Enhancement of DVRPC'S Travel Simulation Models

TASK 9

NON-MOTORIZED TRAVEL MODEL

PREPARED FOR
DELAWARE VALLEY REGIONAL PLANNING COMMISSION

BY
CAMBRIDGE SYSTEMATICS, INC.

NOVEMBER 1996

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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 for the orderly growth and development 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. The Commission is an advisory agency which divides its planning and service functions between the Office of the Executive Director, the Office of Public Affairs, and three line Divisions: Transportation Planning, Regional Planning, and Administration. DVRPC's mission for the 1990s is to emphasize technical assistance and services, and to conduct high priority studies for member state and local governments, while determining and meeting the needs of the private sector.

The DVRPC logo is adapted from the official seal of the Commission 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 flowing through it. The two adjoining crescents represent the Commonwealth of Pennsylvania and the State of New Jersey. The logo combines these elements to depict the areas served by DVRPC.

DELAWARE VALLEY REGIONAL PLANNING COMMISSION

Publication Abstract

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ABSTRACT

This report presents recommendations for modeling non-motorized travel in the DVRPC travel model system, which includes the walk and bicycle modes. Recent interest in reducing congestion and improving air quality, due in large part to federal legislation, and a recognition that non-motorized travel often serves as a substitute for motorized modes have stimulated interest in the analysis of non-motorized modes.

The report presents recommendations for new trip generation rates which include both motorized and non-motorized travel. Also, presented are binary logit mode choice models which can be used to determine mode shares of non-motorized travel based on demographic and area type variables. Included is a measure of the pedestrian environment, which considers sidewalk availability, ease of street crossings, and building setbacks. A procedure for implementing the changes in the model system is presented.

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Table of Contents

List of Tables

List of Figures

Executive Summary

This report describes the recommended methods for modeling non-motorized travel within the DVRPC travel model system. These methods consist of revised trip generation rates and binary logit mode choice models applied to the person trip ends by purpose for each zone in the model system. The models were based on data collected in a household travel survey for the DVRPC region in 1986-1987, the 1990 U.S. Census Transportation Planning Package (CTPP), and household surveys conducted in three other urban areas – Baltimore, Portland, and Seattle – from 1992 to 1995.

Like most U.S. urban area travel demand models, the DVRPC travel model system has focused on travel by highway and transit modes. Metropolitan planning organizations in the U.S. have recently begun to analyze *non-motorized travel*, which includes the walk and bicycle modes. Their interest in reducing congestion and improving air quality, and a recognition that non-motorized travel often serves as a substitute for motorized modes have stimulated interest in the analysis of non-motorized modes.

The recommended trip generation procedures consist of new sets of trip production and attraction rates, which include both motorized and non-motorized trips, for the three trips purposes in the model system: home based work, home based non-work, and non-home based. These rates would replace the existing DVRPC motorized trip generation rates. The new rates are based on the same demographic variables – households by vehicle availability level and employment by type – as the motorized trip rates used in the existing model system.

The new home based work trip production and attraction rates are based on the existing DVRPC motorized trip generation rates, adjusted to reflect total trips (motorized plus non-motorized) using the mode shares by area type from the CTPP. For home based non-work productions, the non-motorized mode shares from the Portland survey data set were applied to the DVRPC motorized trip production rates and adjusted to reflect area type differences. Trip attractions were set so that non-motorized attractions were equal to productions for each zone. A similar procedure was used to compute non-home based trip rates.

A binary logit mode choice model was developed for each of the three trip purposes. For home based work trips, the model was estimated using data from the household travel survey for the DVRPC region. This model estimates the share of non-motorized trips for each zone as a function of vehicle availability, population density, area type, and the pedestrian environment.

For home based non-work trips, the mode choice model was estimated from the Portland area survey data set based on household size and vehicle availability. This model was adjusted using local data to include area type and pedestrian environment variables. A similar model, without the household demographic variables, was developed for non-home based trips.

The pedestrian environment variables used in the mode choice models were designed to reflect local differences in pedestrian friendliness throughout the region. The variables were developed by the members of the consultant team familiar with the region and by DVRPC staff. The pedestrian environment variable is a subjective index ranging from one to three which considers sidewalk availability, ease of street crossings, and building setbacks.

The existing DVRPC modeling process will be revised to incorporate the new non-motorized modeling procedures. The new person trip generation rates will be used in place of the existing motorized trip rates. Next, the mode choice models will be applied to the trips by purpose for each zone, separating motorized from non-motorized trips. The motorized trips will be carried forward into the existing trip distribution, motorized mode choice, and assignment models. The revised procedures will be implemented using revised FORTRAN programs for trip generation.

1.0 Introduction

Like most U.S. urban area travel demand models, the DVRPC travel model system has focused on travel by highway and transit modes. Metropolitan planning organizations have recently begun to analyze *non-motorized travel,* which includes the walk and bicycle modes. Their interest in reducing congestion and improving air quality, and a recognition that non-motorized travel often serves as a substitute for motorized modes have stimulated interest in the analysis of non-motorized modes.

The objective of Task 9 of the *Enhancement of DVRPC's Travel Simulation Models* project is to incorporate the analysis of non-motorized travel into the DVRPC model system. This report presents the recommendations for doing this and the results of the analysis of non-motorized travel in the DVRPC region.

The report is organized as follows. This chapter discusses the need for modeling non-motorized travel, the possible ways in which it could be incorporated into the modeling system, the use of a pedestrian environment variable to measure the "pedestrian friendliness" of each zone, and the data sources used in the estimation of non-motorized travel models. Chapter 2 discusses the trip generation for non-motorized trips, both separately and as part of total person trips. Chapter 3 discusses trip distribution for non-motorized trips. Chapter 4 discusses mode choice modeling for non-motorized trips. Finally, Chapter 5 presents the recommendations for incorporating non-motorized travel into the modeling process.

■ 1.1 Need for Non-Motorized Modeling Procedures

There are several specific reasons why the travel demand models of today need to be capable of analyzing non-motorized travel. These include:

Mode Choice. It is becoming apparent that walking and bicycling are real mode choice alternatives for many trips. Walking is a particularly appropriate alternative for short trips of all purposes, and has a higher mode share than transit in many areas. Bicycling is often a good alternative for longer trips for specific purposes; for example, it has a significant mode share of school trips but a very low share for shopping trips. Bicycling also has higher mode shares than transit in many types of areas, especially communities with many younger residents such as college areas. Both walking and bicycling appear to have higher usage in areas with environments that are particularly friendly toward their use.

Analysis of Transportation Demand Management and Other Measures to Reduce Auto Travel. Travel models are now being used to analyze a wider range of alternatives which discourage auto travel than in the past. Many of these alternatives include policies, such as congestion pricing, which go much further than existing experience in terms of discouraging or penalizing auto use. It is reasonable to assume that travelers would consider walking and bicycling in response to such policies, especially where transit may not be a feasible option.

Analysis of Effects of Alternative Land Use Patterns. Recent studies have shown that certain types of land use can have significant effects on pedestrian and bicycle usage (and therefore auto travel). Land use characteristics which appear to result in increased non-motorized travel include:

- High density of development;
- "Pedestrian/bicycle friendly" environment, including existence of sidewalks, ease of street crossing, existence of bicycle infrastructure, and lack of building setbacks; and
- Mixed use development.

Transit Access. The quality of transit access is often considered inadequately in urban travel models. High quality transit service will not generate significant ridership if access is poor. While travel models usually consider access time in mode choice decisions, there are other factors that influence access mode choice (and ultimately the choice of whether or not to choose transit at all). While it is important to consider factors affecting auto access, such as parking availability, it is also necessary to consider factors influencing non-motorized access, such as the quality of the pedestrian environment and the presence of bicycle infrastructure.

1.2 Methods for Modeling Non-Motorized Travel

Incorporating Non-Motorized Travel into the Modeling Process

Since there is little benefit to performing trip assignment for non-motorized travel, the objective of including non-motorized travel in the modeling process is to determine, for the scenario under analysis, how many of the generated trips would be made via the non-motorized mode and to ensure that those trips are excluded from the auto and transit assignment processes. This can occur at one of four points in the modeling process:

1. As part of trip generation.
2. Between trip generation and trip distribution.
3. Between trip distribution and mode choice, or
4. As part of mode choice.

These options are discussed in detail below:

As part of trip generation. Separate motorized and non-motorized trip generation rates can be developed. Since the rates in the existing DVRPC trip generation model are for motorized trips, only rates for non-motorized travel would be developed.

The main advantages of analyzing non-motorized travel as part of trip generation are simplicity and the ability to retain the existing trip generation rates (as well as the subsequent trip distribution model) for motorized travel. This would ensure consistency with the existing modeling process and likely make the model recalibration process to be performed at the end of the model enhancement project easier. The major disadvantage is that it would be difficult to identify the effects of transportation level of service and transportation policy changes on the choice between motorized and non-motorized travel. This is the major objective for including non-motorized travel in the modeling process.

Between trip generation and trip distribution. In this procedure, the trip generation model generates total person trips, including trips by both motorized and non-motorized modes. A model is then used to separate motorized from non-motorized trips. The motorized trips are then carried forward into trip distribution.

The major advantages of this method are that the choice between motorized and non-motorized travel is considered, and the existing trip distribution model can be retained. The major disadvantage is that the choice model must be applied to generated trips at the zone level, and measures of zone-to-zone impedance cannot be considered. However, it must be pointed out that the necessary simplification of using analysis zones in the modeling process, which causes some aggregation error throughout the process, would cause even more problems if non-motorized trips were considered on a zone-to-zone basis.

Zones can be several miles across, particularly in outlying rural areas. This means that the zone-to-zone distances used in the modeling process can be off by a mile or more for individual trips where trip ends are not near the zone centroids. This error is generally acceptable for relatively long auto and transit trips, which average several miles. However, non-motorized trips, which are predominantly walk trips, are usually only a mile and are seldom more than two or three miles long. Given that centroids in outlying areas are generally several miles apart, few walk trips would be estimated by the model, and most of those that would be estimated would be intrazonal. Impedances for walk trips between adjacent zones, which could be very short, cannot be accurately modeled.

Between trip distribution and mode choice. Some urban areas have modeled non-motorized trips through a separate mode choice model applied prior to the "main" mode choice model. Portland, for example, uses a "pre-mode choice" model to separate motorized from non-motorized trips at the zone-to-zone level, and then applies the main mode choice model to separate auto and transit trips.

The main advantage to this method is that the mode choice model is applied at the zone-to-zone level, where impedance information can be incorporated. This also would be true if the choice between motorized and non-motorized trips occurs as part of the overall mode choice model, but this method allows for different data sets to be used during estimation. The main disadvantages are the need for a data set sufficient to estimate the mode choice model between motorized and non-motorized travel and the aggregation error problem for impedance, as described above. Another problem is that because the choice is separate from the choice among motorized modes, the ability of non-motorized travel to serve as a true potential substitute in the model for motorized travel is limited. For example, an increase in auto costs might not result in an increase in non-motorized travel unless that variable was specifically included in the "pre-mode" choice model, which might be difficult if different data sets were used.

Because of these problems, particularly the impedance aggregation error issue, it was decided not to pursue this strategy for the DVRPC model.

As part of mode choice. A superior method to the "pre-mode" choice model would be to incorporate the motorized/non-motorized choice into the overall mode choice model. This would allow non-motorized travel to serve as a true potential substitute for motorized travel.

The other major disadvantages of the "pre-mode" choice model, including the aggregation error for impedances, are also associated with this modeling method. It was decided that this strategy would also not be pursued in this project.

To summarize, in this project the modeling of non-motorized travel was considered in two ways: as part of trip generation, and between trip generation and distribution.

Measure of the Quality of the Pedestrian/Bicycle Environment

Several areas, including Portland, Sacramento, and Montgomery County (Maryland), have developed measures of the quality of the pedestrian/bicycle environment and incorporated them into their model systems. It is important to recognize that although pedestrian environment variables have been successfully used in these areas, there are some important limitations that should be noted, including:

- The necessity of zone-based variables (which has implications for both the transferability of the models and the development of subarea models);
- The need for a significant amount of time to be spent by persons familiar with the area to develop and update the values for the zones; and
- The subjective nature of some components of the variables.

For the DVRPC region, a pedestrian environment variable (PEV) was developed. The PEV consists of several components. These include:

- Sidewalk availability;
- Building setbacks;
- Street connectivity; and

- Ease of street crossings.

These components could be combined in a number of ways. For example, a linear combination of these components with equal weights could be used, or sidewalk availability could be assumed to have twice the weight of the other components. In this project, the model estimation procedure was used to determine the weights in a linear combination.

For each component, a quantitative "score" for each of these four categories for each zone in the DVRPC region was assigned. To reduce individual analyst bias, a set of transportation analysts who are familiar with the DVRPC region each assigned one of three values (i.e. high, medium, low) to each zone for each attribute. These analysts were members of the DVRPC and consultant team staffs. The simplicity of having only three possible values for each component of the PEV was necessary due to the subjective nature of the variables.

Since the goal of the process is to identify a single value for each variable for each zone, it was necessary to combine the various responses. It was felt that each final rating should be "low," "medium," or "high" rather than anything in between. The final rating, therefore, was not a an average but the most commonly cited rating, with zone familiarity considered as described below. Using an average would have reduced the number of "low" and "high" ratings, reducing the usefulness of the variable.

The following procedure was used to combine the responses:

1. Obviously, if all respondents agreed on a rating, it became the final rating.

2. If all respondents did not agree, the responses of those evaluators who had the highest familiarity rating were examined. If those responses agreed on a rating, it became the final rating.

3. If those respondents most familiar with a zone did not agree on the rating, the rating which appeared most frequently among those respondents was used. For example, if three respondents were very familiar with a zone, if two assigned ratings of "high" and one of "medium," a rating of "high" was assigned.

4. If there was no clear cut choice among the most familiar respondents as described in step 3, the respondents with the next highest level of familiarity were considered in breaking a tie. For example, say that two respondents had a "high" familiarity with a zone, and one ranked it high and another "medium. Say one additional respondent had a "medium" familiarity with a zone and ranked it "medium." Then "medium" became the final rating.

5. If a tie could not be broken using rule 4, the rating given by the respondent with the highest overall familiarity for the region (usually DVRPC) was used.

6. If there was significant disagreement among respondents on a rating (e.g. two "highs" and two "lows"), a rating of medium was used.

As previously mentioned, the overall PEV was developed as a linear combination of the scores of the individual categories. Preliminary home based work mode choice models were estimated with the individual components as separate variables. The estimated model coefficients were used to develop weights for the components. The final PEV is given by the equation:

PEV = 0.25* (Sidewalk Availability) + 0.30* (Ease of Street Crossing) + 0.45* (Building Setbacks)

The street connectivity variable was not found to have a significant effect.

1.3 Data Sources for Modeling Non-Motorized Travel

The major sources for data for estimating most components of travel models are usually a household travel survey data set and highway and transit networks for determining transportation level of service on a zone-to-zone basis. The survey data set is used for estimating trip generation and mode choice models, as well as calibrating trip distribution models. Other data sources may be used– especially for model validation and application – including census socioeconomic and journey-to-work data, and counts of vehicles or transit riders.

For the analysis of non-motorized travel, household survey data are needed to estimate trip generation and mode choice models. Like most surveys done in the 1980's, the 1986-1987 DVRPC household survey collected data on non-motorized trips only for the home based work purpose, and it appears to undercount even those trips. It is therefore necessary to have alternate data sources for model estimation.

Some more recent household surveys in other urban areas have asked for information about all trips, motorized and non-motorized, for all trip purposes. Data from three such surveys – conducted in Baltimore, Portland, and Seattle – were obtained for use in this project. While socioeconomic and trip distance information was available from all three surveys, it was impossible to use area characteristics from these surveys because of the different context (urban area characteristics, model parameters, etc.) of the survey data sets from the DVRPC context.

In general, the DVRPC household survey was used only for the home based work mode choice model. The surveys from other urban areas were used only for the trip generation models and the mode choice models for other purposes.

2.0 Trip Generation

The first step in modeling non-motorized travel is determining the number of trips. The method for generating non-motorized trips could be a revised total person trip generation method that would include both motorized and non-motorized trips, or it could be a method to estimate trip generation for non-motorized trips only.

Generating total trips by all modes is preferred for two reasons. First, since non-motorized trips would generally not be analyzed in subsequent model steps and would not be used as inputs to most transportation planning analyses, the step might not be worthwhile if other modes of travel are unaffected. Second, it has been shown in other urban areas that walking and bicycling are viewed as substitutes for motorized transportation modes for short trips and when other conditions (congestion, cost, vehicle unavailability) are unfavorable for motorized modes. In some areas, trip generation rates appear to be more consistent over the entire urban area when non-motorized trips are included than when they are excluded. If only non-motorized trips were to be generated, care must be taken to ensure that trip generation is sensitive to such variables as vehicle ownership, development density, and the pedestrian environment.

As described in the work plan for this task, models have been developed for both methods. Following a brief description of the DVRPC trip generation model in the context of non-motorized travel, the descriptions and results of the two methods are presented, and a recommendation for incorporating non-motorized travel into the DVRPC model system is made.

2.1 DVRPC Trip Generation Model

The DVRPC trip generation model produces trip end estimates for 13 categories of trips. Six of these categories are internal person trips, and seven are vehicle trips for various classifications (truck, taxi, etc.). The existing DVRPC model generates trips only by motorized modes (auto and transit) for internal trips. The six categories are:

- Home based work productions;
- Home based work attractions;
- Home based non-work productions;
- Home based non-work attractions;
- Non-home based productions; and
- Non-home based attractions.

The initial estimates of trip ends are computed by applying trip rates to various socioeconomic variables at the zone level. Table 2.1 shows the variables used and the trip rates for each trip category. The trip end estimates are later revised to reflect external-local trips and calibration and balancing adjustments.

Because most non-motorized trips are relatively short, the number of non-motorized trips which cross the regional cordon is small enough to be considered negligible. Therefore, for the analysis of non-motorized trips, it will be assumed that all such trips are internal-internal. (The number of productions and attractions of these trips by purpose will therefore be balanced.) Non-motorized travel must be considered in this process for the six person trip categories.

2.2 Non-Motorized Trip Generation Models

Because no changes (other than those associated with the incorporation of non-motorized travel) are planned for the trip generation model as part of the model enhancement project, it is desirable to have the non-motorized trip generation procedure be as consistent as possible with the existing trip generation model. Thus the home based work trip productions should be based on employed adult workers, the home based non-work productions on households by vehicle ownership level, the home based work attractions on total employment, and both the home based non-work attractions and the non-home based trips on occupied dwelling units and basic, retail, and other employment.

Because the DVRPC survey data underreports non-motorized home based work trips and does not include non-motorized trips for other trip purposes, the dataset cannot be used for trip generation model development. This exercise will rely on the survey data from the other cities.

Home Based Work Trips

Table 2.2 shows the trip production rates per household computed from the three household surveys for home based work trips. The rates are stratified by the number of workers in the household and are separated into motorized and non-motorized trips. For comparison purposes, the average DVRPC motorized trip production rates for households with one, two, and three or more workers is shown below the rates computed from the three survey datasets, as well as the rates estimated from the DVRPC household survey.

Table 2.2 shows significantly different trip generation behavior among the three survey datasets. Seattle's motorized trip generation rates are close to those in the DVRPC model system. Portland shows a much lower motorized trip generation rate, about two thirds of the DVRPC rate. Baltimore, on the other hand, shows a rate of about 40-50 percent higher than the DVRPC rate.

Table 2.1 DVRPC Internal Person Motorized Trip Rates

Trip Category	Socioeconomic Variable	Factors by Area Type					
		CBD	Fringe	Urban	Suburban	Rural	Open Rural
Home Based Work Productions	Employed Adult Residents	0.653	0.918	1.507	1.632	1.628	1.597
Home Based Work Attractions	Total Employment	1.420	1.461	1.504	1.492	1.461	1.461
Home Based Non-Work Productions	Households with 0 Vehicles	0.54	0.57	1.00	1.28	1.28	1.28
	Households with 1 Vehicle	2.36	2.49	2.50	4.25	4.98	4.98
	Households with 2 Vehicles	3.74	3.94	4.05	6.64	7.78	7.78
	Households with 3+ Vehicles	4.24	4.46	4.57	7.53	8.92	8.92
Home Based Non-Work Attractions	Occupied Dwelling Units	0.61	0.71	0.81	1.43	1.43	1.53
	Basic Employment	0.20	0.26	0.36	0.71	0.71	0.71
	Retail Employment	2.04	2.35	3.85	8.37	10.71	11.74
	Other Employment	0.61	0.81	1.02	3.46	3.46	4.58
Non-Home Based Trips	Occupied Dwelling Units	0.22	0.27	0.32	0.54	0.54	0.54
	Basic Employment	0.11	0.16	0.22	0.32	0.22	0.22
	Retail Employment	0.65	1.30	1.95	4.00	4.65	4.65
	Other Employment	0.32	0.43	0.65	1.08	1.30	1.30

Table 2.2 Home Based Work Trip Rates from Household Surveys

Dataset	Motorized Trips	Non-Motorized Trips	Total Trips	% Non-Motorized
1-Worker Households				
Portland	1.16	0.11	1.27	8.4%
Baltimore	2.48	0.28	2.76	10.0%
Seattle	1.57	0.11	1.68	6.4%
DVRPC Simulation	1.54			
DVRPC Survey	1.51			
2-Worker Households				
Portland	2.04	0.11	2.14	5.0%
Baltimore	3.95	0.28	4.24	6.7%
Seattle	2.72	0.10	2.82	3.6%
DVRPC Simulation	3.08			
DVRPC Survey	2.84			
3-Worker Households				
Portland	3.21	0.15	3.37	4.6%
Baltimore	6.11	0.53	6.64	8.0%
Seattle	4.43	0.09	4.52	2.0%
DVRPC Simulation	4.62			
DVRPC Survey	4.56			
All Households				
Portland	1.68	0.11	1.79	6.1%
Baltimore	3.36	0.30	3.66	8.2%
Seattle	2.17	0.10	2.27	4.6%
DVRPC Simulation	1.95			-------
DVRPC Survey	1.90			2.6%

At first glance, the differences in these numbers may appear unusual. It is possible that the Portland survey captured more "trip chains," in which home based work trips are split into home based non-work and non-home based components. If this were the case, however, it would have been reflected in higher trip generation rates for these other purposes.

As far as the Baltimore data are concerned, it appears as if there is a misinterpretation of the trip rates. Table 2.2 indicates an average of over two daily work trips per worker, which seems unrealistically high.

It should be noted that the Baltimore dataset differed significantly from the other two in that each "leg" of a trip was reported. (For example, a trip involving walking to a bus, riding the bus, and walking to the destination was reported as three trips.) Because of these differences, the Baltimore dataset could not be used for trip generation purposes.

For the moment, this leaves the Seattle data as the most reasonable for work trip generation purposes. The average number of non-motorized home based work trips per household is about 0.10, or about five percent of all home based work trips. This is comparable to the percentage of non-motorized trips (5.9 percent) reported for the DVRPC area in the Census Transportation Planning Package (CTPP) data supplied by DVRPC.

The CTPP data do not estimate trips per household, but they do provide information on mode shares and include non-motorized modes. Table 2.3 provides information on the CTPP mode shares by area type (as defined for the DVRPC trip generation model). Also shown are the implied non-motorized trip generation rates, computed from the CTPP mode shares and DVRPC model's motorized trip rates. Table 2.3 shows that the mode shares, especially at the home end, vary substantially by area type. It is interesting to note that the total person trip generation rates (motorized plus non-motorized) for each area type are all approximately 1.5 to 1.6 trips per worker (except for CBD productions).

For home-based work trips, it is recommended that the implied trip rates from Table 2.3 be used. For the method where non-motorized trips are generated separately, these rates are shown in the third and fourth columns of Table 2.3. For the method where motorized and non-motorized trips are generated together, the rates are shown in the fifth and sixth columns. Alternately, a constant rate for total trips could be used, equal to the average rate of about 1.6 trips per worker.

The factors in the last two columns of Table 2.3 are the ratios between the non-motorized trip rate for the area type and the average for all area types. These can be used to relate trip generation to area type for other trip purposes.

Table 2.3 CTPP Work Trip Data for DVRPC Region

	Non-Motorized Share		Non-Motorized Trips (Implied)		Total Trips (Implied)		Factor	
Area Type	**Prod**	**Attr**	**Prod**	**Attr**	**Prod**	**Attr**	**Prod**	**Attr**
CBD	59.7%	7.7%	1.203	0.124	2.016	1.602	12.3	1.4
Fringe	42.9%	7.7%	0.625	0.123	1.456	1.600	6.4	1.4
Urban	10.3%	9.3%	0.176	0.149	1.706	1.596	1.8	1.6
Suburban	3.5%	3.8%	0.058	0.055	1.632	1.466	0.6	0.6
Rural	2.8%	4.5%	0.044	0.069	1.581	1.536	0.5	0.6
Open Rural	2.9%	6.7%	0.047	0.105	1.581	1.572	0.5	0.8
Total	**5.9%**	**5.9%**	**0.098**	**0.091**	**1.643**	**1.526**		

Production rates are per employed adult resident; attraction rates are per employee.

"Total trips" refers to the total work trip rate, including motorized and non-motorized trips.

The "factor" is the ratio of the non-motorized trip rate for the area type to the regional average rate (0.098 trips).

Home Based Non-Work Trips

Table 2.4 displays the survey results for home based non-work trips. Although two of the surveys provided information that could have been used to define specific sub-purposes (school, shop, etc.), the third survey lumped all home based non-work trips together. It was decided to use only the three purposes common to all survey datasets; this definition is also consistent with the trip purposes in the existing DVRPC travel model system.

Several noteworthy observations can be made from Table 2.4. First, the Baltimore survey data once again show more trips per household than the other two datasets. As discussed for home based work trips, data inconsistencies have made it impossible to use the Baltimore data for trip generation purposes. The Portland and Seattle rates are similar for motorized trips, but Portland shows many more non-motorized trips. The DVRPC survey rates for motorized trips are consistent with those found in Portland and Seattle.

The likely reason that the Portland survey has a higher rate of non-motorized trip generation is that this survey made a significant effort to attempt to capture non-motorized trips. This effort included doing an *activity* based survey rather than the traditional trip based method used in the Seattle survey. Activity based surveys are believed to provide more accurate representation of trips, especially walk trips, and are therefore believed to provide more realistic trip rates. Given the relative consistency of the Portland and DVRPC data and the better representation of non-motorized trips, it is recommended that the Portland non-motorized mode shares and the DVRPC survey results be used to estimate non-motorized trip generation. It is clear from the data shown that it is necessary to categorize both motorized and non-motorized home based non-work trips by vehicle ownership categories in trip production models.

It can be expected that the non-motorized trip generation rates will vary by area type as was the case for the home based work trips. Since the survey data from other cities cannot be used in estimating the effects of area type, it is recommended that the factors from Table 2.3 be used to adjust the trip rates by area type.

The following steps were included in the development of the home based non-work trip production rates:

1. The non-motorized mode shares from the Portland survey by vehicle ownership level were applied to the DVRPC trip production rates by vehicle ownership level and area type to obtain initial estimates of non-motorized trip rates (coefficients).

2. The factors by area type from Table 2.3 were applied to these trip production rates. The factors were capped at 2.0 (this affected only CBD and fringe areas).

3. The resultant non-motorized mode shares were applied to the existing DVRPC home based non-work motorized trip rates to obtain non-motorized trip rates.

Table 2.4 Home Based Non-Work Trip Rates from Household Surveys

Dataset	Motorized Trips	Non-Motorized Trips	Total Trips	% Non-Motorized
0-Vehicle Households				
Portland	1.06	1.08	2.14	50.6%
Baltimore	1.68	1.49	3.17	47.0%
Seattle	1.11	0.64	1.75	36.6%
DVRPC Simulation	1.04			
DVRPC Survey	1.04			
1-Vehicle Households				
Portland	2.51	0.54	3.05	17.6%
Baltimore	3.04	0.52	3.56	14.5%
Seattle	2.23	0.19	2.42	7.9%
DVRPC Simulation	3.63			
DVRPC Survey	2.38			
2-Vehicle Households				
Portland	4.15	0.46	4.62	10.0%
Baltimore	4.75	0.34	5.08	6.6%
Seattle	3.65	0.11	3.76	2.8%
DVRPC Simulation	6.44			
DVRPC Survey	3.87			
3+-Vehicle Households				
Portland	4.45	0.43	4.48	8.8%
Baltimore	5.69	0.37	6.06	6.1%
Seattle	4.25	0.14	4.39	3.2%
DVRPC Simulation	7.65			
DVRPC Survey	4.58			
All Households				
Portland	3.47	0.52	3.99	13.0%
Baltimore	3.99	0.55	4.54	12.1%
Seattle	3.34	0.16	3.50	4.5%
DVRPC Simulation	4.64			
DVRPC Survey	3.24			

Table 2.5 Recommended Home Based Non-Work Trip Production Rates

Vehicle Ownership Level	CBD	Fringe	Urban	Suburba n	Rural	Open Rural
Generation of Non-Motorized Trips Only						
0 Vehicles	0.72	0.76	0.80	0.61	0.52	0.39
1 Vehicle	1.11	1.17	1.05	0.59	0.57	0.57
2 Vehicles	1.24	1.31	1.20	0.62	0.60	0.60
3+ Vehicles	1.37	1.44	1.31	0.68	0.66	0.66
Generation of All Home Based Non-Work Trips (including motorized and non-motorized)						
0 Vehicles	1.26	1.33	1.80	1.89	1.80	1.80
1 Vehicle	3.47	3.66	3.55	4.84	5.55	5.55
2 Vehicles	4.98	5.25	5.25	7.26	8.38	8.38
3+ Vehicles	5.61	5.90	5.88	8.21	9.58	9.58

In developing trip attraction estimates, there is a problem in that productions and attractions for home based trips are based on different variables: households for productions and, mainly, employment for attractions. For consistency it would be desirable to base the revised trip generation rates which include non-motorized travel on the same variables DVRPC has been using. However, if this approach were continued, it would be impossible to ensure consistency between non-motorized productions and attractions at the zone level. For example, a zone which is entirely residential would have non-motorized productions, but very few attractions.

It should be noted that it may not be necessary to be entirely consistent at the zone level as long as there is consistency at a more aggregate level. Obviously, interzonal trips could also be very short in reality even where the minimum distance between zones is large. However, an examination of the consistency between productions at the area type level showed that continuing to use the same variables for productions and attractions would result in vastly different numbers of productions and attractions for some area types.

It therefore appears that the best method will be to set home based non-work non-motorized attractions equal to productions at the zone level. This implies that home based non-work attractions will be based on variables not currently used in trip attraction equations, namely households by auto ownership level. The resulting trip attraction models are shown in Table 2.6.

It is important to note that the home based non-work trip generation rates used in the DVRPC model system are significantly higher than the survey results. This difference stems from a calibration adjustment reflecting an underreporting of home based non-work trips, which is a common problem in household travel survey data. For now, the same relative calibration adjustment for each vehicle ownership level can be used, but it will be necessary to revisit the calibration factors when the entire model system is revalidated.

Non-Home Based Trips

Table 2.7 shows the non-home based trip generation rates computed from the three survey datasets. The rates are shown on a per household basis to provide a consistent measure for comparison; it is understood that non-home based trip generation cannot be based only on the number of households.

The Portland and Baltimore datasets show similar numbers of non-home based trips while the Seattle survey shows about 50 percent more trips. The DVRPC survey showed an average of 1.72 non-home based trips per household, a little higher than the Baltimore and Portland rates. Once again, the Portland survey showed the highest amount of non-motorized travel.

The recommendation is to use the Portland non-motorized trip mode share and the existing DVRPC motorized trip rates to generate non-motorized and total trip rates for non-home based trips. These rates were adjusted using the area type factors from Table 2.3. The process for doing so is the same as for home based non-work trips, as described above, and these results are shown in Table 2.8.

Table 2.6 Recommended Home Based Non-Work Trip Attraction Rates

Vehicle Ownership Level	CBD	Fringe	Urban	Suburban	Rural	Open Rural
Generation of Non-Motorized Trips Only						
0 Vehicles	0.74	0.78	0.76	0.40	0.39	0.39
1 Vehicle	0.99	1.04	1.02	0.53	0.52	0.52
2 Vehicles	1.07	1.13	1.10	0.57	0.56	0.56
3+ Vehicles	1.17	1.23	1.21	0.64	0.62	0.62
Generation of All Home Based Non-Work Trips (including motorized and non-motorized)						
Socioeconomic Variable						
0 Vehicle Households	0.74	0.78	0.76	0.40	0.39	0.39
1 Vehicle Households	0.99	1.04	1.02	0.53	0.52	0.52
2 Vehicle Households	1.07	1.13	1.10	0.57	0.56	0.56
3+ Vehicle Households	1.17	1.23	1.21	0.64	0.62	0.62
Occupied Dwelling Units	0.61	0.71	0.81	1.43	1.43	1.53
Basic Employment	0.20	0.26	0.36	0.71	0.71	0.71
Retail Employment	2.04	2.55	3.85	8.37	10.71	11.74
Other Employment	0.61	0.81	1.02	3.46	3.46	4.58

Table 2.7 Non-Home Based Trip Rates from Household Surveys
All Households

Dataset	Motorized Trips	Non-Motorized Trips	Total Trips	% Non-Motorized
Portland	1.53	0.24	1.77	14.1%
Baltimore	1.60	0.13	1.73	7.5%
Seattle	2.45	0.14	2.59	5.5%
DVRPC Simulation	1.83			
DVRPC Survey	1.72			

Table 2.8 Recommended Non-Home Based Trip Rates

Socioeconomic Variable	CBD	Fringe	Urban	Suburban	Rural	Open Rural
Generation of Non-Motorized Trips Only						
Occupied Dwelling Units	0.08	0.10	0.11	0.06	0.05	0.05
Basic Employment	0.04	0.06	0.07	0.03	0.02	0.02
Retail Employment	0.25	0.51	0.69	0.47	0.45	0.45
Other Employment	0.12	0.16	0.22	0.12	0.12	0.12
Generation of All Non-Home Based Trips (including motorized and non-motorized)						
Occupied Dwelling Units	0.30	0.37	0.43	0.60	0.59	0.59
Basic Employment	0.15	0.22	0.29	0.35	0.24	0.24
Retail Employment	0.90	1.81	2.64	4.47	5.10	5.10
Other Employment	0.44	0.59	0.87	1.20	1.42	1.42

3.0 Trip Distribution

As discussed earlier and described in more detail in the next section, the recommended procedure is to apply the motorized versus non-motorized mode choice model at the zone level rather than the zone interchange level. This implies that the trip distribution step is applied after this mode choice model to motorized trips only. If this procedure is followed, then no changes to the existing DVRPC trip distribution model are needed.

Modeling the mode choice of motorized versus non-motorized travel at the zone interchange level would require a rethinking of the trip distribution process. Obviously, the origin-destination patterns of non-motorized trips are quite different from those of auto and transit trips. The primary difference, of course, is that non-motorized trips tend to be shorter. The remainder of this section discusses the types of changes that would be needed if this mode choice model were applied at the zone interchange level.

3.1 Use of Composite Impedance

The existing DVRPC model system uses the traditional gravity model for trip distribution. However, unlike the gravity models used in most U.S. urban areas, the DVRPC model uses a "composite impedance" variable as a measure of zonal separation rather than simply auto travel time. The composite impedance variable provides a more accurate model since it considers the fact that a significant number of trips for many origin-destination pairs use transit.

The inclusion of non-motorized travel in the model system requires that the composite impedance variable be revised to include non-motorized modes as well as auto and transit. If the existing variable were to continue to be used, the attractiveness of nearby destinations would be underestimated, and not enough short trips would be modeled. This would result in an underestimate of non-motorized trips and, therefore, an overestimate of motorized trips.

Perhaps the best procedure is to use a composite impedance variable that includes auto, transit, and non-motorized travel characteristics. This variable will be developed from the mode choice model utility functions for the various modes. As will be described in the next section, the mode choice model will be a two stage model, with the choice between motorized and non-motorized trips modeled first, followed by the mode choice model for auto and transit trips.

The composite utility will be computed as if the mode choice model (in terms of the motorized/non-motorized choice) were nested rather than sequential. The precise form of the variable cannot be determined until the final mode choice model is developed. However, it will be a logsum variable representing the maximum expected utility from the mode choice model. This has the form:

Composite utility = ln [exp(utility of non-motorized mode)

+ exp(utility of motorized mode)]

The utility for the motorized mode will also be a logsum composite utility of the auto and transit modes; the form of this variable will depend on the final nesting structure of the mode choice model.

Composite Impedance Coefficient

An important point should be made concerning the use of the composite impedance variable. The coefficient of the variable is likely to be significantly greater than 1.0.[1] This is equivalent to a nesting coefficient of greater than 1.0 in a nested model of destination and mode choice. Such a coefficient would generally be unacceptable in a true nested model since it would imply that an increase in the utility of one alternative in a nest would increase the choice probabilities of all competing alternatives in the nest. For example, a decrease in *auto* travel time to a zone would result in an increase in *transit* trips to that zone (as well as an increase in auto trips, of course). Assuming that transit utility remains unchanged, this is not reasonable.

The dilemma occurs because travel time likely is a more important factor in destination choice than mode choice. In a traditional nested model estimation, the likely method for correcting such a problem would be to reverse the ordering of the nests. In this case, reversing the order would require the reversal of the mode choice and trip distribution steps. This would be not only well beyond the scope of the model enhancement project, but it would likely be an impractical model estimation exercise.

Given the nature of this dilemma, it is recommended that no correction be attempted. Such a correction would be beyond the "best practice" in travel demand modeling and beyond the practice in nearly every U.S. travel demand model system.

[1] Whether the sign is positive or negative depends on the definition of the variable as "utility" or, as is more common in trip distribution models, "disutility." Since travel impedance is inversely related to the desirability of a destination, impedance is equivalent to "disutility."

4.0 Mode Choice

The mode choice model is the part of the modeling process that is perhaps the most critical in terms of the analysis of non-motorized travel. If non-motorized trips can serve as substitutes for auto and transit modes under certain conditions, the mode choice model is where this choice is examined.

As discussed in Section 1.2, the non-motorized mode choice model will be applied at the zone level prior to trip distribution. However, to illustrate the importance of impedance in the non-motorized mode choice and its relationship with zone level variables such as area type and pedestrian environment, some preliminary models were run including trip distance as a variable. This was done using both local data (the DVRPC household survey) and data from other urban areas. The final recommended models do not include impedance or any zone interchange level variables.

In this section, the enhancements to the DVRPC mode choice model are briefly discussed. The local information on non-motorized mode choice are used to prepare some models of non-motorized mode choice, and data from other cities is used to estimate models where the local data are insufficient. The incorporation of pedestrian environment and area type information is also discussed. Finally, the recommended mode choice modeling procedure is presented.

4.1 DVRPC Mode Choice Model

The existing DVRPC mode choice model is a binary choice model of the choice between auto and transit. Since non-motorized trips are not generated, they are not included in mode choice. Since the existing mode choice model is to be revised in Task 3 of this project, the existing model will not be used to analyze non-motorized travel.

The new mode choice model to be developed in Task 3 will have a nested logit structure. This structure will include submodes of the auto and transit modes. In addition, the mode choice for non-motorized travel must be accommodated in the new mode choice procedure. The proposed mode choice model is described in more detail in the Work Plan for Task 3, and the final mode choice model will be documented in the Task 3 report.

Ideally, non-motorized travel would be estimated as a separate mode or modes in the mode choice model, using information from the local survey data which comprise the model estimation data set. However, since the DVRPC household survey did not include information on most non-motorized travel, this cannot be done. Instead, information from other areas must be used. Since the non-local information cannot be combined with the local survey data in the model estimation data set, the non-motorized mode choice must be examined separately.

The way in which the separate modeling of non-motorized mode choice can be handled is through the use of a sequential mode choice model. In this model structure, the mode choice is modeled in two steps. First, the choice between motorized and non-motorized modes is modeled. This is done using a binary logit model. This model has the following form:

Probability of using non-motorized mode = $[1 + \exp(U_{\text{Non-Motorized}})]^{-1}$

where $U_{\text{Non-Motorized}}$ represents the utility of the non-motorized alternative. This utility is a linear combination of attributes:

$U_{\text{Non-Motorized}} = B_0 + B_1 x_1 + B_2 x_2 + \ldots + B_n x_n$

where:

B_i = estimated model coefficients

x_i = model variables, including

- household characteristics (e.g., auto ownership);
- level of service variables (e.g., travel time); or
- area characteristics (e.g., PEV).

Next, for trips which choose the motorized mode, the choice between the various auto and transit modes is modeled. The initial binary model can be estimated using non-local data while the latter can be estimated using only local data.

4.2 Modeling Using Local Data

While it is clear that at least some parts of the mode choice process cannot be modeled using local data, there is a limited amount of local information on non-motorized work trips. The two sources for these data are the DVRPC household survey and the 1990 Census Journey to Work information.

It is clearly preferable to have as much of the mode choice modeling process as possible based on local data. Not only does that minimize any concern about differences in travel behavior between Delaware Valley residents and residents of other areas, but use of local data allows consideration of local information not available in other data sets, mainly area type and pedestrian environment.

DVRPC Household Survey Data Set

With that goal in mind, the DVRPC household survey data set was used to estimate a binary logit model of the choice between motorized and non-motorized modes for home-based work trips. Table 4.1 shows the results of the best model estimated using local data. The model includes variables for the average auto ownership per person, the zone's population density and pedestrian environment (as measured by the PEV), and dummy variables representing the zone's area type. Other variables were tested but found to be insignificant, including employment density and household size.

Since the motorized mode is the "base" mode, positive model coefficients represent variables where higher values are more likely to result in a non-motorized mode choice. The positive coefficients for population density and PEV are therefore reasonable, as is the negative coefficient for auto ownership. The positive coefficients for the CBD and fringe area types also make sense, as does the negative coefficient for rural areas. The positive sign for the suburban area type coefficient is somewhat surprising, but this coefficient is fairly low and not very significant.

It is recommended that the model shown in Table 4.1 be used as the non-motorized mode choice model for home-based work trips. As discussed in Section 4.3, the model coefficients are consistent with those in the models estimated from the data sets for other urban areas.

Census Journey to Work Data

Another source of local mode choice data for home-based work trips is the 1990 U.S. Census Journey to Work data. These data have been compiled at the zone interchange level by DVRPC. TRANPLAN trip tables were created by mode. However, there is a critical difference between the census data and the household survey data set in that the census data are *aggregate*. This means that a disaggregate mode choice model cannot be directly estimated from the data set since the behavior of individual households is unknown. For example, we may know that five percent of the households in zone X used non-motorized modes to travel to work, but we would not know if they were the low income households, the low auto ownership households, or anything else about them.

To attempt to use the much larger data set available from the census data, it was attempted to build a "pseudo-disaggregate" data set from the TRANPLAN trip tables. In this data set, each zone interchange which had at least one work trip constituted a data record, with socioeconomic attributes such as auto ownership and household size based on the zonal averages. This data set could then be used for model estimation, with each record being weighted by the number of work trips.

The pseudo-disaggregate data set is clearly inferior to a true disaggregate data set in that individual household characteristics were not known. For example, for all records where the home end of the trip was zone 507, the autos per household variable was equal to 1.98,

Table 4.1 Recommended Home-Based Work Mode Choice Model Coefficients

	Motorized		Non-Motorized	
	Coefficient	t-stat	Coefficient	t-stat
Constant	0	------	-4.75	-4.2
Autos/person	0	------	-2.13	-5.5
Pop density/acre	0	------	0.017	2.1
PEV	0	------	0.63	1.7
Area type CBD	0	------	3.51	6.2
Area type fringe	0	------	3.68	3.9
Area type suburban	0	------	0.37	1.0
Area type rural	0	------	-1.47	-1.3
Log-Likelihood	-340.5			
Rho-Squared	0.887			

even those where the non-motorized mode was chosen. The only way that a zero-vehicle household would be modeled would be in a zone where no household owned a vehicle (there are three such zones).

Despite these concerns, an attempt was made to estimate, using the pseudo-disaggregate data set, a mode choice model similar to the ones estimated using the household survey data set. Unfortunately, the aggregation errors apparently were too great to overcome as the model coefficients, for the most part, did not make sense. The recommended model for home-based work mode choice, therefore, must be the best model generated using the household survey data set.

4.3 Modeling Using Non-Local Data

Because there are no local data on non-motorized non-work trips, it is necessary to examine data from other urban areas. To validate the use of non-local data, the model coefficients for work trips can be compared. Models similar to the one shown in Table 4.1 were estimated using survey data from Portland, Seattle, and Baltimore. The comparison of the results of model runs is shown in Table 4.2.

As Table 4.2 shows, there are similarities among the four models in terms of the coefficients for the three variables. The DVRPC model is probably most similar to the one estimated using Seattle survey data. This comparison confirms that the models developed using the DVRPC household survey data set are reasonable.

Home-Based Non-Work Trips

Models were also estimated using the non-local survey data sets for home-based non-work trips. These model estimation results are shown in Table 4.3. There is reasonable consistency among the three models for this trip purpose.

It would probably be reasonable to use any of the three models for home-based non-work trips. A closer look at Table 4.3 reveals that the model estimated using Portland's data is probably the closest to the average of the three models. Therefore, Portland's model will be used as the basis for the home-based non-work mode choice model.

Because the PEV is a purely local variable, it was impossible to estimate a coefficient for the PEV using non-local data. However, Portland's existing model system has a motorized/non-motorized mode choice model which includes a pedestrian environment variable (called "PEF") similar to the PEV developed for this project. While Portland's model coefficients cannot be used directly in the DVRPC models, a coefficient for the PEV in the DVRPC home-based non-work model could be estimated by multiplying the ratio of the home-based work to home-based non-work coefficient in the Portland model by the coefficient for the home-based work model we have already estimated. These coefficients are:

Table 4.2 Home-Based Work Model Comparison for DVRPC and Three Other Urban Areas

	Portland		Seattle		Baltimore		DVRPC	
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
Constant	1.27	5.5	0.97	2.5	1.94	10.7	0.76	2.3
Distance (mi)	-0.47	-12.2	-0.51	-8.0	-0.56	-20.9	-0.47	-7.5
Household size	-0.35	-5.7	-0.34	-3.9	-0.21	-5.9	-0.37	-4.5
Autos/ person	-1.80	-9.3	-1.78	-6.0	-2.51	-16.7	-2.41	-7.5

Coefficients are specific to the non-motorized mode; all coefficients for the motorized mode are zero.

Table 4.3 Home-Based Non-Work Model Summaries

	Portland		Seattle		Baltimore	
	Coefficient	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
Constant	-0.17	-1.7	-1.07	-3.8	-0.31	-2.6
Household size	-0.24	-11.2	-0.34	-5.1	-0.11	-4.4
Autos/person	-1.40	-15.8	-2.05	-8.6	-2.53	-21.0

- DVRPC home-based work PEV coefficient = 0.63
- Portland home-based work PEF coefficient = 0.063
- Portland home-based non-work PEF coefficient = 0.062

(Note that the scales of the DVRPC and Portland variables are different, and so the differences in magnitude of the coefficients are irrelevant.) Since the DVRPC home-based work PEV coefficient is ten times the Portland PEF coefficient, the coefficient of the PEV for the DVRPC home-based non-work model should be ten times the Portland home-based non-work PEF coefficient, or 0.62.

It is also important to consider area type in the home-based non-work non-motorized mode choice process. It was decided to calibrate the models by area type to the *motorized* trip production totals for each zone. The procedure for adjusting the mode choice model was as follows:

1. Determine the trip productions for all person trips in each zone using the rates shown in Tables 2.5 and 2.8.
2. Apply the mode choice model, including the PEV coefficient, to obtain preliminary mode shares for each zone. This also yields a corresponding number of non-motorized and motorized trips when each share is applied to the trip totals from Step 1.
3. Compare the motorized totals for each zone to the trip production estimates for motorized trips in the existing DVRPC model system.
4. Determine the necessary adjustment to the constant term in the Portland model to create a revised mode share which yields the same number of motorized trips in each zone as the estimates from the existing DVRPC model.
5. Average the adjustments to the constant term over each area type. The average adjustment is the dummy variable coefficient for the area type.

The resulting model for home based non-work trips using the Portland model, the area type adjustments, and the transferred Portland PEV coefficient is shown in Table 4.4.

Table 4.4 Recommended Home Based Non-Work Model

	Coefficient
Constant	-0.174
Area type = CBD/Fringe	-1.327
Area type=Urban	-1.257
Area type=Suburban	-1.869
Area type=Rural	-1.324
Area type=Open rural	-1.191
PEV	0.620
Household Size	-0.243
Autos/person	-1.403

Non Home-Based Trips

For non-home-based trips, a zone level choice model could not be developed. Since level of service variables cannot be used, the two types of variables that could be used in such a model are household characteristics and area type. However, household characteristics variables would not be available for application of a non-home-based mode choice model, and area type characteristics are not available in the non-local data sets. The best starting point, therefore, is a deterministic model.

The original deterministic model is shown in Table 4.5. It consists of a simple lookup table of non-motorized mode share by area type. The mode shares are obtained from the trip generation models for non-home-based trips shown in Table 2.8.

To incorporate the PEV into the model, it was necessary to represent the deterministic model as a logit model. This logit model has a constant utility function for each area type set so that the choice probability for non-motorized is equal to the value shown in Table 4.5. The next step was to add the PEV coefficient in the same manner as was done for home-based non-work trips. The utility function would then have the form:

Utility of non-motorized mode =

B1*(CBD/fringe) + B2*(Urban) + B3*(Suburban) + B4*(Rural) + B5*(Open Rural)

+B6*(PEV)

The Portland model has two non-home-based trip purposes: work related and non-work related. The coefficients for the PEF for these purposes are 0.178 and 0.117 respectively. This implies a coefficient of between 1.17 and 1.78 for the PEV in the DVRPC model.

Because PEV is the only variable in the model for each area type, there is concern about the sensitivity of the model to PEV. Table 4.6 shows the range of mode shares computed using the minimum and maximum values for the PEV coefficient. As the table shows, the model is extremely sensitive to PEV. As a result, it is recommended that the home-based non-work PEV coefficient of 0.62 be used for non-home-based trips.

The area type coefficients were estimated in the same manner as for home-based non-work trips. The resulting model is shown in Table 4.7.

Table 4.5 Non-Home-Based Non-Motorized Mode Share by Area Type

	Non-Motorized Mode Share
Area type=CBD	28.0%
Area type=Fringe	28.0%
Area type=Urban	26.1%
Area type=Suburban	10.5%
Area type=Rural	8.8%
Area type=Open rural	8.8%

Table 4.6 Range of Estimated Mode Shares by Area Type: Non-Home-Based Mode Choice Model

	PEV Coefficient = 0.62	PEV Coefficient = 1.17	PEV Coefficient = 1.78
Area type=CBD/fringe	28.0%	28.0%	28.0%
Area type=Urban	9.9-27.5%	3.7-28.6%	1.2-29.5%
Area type=Suburban	5.0-15.4%	2.4-20.6%	1.0-26.9%
Area type=Rural	6.9-20.4%	5.2-36.3%	3.6-56.5%
Area type=Open rural	8.8%	8.8%	8.8%

Table 4.7 Recommended Non-Home Based Mode Choice Model

	Motorized	Non-Motorized
Area type=CBD/fringe	0	-2.81
Area type=Urban	0	-2.83
Area type=Suburban	0	-3.57
Area type=Rural	0	-3.22
Area type=Open rural	0	-2.95
PEV	0	0.62

5.0 Summary

This report presents a method for incorporating non-motorized travel into the DVRPC model system. The recommended way in which this can be done is summarized as follows:

- Use a new set of home-based trip production rates to generate total person trips, including both motorized and non-motorized trips. These rates, shown in Tables 2.3 and 2.5, would replace the existing DVRPC motorized trip generation rates for home-based productions.
- Use new home-based attraction and non-home-based trip generation rates to generate total person trips, including both motorized and non-motorized trips. These rates, shown in Tables 2.3, 2.6 and 2.8, would replace the existing DVRPC motorized trip generation rates for home-based attractions and non-home-based trips. The home-based attraction rate is the original motorized attraction rate with additional terms representing non-motorized trip generation.
- Apply new mode choice models by trip purpose to the trip ends generated in Steps 1 and 2 to separate motorized and non-motorized trips. These binomial logit models are presented in Tables 4.1, 4.4, and 4.7. The motorized trip ends would then be used as inputs to the existing DVRPC trip distribution model.

This procedure is shown in Figure 5.1. (Note that this figure depicts only the steps of trip generation, distribution, and mode choice and not the entire DVRPC model system.)

5.1 Implementation

It is recommended that these procedures be implemented by revising the existing DVRPC FORTRAN trip generation programs. The new trip generation rates and equations would simply replace those embedded in the existing program, and a separate routine would be added to apply the mode choice models by trip purpose. As is the case with the existing trip generation programs, the outputs would be trip productions and attractions by trip purpose.

Figure 5.1 Recommended Procedures for Modeling Non-Motorized Travel