    7[ ] Car not available
    8[ ] Bus not convenient
    9[ ] Other (Specify)________

16. **How long have you been using PATCO for this trip?** ___/___ mos / yrs

17. **How did you make this trip before using PATCO?** (Check one)

    1[ ] Did not make this trip
    2[ ] Car (drove alone)
    3[ ] Carpool
    4[ ] Vanpool
    5[ ] Bus
    6[ ] Other ____________

18. **Do you have a vehicle that <u>could</u> have been used for this trip?** [ ] Yes [ ] No

19. **How would you rate PATCO service?** (Circle the NUMBER for each of the following)

	Excellent		Average		Poor
Reliability	1	2	3	4	5
Express service	1	2	3	4	5
Travel time	1	2	3	4	5
Easily understood schedules	1	2	3	4	5
Customer assistance & notices	1	2	3	4	5
Train destination signs	1	2	3	4	5
Cleanliness of stations	1	2	3	4	5
Cleanliness of train	1	2	3	4	5
Heating & air conditioning	1	2	3	4	5
Cost of travel	1	2	3	4	5
Vehicle comfort	1	2	3	4	5
Frequency of service	1	2	3	4	5
Safety/security	1	2	3	4	5
Overall Performance	1	2	3	4	5

20. **Are you:** 1[ ] male 2[ ] female

21. **What is your age?** ____ years

22. **What is your race?** 1[ ] White 2[ ] Black 3[ ] Asian 4[ ] Other ________

23. **What is your household income per year?** (Check one)

1[ ] Under $10,000
2[ ] $10,000 - $15,000
3[ ] $15,000 - $25,000
4[ ] $25,000 - $35,000
5[ ] $35,000 - $50,000
6[ ] $50,000 - $75,000
7[ ] $75,000 - $100,000
8[ ] $100,000 or more

24. **Are you:** (Check one)

1[ ] Employed Full-time
2[ ] Employed Part-time
3[ ] Retired
4[ ] Currently Unemployed
5[ ] Homemaker
6[ ] Student

25. **What is the highest level of schooling you have completed?** (Check one)

1[ ] Elementary School
2[ ] Some High School
3[ ] Graduated High School
4[ ] Some College
5[ ] Graduated College
6[ ] Post-Graduate School
7[ ] Vocational School
8[ ] Special School
9[ ] Other ________

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SEPTA PASSENGER SURVEY

The Pennsylvania Department of Transportation and SEPTA, in cooperation with Amtrak and the Delaware Valley Regional Planning Commission, are conducting this survey to assess your transportation needs and to help us improve transportation in major travel corridors in Southeastern Pennsylvania. It will take only a few minutes to complete this questionnaire and drop it in a mailbox. NO POSTAGE NECESSARY. Thank you for your assistance.

1. What time was it when you received this survey? ________ am / pm

2. Where did you START this trip? (where trip began, not the station)

   ____
   (Street Address or Nearest Intersection)

   ____
   (City or Town) (State) (Zip Code)

3. At which station did you BOARD this train? ________________
   Route #: R___

4. How did you get to this station? (Check one)
   - 1☐ Walked
   - 2☐ Was dropped off
   - 3☐ Drove auto & parked
   - 4☐ Took taxi
   - 5☐ Took bus/trolley
   - 6☐ Took subway/elevated
   - 7☐ Transferred from Amtrak train
   - 8☐ Transferred from SEPTA/NJT train
   - 9☐ Other ____________

5. Why did you use this station? (Check the most important reasons)
   - 1☐ Closest to STARTING point
   - 2☐ Parking available
   - 3☐ Convenient highway access
   - 4☐ Lower fare
   - 5☐ Transit service available
   - 6☐ Better train service
   - 7☐ Other ____________

6. How long did it take you to reach this station from your STARTING point? _____ minutes

7. How far is this station from your STARTING point? _____ miles

8. What type of ticket did you buy?
   - 1☐ One-way
   - 2☐ Ten-trip ticket
   - 3☐ Monthly pass
   - 4☐ Weekly pass
   - 5☐ Senior citizen
   - 6☐ Handicapped
   - 7☐ Other ____________

9. At which station did you get off this train? ________________

10. After leaving this train, how did you reach your DESTINATION? (Check one)
    - 1☐ Walked
    - 2☐ Was picked up
    - 3☐ Drove auto I had parked
    - 4☐ Took taxi
    - 5☐ Took bus/trolley
    - 6☐ Took subway/elevated line
    - 7☐ Transferred to SEPTA/NJT train
    - 8☐ Transferred to Amtrak train
    - 9☐ Other ____________

11. Where was your DESTINATION? (Where the trip ended, not the station)

    ____
    (Street Address or Nearest Intersection)

    ____
    (City or Town) (State) (Zip Code)

12. How long did it take you to reach your DESTINATION after leaving the train? _____ minutes

13. How long did it take you to travel from your STARTING point to your DESTINATION? _____ minutes (door to door travel time)

14. What was the main purpose of this trip?
    - 1☐ Going to work
    - 2☐ Returning from work
    - 3☐ School
    - 4☐ Company business
    - 5☐ Social/recreation
    - 6☐ Medical/personal
    - 7☐ Shopping
    - 8☐ Other ____________

15. Why did you decide to take a train for this trip? (Check the most important reasons)
    - 1☐ Avoid driving
    - 2☐ Solve parking problem
    - 3☐ No car available
    - 4☐ Unable to drive
    - 5☐ Save money
    - 6☐ Save time
    - 7☐ More convenient than other modes
    - 8☐ Other ____________

16. How would you have taken this trip if no train service had been available?
    - 1☐ Bus/trolley
    - 2☐ Subway/elevated
    - 3☐ Car
    - 4☐ Car pool
    - 5☐ Van pool
    - 6☐ Would NOT have taken this trip
    - 7☐ Other ____________

17. How often do you ride trains on this line? (Count one-way trips)
    - 1☐ More than 10 times per WEEK
    - 2☐ 8 to 10 times per WEEK
    - 3☐ 4 to 7 times per WEEK
    - 4☐ 2 to 3 times per WEEK
    - 5☐ 4 to 7 times per MONTH
    - 6☐ 2 to 3 times per MONTH
    - 7☐ Less than 2 times per MONTH

over -->

18. How would you rate your rail service? (Circle the number for each of the following)

	Excellent		Average		Poor
Reliability	5	4	3	2	1
Express service	5	4	3	2	1
Customer service & information	5	4	3	2	1
Cleanliness of stations	5	4	3	2	1
Cleanliness of trains	5	4	3	2	1
Heating & air conditioning	5	4	3	2	1
Availability of seats	5	4	3	2	1
Announcements explaining delays	5	4	3	2	1
Safety & security	5	4	3	2	1
Availability of parking at stations	5	4	3	2	1
Overall Performance	5	4	3	2	1

19. Are you: ___ Male ___ Female

20. Are you: (Check all that apply)
- 1☐ Employed full time
- 2☐ Employed part time
- 3☐ Currently unemployed
- 4☐ Retired
- 5☐ Homemaker
- 6☐ Student
- 7☐ Military
- 8☐ Other

21. How old are you? ________

22. How many vehicles are owned by members of your HOUSEHOLD? ____

23. What is your HOUSEHOLD income per year?
- 1☐ Under $10,000
- 2☐ $10,000 - 14,999
- 3☐ $15,000 - $24,999
- 4☐ $25,000 - $34,999
- 5☐ $35,000 - $49,999
- 6☐ $50,000 - $74,999
- 7☐ $75,000 - $99,999
- 8☐ $100,000 - $124,999
- 9☐ $125,000 - $149,999
- 10☐ $150,000 or more

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NJ TRANSIT PASSENGER SURVEY

The Delaware Valley Regional Planning Commission, in cooperation with NJ TRANSIT and PATCO, is conducting this survey to assess your transportation needs and to help us improve service. Please fill out this survey and mail the completed form. NO POSTAGE NECESSARY. Thank you for your cooperation.

1. **What time was it when you picked up this survey?** ___:___ am / pm

2. **Where did you START this trip?** (where trip began, not the bus stop)

_______________________________ [Street address or nearest intersection]

_______________ [City or Town] _____ [State] _______ [Zip Code]

3. **Where did you BOARD this bus?** (location of bus stop)

_______________________________ [Street address or nearest intersection]

_______________ [City or Town] _____ [State] _______ [Zip Code]

4. **How did you get to this bus stop?** (Check one)

1[ ] Walked
2[ ] Was dropped off
3[ ] Drove auto & parked
4[ ] Took PATCO
5[ ] Transferred from NJ TRANSIT route # ______
6[ ] Transferred from SEPTA subway line ______
7[ ] Transferred from SEPTA bus route # ______
8[ ] Other ______________

5. **How long did it take you to get from your START location to this bus stop?** _____ minutes.

6. **How far is your START location from this bus stop?** (Check one)

1[ ] ¼ mile
2[ ] ½ mile
3[ ] 1 mile
4[ ] 1-2 miles
5[ ] 2-3 miles
6[ ] 3-5 miles
7[ ] 5-7 miles
8[ ] 7-10 miles
9[ ] 10 or more miles

7. **What type of fare did you pay for this trip?** (Check one)

1[ ] Cash
2[ ] Ten-trip Ticket
3[ ] Monthly Pass
4[ ] Transfer Ticket
5[ ] Student Ticket
6[ ] Senior Citizen Fare
7[ ] Handicapped Fare
8[ ] Family Fare
9[ ] Other ______________

8. **Where will you get off this bus?** (location of bus stop)

_______________________________ [Street address or nearest intersection]

_______________ [City or Town] _____ [State] _______ [Zip Code]

9. **After getting off this bus, how will you get to your final destination?** (Check one)

1[ ] Walk only
2[ ] Will be picked up
3[ ] Drive auto I parked
4[ ] Take PATCO
5[ ] Transfer to NJT bus route # ______
6[ ] Transfer to SEPTA subway line ______
7[ ] Transfer to SEPTA bus route # ______
8[ ] Other ______________

10. **Where is your FINAL destination?** (where trip ends, not the bus stop)

_______________________________ [Street address or nearest intersection]

_______________ [City or Town] _____ [State] _______ [Zip Code]

11. **How long does it take you to travel from your START location to your FINAL destination?** ______ minutes.

12. **What is the main purpose of this trip?** (Check one)

1[ ] Going to Work
2[ ] Returning from Work
3[ ] School
4[ ] Company business
5[ ] Shopping
6[ ] Medical/Personal
7[ ] Recreation/Social
8[ ] Going out to eat
9[ ] Other ______________

13. **Please enter the NUMBER of times you boarded an NJ TRANSIT bus on <u>each</u> of the last seven days?** (ie, If you used one bus to get to work but had to transfer from one bus to another to get home, that counts as 3 buses on that day.)

1____ Monday
2____ Tuesday
3____ Wednesday
4____ Thursday
5____ Friday
6____ Saturday
7____ Sunday

14. **Why do you use this bus route?** (Check the most important reasons)

1[ ] Saves time
2[ ] Frequent service
3[ ] Avoid driving
4[ ] Saves money
5[ ] Convenient schedule
6[ ] Comfortable ride
7[ ] Car not available
8[ ] PATCO not convenient
9[ ] Other (Specify)________

15. **How long have you been using NJ TRANSIT for this trip?** ___/___ mos / yrs

16. **Do you have a vehicle that could have been used for this trip?** [ ] Yes [ ] No

17. **Which of the following statements best applies to you?** (Check only one)

[1][ ] I use NJ TRANSIT buses because they are my <u>only practical choice</u>.
[2][ ] Although there are other ways I could travel, I use the bus because it is the <u>best choice</u> for me.
[3][ ] I occasionally take a bus, but usually I use <u>another type</u> of transportation.

18. **How would you rate NJ TRANSIT bus service?** (Circle the NUMBER for each of the following)

	Excellent		Average		Poor
On-time performance	1	2	3	4	5
Express service	1	2	3	4	5
Travel time	1	2	3	4	5
Easily understood schedules	1	2	3	4	5
Customer notices	1	2	3	4	5
Bus destination signs	1	2	3	4	5
Cost of travel	1	2	3	4	5
Cleanliness of bus	1	2	3	4	5
Heating & air conditioning	1	2	3	4	5
Driver attitude	1	2	3	4	5
Bus comfort	1	2	3	4	5
Frequency of service	1	2	3	4	5
Safety/security	1	2	3	4	5
Overall Performance	1	2	3	4	5

19. **Are you:** [1][ ] male [2][ ] female

20. **What is your age?** ____ years

21. **What is your race?** [1][ ] White [2][ ] Black [3][ ] Asian [4][ ] Other ________

22. **What is your <u>household</u> income per year?** (Check one)

[1][ ] Under $10,000
[2][ ] $10,000 - $15,000
[3][ ] $15,000 - $25,000
[4][ ] $25,000 - $35,000
[5][ ] $35,000 - $50,000
[6][ ] $50,000 - $75,000
[7][ ] $75,000 - $100,000
[8][ ] $100,000 or more

23. **Are you:** (Check one)

[1][ ] Employed Full-time
[2][ ] Employed Part-time
[3][ ] Retired
[4][ ] Currently Unemployed
[5][ ] Homemaker
[6][ ] Student

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E. Truck Survey Form

DELAWARE VALLEY
REGIONAL PLANNING COMMISSION

The Bourse Building, 111 South Independence Mall East
Philadelphia, PA 19106-2515

Telephone: (215)592-1800
Fax: (215)592-9125
www.dvrpc.org

October 2000

Dear Truck Owner or Driver:

How can we improve driving conditions on highways like the Schuylkill Expressway, NJ 42, US 322, and US 1? How can we reduce congestion and allow drivers to meet delivery deadlines? How can we make our highways better serve the commercial vehicle operations which are so vital to the Delaware Valley?

Help us find out by completing the enclosed **Weekday Truck Travel Diaries** . The Delaware Valley Regional Planning Commission (DVRPC), in cooperation with the Pennsylvania and New Jersey Departments of Transportation, is sponsoring this survey to determine your transportation needs and develop plans for improving highway facilities. DVRPC is an interstate public agency which provides transportation planning for the region and programs more than one billion dollars per year for transportation improvements.

Your trucks have been randomly selected for the survey from thousands of trucks serving the DVRPC 9-county area which consists of Bucks, Chester, Delaware, Montgomery, and Philadelphia counties in Pennsylvania, and Burlington, Camden, Gloucester, and Mercer counties in New Jersey. You can help by telling us about the kind of weekday trips your trucks make and the type of commodities they carry. Can we count on you to fill out the truck diary forms?

It's simple to do. Please complete the enclosed **twelve copies** of a weekday truck travel diary, one diary for each truck. Please select different types of trucks as shown under **Question 1** of the diary questionnaire, or use whatever trucks you have in your operation. By filling out the daily truck trip diaries, you will be providing information that we cannot get anywhere else. After the completion of these diaries, please fold and return all of them in the enclosed envelope, **no postage necessary. All information gathered for this survey will be kept confidential.** You have our promise that none of this information will be used for any other purpose, or be provided to any other agency or business.

Thank you very much for your help in this important effort. If you have any questions or concerns about this survey, please call Ted Dahlburg at (215) 238-2844.

Sincerely,

John J. Coscia

John J. Coscia
Executive Director

A PERSONAL MESSAGE TO THE TRUCK DRIVER

No. 1,000

Before you complete this **Weekday Truck Travel Diary,** please read the attached example which illustrates the weekday trips made by a hypothetical tractor-trailer in a 24 hour period. For any weekday, please answer all questions in the diary and record each trip in the order you make it from the starting address of the first trip to the address of the last trip.

1. What type of truck is used for your trips today ? ***(check one)***

1[ ] Pickup 2[ ] Panel 3[ ] Single Unit 4[ ] Dump Truck 5[ ] Flatbed 6[ ] Tractor-Trailer 7[ ] Double Trailer 8[ ] Other

2. Where is this truck garaged or parked when not in service? ***(check one)***

1[ ] Bucks Co. 2[ ] Chester Co. 3[ ] Delaware Co. 4[ ] Montgomery Co. 5[ ] Philadelphia 6[ ] Other Pennsylvania county

7[ ] Burlington Co. 8[ ] Camden Co. 9[ ] Gloucester Co. 10[ ] Mercer Co. 11[ ] Other New Jersey county 12[ ] Other State

3. What is the starting address of your first truck trip today? **4. Is this your home?** 1[ ] Yes 2[ ] No

Street address or nearest intersection

City or Town County State Zip Code

5. Start Odometer Reading ______________ **6. Date :** ____ ____ **, 2000**
Month Day

WEEKDAY TRUCK TRAVEL DIARY

TRIP #	Start Time *(check AM or PM)*	Stop Time *(check AM or PM)*	Stop Odometer Reading	Location of Stop	Stop Purpose *(check one)*	Commodity Carried to Location of Stop *(check one)*	Land Use at Stop *(check one)*
TRIP 1	: 1[ ] AM 2[ ] PM	: 1[ ] AM 2[ ] PM	*(Mileage)*	Street address or nearest intersection City or Town County State Zip Code	1[ ] Pickup, Load 2[ ] Dropoff, Unload 3[ ] Unload & Load 4[ ] Fuel Service 5[ ] Eat, Personal	1[ ] Empty 6[ ] Parcels 2[ ] Manufact. Products 7[ ] Retail Store Merchandise 3[ ] Petroleum Products 8[ ] Refregerated Products 4[ ] Agriculture Products 9[ ] Hazardous Materials 5[ ] Building Materials 10[ ] Other	1[ ] Residential 6[ ] Service 2[ ] Retail, Commercial 7[ ] Government 3[ ] Manufact - uring 8[ ] Transportation 4[ ] Ware - housing 9[ ] Utilities 5[ ] Office 10[ ] Other
TRIP 2	: 1[ ] AM 2[ ] PM	: 1[ ] AM 2[ ] PM	*(Mileage)*	Street address or nearest intersection City or Town County State Zip Code	1[ ] Pickup, Load 2[ ] Dropoff, Unload 3[ ] Unload & Load 4[ ] Fuel Service 5[ ] Eat, Personal	1[ ] Empty 6[ ] Parcels 2[ ] Manufact. Products 7[ ] Retail Store Merchandise 3[ ] Petroleum Products 8[ ] Refregerated Products 4[ ] Agriculture Products 9[ ] Hazardous Materials 5[ ] Building Materials 10[ ] Other	1[ ] Residential 6[ ] Service 2[ ] Retail, Commercial 7[ ] Government 3[ ] Manufact - uring 8[ ] Transportation 4[ ] Ware - housing 9[ ] Utilities 5[ ] Office 10[ ] Other
TRIP 3	: 1[ ] AM 2[ ] PM	: 1[ ] AM 2[ ] PM	*(Mileage)*	Street address or nearest intersection City or Town County State Zip Code	1[ ] Pickup, Load 2[ ] Dropoff, Unload 3[ ] Unload & Load 4[ ] Fuel Service 5[ ] Eat, Personal	1[ ] Empty 6[ ] Parcels 2[ ] Manufact. Products 7[ ] Retail Store Merchandise 3[ ] Petroleum Products 8[ ] Refregerated Products 4[ ] Agriculture Products 9[ ] Hazardous Materials 5[ ] Building Materials 10[ ] Other	1[ ] Residential 6[ ] Service 2[ ] Retail, Commercial 7[ ] Government 3[ ] Manufact - uring 8[ ] Transportation 4[ ] Ware - housing 9[ ] Utilities 5[ ] Office 10[ ] Other

WEEKDAY TRUCK TRAVEL DIARY (Continued)

TRIP #	Start Time (check AM or PM)	Stop Time (check AM or PM)	Stop Odometer Reading	Location of Stop	Stop Purpose (check one)	Commodity Carried to Location of Stop (check one)	Land Use at Stop (check one)
TRIP 4	: 1[ ] AM 2[ ] PM	: 1[ ] AM 2[ ] PM	*(Mileage)*	Street address or nearest intersection City or Town County State Zip Code	1[ ] Pickup, Load 2[ ] Dropoff, Unload 3[ ] Unload & Load 4[ ] Fuel Service 5[ ] Eat, Personal	1[ ] Empty 6[ ] Parcels 2[ ] Manufact. Products 7[ ] Retail Store Merchandise 3[ ] Petroleum Products 8[ ] Refregerated Products 4[ ] Agriculture Products 9[ ] Hazardous Materials 5[ ] Building Materials 10[ ] Other	1[ ] Residential 6[ ] Service 2[ ] Retail, Commercial 7[ ] Government 3[ ] Manufact - uring 8[ ] Transportation 4[ ] Ware - housing 9[ ] Utilities 5[ ] Office 10[ ] Other
TRIP 5	: 1[ ] AM 2[ ] PM	: 1[ ] AM 2[ ] PM	*(Mileage)*	Street address or nearest intersection City or Town County State Zip Code	1[ ] Pickup, Load 2[ ] Dropoff, Unload 3[ ] Unload & Load 4[ ] Fuel Service 5[ ] Eat, Personal	1[ ] Empty 6[ ] Parcels 2[ ] Manufact. Products 7[ ] Retail Store Merchandise 3[ ] Petroleum Products 8[ ] Refregerated Products 4[ ] Agriculture Products 9[ ] Hazardous Materials 5[ ] Building Materials 10[ ] Other	1[ ] Residential 6[ ] Service 2[ ] Retail, Commercial 7[ ] Government 3[ ] Manufact - uring 8[ ] Transportation 4[ ] Ware - housing 9[ ] Utilities 5[ ] Office 10[ ] Other
TRIP 6	: 1[ ] AM 2[ ] PM	: 1[ ] AM 2[ ] PM	*(Mileage)*	Street address or nearest intersection City or Town County State Zip Code	1[ ] Pickup, Load 2[ ] Dropoff, Unload 3[ ] Unload & Load 4[ ] Fuel Service 5[ ] Eat, Personal	1[ ] Empty 6[ ] Parcels 2[ ] Manufact. Products 7[ ] Retail Store Merchandise 3[ ] Petroleum Products 8[ ] Refregerated Products 4[ ] Agriculture Products 9[ ] Hazardous Materials 5[ ] Building Materials 10[ ] Other	1[ ] Residential 6[ ] Service 2[ ] Retail, Commercial 7[ ] Government 3[ ] Manufact - uring 8[ ] Transportation 4[ ] Ware - housing 9[ ] Utilities 5[ ] Office 10[ ] Other
TRIP 7	: 1[ ] AM 2[ ] PM	: 1[ ] AM 2[ ] PM	*(Mileage)*	Street address or nearest intersection City or Town County State Zip Code	1[ ] Pickup, Load 2[ ] Dropoff, Unload 3[ ] Unload & Load 4[ ] Fuel Service 5[ ] Eat, Personal	1[ ] Empty 6[ ] Parcels 2[ ] Manufact. Products 7[ ] Retail Store Merchandise 3[ ] Petroleum Products 8[ ] Refregerated Products 4[ ] Agriculture Products 9[ ] Hazardous Materials 5[ ] Building Materials 10[ ] Other	1[ ] Residential 6[ ] Service 2[ ] Retail, Commercial 7[ ] Government 3[ ] Manufact - uring 8[ ] Transportation 4[ ] Ware - housing 9[ ] Utilities 5[ ] Office 10[ ] Other
TRIP 8	: 1[ ] AM 2[ ] PM	: 1[ ] AM 2[ ] PM	*(Mileage)*	Street address or nearest intersection City or Town County State Zip Code	1[ ] Pickup, Load 2[ ] Dropoff, Unload 3[ ] Unload & Load 4[ ] Fuel Service 5[ ] Eat, Personal	1[ ] Empty 6[ ] Parcels 2[ ] Manufact. Products 7[ ] Retail Store Merchandise 3[ ] Petroleum Products 8[ ] Refregerated Products 4[ ] Agriculture Products 9[ ] Hazardous Materials 5[ ] Building Materials 10[ ] Other	1[ ] Residential 6[ ] Service 2[ ] Retail, Commercial 7[ ] Government 3[ ] Manufact - uring 8[ ] Transportation 4[ ] Ware - housing 9[ ] Utilities 5[ ] Office 10[ ] Other
TRIP 9	: 1[ ] AM 2[ ] PM	: 1[ ] AM 2[ ] PM	*(Mileage)*	Street address or nearest intersection City or Town County State Zip Code	1[ ] Pickup, Load 2[ ] Dropoff, Unload 3[ ] Unload & Load 4[ ] Fuel Service 5[ ] Eat, Personal	1[ ] Empty 6[ ] Parcels 2[ ] Manufact. Products 7[ ] Retail Store Merchandise 3[ ] Petroleum Products 8[ ] Refregerated Products 4[ ] Agriculture Products 9[ ] Hazardous Materials 5[ ] Building Materials 10[ ] Other	1[ ] Residential 6[ ] Service 2[ ] Retail, Commercial 7[ ] Government 3[ ] Manufact - uring 8[ ] Transportation 4[ ] Ware - housing 9[ ] Utilities 5[ ] Office 10[ ] Other

(Continued)

WEEKDAY TRUCK TRAVEL DIARY (Continued) No. 3,000

TRIP #	Start Time *(check AM or PM)*	Stop Time *(check AM or PM)*	Stop Odometer Reading	Location of Stop	Stop Purpose *(check one)*	Commodity Carried to Location of Stop *(check one)*	Land Use at Stop *(check one)*
TRIP 10	: 1[ ] AM 2[ ] PM	: 1[ ] AM 2[ ] PM	*(Mileage)*	Street address or nearest intersection; City or Town, County; State, Zip Code	1[ ] Pickup, Load 2[ ] Dropoff, Unload 3[ ] Unload & Load 4[ ] Fuel Service 5[ ] Eat, Personal	1[ ] Empty 2[ ] Manufact. Products 3[ ] Petroleum Products 4[ ] Agriculture Products 5[ ] Building Materials 6[ ] Parcels 7[ ] Retail Store Merchandise 8[ ] Refregerated Products 9[ ] Hazardous Materials 10[ ] Other	1[ ] Residential 2[ ] Retail, Commercial 3[ ] Manufact-uring 4[ ] Ware-housing 5[ ] Office 6[ ] Service 7[ ] Government 8[ ] Transportation 9[ ] Utilities 10[ ] Other
TRIP 11	: 1[ ] AM 2[ ] PM	: 1[ ] AM 2[ ] PM	*(Mileage)*	Street address or nearest intersection; City or Town, County; State, Zip Code	1[ ] Pickup, Load 2[ ] Dropoff, Unload 3[ ] Unload & Load 4[ ] Fuel Service 5[ ] Eat, Personal	1[ ] Empty 2[ ] Manufact. Products 3[ ] Petroleum Products 4[ ] Agriculture Products 5[ ] Building Materials 6[ ] Parcels 7[ ] Retail Store Merchandise 8[ ] Refregerated Products 9[ ] Hazardous Materials 10[ ] Other	1[ ] Residential 2[ ] Retail, Commercial 3[ ] Manufact-uring 4[ ] Ware-housing 5[ ] Office 6[ ] Service 7[ ] Government 8[ ] Transportation 9[ ] Utilities 10[ ] Other
TRIP 12	: 1[ ] AM 2[ ] PM	: 1[ ] AM 2[ ] PM	*(Mileage)*	Street address or nearest intersection; City or Town, County; State, Zip Code	1[ ] Pickup, Load 2[ ] Dropoff, Unload 3[ ] Unload & Load 4[ ] Fuel Service 5[ ] Eat, Personal	1[ ] Empty 2[ ] Manufact. Products 3[ ] Petroleum Products 4[ ] Agriculture Products 5[ ] Building Materials 6[ ] Parcels 7[ ] Retail Store Merchandise 8[ ] Refregerated Products 9[ ] Hazardous Materials 10[ ] Other	1[ ] Residential 2[ ] Retail, Commercial 3[ ] Manufact-uring 4[ ] Ware-housing 5[ ] Office 6[ ] Service 7[ ] Government 8[ ] Transportation 9[ ] Utilities 10[ ] Other

Please fold here and return

7. If your truck makes more than 12 trips on the survey day, write the total number here ____

8. Comments : ____

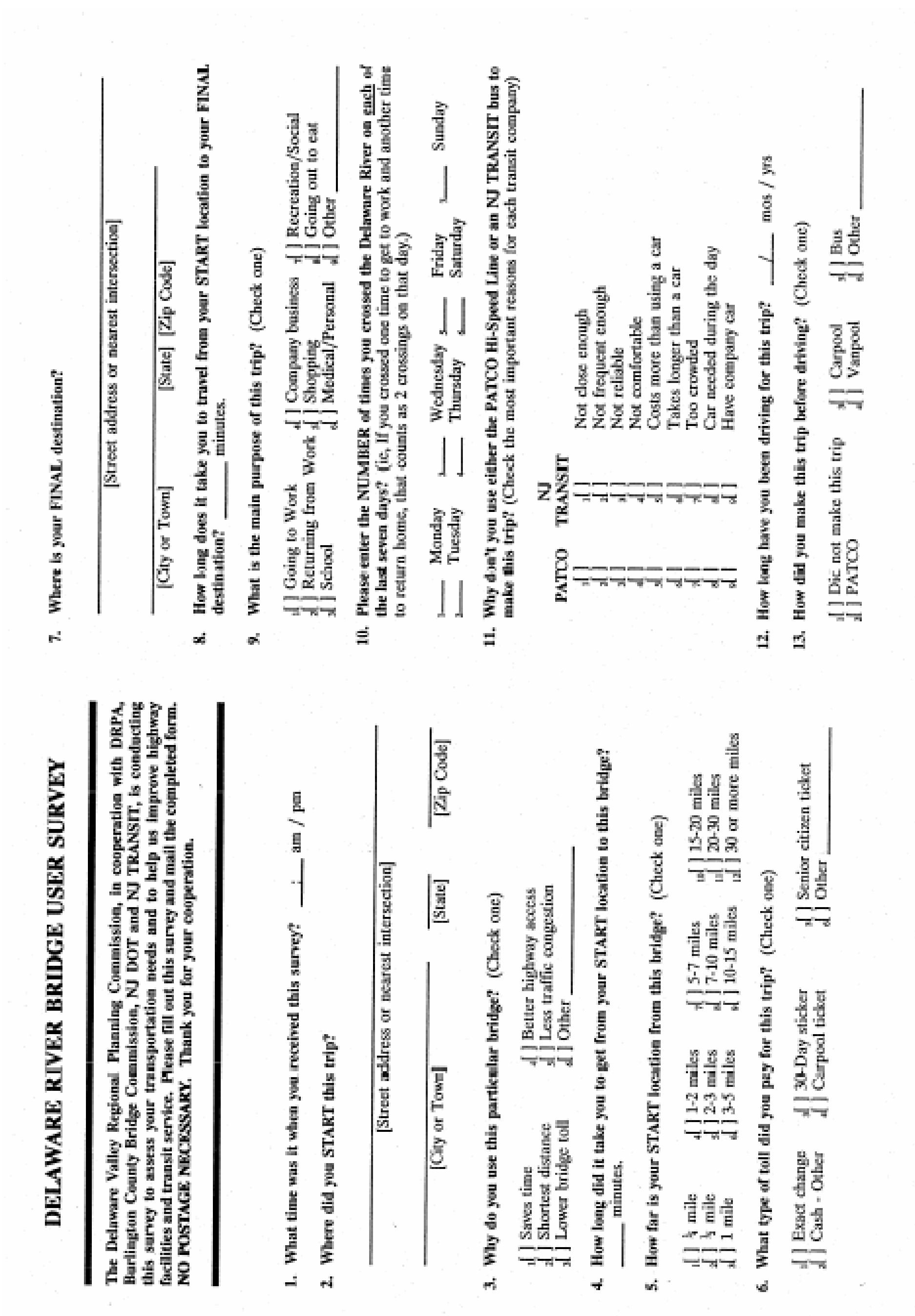
DVRPC

Transportation for the 21st Century Truck Travel Survey

Your One-Day Truck Travel Diary

Please complete this diary and return it, along with the other diaries to DVRPC within four weeks. We want you to know that your participation is greatly appreciated.

F. Bridge Survey Form



DELAWARE RIVER BRIDGE USER SURVEY

The Delaware Valley Regional Planning Commission, in cooperation with DRPA, Burlington County Bridge Commission, NJ DOT and NJ TRANSIT, is conducting this survey to assess your transportation needs and to help us improve highway facilities and transit service. Please fill out this survey and mail the completed form. NO POSTAGE NECESSARY. Thank you for your cooperation.

1. What time was it when you received this survey? ___:___ am / pm

2. Where did you START this trip?

____
[Street address or nearest intersection]

______________________ ______ ________
[City or Town] [State] [Zip Code]

3. Why do you use this particular bridge? (Check one)

- [ ] Saves time
- [ ] Shortest distance
- [ ] Lower bridge toll
- [ ] Better highway access
- [ ] Less traffic congestion
- [ ] Other ____________

4. How long did it take you to get from your START location to this bridge?
_____ minutes.

5. How far is your START location from this bridge? (Check one)

- [ ] ¼ mile
- [ ] ½ mile
- [ ] 1 mile
- [ ] 1-2 miles
- [ ] 2-3 miles
- [ ] 3-5 miles
- [ ] 5-7 miles
- [ ] 7-10 miles
- [ ] 10-15 miles
- [ ] 15-20 miles
- [ ] 20-30 miles
- [ ] 30 or more miles

6. What type of toll did you pay for this trip? (Check one)

- [ ] Exact change
- [ ] Cash - Other
- [ ] 30-Day sticker
- [ ] Carpool ticket
- [ ] Senior citizen ticket
- [ ] Other ____________

7. Where is your FINAL destination?

____
[Street address or nearest intersection]

____
[City or Town] [State] [Zip Code]

8. How long does it take you to travel from your START location to your FINAL destination? ______ minutes.

9. What is the main purpose of this trip? (Check one)

- [ ] Going to Work
- [ ] Returning from Work
- [ ] School
- [ ] Company business
- [ ] Shopping
- [ ] Medical/Personal
- [ ] Recreation/Social
- [ ] Going out to eat
- [ ] Other ____________

10. Please enter the NUMBER of times you crossed the Delaware River on each of the last seven days? (ie, If you crossed one time to get to work and another time to return home, that counts as 2 crossings on that day.)

____ Monday ____ Tuesday ____ Wednesday ____ Thursday ____ Friday ____ Saturday ____ Sunday

11. Why don't you use either the PATCO Hi-Speed Line or an NJ TRANSIT bus to make this trip? (Check the most important reasons for each transit company)

PATCO	NJ TRANSIT	
[ ]	[ ]	Not close enough
[ ]	[ ]	Not frequent enough
[ ]	[ ]	Not reliable
[ ]	[ ]	Not comfortable
[ ]	[ ]	Costs more than using a car
[ ]	[ ]	Takes longer than a car
[ ]	[ ]	Too crowded
[ ]	[ ]	Car needed during the day
[ ]	[ ]	Have company car

12. How long have you been driving for this trip? ___/___ mos / yrs

13. How did you make this trip before driving? (Check one)

- [ ] Did not make this trip
- [ ] PATCO
- [ ] Carpool
- [ ] Vanpool
- [ ] Bus
- [ ] Other ____________

14. Which of the following best describes the vehicle you used on this trip? (Check one)

- 1[ ] My own car
- 2[ ] Company car
- 3[ ] My own passenger van
- 4[ ] Company van
- 5[ ] Other ______________

15. How many people, including the driver, were in your vehicle? ____ persons

16. How much do you pay to park your vehicle at your FINAL destination?

- 1[ ] Free parking provided
- 2[ ] Employer pays
- 3[ ] I pay daily charge of $ ______
- 4[ ] I pay monthly charge of $ ______

---

17. **Are you:** 1[ ] male 2[ ] female

18. **What is your age?** ____ years

19. **What is your race?** 1[ ] White 2[ ] Black 3[ ] Asian 4[ ] Other ______

20. **What is your household income per year?** (Check one)

- 1[ ] Under $10,000
- 2[ ] $10,000 - $15,000
- 3[ ] $15,000 - $25,000
- 4[ ] $25,000 - $35,000
- 5[ ] $35,000 - $50,000
- 6[ ] $50,000 - $75,000
- 7[ ] $75,000 - $100,000
- 8[ ] $100,000 or more

21. **Are you:** (Check one)

- 1[ ] Employed Full-time
- 2[ ] Employed Part-time
- 3[ ] Retired
- 4[ ] Currently Unemployed
- 5[ ] Homemaker
- 6[ ] Student

22. **What is the highest level of schooling you have completed?** (Check one)

- 1[ ] Elementary School
- 2[ ] Some High School
- 3[ ] Graduated High School
- 4[ ] Some College
- 5[ ] Graduated College
- 6[ ] Post-Graduate School
- 7[ ] Vocational School
- 8[ ] Special School
- 9[ ] Other ______

Thank you. Now please fold, seal and drop in ANY MAILBOX.
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CHAPTER VII APPENDICES:

Appendix VII-1	Regional Cordon Station Counts for 2000
Appendix VII-2	Highway Through Trips by Cordon Station
Appendix VII-3	Transit Trips by Cordon Station
Appendix VII-4	Cordon Station Factors for Disaggregating External-Internal Highway Trips to Three Time Periods
Appendix VII-5	Trip Generation Program Descriptions
Appendix VII-6	Trip Generation Model Execution Parameters
Appendix VII-7	2000 Daily Internal Trip Generation by County Planning Area
Appendix VII-8	2000 and 2005 Daily Trip Generation Summaries by Trip Purpose, County, and State

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APPENDIX VII-1 REGIONAL CORDON STATION COUNTS FOR 2000 AND 2005

Cordon Station Centroid		Cordon Station Daily Traffic Counts	
2000	**Station Location**	**2000**	**2005**
1913	Post Rd (US 13) at Delaware State Line, Marcus Hook Boro	6,089	7,060
1914	Ridge Rd at Delaware State Line, Lower Chichester Twp	7,815	8,870
1915	Naamans Creek Rd (PA 491) at Delaware State Line, Lower Chichester Twp	3,361	3,547
1916	Interstate 95 between PA 491 and Delaware State Line, Lower Chichester Twp	105,230	107,174
1917	Meetinghouse Rd between Naamanwood Dr and Delaware State Line, Upper Chichester Twp	7,544	9,661
1918	Zebley Rd between Pinecrest Dr and Delaware State Line, Bethel Twp	4,849	4,138
1919	Foulk Rd (PA 261) between Zebley Rd and Delaware State Line, Bethel Twp	7,181	8,342
1920	Ebright Rd between Red Oak Dr and Gateway Ave, Bethel Twp	3,378	4,013
1921	Wilmington-West Chester Pike (US 202) between Pyle Rd and Delaware State Line, Bethel Twp	34,945	41,904
1922	Beaver Valley Rd north of Delaware State Line, Chadds Ford Twp	602	498
1923	Smith Bridge Rd between Ridge Rd and Delaware State Line, Chadds Ford Twp	1,556	1,095
1924	Ridge Rd between Rocky Hill Rd and Smith Bridge Rd, Chadds Ford Twp	661	792

	Delaware County Total	**183,211**	**197,094**
1925	Chadds Ford Rd (PA 100 [Brookfield-Cossart Rd]) north of Delaware State Line, Pennsbury Twp	2,103	2,335
1926	Kennett Pike (PA 52) between Rain Tree Rd and Delaware State Line, Pennsbury Twp	12,242	12,935
1927	Center Mill Rd between Burnt Mill Rd and Delaware State Line, Kennett Twp	346	447
1928	Old Kennett Rd between Ashland Rd and Delaware State Line, Kennett Twp	2,180	2,723
1929	Creek Rd (PA 82) north of Delaware State Line, Kennett Twp	974	973
1930	Ewart Rd between Chandler Mill Rd and Delaware State Line, Kennett Twp	2,128	2,604
1931	Newport-Lancaster Pike (PA 41) between Kaolin Rd and Delaware State Line, Kennett Twp	13,454	14,168
1932	Limestone Rd between Southwood Rd and Delaware State Line, New Garden Twp	11,544	16,176
1933	Newark Rd between Broad Run Rd and Delaware State Line, New Garden Twp	4,911	5,299
1934	Yeatmans Station Rd between Watson Mill Rd and Delaware State Line, New Garden Twp	1,175	1,302
1935	New London Rd (PA 896) between Morgan Hollow Way and Elbow Lane, London-Britain Twp	6,963	7,825
1936	Elkton Rd just north of Maryland State Line, Franklin Twp	1,555	1,818
1937	Lewisville-Chesterville Rd (PA 841 [Westgrove-Lewisville Rd]) between Oxford-Lewisville Rd and Maryland State Line, Elk Twp	3,156	3,233
1938	State Rd between Chrome Rd and Maryland State Line	420	566

1939	Chrome-Calvert Rd (PA 272) between Greenhouse Rd and Maryland State Line, East Nottingham Twp	6,725	6,967
1940	Baltimore Pike (US 1) between West Ridge Rd and Sylmar Rd, West Nottingham Twp	8,234	8,532
1941	Freemont Rd between Pleasant Dr and Maryland State Line, West Nottingham Twp	628	775
1942	Christine Rd (PA 272) between Glenroy Rd and Chester Co Line, West Nottingham Twp	4,511	5,102
1943	Forge Rd between Street Rd and Chester Co Line, Lower Oxford Twp	659	760
1944	Lancaster Pike (PA 472) between Street Rd and Chester Co Line, Lower Oxford Twp	5,865	5,562
1945	Street Rd between Newcomers Rd and Lancaster Co Line, Upper Oxford Twp	290	323
1946	Newark Rd (PA 896) between Homeville Rd and Chester Co Line, Upper Oxford Twp	2,582	2,579
1947	Schoff Rd between Old Forge Rd and Lancaster Co Line, West Fallowfield Twp	448	479
1948	Valley Ave (PA 372) west of railroad overpass and Chester Co Line, West Sadsbury Twp	2,005	1,902
1949	Zion Rd between Zook Rd and Lancaster Co Line, West Sadsbury Twp	2,699	1,403
1950	Newport-Lancaster Pike (PA 41) between Zook Rd and Lancaster Co Line, West Sadsbury Township	15,279	15,423
1951	Strasburg Rd between Zook Rd and Lancaster Co Line, West Sadsbury Twp	1,489	1,642
1952	Lincoln Hwy (US 30) between Newlin Lane and Lancaster Co Line, West Sadsbury Twp	18,286	22,243

1953	Philadelphia Pike (PA 340) between Compass Rd (PA 10) and Lancaster Co Line, West Cain Twp	4,114	4,620
1954	Beaver Dam Rd between Cambridge Rd and Lancaster Co Line, Honey Brook Twp	572	718
1955	Main St (Cambridge Rd) between Lombard and Lancaster Co Line, Honey Brook Twp	849	724
1956	White Horse Pike (US 322) between Mill Rd and Lancaster Co Line, Honey Brook Twp	11,885	8,114
1957	Conestoga Ave (PA 10) between Reservoir Rd and Lancaster Co Line, Honey Brook Twp	7,592	8,510
1958	Morgantown Rd between Taborville Rd and Lancaster Co Line, Honey Brook Twp	1,814	1,947
1959	Pennsylvania Turnpike (I-76) between Downingtown, Int. 23-old number, and new Number 312 and Morgantown Int. old number 22 and new number 298	39,152	46,215
1960	Conestoga Rd (PA 401) in Berks Co	4,341	6,166
1961	Main St (PA 23) in Berks Co	7,364	8,060
1962	Water St (PA 82) west of intersection with Park Ave in Berks Co	924	926
1963	Pine Swamp Rd (PA 345) between Laurel Rd and Chester Co. Line, Warwick Twp	1,077	1,303
1964	Unionville Rd between Temple Rd and Berks Co Line, North Coventry Twp	758	985
1965	Schuylkill Rd (PA 724) between Scholl Rd and Berks Co Line, North Coventry Twp	4,834	5,817
	Chester County Total	**218,127**	**240,201**

1966	Pottstown Bypass (US 422) between Ben Franklin Hwy & Old Reading Pike, Douglass Twp (Berks County)	25,468	33,454
1967	Benjamin Franklin Hwy between Montgomery Co Line and US 422, Douglass Twp (Berks County)	10,918	11,975
1968	Pine Forge Rd between Douglass Dr and Woodsbrook Dr, Douglass Twp (Berks County)	906	869
1969	Reading Ave (PA 562), between Fancy Sunrise Lane and Fancy Vale Dr, Douglass Twp (Berks County)	7,116	7,747
1970	West Philadelphia Ave (PA 73) between Pond Rd and Grims Mill, Colebrookdale Twp (Berks County)	11,232	9,416
1971	PA 100 between Pit Rd and Miller St, Colebrookdale Twp (Berks County)	17,629	17,745
	Berks County Total	**73,269**	**81,206**
1972	Hoffmansville Rd between Miller Rd Berks Co Line, Douglass Twp	1,994	2,233
1973	Niantic Rd between Miller Rd and Berks Co Line, Douglass Twp	2,218	2,907
1974	Kutztown Rd between Bethesda Church Rd and Berks Co Line, Upper Hanover Twp	1,261	1,607
1975	Gravel Pike (PA 29) between Stauffer Rd and Berks Co Line, Upper Hanover Twp	10,426	11,824
1976	Wasser Rd between Ridge Way and Lehigh Co Line, Upper Hanover Twp	188	300
	Montgomery County Total	**16,087**	**18,871**

1977	Geryville Pk (Kings High Rd) between Titlow Rd and Lehigh Co Line, Milford Twp	2,493	2,791
1978	Spinnerstown Rd between Gateway Dr and Lehigh Co Line, Milford Twp	2,259	2,719
1979	PA Turnpike Northeast Ext (I-476) between Quakertown, Int. 32 old number and 44 new number and Lehigh Valley, Int. 33 old number and 56 new number, Milford Township	38,295	48,581
1980	Cassell Rd between Possum Hollow Rd and Lehigh Co Line, Milford Twp	503	577
1981	Allentown Rd between Grant Rd and Lehigh Co Line, Milford Twp	3,099	3,244
1982	Old Bethlehem Pike between Blue Church Rd and Lehigh Co Line, Springfield Twp	3,512	3,768
1983	Bethlehem Pike (PA 309) between Springfield St and Lehigh Co Line, Springfield Twp	32,466	37,834
1984	State Rd between Tumblebrook Rd and Lehigh Co Line, Springfield Twp	2,366	1,705
1985	Richlandtown Pike between Highpoint Rd and Northampton Co Line, Springfield Twp	4,822	3,923
1986	Hellertown Rd (PA 412) between Highpoint Rd and Northampton Co Line, Springfield Twp	5,022	5,984
1987	Springtown Rd between Saucon Rd and Northampton Co Line, Springfield Twp	787	997
1988	Durham Rd between Round St and Northampton Co Line, Springfield Twp	668	656
1989	Easton Rd (PA 611) between Spring Hill and Northampton Co Line, Riegelsville Boro	5,786	5,002
1990	Riegelsville Bridge across Delaware River, Riegelsville Boro	4,055	3,133

1991	Milford-Upper Black Eddy Bridge across Delaware River, Bridgeton Twp	4,284	3,674
1992	Frenchtown-Uhlerstown Bridge across Delaware River, Tinicum Twp	4,644	3,991
1993	Stockton-Centre Bridge across Delaware River, Solebury Twp	5,064	4,846
1994	New Hope-Lambertville Toll Bridge (US-202) over Delaware River, Solebury Twp	9,779	11,145
1995	Bridge St Bridge (PA 179) across Delaware River, New Hope Boro	15,949	13,191
	Bucks County Total	**145,853**	**157,761**
	PENNSYLVANIA TOTAL	**636,547**	**695,133**
	NEW JERSEY		
1996	River Rd (NJ 29) between Valley Rd and Hunterdon Co Line, Hopewell Twp	12,571	10,721
1997	Hunter Rd between Pleasant Valley Rd and Hunterdon Co Line, Hopewell Twp	1,200	1,100
1998	Lambertville-Hopewell Rd (CR 518) between Harbourton-Mt Airy Rd (CR 601) and Hunterdon Co Line, Hopewell Twp	5,843	4,887
1999	Harbourton-Rocktown Rd (CR 579) between Lambertville-Hopewell Rd (CR 518) and Hunterdon Co Line, Hopewell Twp	5,126	7,390
2000	NJ 31 just north of intersection with Lambertville-Hopewell Rd (CR 518), Hopewell Twp	16,138	15,333
2001	Hopewell-Wertsville Rd (CR 607) between Minnietown Lane and Hunterdon Co Line, Hopewell Twp	3,751	3,407
2002	Hopewell-Rocky Hill Rd (CR 518) between Hopewell-Amwell Rd and Somerset Co Line, Hopewell Twp	14,120	11,122

2003	Great Rd (CR 601) north of Cherry Valley Rd Somerset Co Line), Somerset Co	9,170	9,129
2004	US 206 (CR 533), north of Cherry Valley Rd (Somerset Co Line), Somerset Co	22,826	20,616
2005	Princeton Ave, east of Cherry Valley Rd Somerset Co	5,190	7,888
2006	River Rd (CR 605) between Herrontown Rd and Somerset Co Line, Princeton Twp	2,764	4,928
2007	Lincoln Hwy (NJ 27) between Dodds La and Middlesex Co Line, Princeton Twp	11,755	14,002
2008	Brunswick Pike (US 1) between Harrison St S (CR 629) and Middlesex Co Line West Windsor Twp	74,571	84,210
2009	Cranbury Rd (CR 615) between Rabbit Hill Rd and Middlesex Co Line, West Windsor Twp	5,783	6,930
2010	Southfield Rd between Sheridan Dr and Middlesex Co Line, West Windsor Twp	4,311	4,219
2011	Old Trenton Rd (CR 535 [Cranbury-Edinburg]) between One Mile Rd and Middlesex Co Line, East Windsor Twp	8,739	11,163
2012	US 130, between Old Cranbury Rd and Middlesex Co Line, East Windsor Twp	29,589	25,209
2013	North Main Street (CR 539), between Old Cranberry Rd and Middlesex Co Line, East Windsor Twp	7,798	6,966
2014	NJ Turnpike between Interchanges 8 and 8A, East Windsor Twp	123,900	135,596
2015	Freehold Rd, (NJ 33) between Mercer Co Line and Applegarth Rd, Middlesex Co	24,098	27,467
2016	Etra Rd (CR 571) between Fieldsher Rd and Monmouth Co Line, East Windsor Twp	4,509	4,097

2017	Herbert Rd east of Monmouth Co Line, Monmouth Co	5,685	3,436
2018	Interstate 195 east of Interchange 8, Monmouth Co	37,545	47,972
2019	Robbinsville-Allentown Rd (CR 526) between Circle Dr and Monmouth Co Line, Washington Twp	13,614	8,115
2020	Yardville-Allentown Rd (CR 524) between Doctors Creek Rd and Mercer/ Monmouth Co Line, Hamilton Township	2,208	5,224
2021	Old York Rd between Hidden Hollow Rd and Monmouth Co Line, Hamilton Twp	1,555	1,840
	Mercer County Total	**454,359**	**482,967**
2022	Ellisdale Rd between Orr/Extonville Rd and Province Line Rd (Monmouth Co Line), North Hanover Twp	540	490
2023	Chesterfield-Arneytown Rd (CR 664) between Jacobtown-Arneytown Rd Monmouth Co Line, North Hanover Twp	1,371	2,435
2024	Monmouth Rd (CR 537) between Meany Rd and Monmouth/Ocean Co Line, North Hanover Twp	7,061	6,984
2025	Jacobstown-New Egypt Rd (CR 528) between Meany Rd and Ocean Co Line, North Hanover Twp	4,125	4,401
2026	Cookstown-New Egypt Rd (CR 528 Spur) between Mary St and Ocean Co Line, North Hanover Twp	5,128	5,072
2027	Bunting Bridge Rd between Brindletown Rd and Ocean Co Line, North Hanover Twp	1,607	1,449
2028	NJ 70 between Lakehurst Rd (CR 530) and Ocean Co Line, Pemberton Twp	9,928	9,829
2029	Barnegat Rd (NJ 72) between Stephenson Rd and Ocean Co Line, Woodland Twp	7,038	7,779

2030	Andrews Rd between Munion Field Rd and Ocean Co Line, Bass River Twp	300	300
2031	Garden State Prkwy between Bass River State Forest Tollgate and Ocean Co Line, Bass River Twp	58,800	47,676
2032	Stage Rd between Munion Field Rd and Ocean Co Line, Bass River Twp	1,878	1,197
2033	US 9 between Ash Rd and Ocean Co Line, Bass River Twp	10,340	10,103
2034	Garden State Prkwy between Int. 50S and Atlantic Co Line, Bass River Twp	57,700	55,559
2035	CR 563 between CR 542 and Atlantic Co Line, Washington Twp	732	904
2036	Batsto-Bridgeport Rd (CR 542) between Elmwood-Batsto Rd and Atlantic Co Line, Washington Twp	2,502	2,416
2037	US 206 north of Atlantic Co Line, Shamong Twp	12,128	12,288
	Burlington County Total	**181,178**	**168,882**
2038	Chew Rd (CR 536) between Causeway Rd and Atlantic Co Line, Waterford Twp	1,042	930
2039	Union Rd between Walker Rd and Atlantic Co Line, Winslow Twp	404	486
2040	White Horse Pike (US 30) between Walker Rd and Atlantic Co Line, Winslow Twp	12,310	12,766
2041	Wiltseys Mill Rd (CR 724) between Lexington Ave and Atlantic Co Line, Winslow Twp	2,111	2,701
2042	Cedarbrook Rd (CR 561) between Laurel Ave and Atlantic Co Line, Winslow Twp	5,430	4,733
2043	Atlantic City Expressway at Mile Post 42, Winslow Twp	49,063	44,199

2044	Mays Landing Rd (CR 561 Spur) between Cains Mill Rd and Atlantic Co Line, Winslow Twp	5,556	5,000
	Camden County Total	**75,916**	**70,815**
2045	Black Horse Pike (US 322) between Hospitality Rd and Atlantic Co Line, Monroe Twp	12,263	11,467
2046	Jackson Rd between Dutch Mill Rd and Atlantic Co Line, Monroe Twp	541	283
2047	Harding Hwy (US 40) just east of Tuckahoe Rd (CR 557), Atlantic Co	8,345	9,426
2048	Main Rd (CR 555) between Garden Rd and Cumberland Co Line, Franklin Twp	9,262	10,374
2049	West Boulevard (CR 615) between Catawba Av (CR 661) and Cumberland Co Line, Newfield Boro	5,381	4,744
2050	Old Delsea Dr (NJ 47) between Malaga Terr and Cumberland Co Line, Franklin Twp	10,172	7,169
2051	NJ 55 Freeway between US 40 Int. and Salem Co Line, Franklin Twp	35,100	37,177
2052	Harding Hwy (US 40) between Porchtown Rd (CR 613) and Salem Co Line, Franklin Twp	12,593	17,331
2053	Willow Grove Rd between Taylor Rd and Salem Co Line, Franklin Twp	766	744
2054	Buck Rd (CR 553) between Garrison Rd and Salem Co Line, Franklin Twp	5,124	5,677
2055	Monroeville Rd (CR 604) between Dutch Row Rd and Salem Co Line, Elk Twp	1,676	2,211
2056	Elmer-Barnsboro Rd (CR 609) between Elk Rd (CR 538) and Salem Co Line, Elk Twp	1,407	1,343
2057	Bridgeton Pike (NJ 77) between Ferrell Rd (CR 641) and Salem Co Line, Elk Twp	5,530	5,886

2058	Monroeville Rd (CR 694) between Lincoln Rd and Salem Co Line, South Harrison Twp	1,897	2,725
2059	Commissioners Rd (CR 581) between Lincoln Rd and Salem Co Line, South Harrison Twp	1,472	917
2060	Mullica Hill Rd (CR 617) between Marl Rd and Salem Co Line, South Harrison Twp	789	766
2061	Woodstown-Mullica Hill Rd (NJ 45) between Marl Rd and Salem Co Line, South Harrison Twp	3,183	3,764
2062	Woodstown Rd (CR 605) between Oliphant's Mill/Porches Mill Rd and Salem Co Line, South Harrison Twp	2,958	3,743
2063	NJ Turnpike between Interchanges 2 and 1, Woolwich Twp	42,912	36,398
2064	Auburn Rd (CR 551) between Moravian Church Rd and Salem Co Line, Woolwich Twp	1,979	2,112
2065	Interstate 295 between Center Square Rd (CR 620) Int. and Salem Co Line, Logan Twp	49,728	37,175
2066	Pedricktown-Center Square Rd (CR 601) between Harrison Rd (CR 602) and Salem Co Line, Logan Twp	1,393	1,702
2067	US 130 between Center Square Rd (CR 620) and Salem Co Line, Logan Twp	7,946	5,769
	Gloucester County Total	**222,417**	**208,903**
	NEW JERSEY TOTAL	**933,870**	**931,567**
2068	Philadelphia International Airport	68,268	71,000
	REGIONAL TOTAL	**1,570,417**	**1,626,700**

APPENDIX VII-2 HIGHWAY THROUGH TRIPS BY CORDON STATION

Note: The numbers in this table contain slight difference between the numbers in **Appendix VII-1** and the summary figures presented in the tables in **Chapter VII** due to updates and rounding errors.

					2000 Through Trips Per Day			
	Hwy	2000	Percent	Through	Light Trucks		Heavy Trucks	
Station Location	Type	Total	Through	Trips	Percent	Volume	Percent	Volume
PENNSYLVANIA								
Delaware County:								
Post Rd (US 13) at Delaware State Line, Marcus Hook Boro	2	6,089	1.0%	63	9.5%	6	14.3%	9
Ridge Rd at Delaware State Line, Lower Chichester Twp	2	7,815	0.8%	64	9.4%	6	9.4%	6
Naamans Creek Rd (PA 491) at Delaware State Line, Lower Chichester Twp	2	3,361	1.0%	34	8.9%	3	14.9%	5
Interstate 95 between PA 491 and Delaware State Line, Lower Chichester Twp	1	105,230	8.2%	8,578 16,344*	7.7%	662	17.3%	1,485
Meetinghouse Rd between Naamanwood Dr and Delaware State Line, Upper Chichester Twp	2	7,544	1.0%	72	9.7%	7	12.5%	9
Zebley Rd between Pinecrest Dr and Delaware State Line, Bethel Twp	3	4,849	0.8%	38	10.5%	4	10.5%	4
Foulk Rd (PA 261) between Zebley Rd and Delaware State Line, Bethel Twp	2	7,181	2.0%	142	8.5%	12	10.6%	15
Ebright Rd between Red Oak Dr and Gateway Ave, Bethel Twp	3	3,378	0.8%	27	7.4%	2	7.4%	2
Wilmington-West Chester Pike (US 202) between Pyle Rd and Delaware State Line, Bethel Twp	2	34,945	7.1%	2,469	6.9%	171	23.5%	579
Beaver Valley Rd north of Delaware State Line, Chadds Ford Twp	3	602	0.8%	5	0.0%	0	0.0%	0
Smith Bridge Rd between Ridge Rd and Delaware State Line, Chadds Ford Twp	3	1,556	0.9%	14	14.3%	2	14.3%	2
Ridge Rd between Rocky Hill Rd and Smith Bridge Rd, Chadds Ford Twp	3	661	0.6%	4	0.0%	0	0.0%	0
Total		183,211	6.28%	11,510	7.60%	875	18.38%	2,116

Chester County:

Chadds Ford Rd (PA 100 [Brookfield-Cossart Rd]) north of Delaware State Line, Pennsbury Twp	2	2,103	1.2%	26	11.5%	3	11.5%	3
Kennett Pike (PA 52) between Rain Tree Rd and Delaware State LIne, Pennsbury Twp	2	12,242	3.0%	365	8.5%	31	8.8%	32
Center Mill Rd between Burnt Mill Rd and Delaware State Line, Kennett Twp	3	446	0.9%	4	0.0%	0	0.0%	0
Old Kennett Rd between Ashland Rd and Delaware State Line, Kennett Twp	3	2,180	0.9%	19	10.5%	2	15.8%	3
Creek Rd (PA 82) north of Delaware State Line, Kennett Twp	3	974	1.0%	10	20.0%	2	0.0%	0
Ewart Rd between Chandler Mill Rd and Delaware State Line, Kennett Twp	3	2,128	0.8%	18	11.1%	2	11.1%	2
Newport-Lancaster Pike (PA 41) between Kaolin Rd and Delaware State Line, Kennett Twp	2	13,454	33.4%	4,490	4.8%	215	24.6%	1,104
Limestone Rd between Southwood Rd and Delaware State Line, New Garden Twp	2	11,544	20.6%	2,381	5.8%	138	19.5%	465
Newark Rd between Broad Run Rd and Delaware State Line, New Garden Twp	3	4,911	0.8%	41	14.6%	6	7.3%	3
Yeatmans Station Rd between Watson Mill Rd and Delaware State Line, New Garden Twp	3	1,175	0.7%	8	37.5%	3	0.0%	0
New London Rd (PA 896) between Morgan Hollow Way and Elbow Lane, London-Britain Twp	2	6,963	13.3%	924	8.4%	78	9.1%	84
Elkton Rd just north of Maryland State Line, Franklin Twp	3	1,555	0.6%	10	40.0%	4	10.0%	1
Lewisville-Chesterville Rd (PA 841 [Westgrove-Lewisville Rd]) between Oxford-Lewisville Rd and Maryland State Line, Elk Twp	2	3,156	24.1%	762	8.5%	65	9.6%	73

State Rd between Chrome Rd and Maryland State Line	3	520	0.8%	4	0.0%	0	0.0%	0
Chrome-Calvert Rd (PA 272) between Greenhouse Rd and Maryland State Line, East Nottingham Twp	2	6,725	21.6%	1,450	8.0%	116	8.1%	117
Baltimore Pike (US 1) between West Ridge Rd and Sylmar Rd, West Nottingham Twp	1	8,234	11.0%	905	7.3%	66	14.3%	129
Freemont Rd between Pleasant Dr and Maryland State Line, West Nottingham Twp	3	628	0.6%	4	0.0%	0	0.0%	0
Christine Rd (PA 272) between Glenroy Rd and Chester Co Line, West Nottingham Twp	2	4,511	21.4%	965	8.2%	79	9.6%	93
Forge Rd between Street Rd and Chester Co Line, Lower Oxford Twp	3	659	0.9%	6	0.0%	0	0.0%	0
Lancaster Pike (PA 472) between Street Rd and Chester Co Line, Lower Oxford Twp	2	5,865	25.8%	1,511	9.1%	138	11.6%	175
Street Rd between Newcomers Rd and Lancaster Co Line, Upper Oxford Twp	3	490	0.8%	4	0.0%	0	0.0%	0
Newark Rd (PA 896) between Homeville Rd and Chester Co Line, Upper Oxford Twp	2	2,582	21.9%	565	8.8%	50	9.6%	54
Schoff Rd between Old Forge Rd and Lancaster Co Line, West Fallowfield Twp	3	548	0.7%	4	0.0%	0	0.0%	0
Valley Ave (PA 372) west of railroad overpass and Chester Co Line, West Sadsbury Twp	2	2,005	2.0%	41	9.8%	4	14.6%	6
Zion Rd between Zook Rd and Lancaster Co Line, West Sadsbury Twp	3	2,699	0.6%	17	11.8%	2	11.8%	2
Newport-Lancaster Pike (PA 41) between Zook Rd and Lancaster Co Line, West Sadsbury Township	2	15,279	38.9%	5,949	4.4%	263	22.5%	1,336
Strasburg Rd between Zook Rd and Lancaster Co Line, West Sadsbury Twp	3	1,489	0.9%	13	15.4%	2	15.4%	2

Lincoln Hwy (US 30) between Newlin Lane and Lancaster Co Line, West Sadsbury Twp	2	18,286	8.5%	1,557 2,205*	5.8%	90	19.2%	299
Philadelphia Pike (PA 340) between Compass Rd (PA 10) and Lancaster Co Line, West Cain Twp	2	4,114	5.1%	210	7.1%	15	14.3%	30
Beaver Dam Rd between Cambridge Rd and Lancaster Co Line, Honey Brook Twp	3	572	1.0%	6	0.0%	0	0.0%	0
Main St (Cambridge Rd) between Lombard and Lancaster Co Line, Honey Brook Twp	3	849	0.7%	6	0.0%	0	0.0%	0
White Horse Pike (US 322) between Mill Rd and Lancaster Co Line, Honey Brook Twp	2	11,885	4.9%	586	6.5%	38	16.0%	94
Conestoga Ave (PA 10) between Reservoir Rd and Lancaster Co Line, Honey Brook Twp	2	7,592	14.2%	1,077	7.0%	75	15.9%	171
Morgantown Rd between Taborville Rd and Lancaster Co Line, Honey Brook Twp	3	1,814	1.0%	18	11.0%	2	16.5%	3
Pennsylvania Turnpike (I-76) between Downingtown, Int. 23 old umber and 312 new number and Morgantown Int. 22 old number and 298 new number	4	39,152	21.6%	8,458 13,872*	6.6%	560	22.1%	1,870
Conestoga Rd (PA 401) in Berks Co	2	4,341	4.9%	213	6.6%	14	9.9%	21
Main St (PA 23) in Berks Co	2	7,364	4.9%	360	7.5%	27	13.3%	48
Water St (PA 82) west of intersection with Park Ave in Berks Co	3	924	4.3%	40	7.5%	3	10.0%	4
Pine Swamp Rd (PA 345) between Laurel Rd and Chester Co. Line, Warwick Twp	3	1,077	2.1%	23	8.7%	2	17.4%	4
Unionville Rd between Temple Rd and Berks Co Line, North Coventry Twp	3	758	0.9%	7	28.6%	2	0.0%	0
Schuylkill Rd (PA 724) between Scholl Rd and Berks Co Line, North Coventry Twp	2	4,834	4.1%	198	7.6%	15	11.1%	22
Total		218,627	15.21%	33,255	6.35%	2,112	18.79%	6,250

Berks County:								
Pottstown Bypass (US 422) between Ben Franklin Hwy & Old Reading Pike, Douglass Twp (Berks County)	1	25,468	5.4%	1,383 2,031*	6.44%	89	15.0%	208
Benjamin Franklin Hwy between Montgomery Co Line and US 422, Douglass Twp (Berks County)	2	10,918	4.1%	443	6.5%	29	14.4%	64
Pine Forge Rd between Douglass Dr and Woodsbrook Dr, Douglass Twp (Berks County)	3	906	0.9%	8	25.0%	2	0.0%	0
Reading Ave (PA 562), between Fancy Sunrise Lane and Fancy Vale Dr, Douglass Douglass Twp (Berks County)	2	7,116	3.0%	212	6.6%	14	8.5%	18
West Philadelphia Ave (PA 73) between Pond Rd and Grims Mill, Colebrookdale Twp (Berks County)	2	11,232	5.9%	659	6.5%	43	12.1%	80
PA 100 between Pit Rd and Miller St, Colebrookdale Twp (Berks County)	1	17,629	11.1%	1,955	6.9%	134	15.5%	303
Total		73,269	6.36%	4,660	6.67%	311	14.44%	673
Montgomery County:								
Hoffmansville Rd between Miller Rd Berks Co Line, Douglass Twp	3	1,994	1.0%	20	10.0%	2	15.0%	3
Niantic Rd between Miller Rd and Berks Co Line, Douglass Twp	3	2,218	0.8%	18	11.1%	2	11.1%	2
Kutztown Rd between Bethesda Church Rd and Berks Co Line, Upper Hanover Twp	3	1,261	0.9%	11	18.2%	2	18.2%	2
Gravel Pike (PA 29) between Stauffer Rd and Berks Co Line, Upper Hanover Twp	2	10,426	2.9%	299	6.7%	20	13.0%	39
Wasser Rd between Ridge Way and Lehigh Co Line, Upper Hanover Twp	3	388	0.5%	2	0.0%	0	0.0%	0
Total		16,287	2.15%	350	7.43%	26	13.14%	46

Bucks County:

Geryville Pk (Kings High Rd) between Titlow Rd and Lehigh Co Line, Milford Twp	3	2,493	0.8%	19	10.5%	2	10.5%	2
Spinnerstown Rd between Gateway Dr and Lehigh Co Line, Milford Twp	3	2,259	0.8%	18	16.6%	3	11.1%	2
PA Turnpike Northeast Ext (I-476) between Quakertown, Int. 32 old number and 44 new number and Lehigh Valley, Int. 33 old number and 56 new number	4	38,295	17.1%	6,543 7,189*	6.2%	403	22.0%	1,438
Cassell Rd between Possum Hollow Rd and Lehigh Co Line, Milford Twp	3	503	0.8%	4	0.0%	0	0.0%	0
Allentown Rd between Grant Rd and Lehigh Co Line, Milford Twp	3	3,099	1.0%	31	9.7%	3	6.5%	2
Old Bethlehem Pike between Blue Church Rd and Lehigh Co Line, Springfield Twp	3	3,512	5.0%	177	5.1%	9	2.8%	5
Bethlehem Pike (PA 309) between Springfield St and Lehigh Co Line, Springfield Twp	2	32,466	4.0%	1,285	6.5%	84	12.8%	164
State Rd between Tumblebrook Rd and Lehigh Co Line, Springfield Twp	3	2,366	4.8%	114	6.1%	7	7.0%	8
Richlandtown Pike between Highpoint Rd and Northampton Co Line, Springfield Twp	3	4,822	5.2%	250	10.4%	26	5.6%	14
Hellertown Rd (PA 412) between Highpoint Rd and Northampton Co Line, Springfield Twp	2	5,022	9.3%	469	9.0%	42	9.4%	44
Springtown Rd between Saucon Rd and Northampton Co Line, Springfield Twp	3	787	0.8%	6	0.0%	0	0.0%	0
Durham Rd between Round St and Northampton Co Line, Springfield Twp	3	668	0.6%	4	0.0%	0	0.0%	0
Easton Rd (PA 611) between Spring Hill and Northampton Co Line, Riegelsville Boro	2	5,786	23.7%	1,372	7.6%	104	10.2%	140

Riegelsville Bridge across Delaware River, Riegelsville Boro	3	4,055	18.4%	747	7.4%	55	10.8%	81
Milford-Upper Black Eddy Bridge across Delaware River, Bridgeton Twp	3	4,284	16.4%	701	10.0%	70	5.3%	37
Frenchtown-Uhlerstown Bridge across Delaware River, Tinicum Twp	3	4,644	8.2%	381	8.9%	34	6.8%	26
Stockton-Centre Bridge across Delaware River, Solebury Twp	3	5,064	6.0%	306	9.8%	30	8.5%	26
New Hope-Lambertville Toll Bridge (US-202) over Delaware River, Solebury Twp	2	10,779	4.0%	433	6.2%	27	11.1%	48
Bridge St Bridge (PA 179) across Delaware River, New Hope Boro	2	15,949	3.0%	476	9.2%	44	6.9%	33
Total		146,853	9.08%	13,336	7.07%	943	15.52%	2,070
PENNSYLVANIA TOTAL		638,247	9.89%	63,111	6.76%	4,267	17.68%	11,155
NEW JERSEY								
Mercer County:								
River Rd (NJ 29) between Valley Rd and Hunterdon Co Line, Hopewell Twp	2	12,571	8.9%	1,118	6.6%	74	11.7%	131
Hunter Rd between Pleasant Valley Rd and Hunterdon Co Line, Hopewell Twp	3	1,200	0.7%	8	25.0%	2	0.0%	0
Lambertville-Hopewell Rd (CR 518) between Harbourton-Mt Airy Rd (CR 601) and Hunterdon Co Line, Hopewell Twp	2	5,843	18.0%	1,052	7.1%	75	8.4%	88
Harbourton-Rocktown Rd (CR 579) between Lambertville-Hopewell Rd (CR 518) and Hunterdon Co Line, Hopewell Twp	2	5,126	4.9%	250	7.6%	19	7.2%	18
NJ 31 just north of intersection with Lambertville-Hopewell Rd (CR 518), Hopewell Twp	2	16,138	15.0%	2,418	6.3%	153	19.8%	478
Hopewell-Wertsville Rd (CR 607) between Minnietown Lane and Hunterdon Co Line, Hopewell Twp	3	3,751	9.8%	366	7.7%	28	8.5%	31

Hopewell-Rocky Hill Rd (CR 518) between Hopewell-Amwell Rd and Somerset Co Line, Hopewell Twp	2	14,120	13.9%	1,963	6.9%	136	8.5%	166
Great Rd (CR 601) north of Cherry Valley Rd Somerset Co Line), Somerset Co	2	9,170	2.0%	185	9.2%	17	8.6%	16
US 206 (CR 533), north of Cherry Valley Rd (Somerset Co Line), Somerset Co	2	22,826	5.0%	1,134	6.8%	77	12.8%	145
Princeton Ave, east of Cherry Valley Rd Somerset Co	3	5,190	1.9%	100	9.0%	9	6.0%	6
River Rd (CR 605) between Herrontown Rd and Somerset Co Line, Princeton Twp	3	2,764	0.9%	24	8.3%	2	12.5%	3
Lincoln Hwy (NJ 27) between Dodds La and Middlesex Co Line, Princeton Twp	2	11,755	2.0%	237	6.8%	16	10.1%	24
Brunswick Pike (US 1) between Harrison St S (CR 629) and Middlesex Co Line West Windsor Twp	2	74,571	6.0%	4,461	6.2%	275	28.4%	1,265
Cranbury Rd (CR 615) between Rabbit Hill Rd and Middlesex Co Line, West Windsor Twp	2	5,783	0.8%	44	9.1%	4	6.8%	3
Southfield Rd between Sheridan Dr and Middlesex Co Line, West Windsor Twp	3	4,311	0.7%	32	18.8%	6	9.4%	3
Old Trenton Rd (CR 535 [Cranbury-Edinburg]) between One Mile Rd and Middlesex Co Line, East Windsor Twp	2	8,739	2.8%	244	8.2%	20	7.4%	18
US 130, between Old Cranbury Rd and Middlesex Co Line, East Windsor Twp	2	29,589	7.9%	2,339	6.7%	157	13.9%	326
North Main Street (CR 539), between Old Cranberry Rd and Middlesex Co Line, East Windsor Twp	2	7,798	13.5%	1,053	7.5%	79	12.0%	126
NJ Turnpike between Interchanges 8 and 8A, East Windsor Twp	4	123,900	43.2%	53,500	6.0%	3,217	19.3%	10,335
Freehold Rd, (NJ 33) between Mercer Co Line and Applegarth Rd, Middlesex Co	2	24,098	9.0%	2,177	7.8%	169	9.4%	204

Etra Rd (CR 571) between Fieldsher Rd and Monmouth Co Line, East Windsor Twp	2	4,509	2.1%	94	9.6%	9	8.5%	8
Herbert Rd east of Monmouth Co Line, Monmouth Co	2	5,685	2.0%	112	6.3%	7	10.7%	12
Interstate 195 east of Interchange 8, Monmouth Co	1	37,545	14.1%	5,287	6.1%	325	13.8%	729
Robbinsville-Allentown Rd (CR 526) between Circle Dr and Monmouth Co Line, Washington Twp	2	13,614	6.0%	821	8.6%	71	8.4%	69
Yardville-Allentown Rd (CR 524) between Doctors Creek Rd and Mercer/ Monmouth Co Line, Hamilton Township	3	2,208	3.0%	67	7.5%	5	10.4%	7
Old York Rd between Hidden Hollow Rd and Monmouth Co Line, Hamilton Twp	3	1,555	0.6%	10	30.0%	3	0.0%	0
Total		454,359	17.41%	79,096	6.26%	4,955	17.97%	14,211
Burlington County:								
Ellisdale Rd between Orr/Extonville Rd and Province Line Rd (Monmouth Co Line), North Hanover Twp	3	540	0.7%	4	0.0%	0	0.0%	0
Chesterfield-Arneytown Rd (CR 664) between Jacobtown-Arneytown Rd Monmouth Co Line, North Hanover Twp	3	1,371	0.9%	13	15.4%	2	15.4%	2
Monmouth Rd (CR 537) between Meany Rd and Monmouth/Ocean Co Line, North Hanover Twp	2	7,061	2.0%	140	5.7%	8	10.7%	15
Jacobstown-New Egypt Rd (CR 528) between Meany Rd and Ocean Co Line, North Hanover Twp	2	4,125	1.0%	41	7.3%	3	12.2%	5
Cookstown-New Egypt Rd (CR 528 Spur) between Mary St and Ocean Co Line, North Hanover Twp	2	5,128	1.0%	52	5.8%	3	11.5%	6
Bunting Bridge Rd between Brindletown Rd and Ocean Co Line, North Hanover Twp	3	1,607	0.6%	10	30.0%	3	0.0%	0
NJ 70 between Lakehurst Rd (CR 530) and Ocean Co Line, Pemberton Twp	2	9,928	11.0%	1,090	6.1%	66	16.6%	181

Barnegat Rd (NJ 72) between Stephenson Rd and Ocean Co Line, Woodland Twp	2	7,038	6.0%	422	5.9%	25	11.1%	47
Andrews Rd between Munion Field Rd and Ocean Co Line, Bass River Twp	3	400	0.5%	2	0.0%	0	0.0%	0
Garden State Prkwy between Bass River State Forest Tollgate and Ocean Co Line, Bass River Twp	4	58,800	97.4%	57,260	7.1%	4,056	15.1%	8,642
Stage Rd between Munion Field Rd and Ocean Co Line, Bass River Twp	3	1,878	0.7%	14	14.3%	2	14.3%	2
US 9 between Ash Rd and Ocean Co Line, Bass River Twp	2	10,340	75.6%	7,812	7.5%	588	9.4%	733
Garden State Prkwy between Int. 50S and Atlantic Co Line, Bass River Twp	4	57,700	98.2%	56,668	7.0%	3,988	15.0%	8,520
CR 563 between CR 542 and Atlantic Co Line, Washington Twp	3	732	9.2%	67	9.0%	6	9.0%	6
Batsto-Bridgeport Rd (CR 542) between Elmwood-Batsto Rd and Atlantic Co Line, Washington Twp	3	2,502	62.6%	1,566	9.1%	142	14.1%	221
US 206 north of Atlantic Co Line, Shamong Twp	2	12,128	20.0%	2,430	6.5%	157	12.7%	309
Total		181,278	70.38%	127,591	7.09%	9,049	14.65%	18,689
Total (Does not include stations 2031 and 2034)		64,778	21.09%	13,663	7.36%	1,005	11.2%	1,527
Camden County:								
Chew Rd (CR 536) between Causeway Rd and Atlantic Co Line, Waterford Twp	3	1,042	3.9%	41	14.6%	6	19.5%	8
Union Rd between Walker Rd and Atlantic Co Line, Winslow Twp	3	404	0.5%	2	0.0%	0	0.0%	0
White Horse Pike (US 30) between Walker Rd and Atlantic Co Line, Winslow Twp	2	12,310	9.0%	1,110	6.5%	72	11.2%	124
Wiltseys Mill Rd (CR 724) between Lexington Ave and Atlantic Co Line, Winslow Twp	3	2,111	0.9%	19	15.8%	3	10.5%	2

Cedarbrook Rd (CR 561) between Laurel Ave and Atlantic Co Line, Winslow Twp	2	5,430	2.0%	110	8.2%	9	7.3%	8
Atlantic City Expressway at Mile Post 42, Winslow Twp	4	49,063	11.0%	5,395 6,161*	6.1%	328	13.4%	721
Mays Landing Rd (CR 561 Spur) between Cains Mill Rd and Atlantic Co Line, Winslow Twp	2	5,556	2.0%	111	5.4%	6	13.5%	15
Total		75,916	8.94%	6,788	6.25%	424	12.93%	878
Gloucester County:								
Black Horse Pike (US 322) between Hospitality Rd and Atlantic Co Line, Monroe Twp	2	12,263	6.1%	745	5.8%	43	17.7%	132
Jackson Rd between Dutch Mill Rd and Atlantic Co Line, Monroe Twp	3	541	0.7%	4	0.0%	0	0.0%	0
Harding Hwy (US 40) just east of Tuckahoe Rd (CR 557), Atlantic Co	2	8,345	30.5%	2,546	6.8%	174	14.1%	360
Main Rd (CR 555) between Garden Rd and Cumberland Co Line, Franklin Twp	2	9,262	3.0%	279	7.2%	20	9.7%	27
West Boulevard (CR 615) between Catawba Av (CR 661) and Cumberland Co Line, Newfield Boro	3	5,381	1.0%	52	7.7%	4	7.7%	4
Old Delsea Dr (NJ 47) between Malaga Terr and Cumberland Co LIne, Franklin Twp	2	10,172	5.0%	508	9.3%	47	9.4%	48
NJ 55 Freeway between US 40 Int. and Salem Co Line, Franklin Twp	1	35,100	20.9%	7,320 8,204*	4.8%	355	18.6%	1,358
Harding Hwy (US 40) between Porchtown Rd (CR 613) and Salem Co Line, Franklin Twp	2	12,593	27.1%	3,414	7.0%	239	14.0%	479
Willow Grove Rd between Taylor Rd and Salem Co Line, Franklin Twp	3	766	0.7%	5	0.0%	0	0.0%	0
Buck Rd (CR 553) between Garrison Rd and Salem Co Line, Franklin Twp	2	5,124	1.0%	53	7.5%	4	13.2%	7

Monroeville Rd (CR 604) between Dutch Row Rd and Salem Co Line, Elk Twp	3	1,676	1.1%	18	11.1%	2	11.1%	2
Elmer-Barnsboro Rd (CR 609) between Elk Rd (CR 538) and Salem Co Line, Elk Twp	3	1,407	0.9%	12	16.7%	2	16.7%	2
Bridgeton Pike (NJ 77) between Ferrell Rd (CR 641) and Salem Co Line, Elk Twp	3	5,530	10.1%	556	8.8%	49	22.1%	123
Monroeville Rd (CR 694) between Lincoln Rd and Salem Co Line, South Harrison Twp	3	1,897	0.8%	16	12.5%	2	12.5%	2
Commissioners Rd (CR 581) between Lincoln Rd and Salem Co Line, South Harrison Twp	3	1,472	1.2%	17	11.8%	2	11.8%	2
Mullica Hill Rd (CR 617) between Marl Rd and Salem Co Line, South Harrison Twp	3	789	0.8%	6	0.0%	0	0.0%	0
Woodstown-Mullica Hill Rd (NJ 45) between Marl Rd and Salem Co Line, South Harrison Twp	2	3,183	3.0%	96	7.3%	7	11.5%	11
Woodstown Rd (CR 605) between Oliphant's Mill/Porches Mill Rd and Salem Co Line, South Harrison Twp	3	2,958	0.8%	23	8.7%	2	8.7%	2
NJ Turnpike between Interchanges 2 and 1, Woolwich Twp	4	42,912	84.0%	36,035	5.9%	2,144	19.3%	6,947
Auburn Rd (CR 551) between Moravian Church Rd and Salem Co Line, Woolwich Twp	3	1,979	1.0%	19	10.5%	2	10.5%	2
Interstate 295 between Center Square Rd (CR 620) Int. and Salem Co Line, Logan Twp	1	49,728	15.0%	7,443 7,739*	6.2%	464	21.9%	1,633
Pedricktown-Center Square Rd (CR 601) between Harrison Rd (CR 602) and Salem Co Line, Logan Twp	3	1,393	0.6%	8	25.0%	2	25.0%	2
US 130 between Center Square Rd (CR 620) and Salem Co Line, Logan Twp	2	7,946	3.0%	239	7.9%	19	12.6%	30
Total		222,417	26.71%	59,414	6.03%	3,583	18.81%	11,173

NEW JERSEY TOTAL	933,970	29.22%	272,889	6.60%	18,011	16.47%	44,951
NEW JERSEY TOTAL (Does not include stations 2031 and 2034)	817,470	19.45%	158,961	6.27%	9,967	17.48%	27,789
Philadelphia International Airport	1 68,268	25.0%	17,068	0.0%	0	0.0%	0
REGIONAL TOTAL	1,572,217	21.37%	336,000	6.63%	22,278	16.70%	56,106

*Includes Trips to the Philadelphia International Airport

Source: DVRPC July 2008

APPENDIX VII-3 TRANSIT TRIPS BY CORDON STATION

Station Location	Transit Mode	Transit Trips Per Day 2000 Total	2000 Ext.-Int.	2000 Through Trips	2005 Total
Post Rd (US 13) at Delaware State Line, Marcus Hook Boro	1	13,475	8,248	5,227	14,791
Ridge Rd at Delaware State Line, Lower Chichester Twp	5	2,745	2,745	0	2,779
Interstate 95 between PA 491 and Delaware State Line, Lower Chichester Chichester Twp	2	576	564	12	623
Delaware County Total		**16,796**	**11,557**	**5,239**	**18,193**
Zion Rd between Zook Rd and Lancaster Co Line, West Sadsbury Twp	1	2,434	2,212	222	2,451
Philadelphia Pike (PA 340) between Compass Rd (PA 10) and Lancaster Co Line, West Cain Twp	2	782	782	0	863
Pennsylvania Turnpike (I-76) between Downingtown, Int. 23 old number and 312 new number and Morgantown, Int. 22 old number and 298 new number	2	314	196	118	340
Chester County Total		**3,530**	**3,190**	**340**	**3,654**
Pottstown Bypass (US 422) between Ben Franklin Hwy & Old Reading Pike, Douglass Twp (Berks County)	2	128	128	0	138
Montgomery County Total		**128**	**128**	**0**	**138**
PA Turnpike Northeast Ext (I-476) between Quakertown, Int 32 old number and 44 new number and Lehigh Valley, Int. 33 old number and 56 new number	2	66	66	0	70
Bethlehem Pike (PA 309) between Springfield St and Lehigh Co Line, Springfield Twp	2	112	112	0	122

Easton Rd (PA 611) between Spring Hill and Northampton Co Ln, Riegelsville Boro	2	90	90	0	94
New Hope-Lambertville Toll Bridge - (US 202) over Delaware River, Solebury Twp	2	270	270	0	292
Bucks County Total		**538**	**538**	**0**	**578**
PENNSYLVANIA TOTAL		**20,992**	**15,413**	**5579**	**22,563**
River Rd (NJ 29) between Valley Rd and Hunterdon Co Line, Hopewell Twp	3	104	104	0	109
Brunswick Pike (US 1) between Harrison St S (CR 629) and Middlesex Co Line, West Windsor Twp	3	936	936	0	997
Cranbury Rd (CR 615) between Rabbit Hill Rd and Middlesex Co Line, West Windsor Twp	1	19,914	14,390	5,524	22,029
Southfield Rd between Sheridan Dr and & Middlesex Co Line, West Windsor Twp	4	22,012	22,012	0	25,117
NJ Turnpike between Interchanges 8 and 8A, East Windsor Twp	2	1,870	1,248	622	2,072
Mercer County Total		**44,836**	**38,690**	**6,146**	**50,324**
Cookstown-New Egypt Rd (CR 528 Spur) between Mary St and Ocean Co Line, North Hanover Twp	3	306	306	0	319
Garden State Prkwy between Bass River State Forest Tollgate and Ocean Co Line, Bass River Twp	3	462	0	462	441
US 9 between Ash Rd and Ocean Co Line, Bass River Twp	3	1,773	0	1,773	1,691
Garden State Prkwy between Int. 50S and Atlantic Co Line, Bass River Twp	3	2,235	0	2,235	2,132
Burlington County Total		4,776	306	4470	4,583
White Horse Pike (US 30) between Walker Rd and Atlantic Co Line, Winslow Twp	3	1,188	1,188	0	1,276

Cedarbrook Rd (CR 561) between Laurel Ave and Atlantic Co Line, Winslow Twp	4	2,214	2,214	0	2,835
Atlantic City Expressway at Mile Post 42, Winslow Twp	3	1,170	1,170	0	1,263
Mays Landing Rd (CR 561 Spur) between Cains Mill Rd and Atlantic Co, Line, Winslow Twp	2	764	764	0	852
Camden County Total		**5,336**	**5,336**	**0**	**6,226**
Black Horse Pike (US 322) between Hospitality Rd and Atlantic Co Line, Monroe Twp	3	80	80	0	80
West Boulevard (CR 615) between Catawba Av (CR 661) and Cumberland Co Line, Newfield Boro	3	850	850	0	900
Bridgeton Pike (NJ 77) between Ferrell Rd (CR 641) and Salem Co Line, Elk Twp	3	744	744	0	786
Woodstown Rd (CR 605) between Oliphant's Mill/Porches Mill Rd and Salem Co Line, South Harrison Twp	3	432	432	0	458
NJ Turnpike between Interchanges 2 and 1, Woolwich Twp	2	550	16	534	606
US 130 between Center Square Rd (CR 620) and Salem Co Line, Logan Twp	3	108	108	0	110
Gloucester County Total		**2,764**	**2,230**	**534**	**2,940**
NEW JERSEY TOTAL		**57,712**	**46,562**	**11,150**	**64,073**
REGIONAL TOTAL		**78,704**	**61,975**	**16,729**	**86,636**

Transit Mode legend:

1 = AMTRAK
2 = Intercity Bus Service
3 = NJ TRANSIT Bus Service
4 = NJ TRANSIT Rail Service
5 = SEPTA Rail Service

Source: DVRPC July 2008

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APPENDIX VII-4 2000 CORDON STATION FACTORS FOR DISAGGREGATING EXTERNAL-INTERNAL HIGHWAY TRIPS TO THREE TIME PERIODS

2000 Cordon Station	Time Period Percentage			Local Attraction Factor*
	Peak	Midday	Night	
1913	37.4%	33.9%	28.7%	1.0
1914	31.6%	34.1%	34.3%	1.0
1915	37.2%	31.8%	31.0%	1.0
1916	35.0%	30.6%	34.4%	1.0
1917	36.9%	32.4%	30.7%	1.0
1918	45.2%	26.2%	28.6%	41.4
1919	35.7%	35.5%	28.8%	1.0
1920	36.7%	30.0%	33.3%	41.4
1921	37.6%	34.4%	28.0%	1.0
1922	42.1%	31.7%	26.2%	41.4
1923	39.5%	36.0%	24.5%	41.4
1924	43.1%	38.8%	18.1%	41.4
1925	51.1%	28.8%	20.1%	1.0
1926	39.5%	31.6%	28.9%	1.0
1927	39.8%	30.9%	29.3%	41.4
1928	45.0%	29.6%	25.4%	41.4
1929	41.0%	32.7%	26.3%	41.4
1930	37.1%	31.4%	31.5%	41.4
1931	34.2%	33.9%	31.9%	1.0
1932	34.0%	33.6%	32.4%	1.0
1933	37.0%	30.3%	32.7%	41.4
1934	38.6%	29.8%	31.6%	41.4
1935	34.4%	32.0%	33.6%	1.0
1936	37.3%	30.5%	32.2%	41.4
1937	36.0%	31.7%	32.3%	1.0
1938	37.1%	31.0%	31.9%	41.4
1939	31.8%	35.5%	32.7%	1.0
1940	33.3%	33.9%	32.8%	1.0
1941	32.1%	29.3%	38.6%	41.4
1942	35.2%	32.5%	32.3%	1.0
1943	38.2%	28.6%	33.2%	41.4
1944	33.1%	33.7%	33.2%	1.0
1945	38.4%	32.8%	28.8%	41.4
1946	34.4%	37.9%	27.7%	1.0
1947	34.8%	28.0%	37.2%	41.4
1948	35.8%	34.6%	29.6%	1.0
1949	32.4%	33.1%	34.5%	41.4

1950	29.7%	39.1%	31.2%	1.0
1951	37.2%	33.1%	29.7%	41.4
1952	32.8%	35.3%	31.9%	1.0
1953	35.2%	32.7%	32.1%	1.0
1954	34.7%	38.7%	26.6%	41.4
1955	35.8%	30.0%	34.2%	41.4
1956	34.8%	33.2%	32.0%	1.0
1957	34.8%	37.5%	27.7%	1.0
1958	35.1%	30.6%	34.3%	41.4
1959	34.3%	30.4%	35.3%	1.0
1960	36.9%	33.6%	29.5%	1.0
1961	35.7%	39.2%	25.1%	1.0
1962	36.2%	30.3%	33.5%	41.4
1963	44.1%	25.9%	30.0%	41.4
1964	34.1%	34.0%	31.9%	41.4
1965	38.8%	31.4%	29.8%	1.0
1966	36.2%	29.5%	34.3%	1.0
1967	32.3%	33.9%	33.8%	1.0
1968	39.1%	25.2%	35.7%	41.4
1969	37.9%	32.0%	30.1%	1.0
1970	33.8%	30.8%	35.4%	1.0
1971	33.6%	33.7%	32.7%	1.0
1972	35.2%	26.8%	38.0%	41.4
1973	35.2%	28.7%	36.1%	41.4
1974	33.4%	29.6%	37.0%	41.4
1975	34.3%	32.1%	33.6%	1.0
1976	37.4%	33.0%	29.6%	41.4
1977	43.9%	23.3%	32.8%	41.4
1978	40.5%	25.2%	34.3%	41.4
1979	24.1%	25.7%	50.2%	1.0
1980	35.7%	33.7%	30.6%	41.4
1981	45.8%	22.8%	31.4%	41.4
1982	40.2%	31.6%	28.2%	40.6
1983	35.8%	31.8%	32.4%	1.0
1984	38.7%	36.7%	24.6%	41.3
1985	40.7%	31.2%	28.1%	40.5
1986	38.6%	28.2%	33.2%	1.0
1987	41.0%	29.7%	29.3%	41.4
1988	40.8%	27.4%	31.8%	41.4
1989	38.8%	31.0%	30.2%	1.0
1990	36.6%	27.4%	36.0%	41.4
1991	34.8%	36.3%	28.9%	41.4
1992	34.8%	36.3%	28.9%	41.4
1993	43.0%	31.0%	26.0%	47.4
1994	35.4%	33.0%	31.6%	1.0
1995	37.1%	33.6%	29.3%	1.0
1996	39.1%	35.8%	25.1%	1.0
1997	46.6%	26.3%	27.1%	41.4
1998	44.8%	26.6%	28.6%	1.0

1999	46.5%	22.9%	30.6%	1.0
2000	36.4%	33.2%	30.4%	1.0
2001	43.6%	26.2%	30.2%	37.0
2002	46.1%	29.3%	24.6%	1.0
2003	49.0%	28.6%	22.4%	1.0
2004	36.3%	35.8%	27.9%	1.0
2005	39.9%	29.5%	30.6%	74.0
2006	49.7%	26.3%	24.0%	74.0
2007	38.8%	34.1%	27.1%	1.0
2008	36.6%	32.2%	31.2%	1.0
2009	50.7%	20.6%	28.7%	1.0
2010	47.6%	26.9%	25.5%	74.0
2011	43.5%	24.5%	32.0%	1.0
2012	38.1%	33.1%	28.8%	1.0
2013	37.7%	32.2%	30.1%	1.0
2014	32.2%	31.9%	35.9%	1.0
2015	39.5%	30.0%	30.5%	1.0
2016	46.6%	23.9%	29.5%	1.0
2017	44.2%	29.3%	26.5%	1.0
2018	35.7%	33.6%	30.7%	1.0
2019	37.9%	31.9%	30.2%	1.0
2020	37.1%	38.5%	24.4%	74.0
2021	39.1%	30.4%	30.5%	74.0
2022	31.1%	35.0%	33.9%	74.0
2023	38.0%	29.0%	33.0%	74.0
2024	37.4%	34.4%	28.2%	1.0
2025	34.9%	33.6%	31.5%	1.0
2026	36.2%	33.8%	30.0%	1.0
2027	37.1%	33.0%	29.9%	74.0
2028	35.8%	33.5%	30.7%	1.0
2029	37.8%	32.3%	29.9%	1.0
2030	15.2%	60.6%	24.2%	74.0
2031	31.9%	36.8%	31.3%	1.0
2032	42.6%	28.8%	28.6%	83.9
2033	38.6%	29.7%	31.7%	1.0
2034	31.9%	36.8%	31.3%	1.0
2035	36.8%	32.5%	30.7%	77.0
2036	36.0%	32.6%	31.4%	82.7
2037	36.4%	29.8%	33.8%	1.0
2038	41.6%	26.8%	31.6%	69.3
2039	39.7%	33.6%	26.7%	74.0
2040	34.6%	35.3%	30.1%	1.0
2041	38.6%	35.0%	26.4%	74.0
2042	36.6%	35.2%	28.2%	1.0
2043	33.3%	34.4%	32.3%	1.0
2044	37.7%	32.0%	30.3%	1.0
2045	34.2%	32.3%	33.5%	1.0
2046	31.2%	48.3%	20.5%	74.0
2047	33.1%	35.5%	31.4%	1.0

2048	34.8%	33.8%	31.4%	1.0
2049	37.3%	36.5%	26.2%	74.0
2050	31.9%	35.4%	32.7%	1.0
2051	33.4%	35.7%	30.9%	1.0
2052	30.8%	37.9%	31.3%	1.0
2053	34.9%	32.4%	32.7%	74.0
2054	37.4%	27.9%	34.7%	1.0
2055	40.4%	28.2%	31.4%	68.9
2056	37.2%	34.5%	28.3%	74.0
2057	35.5%	34.6%	29.9%	69.1
2058	38.4%	26.0%	35.6%	74.0
2059	39.9%	28.5%	31.6%	70.9
2060	39.3%	35.3%	25.4%	74.0
2061	35.8%	34.1%	30.1%	1.0
2062	41.4%	25.9%	32.7%	74.0
2063	31.7%	33.0%	35.3%	1.0
2064	38.6%	30.7%	30.7%	70.2
2065	34.5%	29.7%	35.8%	1.0
2066	36.7%	32.8%	30.5%	74.0
2067	38.5%	30.7%	30.8%	1.0
2068	33.7%	330.9%	35.4%	1.0

Source: DVRPC July 2008

** - See appendix VII-5 for definition*

APPENDIX VII-5 TRIP GENERATION PROGRAM DESCRIPTIONS

Each of the computer programs used in trip generation is now discussed in detail. They are discussed in the order of execution. ***Figure A-VII-1*** shows a schematic diagram of how the various trip generation programs interact with one another and the various input, output, and control files.

A. EXTERN00

EXTERN00 disaggregates total external travel into auto driver, light truck, and heavy truck trips. These trips are further disaggregated into external-internal and through trips. EXTERN00 divides the light and heavy truck trip ends and distributes half of each to the origin and destination data fields. EXTERN00 also produces external trip generation summaries.

B. TRIPGENA

TRIPGEN A is used to calculate the preliminary or "raw" trip productions and attractions for each internal zone. This program was updated from a previous version to include group quarters travel.

All trip purposes are calculated except external-internal auto driver productions and attractions. The program reads the zonal demographic and employment data, a set of zonal area types, and a file with trip rates (by area type and trip purpose). TRIPGEN A then produces a file of the preliminary trip quantities and summarizes these values by CPA, by state, and for the region. Special equivalency card images are used to specify the analysis areas to be summarized.

TRIPGEN A was executed with the 2000 area type, demographic, and employment data as input. The trip rate factors for each of the trip categories are shown in ***Tables VII-2***, (page 121,) ***VII-3***, (page 123) ***VII-4,*** (page 128) ***and VII-7*** (page 132). TRIPGEN A produces summary trip quantities for the 74 CPAs.

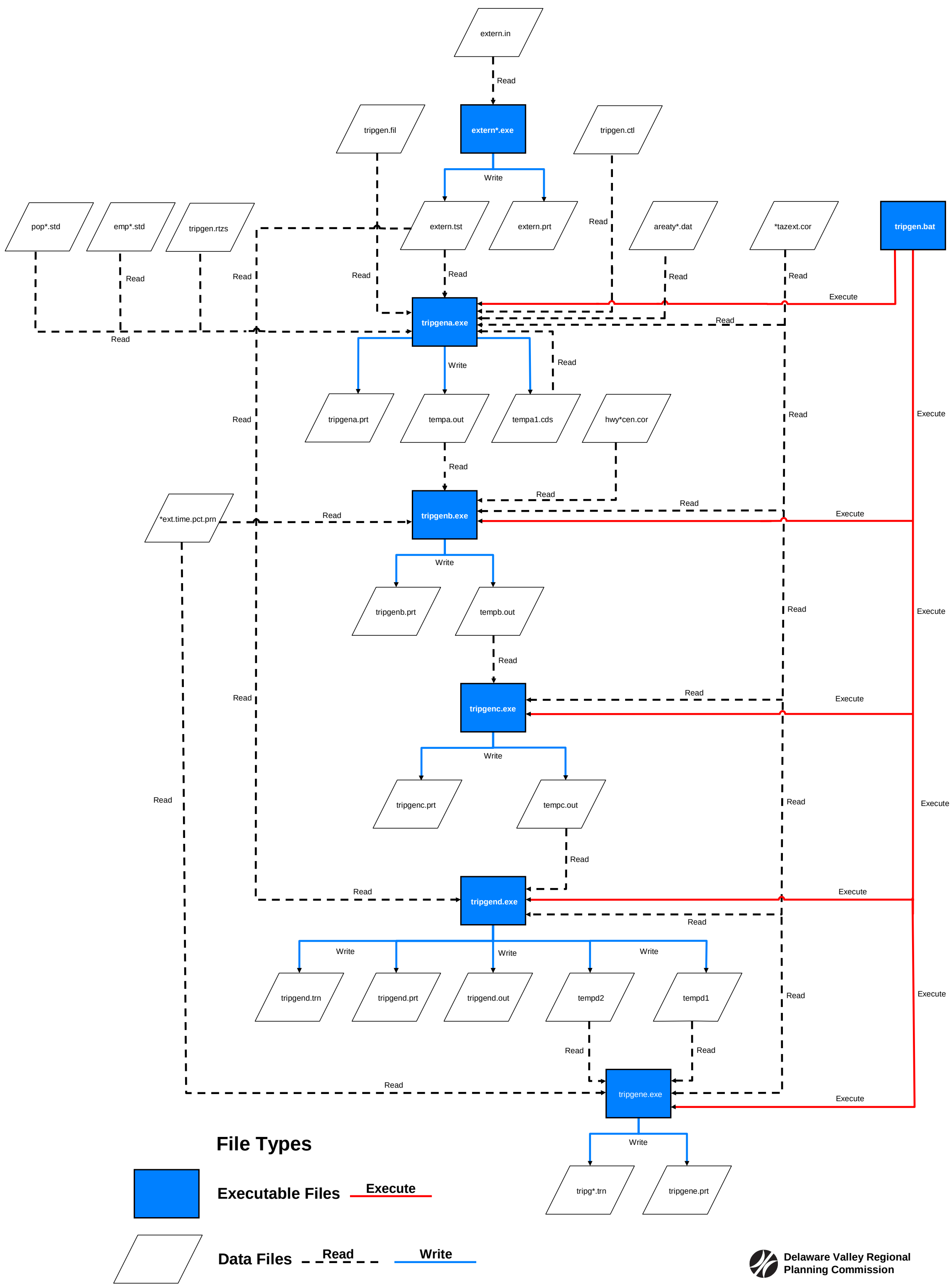

Figure A-VII-1 Trip Generation Program Flow

C. TRIPGEN B

TRIPGEN B is used to calculate a preliminary set of external-internal auto driver trip attractions (the internal trip end). This is different than EXTERN00 which is used to compute external-internal auto driver productions (the external trip end). All external-internal trips are assumed to be produced at the external stations and attracted internally. TRIPGEN B was modified from previous versions for the 2000 validation to calculate turnpike trips separately from other freeway trips as described in **Chapter II.E.4**. The model calculates external-internal attractions for turnpikes, freeways, arterials, and local facilities. These four roadway classes have significantly different trip length frequency distributions. They each have different trip distribution models, and hence require trip attractions to be calculated separately.

As in previous versions of this model, it was found that the number of external-internal auto driver trips attracted to a zone was proportional to the total number of trip ends in the zone, and inversely proportional to a function of the distance to the cordon line. TRIPGEN B computes the number of external-internal auto driver trip attractions according to the following formulas:

Freeway:

$$ELADTA = \frac{0.3370 \times TIPA}{(DIST)^{1.39}}$$

Arterial:

$$ELADTA = \frac{0.3430 \times TIPA}{(DIST)^{2.09}}$$

Local:

$$ELADTA = \frac{0.4160 \times TIPA \times LATF}{(DIST)^{3.82}}$$

Turnpike:

$$ELADTA = TIPA$$

where:

ELADTA = the preliminary number of external-internal auto driver trip attractions to a zone.

TIPA = the total number of internal person-trip productions and attractions in that zone (all trip purposes - home-based work, home based non-work, non-home based).

LATF = local external attraction factor applied to traffic zones less than 6 miles from the cordon station.

DIST = airline distance from the centroid of the zone to the closest external station in miles - computed from coordinates.

The local attraction model includes an additional attraction factor (LATF) to compensate for the lack of person trip ends in the immediate vicinity of the cordon station in the regional distribution of person trip ends. The double constraint of trip attractions in the trip distribution model produced excessive local station average trip lengths because there were not sufficient trip attractions in the regional trip generation output in the immediate vicinity of the cordon station. The LATF factor varies by local cordon depending on the availability of nearby trip attractions. **Appendix VII-4** also contains the LATF utilized in the 2000 travel simulation model validation for each local cordon station.

After the attractions are calculated with the formulas given above, the regional totals of external-internal trip attractions are normalized to the traffic counted totals of productions with the following adjustment factors:

	Peak	**Midday**	**Evening**
Freeway	0.687	0.698	1.063
Arterial	2.112	2.079	2.105
Local	0.047	0.041	0.0433
Turnpike	0.003	0.003	0.0004

Source: DVRPC July 2008

These factors vary by time period based on the interplay of the internal temporal distributions given in ***Tables VII-9*** (page 141), and ***VII-10*** (page 142), and the external cordon station values given in **Appendix VII-4**. These factors also vary into the future depending on the exact patterns of internal and external growth. Rather than re-estimate these factors for each forecast year, the TRANPLAN gravity model program automatically updates these factors and no changes to the TRIPGEN B computer program are required.

TRIPGEN B requires the output files from TRIPGEN A along with a coordinate file of centroid and station X-Y coordinates (the same as those used for plotting the highway network). TRIPGEN B writes a new file containing the estimated external-internal auto driver trip attractions. TRIPGEN B also calculates summaries of external-internal trip attractions by county, state, and region.

D. TRIPGEN C

TRIPGEN C is used to adjust the total external-internal auto driver attractions to a control total (by state) established by the external-internal auto driver productions analysis.

In previous models, TRIPGEN C performed an additional function. The program reduced the number of internal person-trips by purpose by an amount equivalent to the number of external-internal attractions. Briefly, the generalized trip rate method of producing trips (TRIPGEN A) theoretically generates all trips made by the households, not just the internal-to-internal trips. Therefore, those trips by residents of the area made externally must be subtracted from the trip totals.

E. TRIPGEN D

TRIPGEN D combines the internal-internal trip productions and attractions, the external-internal productions, and the external-internal attractions. Trips may be factored by trip purpose and by state (Pennsylvania or New Jersey) if required.

TRIPGEN D is also used to balance the trips to pre-established control values. As a result of the predicted versus actual highway screenline analysis and transit ridership checks, internal person trips were increased by 5.8 percent, except for trips associated with Delaware County, which were reduced by 4.8 percent. The Delaware County trip reduction was needed to achieve screenline validation on the Delaware Inter Cordon Line and SEPTA Victory and Frontier Division ridership checks, which tended to be overestimated.

F. TRIPGEN E

The TRIPGEN A-D programs are used to estimate daily trip productions and attractions. After the daily trip generation analysis is performed, program TRIPGEN E is applied to separate the final trip production and attraction by time period and produce the trip generation input files to the trip distribution model. This is done by applying the time period factors discussed in **Chapter VII**.

TRIPGEN E also calculates summaries of the trip generation inputs to the trip distribution models. Included are tabulations by trip purpose/vehicle type, county and state, and CPA. TRIPGEN E also produces a trip balance analysis by CPA. When the trip attractions are subtracted from the productions, a negative result indicates that the area will be importing travel. Conversely, a positive value indicates that the area will be exporting travel for that trip purpose. This difference, divided by the total number of trip ends, indicates the relative degree of importing or exporting travel. These percentages demonstrate if the area is acting as a "bedroom" community, a self-contained area, or is absorbing travel from other parts of the region. Generally, areas with high levels of economic activity, like Center City Philadelphia, the King of Prussia Mall, and industrial parks import work trips as the attractions exceed the number of productions. Predominately residential areas which act as "bedroom" communities have a surplus of work trip productions over attractions.

APPENDIX VII-6 TRIP GENERATION MODEL EXECUTION PARAMETERS

Several input files required to run the trip generation programs. These files are ASCII plain-text, editable in standard text editors. These files are described below and listed in the following table.

Trip Generation Input Files

Default File Name	Note
TRIPGEN.FIL	Input profile; can be any file name; specified as parameter from command prompt when running TRIPGEN
POP2000.STD	Population Data File
EMP2000.STD	Employment Data File
AREATY00.DAT	Area Type File
2000TAZEXT.COR	Correspondence File
EXTERN00.TST	Cordon Station External-internal File
TRIPGEN.RTZS03	Trip generation rates by trip category and area type
TRIPGEN.CTL	Flag Values File
HWY00CEN.COR	XY coordinates of highway network centroids
2000EXT.TIME.PCT.PRN	Cordon station time period percentages and external-internal multipliers

Source: DVRPC July 2008

Data values of the input files are space delimited and generally listed in rows by TAZ, except where noted below.

A. TRIPGEN Profile

The names of several other files necessary to execute TRIPGEN are specified in a profile, named TRIPGEN.FIL by default. These parameters are listed in the following table.

TRIPGEN.FIL Specifications

Row	Begin Col	End Col	Parameter	Note
1	1	4	Internal Centroid	Number of last internal centroid
1	6	9	Cordon Stations	Number of last cordon station
2	1		Population File	Reference to Population Data File Name
3	1		Employment File	Reference to Employment Data File Name
4	1		Area Type File	Reference to Area Type File Name
5	1		Correspondence File	Reference to Correspondence File Name
6	1		Cordon External-internal File	Reference to Cordon Station External-internal File Name

Source: DVRPC July 2008

The first row of TRIPGEN.FIL contains values of the last internal centroid between columns 1 and 4 and last cordon station between columns 6 and 9, both right-justified. These numbers may change when additional zones are added to the base network.

B. Population Data File

The population data file—referenced in TRIPGEN.FIL and named POP2000.STD by default—contains demographic data for each TAZ. Each line contains data for one TAZ, listed right-justified in ascending order between columns 1 and 5. Other parameters in this file, with descriptions, are listed in the table below.

Population Data File Specifications

Begin Col	End Col	Parameter	Note
1	5	TAZ	
6	8	State FIPS	2-Digit State FIPS Code
9	12	County FIPS	3-Digit County FIPS Code
13	16	1990 MCD FIPS	Old 3-Digit MCD FIPS Code (County Planning Area Number for Philadelphia)
17	24	2000 MCD Place FIPS	5-Digit MCD FIPS Code
25	31	Population	Total Population
32	38	Group Quarters	Non-Institutionalized Group Quarters Population
39	45	Households	Total Households (Occupied Dwelling Units)
46	52	Vehicles Available	Total Vehicles Available
53	59	0 Vehicle Households	
60	66	1 Vehicle Households	
67	73	2 Vehicle Households	
74	80	3+ Vehicle Households	
81	87	Employed Persons	Employed Persons at Place of Residence
88	132	Identifier	Place identifier

Source: DVRPC July 2008

C. Employment Data File

The employment data file—referenced in TRIPGEN.FIL and named EMP2000.STD by default—contains employment data for each TAZ. Each line contains data for one TAZ, listed right-justified in ascending order between columns 1 and 4. Other parameters in this file, with descriptions, are listed in the table below.

Employment Data File Specifications

Begin Col	End Col	Parameter	Note
1	4	TAZ	
5	6	State FIPS	2-Digit State FIPS Code
7	9	County FIPS	3-Digit County FIPS Code
10	12	1990 MCD FIPS	Old 3-Digit MCD FIPS Code (County Planning Area Number for Philadelphia)
13	20	2000 MCD Place FIPS	5-Digit MCD FIPS Code
21	25	Agriculture	Agriculture Sector Employment
26	30	Mining	Mining Sector Employment
31	35	Construction	Construction Sector Employment
36	40	Manufacturing	Manufacturing Sector Employment
41	45	Transportation & Utility	Transportation & Utility Sector Employment
46	50	Wholesale	Wholesale Sector Employment
51	55	Retail	Retail Sector Employment
56	60	FIRE	Finance, Insurance, and Real Estate Sector Employment
61	65	Service	Service Sector Employment
66	70	Government	Government Sector Employment
71	75	Military	Military Sector Employment
76	80	Total Employment	
81	132	Identifier	Place identifier

Source: DVRPC July 2008

D. Area Type File

The employment data file—referenced in TRIPGEN.FIL and named AREATY00.DAT by default—contains one of five area type codes for each TAZ, which are listed elsewhere in this documentation. Each of the first 50 columns contains an area type code corresponding to a TAZ, listed in ascending order and wrapped to subsequent lines. External cordon stations are included at the end of this file, each with a value of "6." The number of the TAZ for a given area type value is equal to the column in which the value is listed and added to the number of the previous row multiplied by 50.

Other columns in this file list row numbers and optional user-input identifiers, in the following format:

Area Type File Specifications

Begin Col	End Col	Parameter	Note
1	50	Area Type	Area Type for each TAZ, in numerically ascending order (50 per line, cordon stations are "6")
74	74	Identifier	User-input identifier
79	80	Row Number	

Source: DVRPC July 2008

E. Correspondence File

The correspondence file—referenced in TRIPGEN.FIL and named 2000TAZEXT.COR by default—lists each TAZ with its corresponding area type and FIPS state, county and MCD place codes, in the following format:

Correspondence File Specifications

Begin Col	End Col	Parameter	Note
5	8	TAZ	
16	16	Area Type	
23	24	State FIPS	2-Digit State FIPS Code
30	32	County FIPS	3-Digit County FIPS Code
37	41	MCD Place FIPS	5-Digit MCD Place FIPS Code
43	72	Identifier	Place identifier

Source: DVRPC July 2008

F. External-internal File

The cordon station external-internal file—referenced in TRIPGEN.FIL and named EXTERN00.TST by default—lists daily traffic volumes by facility functional class for each cordon station in the region. The file format is listed in the following table.

External-internal File Specifications

Begin Col	End Col	Parameter	Note
1	4	TAZ	Two rows for each TAZ: one each for productions and attractions in this order
16	20	Freeway Volume	Two rows for each TAZ: one each for productions and attractions in this order
22	26	Arterial Volume	Two rows for each TAZ: one each for productions and attractions in this order
28	32	Local Volume	Two rows for each TAZ: one each for productions and attractions in this order
34	38	Turnpike Volume	Two rows for each TAZ: one each for productions and attractions in this order
40	44	Light Truck Volume	Two rows for each TAZ: one each for productions and attractions in this order
46	50	Heavy Truck Volume	Two rows for each TAZ: one each for productions and attractions in this order

Source: DVRPC July 2008

G. Trip Rates File

The trip rates file—named TRIPGEN.RTZS03 -- contains trip rates (trips per unit) for variables in each of several trip categories. Each category is indicated by a “rate deck” code and is listed in the column (or columns) specified in the table below.

Trip Category Rate Deck Codes and Trip Rate Variables

Trip Category	Rate Deck	Variable	Trip Rate Col(s)
Home-Based Work Person-Trip Productions	1	Employed Residents	1
		Group Quarters Population	14
Home-Based Work Person-Trip Attractions	4	Total Employment	1-4,6-11
Home-Based Non-Work Person Trip Productions	2	Households with 0 Vehicles	1
		Households with 1 Vehicles	2
		Households with 2 Vehicles	3
		Households with 3 or More Vehicles	4
		Group Quarters Population	14
Home-Based Non-Work Person-Trip Attractions	5	Households	13
		Basic Employment	1-4,7
		Retail Employment	8
		Other Employment	6,9-11
Non-Home-Based Person-Trip Origins or Destinations	3	Households	13
		Basic Employment	1,3,4,7
		Retail Employment	8
		Other Employment	2,6,9-11
		Group Quarters Population	14
Light Truck Vehicle-Trip Origins or Destinations	6	Households	13
		Retail Employment	8
		Other Employment	1-4,6,9-12
Heavy Truck Vehicle-Trip Origins or Destinations	7	Households	13
		Manufacturing and Wholesale Employment	4,7
		Retail Employment	8
		Other Employment	1-3,6,9-12
Taxi Vehicle-Trip Origins or Destinations	8	Households	13
		Transportation Employment	6
		Retail Employment	1-4,7-12

Source: DVRPC July 2008

Trip rates are organized in the trip rate data file by area type and rate deck code in the format specified in the table below.

Trip Rates File Specifications

Begin Col	End Col	Parameter	Note
1	2	Area Type	One row each by trip category
3	4	Rate Deck	Trip category number; one row each by area type
6	10	Trip Rate Column 1	See separate table of trip rate variables by trip category
11	15	Trip Rate Column 2	See separate table of trip rate variables by trip category
16	20	Trip Rate Column 3	See separate table of trip rate variables by trip category
21	25	Trip Rate Column 4	See separate table of trip rate variables by trip category
26	30	Trip Rate Column 5	See separate table of trip rate variables by trip category
31	35	Trip Rate Column 6	See separate table of trip rate variables by trip category
36	40	Trip Rate Column 7	See separate table of trip rate variables by trip category
41	45	Trip Rate Column 8	See separate table of trip rate variables by trip category
46	50	Trip Rate Column 9	See separate table of trip rate variables by trip category
51	55	Trip Rate Column 10	See separate table of trip rate variables by trip category
56	60	Trip Rate Column 11	See separate table of trip rate variables by trip category
61	65	Trip Rate Column 12	See separate table of trip rate variables by trip category
66	70	Trip Rate Column 13	See separate table of trip rate variables by trip category
71	75	Trip Rate Column 14	See separate table of trip rate variables by trip category

Source: DVRPC July 2008

Also appended to the trip rates input file—as rate deck 10—are factors used to calculate the percentage of 0-vehicle households. These factors are formatted as follows:

Trip Rates 0-Vehicle Factor Specifications

Factors used to calculate 0-vehicle household percentage	Rate Deck		Trip Rate Col 1	Trip Rate Col 2	Trip Rate Col 3	Trip Rate Col 4
	10	Area Type 1	1.00	1.84	2.44	3.54
		Area Type 2	1.00	4.23	6.45	7.75

Source: DVRPC July 2008

H. Flag Values File

The flag values file – named TRIPGEN.CTL – contains threshold values for each area type (in order) and is used by TRIPGENA to flag trips generated by the program that may be too high for further examination in the output file, TRIPGENA.PRT.

I. Centroid Coordinates File

The centroid coordinate file, referenced in TRIPGEN.FIL and named HWY00CEN.COR by default, contains the latitude and longitude for each TAZ centroid and is used by TRIPGENC when calculating the distance of each centroid from cordon stations. The file is formatted as follows:

Centroid Coordinates File Specifications

Begin Col	End Col	Parameter	Note
1	1	Node Identifier	Always “N” to indicate node
2	6	Node Number	Centroid number
7	17	X	Longitude in travel model projection
18	28	Y	Latitude in travel model projection

Source: DVRPC July 2008

The latitude and longitude for each centroid are specified in North American Datum 1927, Transverse Mercator projection in US miles with false easting of 31068.50, false northing of –200000.00, a central meridian of –75.00, a scale factor of 99.96 and a latitude of origin of 0.00.

J. Cordon Stations File

The cordon stations file –named 2000EXT.TIME.PCT.PRN – contains the percentage of daily traffic traveling during each time period at each cordon station, in the following format:

Cordon Stations File Specification

Begin Col	End Col	Parameter	Note
1	8	Cordon Station	Node number of cordon station
9	16	Peak %	Peak period percentage of daily traffic
17	24	Midday %	Midday period percentage of daily traffic
25	32	Evening %	Evening period percentage of daily traffic
33	40	Cordon Type	Cordon Station Type (Functional Class)
41	49	Attraction Factor	External-internal Attraction Multiplier
49	50	(Unused)	“1”
51	80	Identifier	User-input identifier

Source: DVRPC July 2008

K. Executing TRIPGEN

The trip generation programs are executed from the batch file TRIPGEN.BAT, which is executed from MS-DOS or the Windows Command Prompt. The command statement is:

```
TRIPGEN
```

Each program executes sequentially and generates an output file for further examination and reporting purposes, named TRIPGEN*.PRT, where the wildcard represents the letter of the trip generation program creating the file.

The final program outputs, created by TRIPGENE, are three files, one for each time period, of productions and attractions for each zone by trip category for subsequent use by the TRANPLAN gravity model. The files, named TRIPG00*.TRN, where the wildcard represents the letter code for the (P)eak, (M)idday or (N)ight time period, are formatted as follows, consistent with TRANPLAN specifications for its gravity model input files:

TRANPLAN Gravity Model File Specification

Begin Col	End Col	Parameter	Note
1	2	Trip Type	"GP" to indicate productions or "GA" for attractions
4	7	TAZ	
9	9	Record Number Type	"1" to indicate the first production/attraction record for the zone.
11	17	Home-Based Work Trips	Purpose 1
18	24	Home-Based Non-Work Trips	Purpose 2
25	31	Non-Home-Based Trips	Purpose 3
32	38	Light Truck Trips	Purpose 4
39	45	Heavy Truck Trips	Purpose 5
46	52	Taxi Trips	Purpose 6
53	59	Freeway External-internal Trips	Purpose 7
60	66	Arterial External-internal Trips	Purpose 8
67	73	Local External-internal Trips	Purpose 9
74	80	Turnpike External-internal Trips	Purpose 10

Source: DVRPC July 2008

APPENDIX VII-7 2000 AND 2005 DAILY INTERNAL TRIP GENERATION BY COUNTY PLANNING AREA

2000 Internal Trip Generation

	Home-based Work		Home-based Non-work		Non-home based		Light Truck		Heavy Truck		Taxi	
CPA	Prod.	Attr.	Prod.	Attr.	Orig.	Dest.	Orig.	Dest.	Orig.	Dest.	Orig.	Dest.
1	32,267	380,739	59,707	229,006	108,572	108,572	51,994	51,994	22,366	22,366	53,748	53,748
2	85,552	65,800	225,523	137,477	107,209	107,209	33,813	33,813	15,716	15,716	1,949	1,949
3	37,597	31,802	99,594	79,615	48,607	48,607	16,711	16,711	7,093	7,093	691	691
4	111,847	127,709	294,314	166,114	137,678	137,678	44,820	44,820	19,902	19,902	11,633	11,633
5	58,860	88,328	162,402	119,214	94,383	94,383	32,235	32,235	16,404	16,404	3,755	3,755
6	35,719	46,559	108,616	76,164	59,664	59,664	19,902	19,902	9,687	9,687	1,278	1,278
7	45,492	40,590	126,204	85,700	61,643	61,643	19,802	19,802	9,026	9,026	1,061	1,061
8	35,621	18,167	88,468	58,056	32,865	32,865	11,606	11,606	4,723	4,723	433	433
9	70,354	38,497	178,239	112,280	70,360	70,360	23,674	23,674	10,041	10,041	992	992
10	98,262	35,866	238,671	94,788	85,866	85,866	25,977	25,977	10,646	10,646	1,352	1,352
11	150,612	99,195	399,843	213,004	162,009	162,009	51,081	51,081	23,972	23,972	2,892	2,892
12	124,591	95,627	315,338	295,999	133,333	133,333	54,725	54,725	21,096	21,096	1,538	1,538
13	64,152	47,706	161,589	118,934	63,774	63,774	36,788	36,788	15,720	15,720	939	939
14	76,765	80,876	195,502	246,472	91,313	91,313	46,124	46,124	19,628	19,628	1,013	1,013
15	114,715	56,534	280,182	170,920	100,094	100,094	40,713	40,713	16,042	16,042	1,528	1,528
16	86,401	87,863	228,630	249,210	101,190	101,190	45,922	45,922	20,292	20,292	1,186	1,186
17	36,899	42,434	102,406	114,310	46,365	46,365	21,611	21,611	10,034	10,034	696	696
18	22,406	24,335	61,979	71,730	29,002	29,002	17,681	17,681	8,356	8,356	256	256
19	23,695	59,101	64,956	131,418	45,705	45,705	21,144	21,144	10,381	10,381	542	542
20	25,701	13,645	70,983	45,991	24,142	24,142	9,510	9,510	3,866	3,866	280	280
21	27,250	12,103	78,067	48,115	23,066	23,066	10,224	10,224	3,827	3,827	188	188
22	54,447	40,354	138,686	119,694	50,185	50,185	22,127	22,127	8,996	8,996	452	452
23	88,457	104,319	221,676	283,221	111,844	111,844	47,804	47,804	20,640	20,640	1,327	1,327
24	17,676	18,998	48,106	40,420	20,323	20,323	11,263	11,263	5,251	5,251	239	239
25	44,223	26,552	116,037	86,119	38,633	38,633	17,175	17,175	6,834	6,834	350	350
26	8,744	6,706	23,785	16,617	8,280	8,280	8,507	8,507	4,281	4,281	77	77
27	20,733	10,025	54,143	30,762	15,217	15,217	7,332	7,332	3,044	3,044	137	137
28	10,988	6,069	28,555	18,428	8,982	8,982	6,717	6,717	2,553	2,553	80	80
29	18,285	9,869	46,550	33,849	15,992	15,992	8,907	8,907	3,566	3,566	127	127
30	64,784	84,897	161,962	208,096	82,552	82,552	36,566	36,566	16,226	16,226	1,147	1,147
31	36,311	49,317	96,865	115,730	46,220	46,220	19,913	19,913	9,233	9,233	629	629
32	104,830	85,602	267,147	271,976	111,536	111,536	45,871	45,871	18,998	18,998	1,263	1,263
33	36,399	68,718	92,068	169,178	60,787	60,787	27,006	27,006	12,273	12,273	738	738
34	87,009	156,685	228,832	337,485	140,139	140,139	57,425	57,425	28,713	28,713	2,314	2,314
35	74,910	86,278	187,704	218,396	88,066	88,066	37,821	37,821	17,081	17,081	1,069	1,069
36	78,169	61,997	203,881	170,181	75,932	75,932	33,290	33,290	14,078	14,078	781	781
37	118,727	130,225	295,566	332,092	139,901	139,901	61,829	61,829	24,682	24,682	1,433	1,433
38	30,699	18,525	80,903	51,925	25,411	25,411	12,443	12,443	4,821	4,821	231	231
39	43,880	37,555	114,196	111,774	47,237	47,237	20,590	20,590	8,179	8,179	469	469
40	30,287	24,269	79,449	84,380	33,735	33,735	17,616	17,616	7,761	7,761	267	267
41	15,912	5,598	47,254	24,585	11,971	11,971	10,514	10,514	3,776	3,776	98	98
42	42,466	32,549	109,460	91,808	40,745	40,745	18,032	18,032	7,413	7,413	369	369
43	54,909	51,566	144,046	137,029	59,635	59,635	25,240	25,240	11,442	11,442	748	748
44	24,223	18,619	71,888	68,599	28,717	28,717	12,502	12,502	5,303	5,303	211	211
45	10,140	7,220	29,155	27,087	10,870	10,870	6,973	6,973	2,849	2,849	87	87
46	90,307	57,946	222,700	181,279	77,958	77,958	33,271	33,271	13,085	13,085	705	705
47	27,987	24,872	76,934	64,982	29,472	29,472	18,165	18,165	9,933	9,933	344	344
48	73,229	77,611	172,952	223,952	86,877	86,877	37,592	37,592	15,289	15,289	924	924
49	45,491	40,543	107,678	142,031	50,236	50,236	21,497	21,497	8,704	8,704	427	427
50	75,097	46,891	190,420	162,575	68,230	68,230	28,720	28,720	10,965	10,965	613	613
51	56,744	44,616	135,379	121,579	54,300	54,300	22,968	22,968	8,885	8,885	570	570
52	48,765	83,251	119,587	93,286	61,543	61,543	24,358	24,358	11,926	11,926	5,443	5,443
53	58,493	88,106	145,406	251,831	83,955	83,955	36,038	36,038	17,043	17,043	787	787
54	79,251	54,261	199,844	184,635	74,223	74,223	31,467	31,467	12,518	12,518	692	692
55	18,024	16,205	52,153	48,779	20,975	20,975	13,259	13,259	5,442	5,442	173	173
56	39,726	26,376	96,237	87,652	36,677	36,677	24,050	24,050	10,099	10,099	320	320
57	43,365	77,117	110,059	176,955	68,240	68,240	38,308	38,308	18,351	18,351	989	989
58	132,054	94,539	323,509	311,811	127,393	127,393	53,685	53,685	21,191	21,191	1,174	1,174
59	136,458	144,743	360,506	442,568	165,020	165,020	72,635	72,635	30,480	30,480	1,484	1,484
60	48,125	32,096	125,437	102,553	43,486	43,486	23,611	23,611	11,101	11,101	435	435
61	42,357	41,329	117,872	117,012	51,350	51,350	22,313	22,313	10,004	10,004	599	599
62	16,230	7,841	42,686	24,212	11,515	11,515	7,758	7,758	3,085	3,085	105	105
63	76,151	92,946	189,117	175,670	92,910	92,910	37,576	37,576	15,875	15,875	3,613	3,613
64	98,480	122,634	251,955	354,480	126,099	126,099	53,770	53,770	24,571	24,571	1,323	1,323
65	92,800	51,368	233,454	191,324	85,381	85,381	34,225	34,225	12,915	12,915	859	859
66	51,233	33,881	128,203	113,550	47,485	47,485	25,637	25,637	11,704	11,704	412	412
67	90,361	43,757	217,064	163,604	73,019	73,019	29,812	29,812	10,909	10,909	665	665
68	73,995	70,208	185,833	215,738	84,761	84,761	36,215	36,215	14,817	14,817	856	856
69	33,010	31,464	91,587	86,809	38,245	38,245	22,995	22,995	9,744	9,744	330	330
70	74,117	40,760	179,447	155,960	65,844	65,844	26,413	26,413	10,347	10,347	536	536
71	42,302	19,486	118,669	71,551	35,173	35,173	22,538	22,538	8,911	8,911	296	296
72	11,646	10,325	31,626	26,200	12,303	12,303	10,717	10,717	4,778	4,778	156	156
73	34,801	68,504	98,632	185,126	59,453	59,453	26,970	26,970	12,646	12,646	600	600
74	16,632	9,130	48,773	32,284	14,763	14,763	7,534	7,534	3,224	3,224	122	122
Total	**4,209,197**	**4,188,794**	**10,802,846**	**10,423,936**	**4,746,636**	**4,746,636**	**2,053,617**	**2,053,617**	**885,353**	**885,353**	**128,145**	**128,145**

2005 Internal Trip Generation

	Home-based Work		Home-based Non-work		Non-home based		Light Truck		Heavy Truck		Taxi	
CPA	Prod.	Attr.	Prod.	Attr.	Orig.	Dest.	Orig.	Dest.	Orig.	Dest.	Orig.	Dest.
1	34,279	378,139	64,352	229,049	109,320	109,320	51,955	51,955	22,333	22,333	53,474	53,474
2	83,271	63,776	223,206	134,434	105,010	105,010	33,048	33,048	15,354	15,354	1,899	1,899
3	36,144	33,498	97,653	82,761	48,979	48,979	17,000	17,000	7,356	7,356	711	711
4	108,759	126,941	290,290	163,946	135,651	135,651	44,265	44,265	19,696	19,696	11,461	11,461
5	55,949	85,155	156,959	114,857	90,798	90,798	31,026	31,026	15,835	15,835	3,615	3,615
6	33,435	45,129	104,145	73,757	57,295	57,295	19,146	19,146	9,398	9,398	1,236	1,236
7	44,251	37,929	123,553	82,034	59,223	59,223	18,908	18,908	8,610	8,610	1,005	1,005
8	35,827	18,295	91,453	58,984	33,550	33,550	11,841	11,841	4,802	4,802	440	440
9	68,800	35,851	176,629	106,923	68,181	68,181	22,816	22,816	9,556	9,556	945	945
10	95,755	33,858	234,739	91,474	83,431	83,431	25,168	25,168	10,242	10,242	1,295	1,295
11	148,522	96,640	399,163	209,622	159,931	159,931	50,389	50,389	23,583	23,583	2,842	2,842
12	123,631	94,590	316,931	296,392	133,039	133,039	54,507	54,507	21,083	21,083	1,532	1,532
13	64,341	47,455	163,376	120,061	64,123	64,123	37,749	37,749	15,385	15,385	941	941
14	74,684	80,221	191,876	245,291	90,164	90,164	43,989	43,989	18,913	18,913	999	999
15	111,855	55,309	275,644	167,958	98,314	98,314	39,980	39,980	15,774	15,774	1,503	1,503
16	85,197	87,548	227,659	249,382	100,751	100,751	45,662	45,662	20,312	20,312	1,181	1,181
17	37,160	42,640	104,182	115,268	46,791	46,791	21,814	21,814	10,128	10,128	698	698
18	27,894	25,860	77,835	78,899	32,729	32,729	20,162	20,162	8,928	8,928	289	289
19	26,264	64,551	73,171	145,832	50,343	50,343	23,279	23,279	11,494	11,494	591	591
20	26,570	14,276	74,771	48,285	25,347	25,347	9,983	9,983	4,067	4,067	290	290
21	29,880	13,351	87,436	53,796	25,689	25,689	11,417	11,417	4,285	4,285	209	209
22	59,545	43,202	154,628	132,194	55,245	55,245	24,247	24,247	9,870	9,870	495	495
23	91,420	110,410	233,936	302,733	118,485	118,485	50,663	50,663	21,976	21,976	1,394	1,394
24	19,574	20,125	54,425	44,582	22,293	22,293	12,607	12,607	5,809	5,809	256	256
25	48,035	28,059	128,777	92,847	41,936	41,936	18,638	18,638	7,380	7,380	379	379
26	9,385	7,118	26,048	18,196	8,995	8,995	8,770	8,770	5,313	5,313	83	83
27	24,052	11,582	64,927	36,646	18,090	18,090	8,679	8,679	3,542	3,542	162	162
28	11,330	6,488	30,055	19,723	9,529	9,529	7,192	7,192	3,306	3,306	86	86
29	21,114	10,151	54,918	36,722	17,784	17,784	9,629	9,629	3,687	3,687	141	141
30	65,365	86,638	166,170	214,440	84,395	84,395	37,309	37,309	16,679	16,679	1,169	1,169
31	36,639	50,651	99,583	120,210	47,490	47,490	20,452	20,452	9,561	9,561	646	646
32	102,991	86,359	266,927	273,679	111,774	111,774	45,979	45,979	19,162	19,162	1,269	1,269
33	37,321	69,845	95,954	174,507	62,372	62,372	27,612	27,612	12,626	12,626	753	753
34	86,579	160,632	231,493	347,545	143,031	143,031	58,606	58,606	29,555	29,555	2,365	2,365
35	76,160	88,499	194,520	226,424	90,681	90,681	38,931	38,931	17,683	17,683	1,094	1,094
36	88,441	67,273	234,672	189,525	84,855	84,855	37,090	37,090	15,655	15,655	870	870
37	123,381	133,492	312,569	351,091	146,209	146,209	64,400	64,400	25,841	25,841	1,481	1,481
38	34,316	19,606	92,106	57,118	28,113	28,113	13,724	13,724	5,344	5,344	251	251
39	45,957	38,256	121,787	116,625	49,224	49,224	21,465	21,465	8,529	8,529	484	484
40	33,194	27,813	89,047	96,745	38,513	38,513	20,309	20,309	9,505	9,505	303	303
41	16,133	5,992	48,721	26,037	12,508	12,508	10,740	10,740	4,368	4,368	101	101
42	43,723	33,174	114,799	95,721	42,213	42,213	18,621	18,621	7,697	7,697	379	379
43	60,352	56,922	158,811	152,646	65,901	65,901	28,018	28,018	12,698	12,698	812	812
44	26,323	16,128	79,573	62,934	27,664	27,664	12,018	12,018	4,900	4,900	206	206
45	11,183	6,261	32,821	25,258	10,616	10,616	6,754	6,754	2,535	2,535	86	86
46	95,320	59,324	239,291	190,096	81,936	81,936	34,847	34,847	13,691	13,691	739	739
47	29,754	25,795	83,448	69,012	31,198	31,198	19,565	19,565	11,161	11,161	360	360
48	72,936	79,723	175,090	231,071	88,728	88,728	38,407	38,407	15,776	15,776	944	944
49	48,203	43,162	115,974	151,755	53,625	53,625	22,926	22,926	9,313	9,313	454	454
50	73,622	49,942	190,200	170,801	70,138	70,138	29,653	29,653	11,534	11,534	629	629
51	55,315	45,634	134,176	125,114	54,810	54,810	23,223	23,223	9,108	9,108	576	576
52	48,436	84,145	117,213	93,033	60,838	60,838	24,273	24,273	11,896	11,896	5,571	5,571
53	61,516	94,757	152,201	269,582	88,908	88,908	38,265	38,265	18,324	18,324	838	838
54	80,680	62,270	203,953	205,327	80,042	80,042	34,500	34,500	14,034	14,034	752	752
55	19,431	18,978	55,712	56,587	23,862	23,862	14,281	14,281	6,039	6,039	194	194
56	42,690	29,986	103,161	98,452	40,384	40,384	26,398	26,398	10,835	10,835	354	354
57	49,103	68,555	121,633	171,837	66,415	66,415	38,329	38,329	19,209	19,209	852	852
58	139,230	100,576	340,447	333,368	134,960	134,960	56,892	56,892	22,627	22,627	1,242	1,242
59	143,359	152,476	376,467	469,071	173,148	173,148	76,223	76,223	32,276	32,276	1,558	1,558
60	50,654	34,379	133,851	109,978	46,518	46,518	25,165	25,165	11,485	11,485	456	456
61	47,939	45,335	132,174	131,098	57,130	57,130	24,800	24,800	11,126	11,126	650	650
62	16,955	8,167	44,169	25,694	11,999	11,999	8,031	8,031	3,179	3,179	109	109
63	75,713	93,657	188,219	177,654	92,984	92,984	37,642	37,642	16,026	16,026	3,675	3,675
64	100,273	126,806	256,845	366,552	129,371	129,371	55,203	55,203	25,425	25,425	1,362	1,362
65	91,388	52,076	230,123	192,296	85,015	85,015	34,148	34,148	13,003	13,003	862	862
66	55,071	36,406	137,881	122,435	51,055	51,055	26,972	26,972	11,718	11,718	441	441
67	92,874	45,035	223,238	168,870	75,094	75,094	30,652	30,652	11,266	11,266	683	683
68	78,256	76,181	196,816	234,940	91,111	91,111	39,011	39,011	16,095	16,095	916	916
69	40,359	34,983	112,301	100,896	44,493	44,493	25,062	25,062	10,641	10,641	377	377
70	76,540	43,772	185,572	166,115	69,206	69,206	27,807	27,807	11,035	11,035	563	563
71	45,771	21,298	127,625	78,446	38,151	38,151	24,237	24,237	10,006	10,006	322	322
72	11,978	10,624	32,487	23,581	11,531	11,531	10,757	10,757	5,475	5,475	164	164
73	34,198	70,317	98,762	190,722	60,434	60,434	27,423	27,423	13,023	13,023	611	611
74	18,043	10,094	53,764	35,784	16,299	16,299	8,287	8,287	3,464	3,464	133	133
Total	**4,320,588**	**4,290,141**	**11,205,083**	**10,843,320**	**4,885,958**	**4,885,958**	**2,119,536**	**2,119,536**	**919,145**	**919,145**	**128,808**	**128,808**

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APPENDIX VII-8 2000 AND 2005 DAILY TRIP GENERATION SUMMARIES BY TRIP PURPOSE, COUNTY, AND STATE

2000 Daily Trip Generation Summaries for Person Trip Categories

	HBW-P	HBW-A	HBNW-P	HBNW-A	NHB-O	NHB-D	TOTAL-P	TOTAL-A	P - A
Bucks	546,792	432,300	1,387,315	1,329,886	552,746	552,746	2,486,853	2,264,463	222,390
Chester	391,632	385,375	1,038,949	1,072,044	436,585	436,585	1,867,166	1,855,429	11,737
Delaware	401,338	339,748	1,030,288	971,576	431,738	431,738	1,863,364	1,706,022	157,342
Montgomery	675,718	779,799	1,729,124	1,986,833	817,781	817,781	3,222,623	3,519,882	-297,259
Philadelphia	886,774	1,068,879	2,296,919	1,667,417	1,102,189	1,102,189	4,285,882	3,803,239	482,643
Burlington	375,224	320,548	970,010	998,156	398,764	398,764	1,743,998	1,649,563	94,435
Camden	409,025	344,586	1,019,793	998,628	424,894	424,894	1,853,712	1,714,830	138,882
Gloucester	223,424	161,918	575,536	530,058	224,023	224,023	1,022,983	877,346	145,637
Mercer	287,624	345,316	723,286	843,138	345,613	345,613	1,356,523	1,472,715	-116,192
Berks	11,646	10,325	31,626	26,200	12,303	12,303	55,575	47,815	7,760
PA	**2,913,900**	**3,016,426**	**7,514,221**	**7,053,956**	**3,353,342**	**3,353,342**	**13,781,463**	**13,196,850**	**584,613**
NJ	**1,295,297**	**1,172,368**	**3,288,625**	**3,369,980**	**1,393,294**	**1,393,294**	**5,977,216**	**5,714,454**	**262,762**
Total	**4,209,197**	**4,188,794**	**10,802,846**	**10,423,936**	**4,746,636**	**4,746,636**	**19,758,679**	**18,911,304**	**847,375**

2000 Daily Trip Generation Summaries for Vehicle Trip Categories

	HBW-P	HBW-A	HBNW-P	HBNW-A	NHB-O	NHB-D	TOTAL-P	TOTAL-A	P - A
Bucks	546,792	432,300	1,387,315	1,329,886	552,746	552,746	2,486,853	2,264,463	222,390
Chester	391,632	385,375	1,038,949	1,072,044	436,585	436,585	1,867,166	1,855,429	11,737
Delaware	401,338	339,748	1,030,288	971,576	431,738	431,738	1,863,364	1,706,022	157,342
Montgomery	675,718	779,799	1,729,124	1,986,833	817,781	817,781	3,222,623	3,519,882	-297,259
Philadelphia	886,774	1,068,879	2,296,919	1,667,417	1,102,189	1,102,189	4,285,882	3,803,239	482,643
Burlington	375,224	320,548	970,010	998,156	398,764	398,764	1,743,998	1,649,563	94,435
Camden	409,025	344,586	1,019,793	998,628	424,894	424,894	1,853,712	1,714,830	138,882
Gloucester	223,424	161,918	575,536	530,058	224,023	224,023	1,022,983	877,346	145,637
Mercer	287,624	345,316	723,286	843,138	345,613	345,613	1,356,523	1,472,715	-116,192
Berks	11,646	10,325	31,626	26,200	12,303	12,303	55,575	47,815	7,760
PA	**2,913,900**	**3,016,426**	**7,514,221**	**7,053,956**	**3,353,342**	**3,353,342**	**13,781,463**	**13,196,850**	**584,613**
NJ	**1,295,297**	**1,172,368**	**3,288,625**	**3,369,980**	**1,393,294**	**1,393,294**	**5,977,216**	**5,714,454**	**262,762**
Total	**4,209,197**	**4,188,794**	**10,802,846**	**10,423,936**	**4,746,636**	**4,746,636**	**19,758,679**	**18,911,304**	**847,375**

2005 Daily Trip Generation Summaries for Person Trip Categories

	HBW-P	HBW-A	HBNW-P	HBNW-A	NHB-O	NHB-D	TOTAL-P	TOTAL-A	P - A
Bucks	566,058	449,870	1,461,951	1,397,190	577,850	577,850	2,605,859	2,424,910	180,949
Chester	419,410	409,724	1,135,618	1,158,062	470,469	470,469	2,025,497	2,038,255	-12,758
Delaware	401,131	339,033	1,040,572	976,859	432,872	432,872	1,874,575	1,748,764	125,811
Montgomery	697,150	801,251	1,815,781	2,071,164	848,144	848,144	3,361,075	3,720,559	-359,484
Philadelphia	868,623	1,049,801	2,279,073	1,644,233	1,084,408	1,084,408	4,232,104	3,778,442	453,662
Burlington	398,137	340,933	1,027,108	1,069,209	423,755	423,755	1,849,000	1,833,897	15,103
Camden	415,319	353,980	1,036,306	1,027,807	433,519	433,519	1,885,144	1,815,306	69,838
Gloucester	240,926	176,234	622,314	580,397	242,961	242,961	1,106,201	999,592	106,609
Mercer	301,856	358,691	753,873	894,818	360,449	360,449	1,416,178	1,613,958	-197,780
Berks	11,978	10,624	32,487	23,581	11,531	11,531	55,996	45,736	10,260
PA	**2,964,350**	**3,060,303**	**7,765,482**	**7,271,089**	**3,425,274**	**3,425,274**	**14,155,106**	**13,756,666**	**398,440**
NJ	**1,356,238**	**1,229,838**	**3,439,601**	**3,572,231**	**1,460,684**	**1,460,684**	**6,256,523**	**6,262,753**	**-6,230**
Total	**4,320,588**	**4,290,141**	**11,205,083**	**10,843,320**	**4,885,958**	**4,885,958**	**20,411,629**	**20,019,419**	**392,210**

2005 Daily Trip Generation Summaries for Vehicle Trip Categories

	L TRCK-O	L TRCK-D	H TRCK-O	H TRCK-D	TAXI-O	TAXI-D	TOTAL-P	TOTAL-A
Bucks	248,507	248,507	101,349	101,349	5,589	5,589	355,445	355,445
Chester	206,660	206,660	89,453	89,453	4,830	4,830	300,943	300,943
Delaware	193,980	193,980	83,089	83,089	5,611	5,611	282,680	282,680
Montgomery	364,202	364,202	160,093	160,093	10,382	10,382	534,677	534,677
Philadelphia	380,069	380,069	167,848	167,848	80,455	80,455	628,372	628,372
Burlington	186,889	186,889	79,223	79,223	4,015	4,015	270,127	270,127
Camden	179,797	179,797	74,843	74,843	7,023	7,023	261,663	261,663
Gloucester	104,466	104,466	42,096	42,096	2,178	2,178	148,740	148,740
Mercer	152,061	152,061	69,212	69,212	8,561	8,561	229,834	229,834
Berks	5,034	5,034	2,228	2,228	164	164	7,426	7,426
PA	**1,398,452**	**1,398,452**	**604,060**	**604,060**	**107,031**	**107,031**	**2,109,543**	**2,109,543**
NJ	**623,213**	**623,213**	**265,374**	**265,374**	**21,777**	**21,777**	**910,364**	**910,364**
Total	**2,021,665**	**2,021,665**	**869,434**	**869,434**	**128,808**	**128,808**	**3,019,907**	**3,019,907**

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Chapter IX Appendices

Appendix IX-1 Impedance Data

Appendix IX-2 Modal Split Results by CPA

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APPENDIX IX-1 IMPEDANCE DATA

This appendix contains various data required to compute zone-to-zone impedances needed for the modal split model. The following data is presented in this chapter:

- Table A-IX-1 Toll Bridge Data for Tolling and Delay Models
- Table A-IX-2 Toll Road Facility Data for Delay Model
- Table A-IX-3 PA Turnpike Toll Data
- Table A-IX-4 NJ Turnpike Toll Data
- Table A-IX-5 Atlantic City Expressway Toll Data
- Table A-IX-6 Parking Charges by TAZ
- Table A-IX-7 Highway Terminal and Intrazonal Times by Area Type

Table A-IX-1 Toll Bridge Data for Tolling and Delay Models

Facility	Direction	A-Node	B-Node	# of Lanes	Toll ($)
COMMODORE BARRY BRIDGE	EB	9235	9253	9	1.00
COMMODORE BARRY BRIDGE	WB	19437	19438	9	1.00
WALT WHITMAN BRIDGE	EB	9311	9237	12	1.00
WALT WHITMAN BRIDGE	WB	19090	19091	12	1.00
BEN FRANKLIN BRIDGE	EB	9239	9240	12	1.00
BEN FRANKLIN BRIDGE	WB	19262	19263	12	1.00
BETSY ROSS BRIDGE	EB	9282	9284	12	1.00
BETSY ROSS BRIDGE	WB	20067	20066	12	1.00
TACONY-PALMYRA BRIDGE	EB	9313	9241	6	0.55
TACONY-PALMYRA BRIDGE	WB	20081	20080	6	0.55
BURLINGTON-BRISTOL BRIDGE	EB	9314	9243	3	0.55
BURLINGTON-BRISTOL BRIDGE	WB	9243	9314	3	0.55
TRENTON FREEWAY BRIDGE	EB	16531	16532	4	0.30
TRENTON FREEWAY BRIDGE	WB	9245	9316	4	0.30
US 202 BRIDGE	EB	9287	9288	2	0.20
US 202 BRIDGE	WB	9288	9287	2	0.20
PA TURNPIKE BRIDGE	EB	19891	19890	6	0.15
PA TURNPIKE BRIDGE	WB	9217	9315	6	0.15

Source: DVRPC July 2008

Table A-IX-2 Toll Road Facility Data for Delay Model

Facility	Exit	Direction	A-Node	B-Node	# of Lanes
PA Turnpike	DOWNINGTOWN	In	2313	14316	4
PA Turnpike	DOWNINGTOWN	Out	14316	2313	6
PA Turnpike	VALLEY FORGE	In	2314	14317	5
PA Turnpike	VALLEY FORGE	Out	14317	2314	9
PA Turnpike	NORRISTOWN	In	14319	14318	4
PA Turnpike	NORRISTOWN	Out	14318	14319	6
PA Turnpike	MID-COUNTY	In	19967	19968	6
PA Turnpike	MID-COUNTY	Out	4226	4224	6
PA Turnpike	FT WASHINGTON	In	14321	14320	4
PA Turnpike	FT WASHINGTON	Out	14320	14321	7
PA Turnpike	WILLOW GROVE	In	14323	14322	4
PA Turnpike	WILLOW GROVE	Out	14322	14323	7
PA Turnpike	PHILADELPHIA	In	14324	14325	6
PA Turnpike	PHILADELPHIA	Out	14325	14324	11
PA Turnpike	DELAWARE VALLEY	In	14327	14326	2
PA Turnpike	DELAWARE. VALLEY	Out	14326	14327	3
PA Turnpike	LANSDALE	In	14329	14328	2
PA Turnpike	LANSDALE	Out	14328	14329	3
PA Turnpike	QUAKERTOWN	In	14331	14330	2
PA Turnpike	QUAKERTOWN	Out	14330	14331	2
NJ Turnpike	SWEDESBORO	In	14332	14333	2
NJ Turnpike	SWEDESBORO	Out	14333	14332	2
NJ Turnpike	WOODBURY	In	14334	14335	3
NJ Turnpike	WOODBURY	Out	14335	14334	4
NJ Turnpike	CAMDEN	In	14336	14337	4
NJ Turnpike	CAMDEN	Out	14337	14336	5
NJ Turnpike	BURLINGTON	In	14339	14338	2
NJ Turnpike	BURLINGTON	Out	14338	14339	2
NJ Turnpike	FLORENCE	In	14340	14341	1
NJ Turnpike	FLORENCE	Out	14341	14340	1
NJ Turnpike	BORDENTOWN	In	14342	2327	2
NJ Turnpike	BORDENTOWN	Out	2327	14342	3
NJ Turnpike	ALLENTOWN	In	14343	14344	4
NJ Turnpike	ALLENTOWN	Out	14344	14343	8
NJ Turnpike	HIGHTSTOWN	In	2329	14345	3
NJ Turnpike	HIGHTSTOWN	Out	14345	2329	3
Atlantic City Expwy	WILLIAMSTOWN	In	14347	14346	1
Atlantic City Expwy	WILLIAMSTOWN	Out	19614	19615	1
Atlantic City Expwy	WINSLOW	In	14349	14348	2
Atlantic City Expwy	WINSLOW	Out	19627	19628	2
Atlantic City Expwy	CROSS KEYS	In	14997	14998	1
Atlantic City Expwy	CROSS KEYS	Out	19605	19604	1

Source: DVRPC July 2008

Table A-IX-3 PA Turnpike Toll Data

Interchange # (Old)	Interchange # (New)	Direction	A-Node	B-Node	Toll (¢)
24	326	EB	9201	9202	0.85
23	312	WB	9202	9201	0.8
25	333	EB	9203	9204	0.5
24	326	WB	9204	9203	0.4
25A	20	EB	9205	9206	0
25	333	WB	9206	9205	0
26	339	EB	9207	9208	0.4
25A	20	WB	9208	9207	0.4
25A	20	SB	9209	9210	0.55
31	31	NB	9210	9209	0.45
27	343	EB	9211	9212	0.15
26A	340	WB	9212	9211	0.35
28	351	EB	9213	9214	0.45
27	343	WB	9214	9213	0.4
29	358	EB	9215	9216	0.4
28	351	WB	9216	9215	0.35
29	358	WB	9217	9315	0.6
30	359	EB	9315	9217	0.25
32	44	NB	9394	9395	0.55
31	31	SB	9395	9394	0.45
33	56	NB	9396	9397	0.4
32	44	SB	9397	9396	0.5
22	298	WB	9398	9399	0.5
23	312	EB	9399	9398	0.5
26	339	WB	9212	9211	0

Source: DVRPC July 2008

Table A-IX-4 NJ Turnpike Toll Data

Interchange #	Direction	A-Node	B-Node	Toll (¢)
1	SB	11076	11075	0.3
2	NB	11075	11076	0.55
2	SB	9224	9223	0.35
3	NB	9223	9224	0.35
3	SB	9226	9225	0.35
4	NB	9225	9226	0.3
4	SB	9228	9227	0.2
5	NB	9227	9228	0.3
5	SB	9230	9229	0.1
6	WB	9220	9219	0.7
7	NB	9231	9232	0.3
7	SB	9234	9233	0.1
7A	NB	9233	9234	0.15
7A	SB	11197	11196	0.2
8	NB	11196	11197	0.25
8	SB	11199	11198	0.4
8A	NB	11198	11199	0.2
6*	NB	9229	9230	0.3
6*	SB	9232	9231	0.3

Source: DVRPC July 2008

Table A-IX-5 Atlantic City Expressway Toll Data

2000 Atlantic Expressway Tolls				
Interchange #	Direction	A-Node	B-Node	Toll (¢)
Cross-Keys	EB OFF	19605	19604	0.1
Cross-Keys	WB ON	14997	14998	0.1
Williamstown	EB OFF	19614	19615	0.25
Williamstown	WB ON	14347	14346	0.25
Winslow	EB OFF	19627	19628	0.25
Winslow	WB ON	14349	14348	0.25

Source: DVRPC July 2008

Table A-IX-6 Parking Charges by TAZ

Daily Parking Charge by TAZ ($0.00 unless listed)

TAZ	Charge ($)	TAZ	Charge ($)	TAZ	Charge ($)
1	$ 9.00	37	$ 9.50	1123	$ 6.99
2	$ 9.00	38	$ 9.50	1396	$ 10.61
3	$ 6.75	39	$ 9.00	1397	$ 10.00
4	$ 9.33	40	$ 7.00	1398	$ 8.25
5	$ 11.50	41	$ 9.92	1399	$ 8.25
6	$ 11.00	42	$ 9.00	1400	$ 10.40
7	$ 10.00	43	$ 9.63	1401	$ 8.50
8	$ 9.30	44	$ 9.00	1402	$ 11.38
9	$ 9.00	45	$ 9.40	1403	$ 11.75
10	$ 9.00	46	$ 8.13	1404	$ 10.50
11	$ 12.50	47	$ 6.80	1405	$ 10.30
12	$ 12.50	48	$ 8.08	1406	$ 10.75
13	$ 12.75	49	$ 6.75	1407	$ 10.00
14	$ 12.00	50	$ 6.75	1408	$ 10.00
15	$ 12.82	51	$ 5.75	1409	$ 10.00
16	$ 10.75	52	$ 6.50	1410	$ 10.00
17	$ 8.00	53	$ 6.00	1411	$ 11.00
18	$ 10.00	54	$ 9.00	1412	$ 11.33
19	$ 11.33	176	$ 7.29	1413	$ 10.50
20	$ 11.00	177	$ 6.57	1414	$ 10.00
21	$ 10.25	178	$ 4.00	1415	$ 10.00
22	$ 10.25	179	$ 6.00	1416	$ 10.42
23	$ 7.50	180	$ 5.33	1417	$ 10.17
24	$ 7.00	181	$ 6.98	1418	$ 10.00
25	$ 7.00	184	$ 3.04	1419	$ 6.00
26	$ 7.50	185	$ 3.04	1420	$ 6.40
27	$ 7.50	200	$ 2.03	1423	$ 5.17
28	$ 7.00	201	$ 2.03	1424	$ 6.00
29	$ 5.00	207	$ 2.03	1425	$ 9.75
30	$ 8.50	208	$ 2.03	1426	$ 6.81
31	$ 9.38	259	$ 2.03	1427	$ 9.25
32	$ 7.00	260	$ 2.03	1428	$ 9.00
33	$ 7.00	986	$ 6.99	1429	$ 8.00
34	$ 6.00	993	$ 6.99	1430	$ 8.75
35	$ 5.75	1120	$ 6.99	1453	$ 5.00
36	$ 6.00	1122	$ 6.99	1454	$ 5.08

Source: DVRPC July 2008

Table A-IX-7 Highway Terminal and Intrazonal Times by Area Type

Area Type	Origin Terminal Time (min)	Destination Terminal Time (min)	Intrazonal Times (min)
1	9	12	4
2	6	9	3
3	3	5	2
4	2	2	1
5	1	1	0
6	1	1	0

Source: DVRPC July 2008

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APPENDIX IX-2 2000 MODAL SPLIT RESULTS BY CPA AND TRIP PURPOSE

- Table A-IX-8 2000 Modal Split Results by CPA and Trip Purpose
- Table A-IX-9 2005 Modal Split Results by CPA and Trip Purpose

Table A-IX-8 2000 Modal Split Results by CPA and Trip Purpose

	HBW		HNBW		NHB		Total	
CPA	Trip Ends	% Transit	Trip Ends	% Transit	Trip Ends	% Transit	Trip Ends	% Transit
1	424,670	57.5%	340,212	48.8%	220,931	25.1%	985,813	47.3%
2	153,637	26.5%	384,238	13.1%	217,796	5.7%	755,671	13.7%
3	69,677	20.0%	190,718	7.7%	98,375	4.0%	358,770	9.1%
4	243,086	33.2%	493,633	15.6%	279,134	7.6%	1,015,853	17.6%
5	149,253	28.3%	308,441	16.2%	192,062	7.1%	649,756	16.3%
6	83,240	20.4%	201,144	9.0%	121,512	4.4%	405,896	10.0%
7	88,012	22.9%	232,488	9.3%	125,542	4.6%	446,042	10.7%
8	53,431	14.3%	154,367	3.3%	66,428	2.9%	274,226	5.3%
9	109,199	15.1%	308,312	4.5%	142,466	3.3%	559,977	6.3%
10	135,441	21.2%	355,066	5.7%	174,031	3.7%	664,538	8.4%
11	253,368	19.0%	660,683	5.7%	329,047	3.8%	1,243,098	7.9%
12	220,899	8.9%	648,789	2.6%	269,431	2.5%	1,139,119	3.8%
13	111,214	3.4%	284,692	0.4%	126,563	0.4%	522,469	1.1%
14	156,961	4.1%	463,753	0.4%	182,926	0.5%	803,640	1.1%
15	171,433	11.5%	473,215	1.2%	201,187	1.0%	845,835	3.2%
16	173,357	5.2%	484,671	0.4%	202,628	0.5%	860,656	1.4%
17	78,774	3.2%	218,349	0.3%	92,385	0.4%	389,508	0.9%
18	46,133	0.6%	132,618	0.1%	57,343	0.1%	236,094	0.2%
19	81,172	1.1%	188,385	0.1%	91,100	0.2%	360,657	0.4%
20	39,051	0.6%	116,308	0.1%	47,870	0.1%	203,229	0.2%
21	39,036	0.1%	129,616	0.0%	45,488	0.1%	214,140	0.1%
22	93,603	0.8%	253,669	0.1%	99,301	0.2%	446,573	0.3%
23	189,763	0.9%	486,299	0.1%	222,551	0.2%	898,613	0.3%
24	36,326	0.0%	96,248	0.0%	39,783	0.0%	172,357	0.0%
25	69,963	1.1%	206,586	0.1%	75,788	0.1%	352,337	0.3%
26	15,241	0.0%	42,117	0.0%	15,995	0.0%	73,353	0.0%
27	30,609	0.0%	92,513	0.0%	29,644	0.0%	152,766	0.0%
28	16,827	0.0%	50,473	0.0%	17,281	0.0%	84,581	0.0%
29	28,076	0.0%	89,497	0.0%	31,162	0.0%	148,735	0.0%
30	150,040	1.9%	373,341	0.2%	165,278	0.3%	688,659	0.6%
31	85,537	2.1%	212,831	0.2%	92,466	0.4%	390,834	0.7%
32	190,749	5.1%	567,693	0.5%	224,227	0.6%	982,669	1.4%
33	104,668	2.5%	256,979	0.5%	121,651	0.6%	483,298	0.9%
34	241,553	4.5%	570,275	0.7%	280,886	0.7%	1,092,714	1.5%
35	159,970	2.0%	388,953	0.4%	175,833	0.5%	724,756	0.8%
36	138,736	0.6%	373,110	0.2%	150,444	0.2%	662,290	0.3%
37	247,928	1.2%	628,456	0.1%	278,633	0.2%	1,155,017	0.4%
38	48,870	0.0%	138,007	0.0%	49,523	0.0%	236,400	0.0%
39	80,550	0.3%	238,378	0.2%	92,989	0.2%	411,917	0.2%
40	54,338	0.0%	168,240	0.0%	66,397	0.0%	288,975	0.0%
41	21,465	0.0%	76,032	0.0%	22,898	0.0%	120,395	0.0%
42	74,784	0.0%	202,036	0.0%	80,513	0.0%	357,333	0.0%
43	106,598	1.2%	279,926	0.1%	118,596	0.2%	505,120	0.3%
44	42,892	0.6%	144,607	0.0%	56,859	0.0%	244,358	0.1%
45	17,337	0.5%	56,942	0.0%	21,286	0.0%	95,565	0.1%
46	148,708	0.9%	406,289	0.0%	155,668	0.1%	710,665	0.2%
47	53,089	0.1%	145,395	0.0%	58,421	0.0%	256,905	0.0%
48	151,725	2.7%	412,615	0.2%	174,105	0.3%	738,445	0.7%
49	86,447	1.8%	254,291	0.1%	100,113	0.2%	440,851	0.5%
50	122,275	1.8%	358,404	0.1%	135,655	0.1%	616,334	0.4%
51	101,941	2.3%	259,482	0.1%	108,278	0.2%	469,701	0.6%
52	129,745	7.8%	208,376	2.5%	123,464	1.2%	461,585	3.6%
53	143,730	1.5%	356,818	0.3%	168,220	0.3%	668,768	0.6%
54	131,944	1.7%	372,357	0.3%	148,451	0.3%	652,752	0.6%
55	33,617	0.3%	97,107	0.0%	41,652	0.1%	172,376	0.1%
56	65,098	0.2%	182,176	0.0%	72,100	0.0%	319,374	0.0%
57	115,195	0.8%	261,148	0.1%	135,542	0.1%	511,885	0.3%
58	229,093	0.9%	625,441	0.1%	253,671	0.2%	1,108,205	0.3%
59	288,218	1.0%	806,442	0.1%	330,076	0.2%	1,424,736	0.3%
60	80,670	0.1%	217,039	0.0%	84,499	0.1%	382,208	0.1%
61	85,073	0.4%	234,122	0.1%	101,632	0.1%	420,827	0.2%
62	24,292	0.7%	66,942	0.1%	22,343	0.0%	113,577	0.2%
63	171,725	10.5%	360,321	2.3%	186,905	1.6%	718,951	4.1%
64	227,949	3.0%	606,965	0.3%	253,314	0.5%	1,088,228	0.9%
65	146,689	6.0%	428,995	0.6%	171,243	0.7%	746,927	1.7%
66	87,322	2.7%	248,963	0.4%	93,975	0.3%	430,260	0.8%
67	136,224	5.1%	390,601	0.4%	145,819	0.5%	672,644	1.4%
68	148,156	1.5%	402,494	0.2%	168,669	0.3%	719,319	0.5%
69	66,272	0.7%	177,590	0.1%	75,330	0.1%	319,192	0.2%
70	117,519	1.3%	356,301	0.2%	130,235	0.3%	604,055	0.4%
71	63,046	0.7%	204,410	0.1%	68,596	0.2%	336,052	0.2%
72	21,562	0.0%	59,881	0.0%	23,958	0.0%	105,401	0.0%
73	101,863	1.3%	270,548	0.1%	118,817	0.3%	491,228	0.4%
74	25,534	0.1%	81,137	0.0%	29,076	0.0%	135,747	0.0%
Total	**8,432,188**	**8.8%**	**21,615,556**	**2.5%**	**9,494,056**	**1.9%**	**39,541,800**	**3.7%**

Table A-IX-9 2005 Modal Split Results by CPA and Trip Purpose

	HBW		HNBW		NHB		Total	
CPA	Trip Ends	% Transit	# Trip Ends	% Transit	Trip Ends	% Transit	Trip Ends	% Transit
1	423,586	58.2%	336,938	48.4%	222,440	25.1%	982,964	47.4%
2	149,262	26.7%	380,421	12.8%	213,411	5.7%	743,094	13.6%
3	69,874	19.1%	192,157	7.1%	99,082	3.8%	361,113	8.5%
4	239,195	32.9%	481,713	15.2%	275,132	7.5%	996,040	17.3%
5	142,979	28.2%	293,923	16.2%	184,686	7.2%	621,588	16.3%
6	79,280	20.3%	192,398	9.2%	116,452	4.5%	388,130	10.0%
7	84,097	23.4%	223,113	9.4%	120,439	4.7%	427,649	10.8%
8	53,778	13.8%	157,904	3.3%	67,813	3.0%	279,495	5.2%
9	105,096	15.4%	300,715	4.6%	137,963	3.3%	543,774	6.4%
10	130,921	21.9%	342,769	6.0%	169,104	3.8%	642,794	8.6%
11	248,414	19.3%	649,647	5.8%	324,457	3.9%	1,222,518	8.0%
12	218,706	9.3%	655,176	2.7%	268,605	2.6%	1,142,487	3.9%
13	111,313	3.3%	290,327	0.4%	127,260	0.4%	528,900	1.0%
14	154,345	4.1%	460,478	0.4%	180,331	0.5%	795,154	1.1%
15	167,472	11.8%	462,236	1.2%	197,678	1.0%	827,386	3.3%
16	171,902	5.1%	482,095	0.4%	201,885	0.5%	855,882	1.3%
17	79,246	3.0%	224,142	0.3%	93,180	0.4%	396,568	0.9%
18	53,368	0.6%	157,240	0.1%	64,727	0.1%	275,335	0.2%
19	89,408	1.0%	209,222	0.1%	100,551	0.3%	399,181	0.4%
20	40,659	1.2%	121,784	0.1%	50,365	0.2%	212,808	0.3%
21	42,942	0.1%	145,497	0.0%	50,598	0.1%	239,037	0.1%
22	101,836	0.8%	284,717	0.1%	109,576	0.1%	496,129	0.2%
23	199,462	0.8%	518,106	0.1%	236,142	0.2%	953,710	0.3%
24	39,756	0.0%	108,004	0.0%	43,793	0.0%	191,553	0.0%
25	75,647	1.0%	232,088	0.1%	82,358	0.1%	390,093	0.3%
26	16,351	0.0%	46,538	0.0%	17,399	0.0%	80,288	0.0%
27	35,721	0.0%	113,028	0.0%	35,377	0.0%	184,126	0.0%
28	17,690	0.0%	53,444	0.0%	18,383	0.0%	89,517	0.0%
29	31,422	0.0%	104,109	0.0%	34,722	0.0%	170,253	0.0%
30	152,526	1.8%	384,718	0.2%	168,883	0.3%	706,127	0.6%
31	87,398	2.0%	218,098	0.2%	95,133	0.4%	400,629	0.7%
32	189,616	5.2%	566,118	0.5%	224,703	0.7%	980,437	1.5%
33	106,682	2.5%	264,921	0.5%	124,942	0.6%	496,545	1.0%
34	245,388	4.3%	580,761	0.7%	286,944	0.7%	1,113,093	1.5%
35	163,659	1.8%	408,489	0.4%	181,375	0.5%	753,523	0.7%
36	154,628	0.7%	432,369	0.2%	168,382	0.2%	755,379	0.3%
37	256,365	1.1%	661,568	0.1%	291,355	0.2%	1,209,288	0.3%
38	53,745	0.0%	155,681	0.0%	54,882	0.0%	264,308	0.0%
39	83,678	0.3%	253,798	0.2%	96,811	0.2%	434,287	0.2%
40	60,995	0.0%	190,022	0.0%	76,018	0.0%	327,035	0.0%
41	22,120	0.0%	79,060	0.0%	23,930	0.0%	125,110	0.0%
42	76,889	0.0%	214,658	0.0%	83,475	0.0%	375,022	0.0%
43	117,506	1.3%	316,488	0.1%	131,184	0.2%	565,178	0.4%
44	42,588	0.6%	148,580	0.0%	54,750	0.0%	245,918	0.1%
45	17,491	0.6%	60,175	0.0%	20,786	0.0%	98,452	0.1%
46	155,206	0.8%	436,439	0.0%	163,394	0.1%	755,039	0.2%
47	55,764	0.2%	156,194	0.0%	61,932	0.1%	273,890	0.1%
48	153,468	2.7%	418,513	0.2%	177,770	0.4%	749,751	0.8%
49	91,806	1.7%	270,169	0.1%	106,845	0.2%	468,820	0.4%
50	123,842	1.6%	361,912	0.1%	139,465	0.1%	625,219	0.4%
51	101,429	2.3%	260,438	0.2%	109,350	0.3%	471,217	0.7%
52	130,563	8.7%	200,654	2.5%	121,993	1.2%	453,210	3.9%
53	153,606	1.5%	387,644	0.3%	178,079	0.3%	719,329	0.6%
54	141,411	1.9%	391,659	0.3%	160,042	0.3%	693,112	0.6%
55	37,764	0.1%	104,227	0.0%	47,492	0.1%	189,483	0.1%
56	71,514	0.3%	194,777	0.0%	79,528	0.0%	345,819	0.1%
57	114,119	0.6%	269,066	0.1%	131,838	0.1%	515,023	0.2%
58	242,198	2.3%	661,023	0.2%	269,032	0.3%	1,172,253	0.6%
59	303,258	1.6%	834,935	0.2%	346,716	0.2%	1,484,909	0.5%
60	85,461	0.3%	243,198	0.1%	90,389	0.1%	419,048	0.1%
61	94,753	0.6%	261,629	0.1%	113,290	0.1%	469,672	0.2%
62	25,272	0.8%	71,263	0.0%	23,235	0.0%	119,770	0.2%
63	172,039	10.8%	361,329	2.2%	186,938	1.6%	720,306	4.1%
64	234,033	2.9%	616,087	0.3%	259,972	0.4%	1,110,092	0.9%
65	145,884	5.7%	423,197	0.5%	170,374	0.6%	739,455	1.6%
66	93,961	2.9%	269,480	0.3%	101,187	0.3%	464,628	0.8%
67	140,152	4.7%	399,781	0.4%	150,100	0.5%	690,033	1.3%
68	158,832	1.7%	440,029	0.2%	181,462	0.3%	780,323	0.6%
69	77,473	0.8%	214,680	0.1%	87,793	0.2%	379,946	0.3%
70	123,196	1.4%	371,244	0.2%	136,982	0.3%	631,422	0.4%
71	68,406	0.8%	219,398	0.1%	74,400	0.2%	362,204	0.2%
72	22,316	0.0%	59,066	0.0%	22,428	0.0%	103,810	0.0%
73	103,256	1.2%	273,642	0.1%	120,928	0.3%	497,826	0.4%
74	28,048	0.1%	92,340	0.0%	32,176	0.0%	152,564	0.0%
Total	**8,654,032**	**8.6%**	**22,419,446**	**2.4%**	**9,772,592**	**1.8%**	**40,846,070**	**3.6%**

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APPENDIX XI-1 APPLICATION OF THE DVRPC FOCUSED TRAVEL SIMULATION PROCESS TO THE US 202 SECTION 700 TRAFFIC STUDY

This appendix gives an overview of the focused simulation process as applied to highway traffic studies. This appendix contains excerpts from the recently published ***"US 202 – Section 700 Traffic Study,"*** which applied the focused simulation process to study a number of proposed highway alternatives to a study area in Bucks and Montgomery Counties. The estimation of socio-economic variables, modeling procedures, validation, and results is all discussed as it applies to the US 202 Section 700 traffic study.

A. Travel Forecasting Procedures

DVRPC's travel simulation models are used to forecast future travel patterns. These models utilize a system of traffic zones that follow Census boundaries and rely on demographic and employment data, land use, and transportation network characteristics to simulate trip making patterns throughout the region.

1. Regional Socio-Economic Projections

DVRPC's long-range population and employment forecasts are revised periodically to reflect changing market trends, development patterns, local and national economic conditions, and available data. The completed forecasts reflect all reasonably known current information and the best professional judgment of predicted future conditions. The revised forecasts adopted by the DVRPC Board in February 2005 are an update to municipal forecasts that were last completed in 2000.

DVRPC uses a multi-step, multi-source methodology to produce its forecasts at the county level. County forecasts serve as control totals for municipal forecasts, which are disaggregated from county totals. Municipal forecasts are based on an analysis of historical data trends adjusted to account for infrastructure availability, environmental constraints to development, local zoning policy, and development proposals. Municipal population forecasts are constrained using density ceilings and floors. County and, where necessary, municipal input is used throughout the process to derive the most likely population forecasts for all geographic levels.

2. US 202 Section 700 Study Area Socio-economic Forecasts

As part of the US 202 Section 700 traffic study, DVRPC staff reviewed the most recent current population and employment estimates, the long-range population and employment forecasts, and all proposed land-use developments in the study area known to Bucks and Montgomery County Planning Commission staff. Based on this review, DVRPC developed 2020 municipal-level population and employment forecasts for use as inputs to the traffic simulation models. Because the long-range forecasts were recently updated, only very minor revisions were made to the 2020 population and employment forecasts for use in this study.

The total population in the greater study area is projected to increase by 61,550 residents to 313,488 between 2000 and 2020. On the Bucks County side, the municipalities with the greatest number of new residents include Warminster, Warrington, Warwick, and Buckingham townships. All of these townships are projected to add 5,000 or more new residents between 2000 and 2020. Warminster Township will add over 8,600 people during this time. The fastest growing study area municipalities in Montgomery County in terms of population growth are Montgomery, Horsham, and Upper Gwynedd townships. None of these, however, will add more than 4,700 residents between 2000 and 2020.

The study area will also add over 40,000 new jobs between 2000 and 2020, an increase of 25 percent. Municipalities that are projected to add 4,000 or more new jobs include Horsham, Montgomery, and Hatfield townships in Montgomery County and Warrington and Doylestown townships in Bucks County.

In 2000, about 56 percent of the study area's population and 39 percent of its jobs were located in the Bucks County portion of the study area. By 2020, the Bucks County portion will account for 60 percent of the population and 42 percent of the study area employment.

3. DVRPC's Travel Simulation Process

A focused simulation process was employed for the US 202 study. A focused simulation process allows the use of DVRPC's regional simulation models but includes a more detailed representation of the study area. Local streets not included in the regional network, but of interest in this study, are added to the highway network. Traffic zones inside the study area are subdivided so that traffic from existing and proposed land use developments may be loaded more precisely on the network. The focusing process increases the accuracy of the travel forecasts within the detailed study area. At the same time, all existing and proposed highways throughout the region, and their impact on both regional and interregional travel patterns, become an integral part of the simulation process.

DVRPC's travel models follow the traditional steps of trip generation, trip distribution, modal split, and traffic assignment. However, an iterative feedback loop is employed from traffic assignment to the trip distribution step. The feedback loop ensures that the congestion levels used by the models when determining trip origins and destinations are equivalent to those that result from the traffic assignment step. Additionally, the iterative model structure allows trip making patterns to change in response to changes in traffic patterns, congestion levels, and improvements to the transportation system.

The enhanced model is disaggregated into separate model chains for the peak (combined AM and PM), midday (the period between the AM and PM peaks), and evening (the remainder of the day) periods for the trip distribution, modal split, and travel assignment phases of the process. The peak period is defined as 7:00 AM to 9:00 AM and 3:00 PM to 6:00 PM. Peak period and midday travel are based on a series of factors which determine the percentage of daily trips that occur during those periods. Evening travel is then defined as the residual after peak and midday travel are removed from daily travel.

External-local productions at the nine-county cordon stations are disaggregated into peak, midday, and evening components using percentages derived from the temporal distribution of traffic counts taken at each cordon station.

For highway trips, the final step in the focused simulation process is the assignment of vehicle trips to the highway network representative of the alternative being modeled. For peak, midday, and evening travel, the assignment model produces the future traffic volumes for individual highway links that are required for the evaluation of the alternatives. The regional nature of the highway network and trip table underlying the focused assignment process allow the diversion of travel into and through the study area to various points of entry and exit in response to the improvements made in the transportation system.

For each Evans iteration, highway trips are assigned to the network representative of a given alternative by determining the best (minimum time) route through the highway network for each zonal interchange and then allocating the interzonal highway travel to the highway facilities along that route. This assignment model is "capacity restrained" in that congestion levels are considered when determining the best route. The Evans equilibrium assignment method is used to implement the capacity constraint. When the assignment and associated trip table reach equilibrium, no path faster than the one actually assigned for each trip can be found through the network given the capacity restrained travel times on each link.

4. Traffic Assignment Validation

Before a focused simulation model can be used to predict future trip making patterns, its ability to replicate existing conditions is validated. The simulated highway assignment outputs are compared to current traffic counts taken on roadways serving the study area. The focused simulation model was executed with current conditions and the results compared with recent traffic counts. Based on this analysis, the focused model produced accurate traffic volumes. The validated model was then executed for the No-build and each Build alternative with socio-economic and land use inputs reflective of 2020 conditions.

The following tabulation summarizes the aggregate error in the assigned daily traffic volumes. A total of 121 locations in the study area with available daily traffic counts were used for model validation. Twenty-two of these locations are along US 202, 32 are on parallel and other north-south facilities, and 67 are on intersecting streets and other east-west facilities. The total assigned traffic on all facilities, 1.70 million vehicles, is within four percent of the total counted volume of 1.77 million vehicles, as shown below:

Facilities	Locations	Counted Volume	Validation Volume	Difference	Percent Difference
Existing US 202	22	377,533	380,190	2,657	0.7 %
Parallel Facilities	32	271,583	240,962	-30,621	-11.3 %
Crossing Facilities	67	1,117,671	1,080,210	-37,461	-3.4 %
All Facilities	**121**	**1,766,787**	**1,701,362**	**-65,425**	**-3.7 %**

Source: DVRPC July 2008

B. Projected Traffic Volumes

Projected traffic volumes for selected locations in the study area are presented and analyzed in this chapter. Average daily traffic volumes for 2020 for the No-build and all Build alternatives are provided for the areas surrounding the US 202 Section 700 corridor. Additionally, daily forecasts are provided for the No-build, Parkway, and Combination alternatives for selected locations north of the Section 700 corridor, in order to quantify the impacts of the new alignment alternatives on US 202 and other facilities north of Section 700.

In addition, AM and PM peak hour intersection turning movement forecasts are provided for the No-build, Parkway, and Combination alternatives for each intersection with a turning movement count shown in Figure 4 (in original document but not included in this appendix). Peak hour forecasts are also provided for new intersections that would result from construction of the US 202 Parkway and Combination alternatives. Intersection turning movement forecasts were not requested for the Widen Upper State Road Alternative.

1. Daily Traffic Forecasts

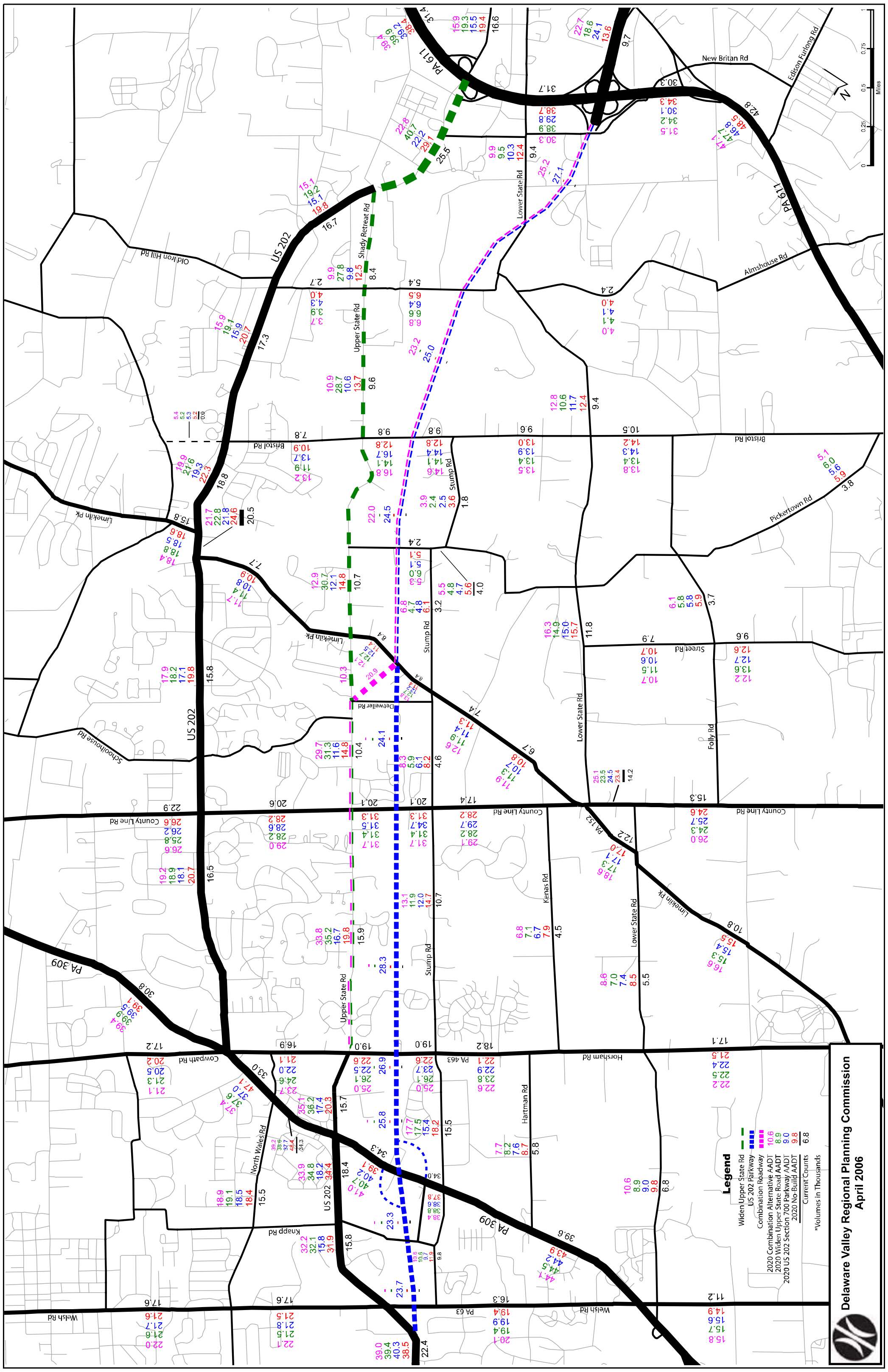
Figure A-XI-1 compares the current average daily traffic volumes to the 2020 projected volumes. In the figure, current volumes are shown in black, underneath the lines representing the highway links. Traffic volumes for the No-build Alternative are shown in red, above the line. The Parkway Alternative volumes are shown in blue, above the No-build volumes, followed by the Widen Upper State Road and Combination alternatives, in green and purple, respectively.

The proposed US 202 Section 700 Parkway is projected to carry between 23,200 and 28,300 vehicles per day in 2020. The highest volumes occur between Horsham and County Line roads, and between Lower State Road and the PA 611 Bypass. The lowest volume occurs between the two Parkway connectors to PA 309.

Traffic volumes on existing US 202 Section 700 are reduced relative to the No-build Alternative with construction of the US 202 Parkway. Traffic volume reductions range from 2,600 to 6,900 vpd, with the largest reductions occurring between Shady Retreat Road and the PA 611 Bypass and between Bristol Road and Almshouse Road. Even larger reductions, as much as 16,200 vpd, occur on US 202 Section 600, south of PA 309.

Construction of the US 202 Parkway does, however, increase traffic volumes along existing US 202 north of the study area, relative to the No-build Alternative. The largest increase, 10,500 vpd, occurs along the US 202 Bypass, between the PA 611 Bypass and PA 611 (Main Street) interchanges. The 2020 volume here, 24,100 vpd, will be easily accommodated by the four-lane, limited-access 202 expressway. As one moves further north, the traffic volume increases along US 202 are less and less pronounced. Between Main Street and Swamp Road, the volume with the Parkway is 6,500 vpd higher than the No-build volume; just north of Swamp Road this difference drops to 2,200 vpd. Once north of Durham Road, there is very little difference between Build and No-build volumes on US 202.

Figure A-XI-1 US 202 Section 700 Study Area Map with Alternatives and Volumes



Traffic volumes on facilities parallel to US 202 Section 700 are also reduced with construction of the US 202 Parkway, relative to the No-build Alternative. Volumes along Upper State Road are reduced by 2,700 to 3,100 vpd. Stump Road volumes are reduced by 1,100 to 2,800 vpd, and volumes on Lower State Road by 700 to 2,100 vpd. Other parallel roads that experience reduced traffic with the US 202 Parkway include Hartman, Kenas, and Folly roads.

Volumes on crossing facilities are generally higher with the Parkway than the No-build volumes, as these facilities are used to access the Parkway. Except for a few locations on Bristol and County Line roads, these increases are generally 1,500 vpd or less. The one crossing facility with significantly lower volumes under the Parkway Alternative is the PA 611 Bypass. The volume between the existing US 202 interchange and the 202 Parkway interchange is reduced by 8,900 vpd, relative to the No-build Alternative, while the volume south of the 202 Parkway interchange is reduced by 4,200 vpd.

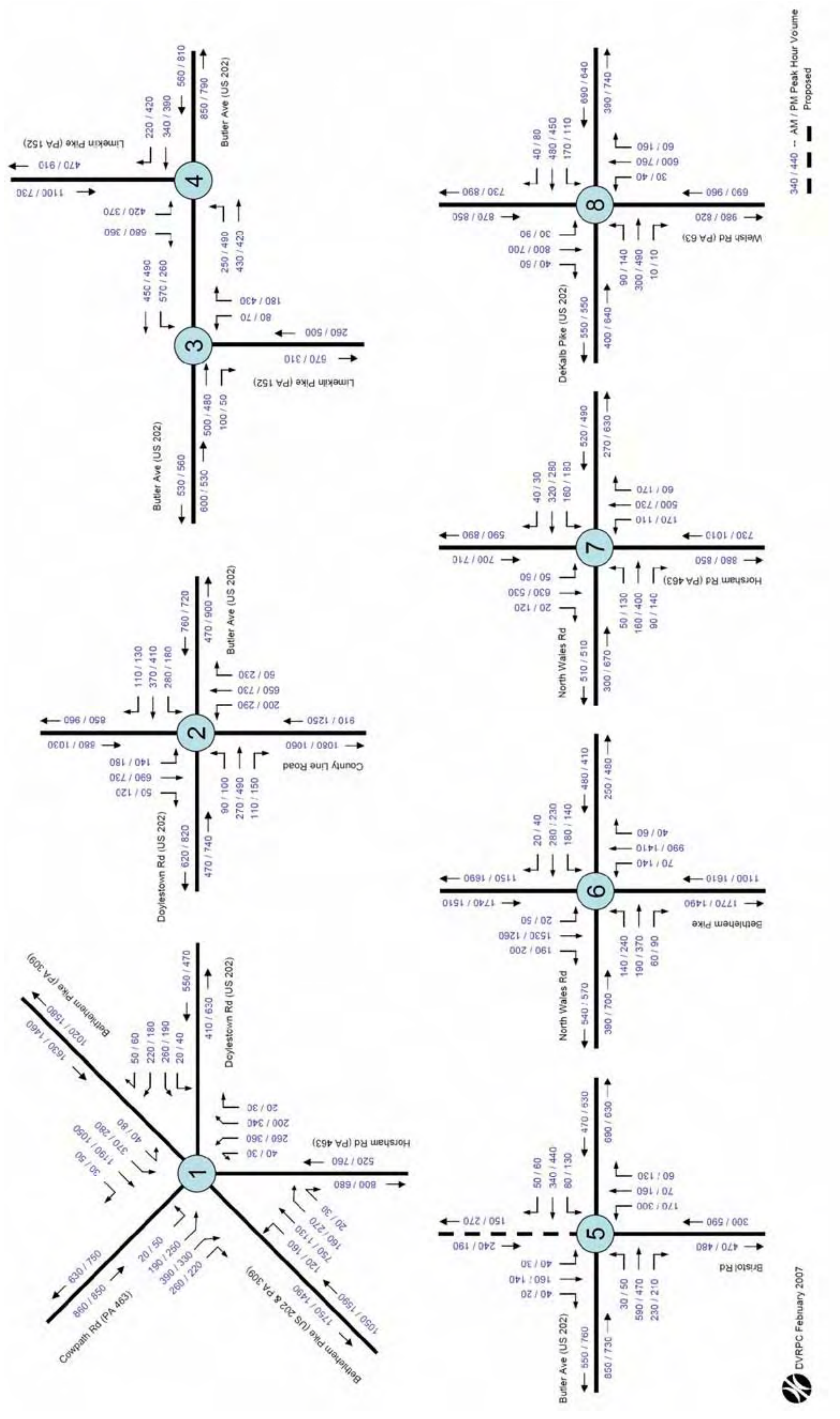
2. AM and PM Peak Hour Forecasts

Year 2020 AM and PM peak hour volumes, including intersection turning movements, for the No-build, Parkway, and Combination alternatives are discussed in this section. Generally, the relationships between current and future peak hour volumes and between the various future year alternatives follow the same patterns and trends as the daily traffic volumes. However, the percentage of daily traffic that occurs during the 2020 AM and PM peak hours, especially in the peak direction, is somewhat less than the percentage under current conditions. This is consistent with the “peak spreading” that occurs as traffic volumes increase. As congestion levels rise, a greater percentage of traffic is shifted to the “shoulders” of the peak period, i.e. immediately before and after the peak hour.

The intersection location map provided in Figure 3 (in original document but not included in this appendix) can also used to identify the individual intersections for which peak hour traffic forecasts are provided. These intersection turning movement forecasts will be used by PENNDOT’s consultants to determine how well traffic operates for the given alternative, including average travel speed and delay along individual facilities and queue lengths at the intersection approaches. These traffic statistics may be used to refine the details for individual intersections under the Build Alternatives, such as the provision of left-turn pockets.

Peak hour traffic forecasts for the proposed US 202 Section 700 Parkway are displayed in ***Figure A-XI-2***. Along the parkway, the southbound direction carries heavier traffic volumes during the AM peak hour and the northbound direction is heavier in the PM peak hour. Southbound AM volumes range from 790 to 1,360 vehicles per hour, although only the portion south of Welsh Road carries less than

Figure A-XI-2 US 202 Section 700 Intersection Turning Movement Volumes



1,000 vph. The highest volume occurs between Horsham and County Line roads. Northbound AM volumes range from 620 to 1,020 vph. In the northbound direction, only the Parkway link between Lower State Road and the PA 611 Bypass carries more than 1,000 vehicles during the AM peak hour.

During the PM peak hour most locations along the Parkway carry over 1,000 vph in both the northbound and southbound directions. Northbound volumes range from 940 to 1,300 vph, while southbound volumes are between 710 and 1,200 vph.

Peak hour traffic volumes on existing US 202 Section 700 and its parallel routes are lower under this alternative, compared to the No-build Alternative traffic forecasts. During the AM peak hour, Section 700 volumes range from 390 to 1,170 vpd in the northbound direction and from 420 to 1,780 vph in the southbound direction. PM peak hour volumes are between 530 and 1,690 vph northbound and between 470 and 1,520 vph southbound.

Southbound volumes along Upper State Road are between 600 and 1,010 vph in the AM peak hour and between 530 and 1,130 in the PM peak. Northbound volumes range from 450 to 650 in the AM peak and from 600 and 910 in the PM peak hour under the 202 Parkway Alternative. Stump Road volumes during the AM peak hour range from 130 to 640 vph northbound and from 200 to 840 vph southbound. PM peak hour volumes on Stump Road range from 240 to 870 vpd northbound and from 140 to 820 vph southbound.

The portion of Bethlehem Pike that is designated as both US 202 and PA 309 carries significantly lower peak hour volumes under this alternative, compared to the No-build Alternative. Its highest peak hour volume is 1,780 vehicles, compared to 2,180 vph under the No-build Alternative. Portions of PA 309 south of the proposed Parkway, however, carry higher volumes compared to the No-build Alternative. These tend to be only about 100 vph higher than the corresponding No-build volume. Most of the other cross-street locations tend to carry marginally higher peak hour volumes, in the range of 50 to 100 vph, compared to the No-build volumes.

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APPENDIX XII-1 APPLICATION OF THE DVRPC SIMULATION PROCESS TO THE QUAKERTOWN RAIL RESTORATION TRAVEL FORECAST STUDY

This appendix gives an overview of the focused simulation process as applied to transit studies. This appendix contains excerpts from the recently published ***"Quakertown Rail Restoration Travel Forecast Study,"*** which applied the focused simulation process to study a number of proposed transit alternatives in a study area in Bucks and Montgomery Counties. The estimation of socio-economic variables, modeling procedures, validation, and results is all discussed as it applies to the Quakertown study.

A. Travel Forecasting Procedure

Regional travel simulation models are used to forecast future travel patterns. They utilize a system of traffic zones that follow census tract and block group boundaries and rely on demographic and employment data, land use, and transportation network characteristics to simulate trip-making patterns throughout the region. The travel models used for this study include the entire nine-county DVRPC region, with special attention focused on the study area.

For this study, a focused simulation process is employed. A focused simulation process allows the use of DVRPC's regional simulation models but includes a more detailed representation of the study area. Traffic zones inside the study area are subdivided so that traffic from existing and proposed land use developments may be loaded more precisely on transit routes and individual stations. The system of split zones developed for the Quakertown Rail Restoration Study Area is shown in ***Figure A-XII-1***. The primary motivation for zone splitting is to be able to accurately delineate the service areas of existing and proposed rail stations and to differentiate between walk and auto approaches for the nested modal split and transit assignment. Overall, eleven traffic zones were added within the study area as a result of the zone splitting process.

The focusing process increases the accuracy of the travel forecasts within the detailed study area. At the same time, all existing and proposed transportation projects throughout the region, their impact on the study area, and regional and interregional travel patterns, are retained as an integral part of the simulation process.

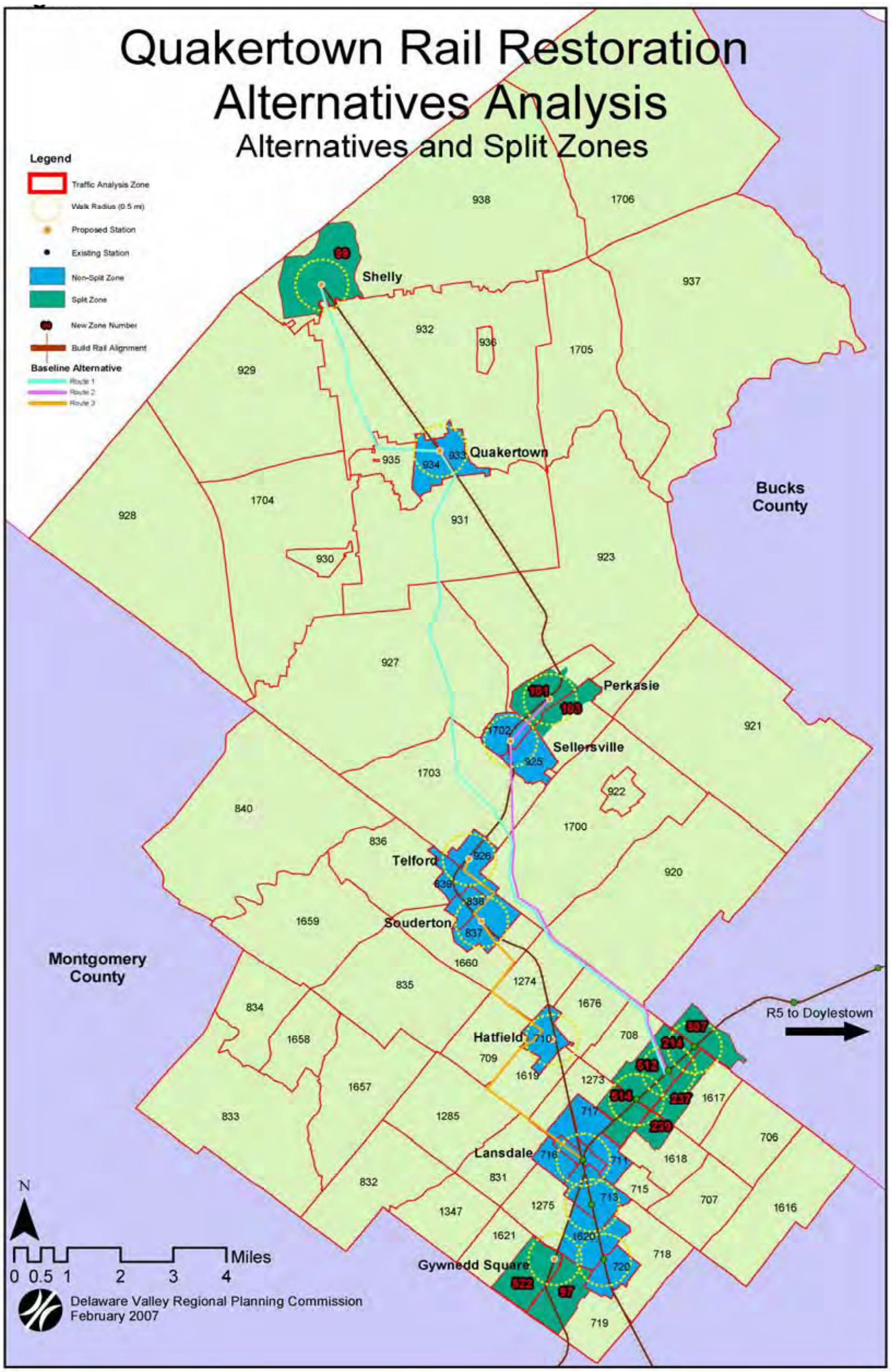

Figure A-XII-1 Quakertown Study Area and Alternatives

1. Socio-Economic Projections

DVRPC's long-range population and employment forecasts are revised periodically to reflect changing market trends, development patterns, local and national economic conditions, and other available data. The completed forecasts reflect all reasonably known current information and the best professional judgment of predicted future conditions.

DVRPC uses a multi-step, multi-source methodology to produce its population and employment forecasts at the county-level. County forecasts serve as control totals for municipal forecasts, which are disaggregated from county totals. Municipal forecasts are based on an analysis of historical data trends adjusted to account for infrastructure availability, environmental constraints to development, local zoning policy, and development proposals. Municipal forecasts are constrained using density ceilings and floors. County and, where necessary, municipal input is used throughout the process to derive the most likely population and employment forecasts for all geographic levels. Other demographic variables, such as the number of households, are also developed once the population forecasts are adopted.

As part of this study, DVRPC staff reviewed its current demographic and employment estimates, its 2030 long-range population and employment forecasts, and all proposed land-use developments in the study area. The magnitude of any population and/or employment growth associated with each proposal was determined and compared to the DVRPC Board-adopted forecast for each municipality in the study area. Based on this review, DVRPC developed revised 2030 municipal-level demographic and employment forecasts for use as inputs to the traffic simulation models.

Table A-XII-1 summarizes the household forecasts used for this study. In 2005, there were 80,906 households within the study area. Strong growth in both population and employment is forecasted for this area. By 2030, the study area is expected to add 25,778 new households and 70,156 additional jobs, increases of 32 and 59 percent, respectively.

Absolute household growth is higher in the Montgomery County portion than in the Bucks County portion of the study area. However, because of the larger base value there, the percentage growth in each county is similar; 34.8 and 30.1 percent, respectively. In Bucks County, Hilltown, Milford, and Richland townships are forecasted to grow by the largest margins and together account for half of all the Bucks study area growth.

Table A-XII-1 Quakertown 2030 Households Forecasts by Municipality

BUCKS COUNTY	DVRPC Board Adopted Households		Quakertown Study	Projected	Growth	Percent Growth w/
Municipality	**2005**	**2030**	**Surcharge**	**2030**	**2005-2030**	**Surcharge**
East Rockhill Twp	1,975	2,774	0	2,774	799	40.5%
Haycock Twp	882	1,293	0	1,293	411	46.6%
Hilltown Twp	4,637	6,670	190	6,860	2,223	47.9%
Milford Twp	3,397	5,349	0	5,349	1,952	57.5%
Perkasie Boro	3,385	3,726	230	3,956	571	16.9%
Quakertown Boro	3,470	3,560	0	3,560	90	2.6%
Richland Twp	4,794	5,916	546	6,462	1,668	34.8%
Richlandtown Boro	440	474	0	474	34	7.7%
Sellersville Boro	1,798	1,970	0	1,970	172	9.6%
Silverdale Boro	341	385	0	385	44	12.9%
Springfield Twp	1,953	3,019	0	3,019	1,066	54.6%
Telford Boro (Bucks)	1,027	1,164	0	1,164	137	13.3%
Trumbauersville Boro	387	431	0	431	44	11.4%
West Rockhill Twp	1,841	3,154	21	3,175	1,334	72.5%
Bucks County Sub-Total	**30,327**	**39,885**	**987**	**40,872**	**10,545**	**34.8%**
MONTGOMERY COUNTY						
Franconia Twp	4,437	7,352	691	8,043	3,606	81.3%
Hatfield Boro	1,120	1,083	113	1,196	76	6.8%
Hatfield Twp	6,539	7,621	746	8,367	1,828	28.0%
Lansdale Boro	6,685	6,889	225	7,114	429	6.4%
Lower Salford Twp	4,830	6,739	543	7,282	2,452	50.8%
Montgomery Twp	8,408	9,994	1,165	11,159	2,751	32.7%
North Wales Boro	1,288	1,279	2	1,281	-7	-0.5%
Salford Twp	862	1,195	381	1,576	714	82.8%
Souderton Boro	2,624	2,655	11	2,666	42	1.6%
Telford Boro (Mont)	943	944	514	1,458	515	54.6%
Towamencin Twp	7,480	8,307	189	8,496	1,016	13.6%
Upper Gwynedd Twp	5,363	5,922	1,252	7,174	1,811	33.8%
Montgomery County Sub-Total	**50,579**	**59,980**	**5,832**	**65,812**	**15,233**	**30.1%**
Total Study Area	**80,906**	**99,865**	**6,819**	**106,684**	**25,778**	**31.9%**

Source: DVRPC July 2008

Table A-XII-2 summarizes the employment forecasts; in 2005 there were a total of 118,909 jobs in the study area. Bucks County municipalities grow faster (83.5 percent) than Montgomery (46.8 percent) County municipalities, though Bucks grows by a larger margin, again because Montgomery has such a large base value. Richland Township and Telford Borough (Bucks), where surcharges of 5,595 and 6,640 jobs result in growth rates of 190 and 591 percent between 2005 and 2030, together account for 70 percent of all growth in the Bucks portion of the study area. In Montgomery County, Montgomery, Upper Gwynedd, and Hatfield townships together account for 66 percent of all growth in the Montgomery portion of the study area. These large surcharges result from planned industrial and commercial developments in each municipality.

Table A-XII-2 2030 Employment Forecasts by Municipality for Quakertown Study

BUCKS COUNTY Municipality	2005	DVRPC Board Adopted Employment 2030	Quakertown Study Surcharge	Projected 2030	Growth 2005-2030	Percent Growth w/ Surcharge
East Rockhill Twp	1,873	2,755	766	3,521	1,648	88.0%
Haycock Twp	88	127	0	127	39	44.3%
Hilltown Twp	5,026	6,401	1,413	7,814	2,788	55.5%
Milford Twp	2,007	4,064	81	4,145	2,138	106.5%
Perkasie Boro	3,377	3,708	258	3,966	589	17.4%
Quakertown Boro	7,945	8,096	431	8,527	582	7.3%
Richland Twp	5,708	10,955	5,595	16,550	10,842	189.9%
Richlandtown Boro	193	231	36	267	74	38.3%
Sellersville Boro	3,596	3,957	136	4,093	497	13.8%
Silverdale Boro	315	294	0	294	-21	-6.7%
Springfield Twp	688	990	138	1,128	440	64.0%
Telford Boro (Bucks)	1,030	1,128	5,988	7,116	6,086	590.9%
Trumbauersville Boro	506	603	0	603	97	19.2%
West Rockhill Twp	3,758	5,912	1,538	7,450	3,692	98.2%
Bucks County Sub-Total	**36,110**	**49,221**	**17,032**	**66,253**	**30,143**	**83.5%**
MONTGOMERY COUNTY						
Franconia Twp	5,791	7,950	625	8,575	2,784	48.1%
Hatfield Boro	2,073	2,000	28	2,028	-45	-2.2%
Hatfield Twp	13,187	19,681	2,347	22,028	8,841	67.0%
Lansdale Boro	10,620	11,200	604	11,804	1,184	11.1%
Lower Salford Twp	6,939	9,400	2,155	11,555	4,616	66.5%
Montgomery Twp	17,995	24,103	5,061	29,164	11,169	62.1%
North Wales Boro	1,770	1,800	33	1,833	63	3.6%
Salford Twp	314	350	0	350	36	11.5%
Souderton Boro	2,780	2,800	63	2,863	83	3.0%
Telford Boro (Mont)	1,047	1,050	0	1,050	3	0.3%
Towamencin Twp	5,706	9,505	1,585	11,090	5,384	94.4%
Upper Gwynedd Twp	14,577	17,900	3,072	20,972	6,395	43.9%
Montgomery County - Sub-Total	**82,799**	**107,739**	**15,657**	**123,396**	**40,597**	**49.0%**
Total Study Area	**118,909**	**156,960**	**32,689**	**189,649**	**70,740**	**59.5%**

Source: DVRPC July 2008

2. DVRPC's Travel Simulation Models

DVRPC's travel models follow the traditional steps of trip generation, trip distribution, modal split, and traffic assignment. However, an iterative feedback loop is employed from traffic assignment to the trip distribution step. The feedback loop ensures that the highway and surface transit roadway congestion levels used by the models when determining trip origins and destinations are similar to those that result from the highway and transit assignment steps. Additionally, the iterative model structure allows trip making patterns to change in response to changes in traffic patterns, congestion levels, and improvements to the transportation system. A single iteration is sufficient to produce reasonable estimates of future highway congestion levels for purposes of estimating projected travel patterns.

For the build alternatives, the FTA currently requires that the No-build person trip table be utilized. This limits the feedback iterations to the modal split and transit/highway assignment model steps, resulting in separate iterative processes. Transit operator scheduled transit times and highway times taken from a travel time survey are used for model calibration. Both the No-build and Build alternative future iterative processes start with current scheduled transit and surveyed highway times.

For future simulations, the iterative portion of the forecasting process involves updating the highway and surface transit network restrained link travel speeds, rebuilding the minimum time paths through the networks, and skimming the inter-zonal travel time from the new congested minimum paths. Then the trip distribution, modal split, transit, and highway assignment models are executed in sequence for the No-build alternative

In response to FTA requirements, congested No-build alternative highway and transit skims were utilized for trip distribution for each build alternative to force the model to reproduce No-build person trip travel patterns. Subsequent to trip distribution, one iteration on future congested highway and surface transit times was performed in the modal split and transit/highway model steps to insure that the impact of the proposed transit facilities on future highway and surface transit congestion patterns is considered.

The modal split model is run separately for the peak, midday, and evening time periods. The modal split model calculates the fraction of each person-trip interchange in the trip table which should be allocated to transit using a binary logit formulation, and then assigns the residual to the highway side. The model is nested by mode of approach (auto versus walk/bus) and stratified by trip purpose (home based work, home based non-work, and non-home based), transit sub-mode (commuter rail, subway elevated, or surface), and auto ownership (zero-vehicle or one-plus vehicle households). The choice between highway and transit usage is made on the basis of comparative cost, travel time, and frequency of service, with other aspects of modal choice being used to modify this basic relationship. In general, the better the transit service, the higher the fraction assigned to transit, although trip purpose and auto ownership also affect the allocation. The model subdivides highway trips into auto drivers and passengers. Auto driver trips are added to the truck, taxi, and external vehicle trips in preparation for assignment to the highway network.

After each model iteration the transit trip tables are assigned to the transit network to produce link and route passenger volumes. The transit person trips produced by the modal split model are "linked" in that they do not include any transfers that occur either between transit trips or between auto approaches and transit lines. The transit assignment procedure accomplishes two major tasks. First, the transit trips are "unlinked" to include transfers, and second, the unlinked transit trips are associated with specific transit facilities to produce link, line, and station volumes. These tasks are accomplished simultaneously within the transit assignment model, which assigns the transit trip matrix to the minimum impedance paths built through the transit network. There is no capacity restraining procedure in the transit assignment model.

3. Model Calibration

For the Quakertown Rail Reactivation Study, the simulation model parameters were fine-tuned as part of the model calibration to accurately reproduce transit route and station volumes and highway screenline volumes throughout the study area. Most of these parameter adjustments were in the sub-mode strata of the modal split model. Within the study area, the regionally validated model parameters tended to significantly underestimate current R5 commuter rail ridership and over-estimate patronage on existing bus routes. The results of the recalibrated modeling chain are displayed in ***Table A-XII-3***. The recalibrated model is able to reproduce regional SEPTA system totals within acceptable levels of accuracy.

Table A-XII-3 2005 Study Area Transit Calibration Volume by Station for Quakertown Focused Simulation

Average Weekday Board and Alight

Study Area R5 Stations	2005 Count	2005 Simulated	Difference Number	Difference Percent
Link Belt	144	137	-7	-4.9%
Colmar	532	600	68	12.8%
Fortuna	134	147	13	9.7%
Lansdale	2,106	2,145	39	1.9%
Pennbrook	826	834	8	1.0%
North Wales	1,411	1,416	5	0.4%
Sub-total Study Area	**5,153**	**5,279**	**126**	**2.4%**
Doylestown/Lansdale Branch Total	**16,645**	**15,468**	**-1,177**	**-7.1%**
Bus Route 132	860	820	-40	-4.7%

Source: DVRPC July 2008

4. Station Parking Requirements

An estimation procedure was developed and calibrated to estimate station parking requirements from simulated station passenger volumes. This procedure is based on special tabulations of simulation model outputs that isolate home to station trips by walk and auto approach modes from the simulated model output. Home to station trips were then categorized by approach mode as walk, park and ride, or kiss and ride. Station parking requirements were then estimated from the park and ride approaches assuming an average vehicle occupancy. The station parking model was calibrated using parking lot utilization data provided by SEPTA.

Table A-XII-4 displays the 2005 results of the calibrated station approach model for the existing stations within the study area. Overall, there is a great deal of variation in the percentage distribution of approach modes by station, depending on the characteristics of each station (parking availability, walk proximity to residential neighborhoods, etc). Overall, ***Table A-XII-4*** shows that the calibrated station approach model reproduced parking lot utilization counts with an acceptable level of accuracy.

Table A-XII-4 Parking Requirements and Station Approach Calibration for Quakertown Study

Station	Simulated Trip Ends Total	Percent Walk	Percent Park & Ride	Percent Kiss & Ride	Parking Requirements 2005 Simulated	2005 Count	Difference Number	Percent
Link Belt	137	100%	0%	0%	0	0	0	n/a
Colmar	600	2%	90%	8%	222	218	-4	-2.0%
Fortuna	147	2%	75%	23%	18	25	7	29.7%
Lansdale	2,145	24%	53%	23%	459	461	2	0.5%
Pennbrook	834	20%	55%	25%	165	158	-7	-4.7%
North Wales	1,416	10%	68%	22%	350	368	18	4.9%
Total	**5,286**	**19%**	**61%**	**21%**	**1,214**	**1,230**	**16**	**1.3%**

Source: DVRPC July 2008

B. Projected Travel Demand

Travel and parking demand were forecast for the year 2030. Findings for the regional rail build alternative is presented and analyzed in this section. Data for transit demand is presented as boardings plus alightings indicating the number of ‘trip-ends’ generated at each station.

1. Regional Rail Alternative

This alternative models a full electrified reactivation of the heavy rail to Springfield Township at Shelly in Bucks County. This alternative provides direct, multiple-unit service from Shelly to Center City. This alternative does not include the Gwynedd Square station on the Stony Creek line.

Under this alternative, total regional rail volume is expected to increase to 114,751 person trips by the year 2030 representing a 4,780 person trip improvement over the No-build; a 4.3 percent increase in total regional rail riding. Within the study area, station volumes are forecast to increase to 12,326 daily person trips, a 110.1 percent increase over the No-build. New stations along the reactivated line host 5,471 new person trips, 44 percent of study area person trips. Individual station volumes for new stations range from 1,363 daily person trips at Telford Station to 636 daily person trips at Quakertown Station. All existing stations experience increased volume with the exception of Colmar Station. The new stations draw riders who once drove to Colmar. Results for the Regional Rail Alternative are presented in ***Table A-XII-5***.

Station parking requirements under the Regional Rail Alternative are presented in ***Table A-XII-6***. Demand for parking at new stations varies greatly from 91 spaces at Souderton Station to 225 spaces at Shelly Station. A total of 1,077 new spaces will be required along the reactivated line. Existing station parking is adequate to accommodate the increased riding under this alternative with the exception of North Wales; 39 additional spaces will be required at this station.

Station approaches by mode are presented in **Table A-XII-7**. In percentage terms, the approaches under the Regional Rail alternative are virtually unchanged from the Shuttle alternative.

Table A-XII-5 2030 Regional Rail Build Alternative Station Ridership for Quakertown Study

	Weekday Boardings and Alightings			
	2030	**2030**	**Difference**	
Study Area Station	**No-build**	**Shuttle**	**Number**	**Percent**
Shelly	0	726	726	n/a
Quakertown	0	636	636	n/a
Perkasie	0	902	902	n/a
Sellersville	0	697	697	n/a
Telford	0	1,363	1,363	n/a
Souderton	0	654	654	n/a
Hatfield	0	763	763	n/a
Sub-total New Stations	**0**	**5,741**	**5,741**	**n/a**
Link Belt	177	207	30	16.9%
Colmar	687	554	-133	-19.4%
Fortuna	196	225	29	14.8%
Lansdale	2,214	2,391	177	8.0%
Pennbrook	917	1,207	290	31.6%
North Wales	1,676	2,001	325	19.4%
Sub-total Study Area	**5,867**	**12,326**	**6,459**	**110.1%**
Total Commuter Rail Person Trips	**109,971**	**114,751**	**4,780**	**4.3%**

Source: DVRPC July 2008

Table A-XII-6 2030 Regional Rail Build Alternative Parking Requirements for Quakertown Study

		Weekday Parking		
Study Area Station	**2030 Station Volume**	**2030 Parking Requirement**	**2005 Existing Parking**	**Additional Parking**
Shelly	726	225	0	225
Quakertown	636	105	0	105
Perkasie	902	215	0	215
Sellersville	697	119	0	119
Telford	1,363	176	0	176
Souderton	654	91	0	91
Hatfield	763	146	0	146
Sub-total New Stations	**5,741**	**1,077**	**0**	**1,077**
Link Belt	207	0	0	0
Colmar	554	135	291	0
Fortuna	225	19	33	0
Lansdale	2,391	352	497	0
Pennbrook	1,207	195	244	0
North Wales	2,001	442	403	39
Sub-total Existing Stations	**6,585**	**1,144**	**1,468**	**39**
Total Study Area	**12,326**	**2,221**	**1,468**	**1,116**

Source: DVRPC July 2008

Table A-XII-7 2030 Regional Rail Build Alternative Station Approaches for Quakertown Study

	Home to Station Approaches[1]			
Station	Walk	Park & Ride	Kiss & Ride	Feeder Bus
Shelly	23	232	76	0
Quakertown	48	109	37	0
Perkasie	64	222	72	0
Sellersville	64	123	41	0
Telford	131	184	60	0
Souderton	85	95	32	0
Hatfield	64	151	50	0
Sub-total	**479**	**1,116**	**368**	**0**
Link Belt	59	0	18	0
Colmar	3	138	13	0
Fortuna	1	20	6	0
Lansdale	251	368	188	11
Pennbrook	74	203	92	0
North Wales	46	455	150	0
Sub-total	**434**	**1,184**	**467**	**11**
Total	**913**	**2,300**	**835**	**11**

1. Excludes reverse commuting

Source: DVRPC July 2008

APPENDIX XIV-1 EXPLANATION OF ADDITIONAL VALIDATION STATISTICS

Chapter XIV presents validation data for both the highway and transit assignment models. This data includes statistics, such as root mean squared error (RMSE). This appendix provides addition discussion on validation statistics. Specifically, the Theil statistics are defined and discussed for both the highway and transit assignment.

The Theil statistics provide more information on the magnitude and nature of simulation errors than can be provided by the RMSE, R, or R^2 statistics. There is an overall Theil statistic (U) which can be decomposed into three parts – a bias statistic (U^M) a variance statistic (U^S), and a covariance statistic (U^C). They are defined as follows:

$$U = \frac{\sqrt{\frac{\sum_{n=1}^{N}\left(V_n^c - V_n^a\right)^2}{N}}}{\sqrt{\frac{\sum_{n=1}^{N}\left(V_n^a\right)^2}{N}} + \sqrt{\frac{\sum_{n=1}^{N}\left(V_n^c\right)^2}{N}}}$$

$$U^M = \frac{\left(\overline{V}^c - \overline{V}^a\right)^2}{\frac{1}{N}\sum_{n=1}^{N}\left(V_n^c - V_n^a\right)^2}$$

$$U^S = \frac{\left(\sigma^c - \sigma^a\right)^2}{\frac{1}{N}\sum_{n=1}^{N}\left(V_n^c - V_n^a\right)^2}$$

$$U^C = \frac{2(1-R)\sigma^c\sigma^a}{\frac{1}{N}\sum_{n=1}^{N}\left(V_n^c - V_n^a\right)^2}$$

where:

- $\overline{V}^C$ The mean value of the counted volumes
- $\overline{V}^a$ The mean value of the assigned volumes
- σ^c The standard deviation of the counted volumes
- σ^a The standard deviation of the assigned volumes
- R The coefficient of correlation

The values for the 2000 highway assignment appear in ***Table XIV-3*** (page 282) The overall statistic, called Theil's inequality coefficient, measures the relative error between the observed and simulated volumes. It ranges between 0 and 1, with 0 meaning a perfect fit and 1 being the worst fit possible between observed and assigned volumes. The value U= 0.15 for the 2000 highway assignment indicates a relatively good fit. The bias measure reflects the degree of systematic deviation between the assigned and counted volumes. This statistic should be as small as possible. The value 0.0011 for the 2000 highway assignment indicates a lack of systematic bias in the results. The variance measure indicates the degree to which the model is able to replicate the variance or scatter present in the counted data. This value should also be small; the value of U^S = 0.0252 for the 2000 highway assignment indicates that the model does a good job representing the variability in the counted facility volumes. The final statistic, the covariance measure, is a measure of the remaining error after considering the bias and variance errors. This statistic should ideally be 1. The value U^C = 0.9762 for the 2000 highway assignment indicates a low degree of remaining error.

The Theil statistics for the 2000 transit assignment are in ***Table XIV-9*** (page 288). The Theil inequality coefficient (U) is 0.1130. This indicates that the assignment results fit well with the passenger counts. The Theil bias and variance coefficients are both close to zero, 0.0070 and 0.1154 respectively. This indicates that the model does a good job replicating both the overall patterns and spread in the data. The Theil covariance coefficient is 0.8833. This indicates that there is some remaining unexplained error, but that it is relatively small.

2000 AND 2005 VALIDATION OF THE DVRPC REGIONAL SIMULATION MODELS

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Key Words: 2000 and 2005 Model Validation, TRANPLAN, INET, Evans Iterative Travel Forecasting Model, FTA Compliant, Traffic Analysis Zones (TAZs), Trip Generation, Trip Distribution, Highway Capacities and Travel and Transit Speeds, Highway Functional Classification, Modal Split, Highway Assignment, Transit Assignment, Focused Traffic Assignment.

ABSTRACT
This report presents the results of the 2000 and 2005 calibration/validation of the DVRPC regional travel simulation models. Input data, structure, parameter estimates, and validation data are presented. Appendices present detailed input and output data and detailed operating instructions for the TRANPLAN modeling environment.

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