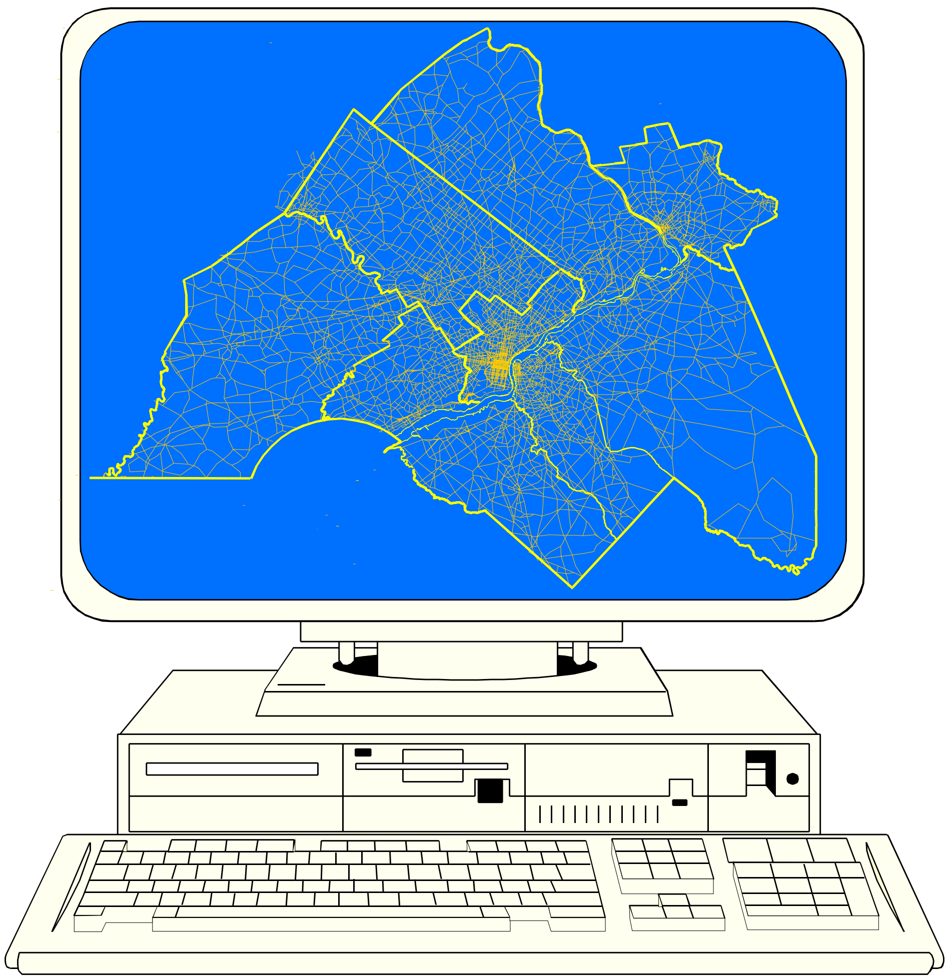
1997 TRAVEL SIMULATION FOR THE DELAWARE VALLEY REGION



Delaware Valley Regional Planning Commission

JANUARY 2000

1997 TRAVEL SIMULATION FOR THE DELAWARE VALLEY REGION

Delaware Valley Regional Planning Commission
The Bourse Building
111 South independence Mall East
Philadelphia, PA 19106-2582
January 2000

- This report is printed on recycled paper -

The preparation of this report was funded through 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. The authors, however, are solely responsible for its findings and conclusions, which may not represent the official views or policies of the funding agencies.

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 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

TITLE	
1997 Travel Simulation For the Delaware Valley Region	**Date Published:** January 2000
	Publication No. 00001

Geographic Area Covered:

Delaware Valley Region

Key Words:

1997 Travel Simulation Models, Highway Assignment, TRANPLAN, Traffic Analysis Zones (TAZ's), Trip Generation, Trip Distribution, Highway Capacities and Travel Speeds, Highway Functional Classification, Modal Split, Transit Assignment.

ABSTRACT

This report presents the results of the 1997 calibration/validation of the DVRPC regional travel simulation models. It also documents the detailed model structure, recalibrated/validated parameter estimates, and operating conventions within the TRANPLAN program battery environment.

For More Information Contact:

Delaware Valley Regional Planning Commission
Transportation Planning Division
The Bourse Building
111 South Independence Mall East
Philadelphia, PA 19106-2582
Telephone: (215) 592-1800 FAX: (215) 592-9125
website: http://www.dvrpc.org/

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

EXECUTIVE SUMMARY

This report documents the travel models used to simulate 1997 travel patterns for the Delaware Valley Region. The 1997 highway and public transit volumes documented herein provide current traffic estimates and model calibrations for most short and long range transportation facility and planning evaluation. These studies principally include design data and environmental impact statements, congestion management studies, and air quality/conformity analyses. These simulations will continue in this capacity until the 2000 Census data are received and evaluated.

The 1997 simulations utilized the 1990 traffic zone structure that was modified to account for the changes in the census tract boundaries in the 1990 Census. Socio-economic inputs to the models for 1997 were prepared using updated Census Bureau estimates and other sources. The highway and transit networks were updated to include facility improvements and new facilities opened to traffic since 1990. Changes in transit route and service levels were included. The 1997 simulation model runs utilize the validated and recalibrated 1990 travel simulation models. All available sources of data were incorporated into that update process including a home interview survey, Census Transportation Planning Package (CTPP) data, nine-county cordon line origin-destination information, transit ridership counts, highway screenline counts, and vehicle miles traveled (VMT) estimates.

Each phase of the 1997 travel simulation process is documented. Separate sections in this report are provided for traffic zone level socio-economic data estimation, external cordon station and internal trip generation, the preparation of the highway and transit networks, trip distribution, modal split, and the highway and public transit assignments.

The updated 1990 models and data sets also provided the starting point for a model enhancement process which was incremental and selective in nature. During the model enhancement process, a new iterative model structure with separate peak and off-peak time periods was developed. This model was required by the federal regulations promulgated by the ISTEA (Intermodal Surface Transportation Efficiency Act of 1991), the Clean Air Act Amendments of 1990, TEA 21 (Transportation Equity Act for the 21st Century) and the Final Transportation Conformity Rule of 1997. As part of the enhanced model implementation process, a preliminary version of the new model was run in parallel with the validated 1997 model to establish comparability of the results and to facilitate switching over to the new model for the ongoing travel forecasting work of the Commission. The 1997 results of the enhanced model are included the last section of this report, together with a brief description of the model enhancements included in this preliminary version.

The 1997 highway and transit travel assignments for both the validated and enhanced models show acceptable levels of accuracy when compared to ground counts. These travel simulations include significant growth in highway travel since 1990, but public transit ridership for the most part has remained stable at 1990 levels.

I. INTRODUCTION

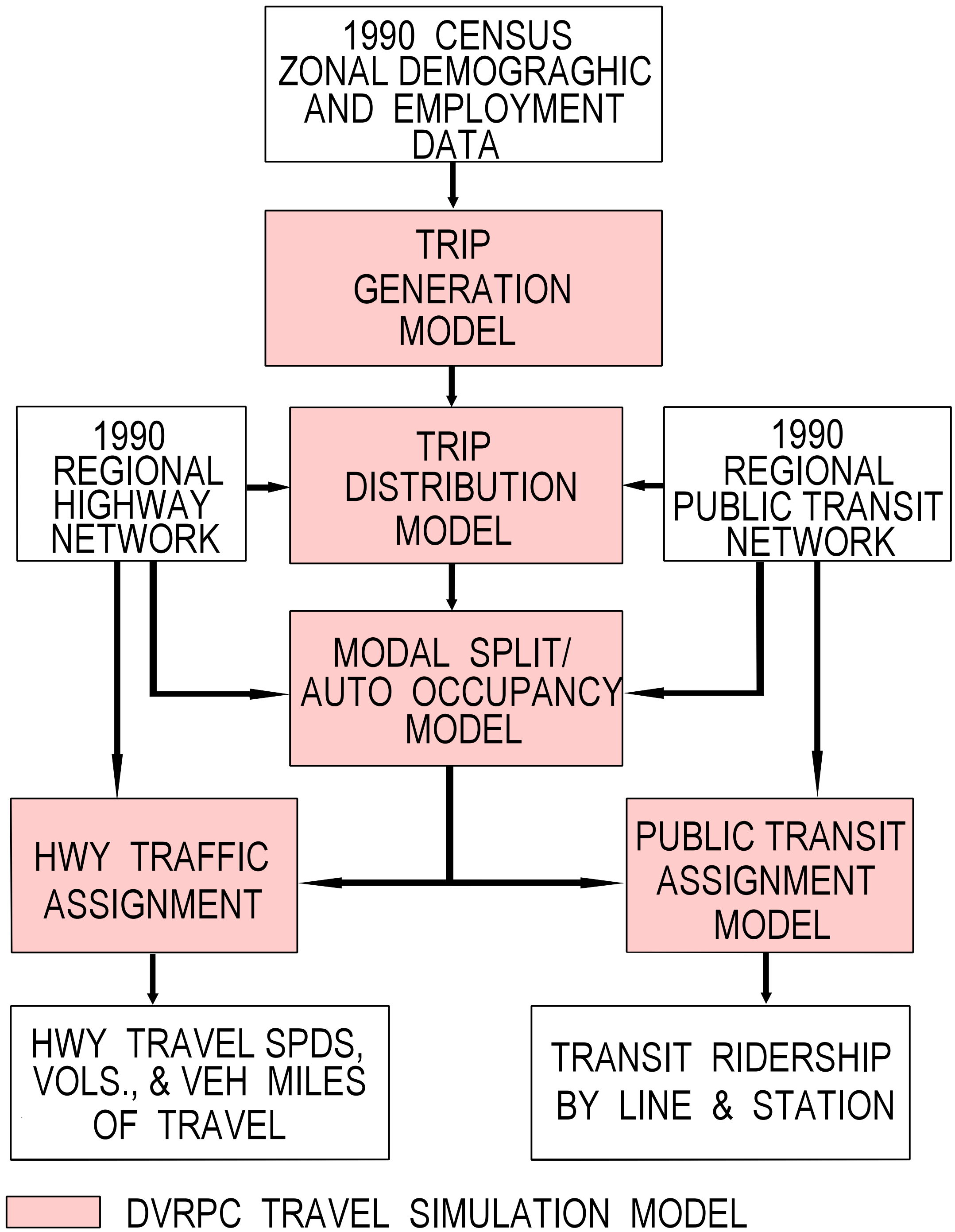
DVRPC's travel simulation models follow the traditional steps of trip generation, trip distribution, modal split, and travel assignment. Generally, these models are similar to those used in other large urban areas. The DVRPC models have formed the basis for most highway and transit facility level preliminary engineering studies, alternative tests, long range plan evaluations, and mobile source emissions calculations for the Delaware Valley Region. Model validation was achieved for 1980 without substantially changing the models or their parameters; simply by updating the socio-economic and network inputs to be reflective of the validation year. The 1990 recalibration/validation effort was different, however. It was undertaken as part of a general model upgrade that was intended to satisfy the new modeling requirements of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, and the Clean Air Act Amendments of 1990. In addition, travel data patterns from a home interview and nine-county cordon surveys were available to supplement the Journey-to-Work data from the Census. These new dimensions made the 1990 model validation/upgrade effort much more comprehensive.

For the 1997 simulation, the basic structure of this calibrated/validated model was retained. Figure 1 represents the basic travel simulation process used for the model. Several model inputs, however were revised to reflect 1997 conditions. Demographic and employment data were updated. Highway and transit networks were edited to reflect new facilities and transit service changes. Cordon station traffic volumes indicative of 1997 conditions were employed. The models were then calibrated and validated with 1997 highway traffic volumes and transit ridership volumes.

Chapter II of this report explains the traffic analysis zone system and area types used by the models. Chapter III documents the demographic and employment data inputs to the models. Chapter IV and Chapter V deal with the trip generation models. Chapter VI discusses the preparation of the highway and transit networks. Chapters VII and VIII explain the trip distribution and modal split models respectively, while Chapters IX and X present the highway and transit assignment results.

The 1997 models runs and outputs reported in this document are primarily focused on the current DVRPC models which simulate daily traffic and transit volumes in a non-iterative fashion. These models and their underlying socio-economic and network inputs were the starting point for the overall model enhancement effort. However, considerable progress has been made in implementing the new iterative, separate peak and off-peak models. These enhanced models have also been run with the 1997 socio-economic data and transportation networks. Selected outputs from the enhanced models are also included in Chapter XI of this report.

Figure 1
DVRPC TRAVEL SIMULATION PROCESS



II. REGIONAL AREAL SYSTEM

The travel simulation models rely on traffic analysis zones (TAZ's) to estimate travel patterns. Population and employment are assigned to these geographic areas. Trips between each pair of zones are determined and assigned to either the highway or transit networks. For convenience, DVRPC's traffic zone boundaries are largely defined by census boundaries.

A. Census Tract Traffic Zone System

The 1990 Census defined 1,312 census tracts within the nine-county metropolitan region. The 1990 Census geography merged the previously distinct "water tracts"—which depicted rivers, estuaries and similar features—with adjacent census tracts. DVRPC reapportioned these merged zones primarily to preserve the integrity of the traffic zone numbering system. Keeping the water tracts as separate traffic analysis zones also gives the modeler some flexibility in examining the effects of large, traffic generating developments (called "special generators") within the simulation.

The 1990 Census geography also contained a tract (No. 366) in the City of Philadelphia which combined tracts and block groups from several previous tracts along the Delaware River. This had the effect of creating a sprawling tract which extended for some distance along the developed riverfront. DVRPC split this tract along block group boundaries in order to maintain the integrity of the zone numbering system and to consider the effects of distinct demographic areas on adjacent highways and transit lines.

The 1990 Census tracts represented a net increase of 23 tracts over the 1980 Census. An additional three census tracts are defined in the three municipalities within Berks County incorporated into the DVRPC study area. Throughout most of the region, these tracts are considered adequate for regional travel simulation purposes. The twelve census tracts defined for the Philadelphia CBD, however, do not provide sufficient detail to accurately forecast travel on all of the modeled highways and transit lines and were split into 54 traffic zones using block group boundaries.

The transportation planning process requires that these zones be numbered in a consecutive, unbroken sequence, beginning with the number "1", for the assignment of centroid numbers. The centroid numbering sequence begins with the 54 zones in the Philadelphia CBD, continues with the remainder of the City of Philadelphia, and proceeds in the order of the 1970 tract centroids with Delaware County and Chester County, and clockwise by county around Philadelphia. In order to maximize the correspondence between the 1980 and 1990 traffic zone numbers, the new tracts added by the 1990 Census were assigned zone numbers in the same clockwise pattern beginning with 1336. There are 114 external stations included at the end of the sequence, beginning with centroid number 1396. Of the 39 additional stations provided since the 1980 travel model validation, 24 of these stations were added in Pennsylvania and 15 were added in New Jersey. Table 1 shows the range of centroid numbers assigned to each area. Within each county, the centroids are assigned to census tracts in increasing numerical order. The 1990 traffic zone system was retained for the 1997 simulation.

Table 1 : Assignment of Centroid Numbers for 1997 Travel Simulation

Area	Census County Number	Centroid Number Range
	Pennsylvania	
Philadelphia	101	1-427
— CBD Core		1-12
— CBD Other		13-54
— Remaining		55-427
Delaware County	045	428-585, 1336-1339
Chester County	029	586-686, 1269-1271, 1340-1345
Montgomery County	091	687-872 , 1272-1285 , 1346-1347
Bucks County	017	873-977, 1286-1302, 1348-1351
Berks County	011	1393-1395
External Stations		1396-1457
	New Jersey	
Mercer County	021	978-1037, 1303, 1352-1353
Burlington County	005	1038-1119, 1304-1330, 1354-1355
Camden County	007	1120-1241, 1331, 1356-1363
Gloucester County	015	1242-1268, 1332-1335, 1364-1392
External Stations		1458-1509

For the 1990 validation effort, the external stations at the nine-county boundary were carefully reviewed. External stations bordering the added municipalities in Berks County were replaced by analogous stations at the external boundary of those municipalities. All highways crossing the expanded boundary with significant daily traffic volumes were selected as external stations. The 114 stations were assigned centroid numbers, beginning with US 13 (Philadelphia Pike) in Delaware County and continuing clockwise around the region through US 130 in Gloucester County. These external stations were reviewed in 1997. Although no new stations were necessary, traffic volumes at these stations were revised to reflect 1997 conditions. The 1990 TAZ boundaries for the DVRPC region are shown on Figure 2 and are the same for the 1997 simulation models.

B. The Analysis Area System

Because of the number of zones in the region, it is convenient to summarize information on the basis of "analysis areas" or groups of zones. Unless this is done, it is virtually impossible to manage the various steps in the process and to monitor the results. It also simplifies the reporting of summary data.

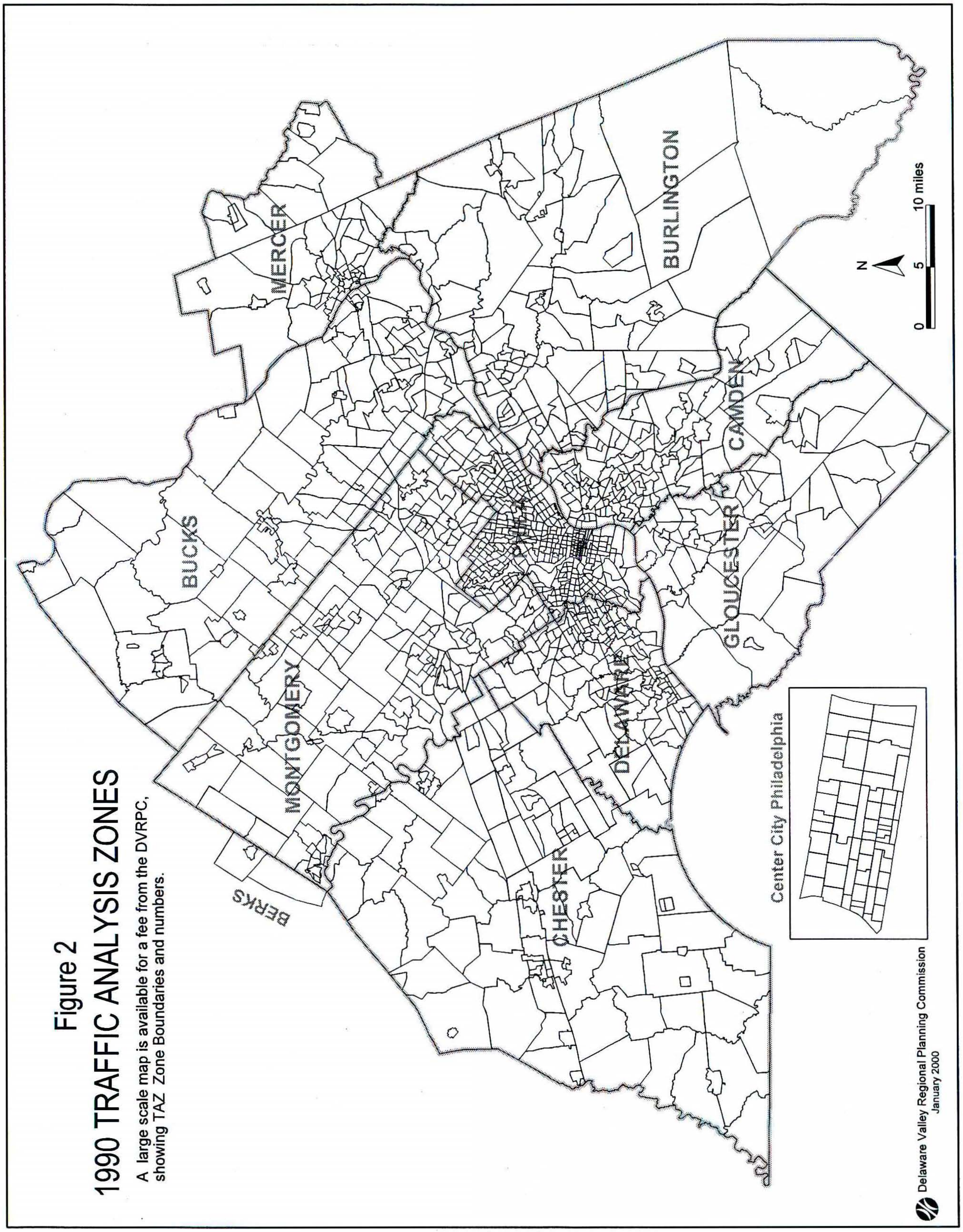


Figure 2
1990 TRAFFIC ANALYSIS ZONES

A large scale map is available for a fee from the DVRPC, showing TAZ Zone Boundaries and numbers.

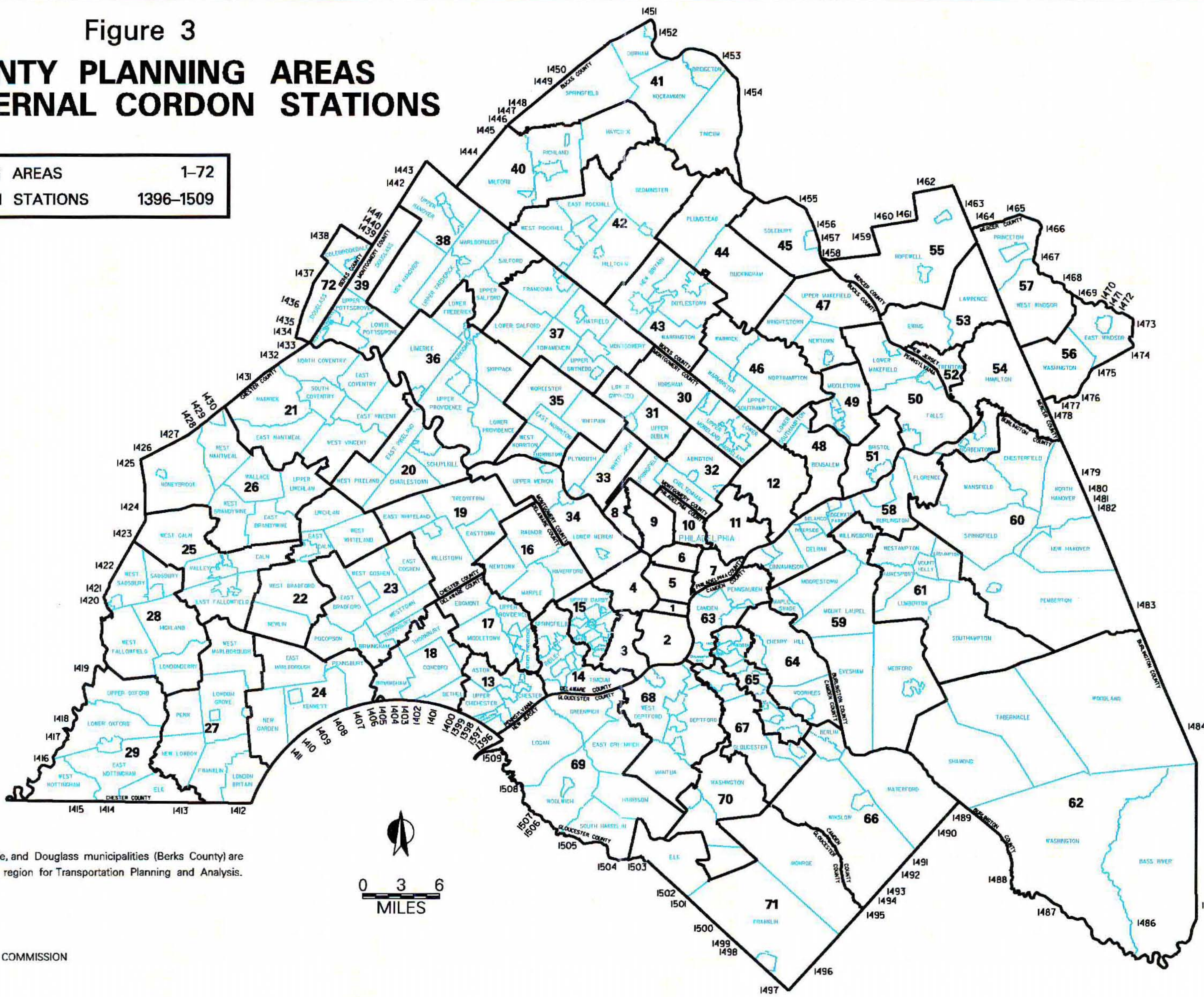
The simulation results are tabulated on the basis of a system of analysis areas called "county planning districts". Of the 72 districts in the DVRPC study area, 71 were developed by each of the nine counties individually and represent those areas that are commonly used for county planning. A 72nd district was created to summarize information for the three Berks County municipalities added to the DVRPC study area 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 will be required when data are passed to member governments for their use.

The 72 county planning areas are shown in Figure 3. Table 2 lists each area with a description and the numbers of the zones included in the district. These district names were provided by the county planning staffs. The computer programs that are used in the modeling process to aggregate and summarize data make use of this equivalency table between zone numbers and the county planning district numbers.

Figure 3

1990 COUNTY PLANNING AREAS AND EXTERNAL CORDON STATIONS

COUNTY PLANNING AREAS	1–72
EXTERNAL CORDON STATIONS	1396–1509



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

DELAWARE VALLEY
REGIONAL PLANNING COMMISSION
JANUARY 2000

Table 2 : County Planning Areas (CPA) and Corresponding 1990 Simulation Centroids

CPA	County Name	Description	Zone Number Range
1	Philadelphia	Center City Philadelphia	1-54
2	Philadelphia	South Philadelphia	55-101
3	Philadelphia	Southwest Philadelphia	102-126
4	Philadelphia	West Philadelphia	127-175
5	Philadelphia	Lower North Philadelphia	176-195, 198-211, 217-224
6	Philadelphia	Upper North Philadelphia	225-231, 253-264
7	Philadelphia	Kensington	196-197, 212-216, 232-252
8	Philadelphia	Roxborough—Manayunk	268-281
9	Philadelphia	Germantown—Chestnut Hill	265-267, 282-316
10	Philadelphia	Olney—Oak Lane	317-349
11	Philadelphia	Near Northeast Philadelphia	350-390, 392-405
12	Philadelphia	Far Northeast Philadelphia	391, 406-427
13	Delaware	Chester	493-530, 1337, 1396-1400
14	Delaware	South Central	473-492, 543-549
15	Delaware	South Eastern	428-472, 1336
16	Delaware	North Eastern	553-579, 1338
17	Delaware	North Central	532-542, 550-552, 580
18	Delaware	North Western	531, 581-585, 1339, 1401-1405
19	Chester	Upper Main Line	586-596, 615-616, 1340
20	Chester	Phoenixville	597-603, 613-614, 684
21	Chester	Northern	604-612, 1431-1433
22	Chester	Downingtown	617-618, 636-637, 639-641, 645, 686, 1271, 1345
23	Chester	West Chester	619-629, 635, 638, 1269-1270, 1341-1343
24	Chester	Kennett	630-634, 666, 1344, 1406-1411
25	Chester	Coatesville	642-643, 652, 654-661, 685, 1423
26	Chester	Upper Brandywine	644, 646-651, 653, 1424-1430
27	Chester	Avon—Grove	662-665, 667-668, 670-671, 1412
28	Chester	Octorara	672-678, 1420-1422
29	Chester	Oxford	669, 679-683, 1413-1419
30	Montgomery	Upper Eastern	687-705,1272
31	Montgomery	Ambler Area	721-730, 1276-1277
32	Montgomery	Lower Eastern	731-756, 868-872, 1278
33	Montgomery	Conshohocken Area	757-761, 780-787, 1280
34	Montgomery	Merions	788-814, 1281-1282
35	Montgomery	Norristown Area	762-779, 830, 1279
36	Montgomery	Lower Perkiomen	815-829, 852-854, 1283-1284, 1346
37	Montgomery	North Penn	706-720, 831-839, 1273-1275, 1285, 1347
38	Montgomery	Upper Perkiomen	840-847, 850-851, 1442-1443
39	Montgomery	Pottstown Area	848-849, 855-867, 1440-1441

Table 2 *(Continued)*

CPA	County Name	Description	Zone Number Range
40	Bucks	Quakertown	928-937, 1444-1445
41	Bucks	Palisades	938-943, 1446-1454
42	Bucks	Pennridge	920-927, 944-945
43	Bucks	Central Bucks West	915-919, 951-956, 1292-1294, 1348
44	Bucks	Central Bucks East	946, 949-950
45	Bucks	New Hope	947-948, 1455-1457
46	Bucks	Centennial	906-914, 957-959, 1289-1291, 1295-1298, 1349
47	Bucks	Newtown	960-963, 1299, 1350
48	Bucks	Bensalem	873-878, 903-905, 1286-1288
49	Bucks	Middletown	892-902
50	Bucks	Pennsbury	964-977, 1300-1302, 1351
51	Bucks	Bristol	879-891
52	Mercer	Trenton	978-1001
53	Mercer	Ewing & Lawrence Twps.	1015-1023
54	Mercer	Hamilton Twp.	1002-1014, 1352, 1478
55	Mercer	Hopewell Twp. & Pennington Boro	1024-1027, 1458-1463
56	Mercer	Hightstown, East Windsor & Washington Twps.	1034-1037, 1303, 1469-1477
57	Mercer	Princeton & West Windsor Twps	1028-1033, 1353, 1464-1468
58	Burlington	River Front Region	1038-1045, 1055-1073, 1075-1078, 1304-1305, 1307-1309
59	Burlington	South Central Region	1046-1054, 1095-1107, 1116-1119, 1306, 1317-1318, 1322-1330, 1354-1355
60	Burlington	North Central Region	1074, 1079-1088, 1310-1316, 1479-1483
61	Burlington	Mount Holly Region	1089-1094, 1108-1110, 1319-1321
62	Burlington	Pine Barrens Region	1111-1115, 1484-1489
63	Camden	River District	1120-1158, 1185-1188, 1239-1241
64	Camden	Cooper Valley District	1159-1172, 1198-1201, 1214-1215, 1356-1358
65	Camden	White Horse District	1173-1184, 1192-1197, 1202-1204, 1211-1213, 1216-1221, 1230
66	Camden	Lower County District	1231-1238, 1331, 1361-1363, 1490-1494
67	Camden	Freeway District	1189-1191, 1205-1210, 1222-1229, 1359-1360
68	Gloucester	Deptford	1242-1245, 1250-1254, 1332-1334, 1364-1374
69	Gloucester	Greenwich	1246-1249, 1264-1268, 1504-1509
70	Gloucester	Mantua & Harrison	1255-1258, 1335, 1375-1386
71	Gloucester	Glassboro—Clayton	1259-1263, 1387-1392, 1495-1503
72	Berks	Boyertown Area	1393-1395, 1434-1439

C. Area Type Classification

Also common to each of the travel demand models is the system of area type codes that were calculated for each internal zone in the region. This is a critical item of information in the process, 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 mode choice analysis, and set the link parameters for the highway traffic assignment (these features will be explained in detail in the appropriate portions of this document). In addition, the area type code creates a useful means for interpreting summary data.

Area type is an indicator of the intensity of travel activity occurring in a zone rather than zone size, land use, etc.. This intensity of activity is measured by computing the following factor for each zone:

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

The employment multiplier of 2.37 used in this equation is empirically derived, and was calculated by dividing the number of trips produced per resident (total population) by the number of trips generated per employee in 1980 and was not changed for the 1997 simulation. The value of this computed factor, falling within a specified range, establishes the area type for each zone. The six area types and the range of factor values are shown in Table 3.

Table 3 : Area Types and Corresponding Range of Factor Values

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

In addition to these changes, however, the zones corresponding to census water tracts also required area type values. Since the population and employment within these zones are zero, they were generally assigned area type codes equal to those of adjacent zones. Since water tracts neither produce nor attract trips, there is no net effect on the model of making these assumptions.

Modelers using the water tracts to consider the effects of special generators or for other purposes, however, need to be familiar with these area type values and their effects on developing, distributing and assigning trips to and from the water tracts to be used. Three data items are required for the calculation of zonal area types — population, total employment, and the zone size in total acres (to the nearest tenth). The 1997 frequency distribution of traffic zones by area type is given in Table 4. These statistics reflect the characteristics of the area type codes used in the travel modeling process. Area type codes were not considered final until they were color coded on a regional zone map and checked for reasonableness. It was considered necessary to adjust only 20 of the 1,395 zonal values as a result of this review. Figure 4 is a map of the DVRPC zonal system showing the 1997 area type for each internal zone.

Table 4 : 1997 Frequency Distribution of Traffic Analysis Zones by Area Type

Area Type Code	Description	Frequency
1	CBD	38
2	Fringe	12
3	Urban	417
4	Suburban	700
5	Rural	195
6	Open Rural	33

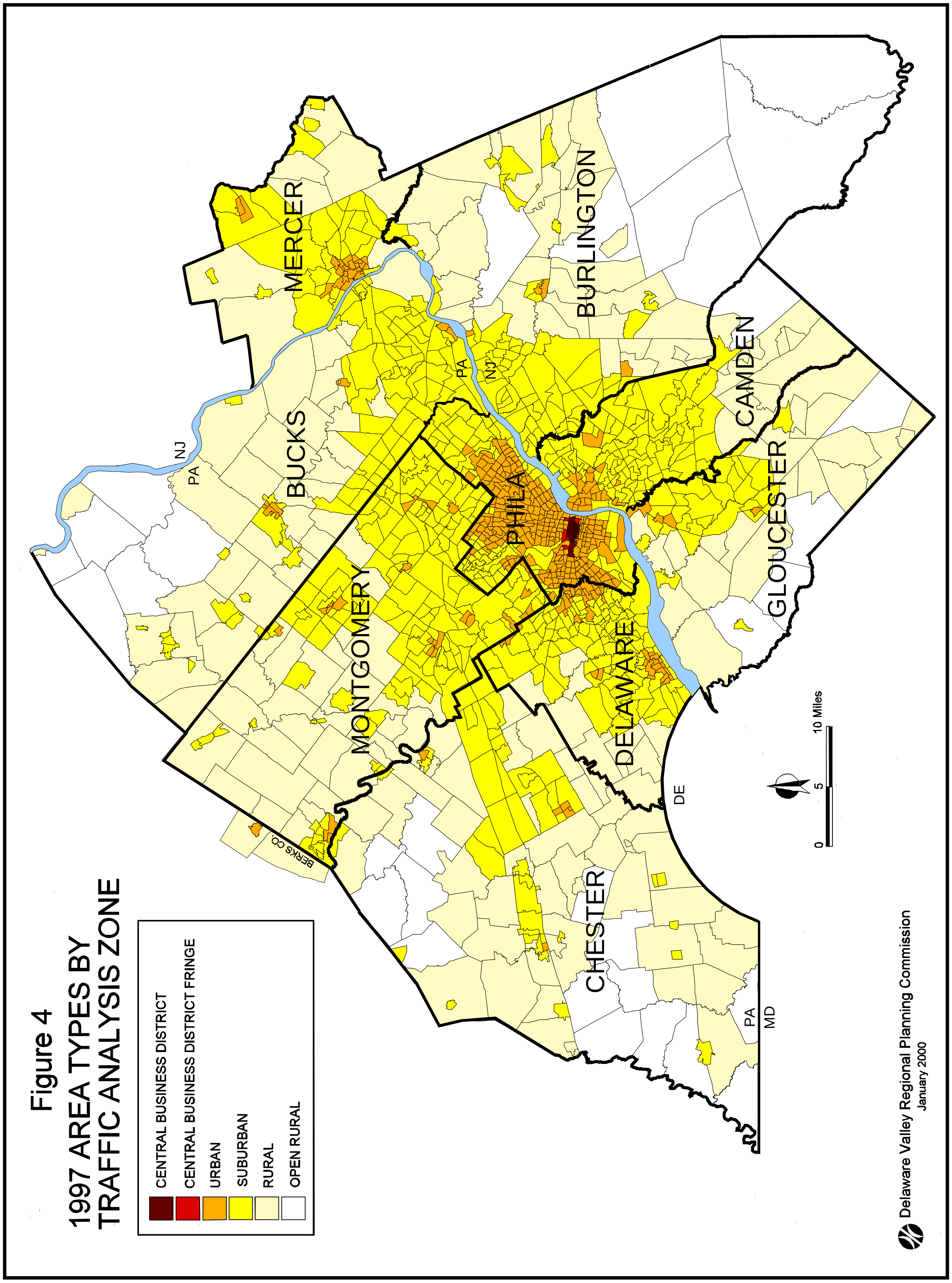


Figure 4
1997 AREA TYPES BY TRAFFIC ANALYSIS ZONE

III. SOCIO - ECONOMIC DATA

A. Demographic Data

The demographic inputs to the travel simulation process were prepared for each Traffic Analysis Zone (TAZ) by DVRPC staff based on DVRPC board adopted municipal forecasts using the shift-share method. The methodology and detailed TAZ level estimates are included in the commission report entitled, "1997 Zonal Population and Employment Estimates," January 1999.

B. 1990 to 1997 Demographic Trends

The 1990 Census showed that the major trends toward suburbanization of the region continued during the 1980's. The 1997 demographic estimates continue these trends. These changes in the distribution of regional activity have major implications for the transit and highway facility volumes produced by the travel simulation. Table 5 depicts the estimated population growth in the region during the last seven years. It shows that rural counties such as Bucks, Chester, Burlington, and Gloucester continued to grow significantly in population, while older areas, principally Philadelphia and urban parts of Delaware, Camden and Mercer counties continued their population decline. Overall, the Pennsylvania portion of the nine county region grew by 0.9 percent during the 1990s, while the New Jersey counties grew by 3.8 percent. The region as a whole grew by about 89,000 persons (1.7 percent) between 1990 and 1997. The added Berks County municipalities also grew by a combined 1.6 percent (roughly 200 persons) during this time period.

This trend toward suburbanization is also apparent in the occupied housing unit estimates given in Table 6. Rural counties grew rapidly and urban counties declined or remained relatively stable. However, the regional total of occupied housing units has increased by 2.3 percent which represents a decreased rate of growth relative to the growth rate experienced during the 1980s. This, however, also reflects the continued reduction in family size experienced during the 1980s. Since trip generation rates are based on occupied housing units rather than population, this phenomenon causes the simulated travel to grow at a higher rate than the population, though this is consistent with observed behavior.

Another major indicator of the propensity to travel is vehicle ownership, represented in this instance by the number of automobiles/personal transportation vehicles per household. Table 7 shows that the regional total of personal transportation vehicles in service increased by 6 percent — roughly twice the rate of growth in occupied housing units — with the highest growth rates occurring in the rural counties. Table 7 also shows that this increase in vehicles was concentrated in two-vehicle and three or more vehicle households.

The final demographic trip production variable considered in the trip generation model is employed residents. This variable is used to estimate the number of work trips produced by the residents of each TAZ. This variable (see Table 8) exhibits the trend towards suburbanization noted previously, although all counties except Philadelphia experience some growth in employed residents between 1990 and 1997.

Table 5 : 1997 DVRPC Population Estimates by County

County	1990 Census Counts	1997 DVRPC Estimate	1990-97 Absolute	Change Percent
Bucks	541,174	586,790	45,616	8.4%
Chester	376,396	418,035	41,639	11.1%
Delaware	547,651	547,843	192	0.0%
Montgomery	678,111	713,971	35,860	5.3%
Philadelphia	1,645,000 *	1,555,000 *	-90,000 *	-5.5%
TOTAL PA	**3,788,332**	**3,821,639**	**33,307**	**0.9%**
Burlington	395,066	419,142	24,076	6.1%
Camden	502,824	509,149	6,325	1.3%
Gloucester	230,082	246,215	16,133	7.0%
Mercer	325,824	335,034	9,210	2.8%
TOTAL NJ	**1,453,796**	**1,509,540**	**55,744**	**3.8%**
TOTAL REGION	**5,242,128**	**5,331,179**	**89,051**	**1.7%**
Berks (portion)	12,798	13,005	207	1.6%

* The City of Philadelphia has challenged the results of the 1990 Census, contending that the final count of 1,585,000 did not include at least 60,000 residents. Given this level of undercount, the 1990 and 1997 population for Philadelphia is estimated to be 1,645,000 and 1,550,000 respectively, The distribution among Philadelphia's 12 planning areas is based on the City's analysis of population and households.

Table 6 : 1997 DVRPC Household Estimates by County

County	1990 Census Counts	1997 DVRPC Estimate	1990-97 Absolute	Change Percent
Bucks	190,507	208,373	17,866	9.4%
Chester	133,257	149,953	16,696	12.5%
Delaware	201,374	202,894	1,520	0.8%
Montgomery	254,995	269,773	14,778	5.8%
Philadelphia	624,858 *	594,094 *	-30,764 *	-4.9%
TOTAL PA	**1,404,991**	**1,425,087**	**20,096**	**1.4%**
Burlington	136,554	146,277	9,723	7.1%
Camden	178,758	182,265	3,507	2.0%
Gloucester	78,845	84,789	5,944	7.5%
Mercer	116,941	121,243	4,302	3.7%
TOTAL NJ	**511,098**	**534,574**	**23,476**	**4.6%**
TOTAL REGION	**1,916,089**	**1,959,661**	**43,572**	**2.3%**
Berks (portion)	4,744	4,846	102	2.2%

* The 1990 and 1997 households have been adjusted based on the City of Philadelphia's challenge of the 1990 Census population. See footnote for Table 5.

Table 7 : 1997 Vehicle Availability Estimates by County

County	Total Households 1990	Total Households 1997	0-Vehicle Households 1990	0-Vehicle Households 1997	1-Vehicle Households 1990	1-Vehicle Households 1997	2-Vehicle Households 1990	2-Vehicle Households 1997	3+ Vehicle Households 1990	3+ Vehicle Households 1997	Total Vehicles 1990	Total Vehicles 1997
Bucks	190,507	208,373	10,035	10,359	54,375	55,589	87,166	98,221	38,931	44,204	359,451	400,560
Chester	133,257	149,953	7,653	7,977	36,638	37,925	61,902	72,323	27,064	31,728	251,320	289,176
Delaware	201,374	202,894	24,591	23,537	74,534	72,804	75,034	78,068	27,215	28,485	315,970	324,653
Montgomery	254,995	269,773	17,878	18,277	83,154	84,683	110,184	119,225	43,779	47,588	450,510	483,031
Phila	603,075	594,094	229,814	228,451	244,325	240,166	106,007	103,184	22,929	22,293	533,212	521,451
Total PA	**1,383,208**	**1,425087**	**289,971**	**288,601**	**493,026**	**491,167**	**440,293**	**471,021**	**159,918**	**174,298**	**1,910,463**	**2,018,871**
Burlington	136,554	146,277	6,715	7,017	43,582	44,763	60,299	65,942	25,958	28,555	251,344	272,595
Camden	178,758	182,265	23,758	22,876	63,692	62,377	66,152	70,374	25,156	26,638	280,459	292,624
Gloucester	78,845	84,789	5,359	5,457	24,339	24,693	34,801	38,708	14,346	15,931	142,129	155,639
Mercer	116,941	121,243	14,735	14,159	40,318	39,832	44,653	48,546	17,235	18,706	187,505	199,777
Total NJ	**511,098**	**534,574**	**50,567**	**49,509**	**171,931**	**171,665**	**205,905**	**223,570**	**82,695**	**89,830**	**861,437**	**920,635**
Total Region	**1,894,306**	**1,949,161**	**340,538**	**338,110**	**664,957**	**662,832**	**646,198**	**694,591**	**242,613**	**264,128**	**2,771,900**	**2,939,506**
Berks	4,744	4,846	346	339	1,243	1,199	2,075	2,170	1,080	1,138	9,019	9,364

1990-97 Change

County	Change 1990-1997 Total Households Number	Total Households Percent	0-Veh.Households Number	0-Veh.Households Percent	1-Veh.Households Number	1-Veh.Households Percent	2-Veh.Households Number	2-Veh.Households Percent	3+Veh.Households Number	3+Veh.Households Percent	Total Vehicles Number	Total Vehicles Percent
Bucks	17,866	9.4%	329	3.3%	1,247	2.3%	11,037	12.7%	5,261	13.5%	41,109	11.4%
Chester	16,696	12.5%	325	4.2%	1,284	3.5%	10,419	16.8%	4,660	17.2%	37,856	15.1%
Delaware	1,520	0.8%	-1,054	-4.3%	-1,730	-2.3%	3,034	4.0%	1,270	4.7%	8,683	2.7%
Montgomery	14,778	5.8%	385	2.2%	1,513	1.8%	9,070	8.2%	3,811	8.7%	32,521	7.2%
Phila	-8,981	-1.5%	-1,370	-0.6%	-4,154	-1.7%	-2,815	-2.7%	-634	-2.8%	-11,761	-2.2%
Total PA	**41,879**	**3.0%**	**-1,385**	**-0.5%**	**-1,840**	**-0.4%**	**30,745**	**7.0%**	**14,368**	**9.0%**	**108,408**	**5.7%**
Burlington	9,723	7.1%	301	4.5%	1,181	2.7%	5,646	9.4%	2,594	10.0%	21,251	8.5%
Camden	3,507	2.0%	-760	-3.2%	-1,227	-1.9%	4,051	6.1%	1,457	5.8%	12,165	4.3%
Gloucester	5,944	7.5%	98	1.8%	352	1.4%	3,910	11.2%	1,588	11.1%	13,510	9.5%
Mercer	4,302	3.7%	-588	-4.0%	-493	-1.2%	3,902	8.7%	1,478	8.6%	12,272	6.5%
Total NJ	**23,476**	**4.6%**	**-949**	**-1.9%**	**-187**	**-0.1%**	**17,509**	**8.5%**	**7,117**	**8.6%**	**59,198**	**6.9%**
Total Region	**65,355**	**3.5%**	**-2,334**	**-0.7%**	**2,027**	**-0.3%**	**48,254**	**7.5%**	**21,485**	**8.9%**	**167,606**	**6.0%**
Berks	102	2.2%	10	-2.9%	51	-4.1%	83	4.0%	50	4.6%	345	3.8%

Table 8 : 1997 DVRPC Employed Resident Estimates by County

County	1990 Census Counts	1997 DVRPC Estimate	1990-97 Absolute	1990-97 Percent
Bucks	284,984	306,375	21,391	7.5%
Chester	198,869	219,093	20,224	10.2%
Delaware	266,760	268,409	1,649	0.6%
Montgomery	359,659	376,445	16,786	4.7%
Philadelphia	657,387	628,925	-28,462	-4.3%
TOTAL PA	**1,767,659**	**1,799,247**	**31,588**	**1.8%**
Burlington	209,378	219,111	9,733	4.6%
Camden	239,526	242,417	2,891	1.2%
Gloucester	112,964	121,649	8,685	7.7%
Mercer	166,688	170,839	4,151	2.5%
TOTAL NJ	728,556	754,016	25,460	3.5%
TOTAL REGION	**2,496,215**	**2,553,263**	**57,048**	**2.3%**
Berks (portion)	6,797	6,917	120	1.8%

C. Employment Data by Place of Work

The travel demand estimates from the simulation model also require estimates of employment at work site TAZs for different types of work as stratified by the Standard Industrial Classification (SIC) system (see Listing). The methodology used to prepare these estimates of 1997 employment is also given in the January 1999 commission report referenced above.

Standard Industrial Classifications (SIC's)

1. Agriculture, Forestry and Fisheries
2. Mining
3. Construction
4. Manufacturing
5. Transportation, Communications and other Public Utilities
6. Wholesale Trade
7. Retail Trade
8. Finance, Insurance and Real Estate (Fire)
9. Service
10. Government
11. Military

D. 1990 to 1997 Employment Trends

A comparison of employment growth trends by county (see Table 9) shows a continued suburbanization of the job base first observed during the 1970s. While employment in Philadelphia may have grown slightly during the 1980s, it was outpaced by the significant employment growth experienced in the suburban and rural portions of the region and declined by 6.1 percent between 1990 and 1997. As noted in the demographic trends, the most rapid growth occurred in the more rural counties (Bucks, Chester, Burlington, and Gloucester); however, all suburban counties made significant employment gains during these seven years.

These trends in the demographic and employment inputs to the simulation process indicate significant changes in the traffic patterns and public transit ridership within the DVRPC region. These evolving travel patterns are clearly indicated in the 1997 traffic and transit ridership counts.

Table 9 : 1997 DVRPC Employment Estimates by County

County	1990 Census Counts	1997 DVRPC Estimate	1990-97 Absolute	1990-97 Percent
Bucks	245,345	264,006	18,661	7.6%
Chester	197,752	224,179	26,427	13.4%
Delaware	230,459	234,405	3,946	1.7%
Montgomery	457,500	485,434	27,934	6.1%
Philadelphia	836,874	786,015	-50,859	-6.1%
TOTAL PA	**1,967,930**	**1,994,039**	**26,109**	**1.3%**
Burlington	191,345	201,145	9,800	5.1%
Camden	227,933	230,782	2,849	1.2%
Gloucester	86,079	97,866	11,787	13.7%
Mercer	220,592	230,275	9,683	4.4%
TOTAL NJ	**725,949**	**760,068**	**34,119**	**4.7%**
TOTAL REGION	**2,693,879**	**2,754,107**	**60,228**	**2.2%**
Berks (portion)	7,247	7,396	149	2.1%

IV. EXTERNAL TRIP GENERATION

A. External Station Selection

A total of 114 cordon stations were utilized for the 1997 model. The locations of all 114 cordon stations are shown in Figure 5. In addition to those above, certain stations are located slightly beyond the boundary of DVRPC's nine county region to take advantage of route convergence or to simplify the analysis. The concepts involved in defining cordon stations have not changed much from the initial development of the travel simulation models. Many of these stations have traffic count records dating back to 1970 or earlier.

Sufficient stations are defined to intercept at least 95 percent of the total traffic crossing the cordon line around the DVRPC region. The station numbering system begins at the Delaware River in the southwest quadrant of the region and proceeds in a clockwise direction through the Pennsylvania Counties and then the New Jersey Counties ending with the 114th station, which is US 130 in Gloucester County, New Jersey. These cordon station numbers are the same as those used in the 1990 travel simulation model runs (and were last updated in 1987).

Philadelphia International Airport, although not on the cordon boundary, provides a portal for very large amounts of daily external-local person travel by both highway and transit. In order to model the effect of this facility on regional travel patterns, zone number 1510 was assigned to the airport and observed travel to and from this facility was distributed with the external-local, auto driver trips in the simulation process.

B. Estimation of 1997 Traffic at Each Station

For each of the 114 external stations, 1997 total daily traffic (i.e., AADT) was estimated by extrapolating pneumatic tube traffic counts taken during the calendar year 1995. These counts were then factored to represent the annual average of daily traffic volume using annualization factors provided by PennDOT and NJDOT. For both Pennsylvania and New Jersey cordon stations, growth in traffic has been substantial, averaging about 9.7 percent over the 1990 count values. This growth in trips across the cordon is much faster than the growth rate for trips throughout the region as a whole, reflecting the rapid growth in the rural areas adjacent to the cordon that occurred during the 1990s.

The model considers cordon roads as being either "Freeway/Parkway" or "Arterial/Local". These groupings are also shown in Table 19 of the DVRPC report entitled, "1990 Validation of DVRPC Travel Simulation Models," October 1997. For the most part, the classification of each cordon station was obvious. One exception was US 202 at the Delaware State Line. Although constructed as an arterial, in its trip length frequencies are more characteristic of a freeway, providing access to King of Prussia and beyond via the US 202 Expressway.

As part of the 1990 travel simulation model update, the highway and transit cordon stations were reconciled, with provision for 114 comparable stations also included in the transit network. This was done primarily to standardize the highway and transit trip matrix sizes at 1510 zones, thereby streamlining the travel simulation process by eliminating unnecessary conversions between the highway and transit trip table structures.

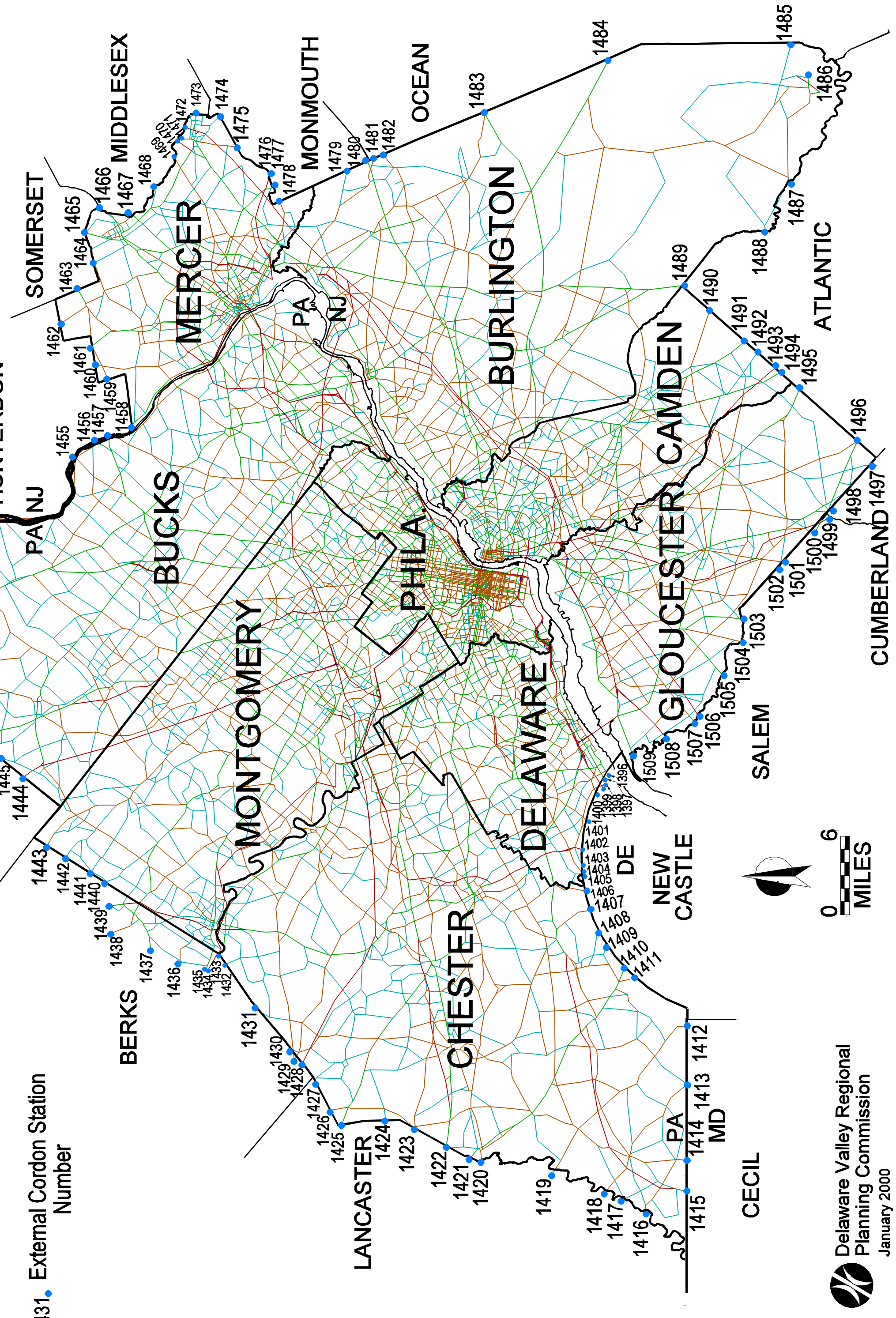
For those highway cordon stations which are served by buses, the highway cordon station number was included in the transit network coding. Rail facilities crossing the regional boundary are assigned the nearest available highway cordon station number. Highway cordon stations completely unserved by transit are omitted from the transit network. Table 19 of the 1990 Validation Report presents a listing of the transit cordon stations, together with the estimate of 1990 transit riders observed at the cordon crossing.

Because NJ TRANSIT and certain SEPTA rail services operate along Amtrak rail lines serving stations jointly with Amtrak, the model must replicate the patronage levels associated with the unique markets for each service. NJ TRANSIT and SEPTA appeal to the traditional urban commutation market, offering frequent and relatively inexpensive service. Amtrak, on the other hand, caters to the intercity travel market offering more comfortable and faster service to major destinations both within and beyond the regional cordon. The dilemma in recognizing both forms of service within the model arises when the mode choice utilities are calculated. Depending on the relative impacts of higher fares versus longer travel times, all of the rail tripends for common stations will be ascribed to either the commuter services or Amtrak, respectively. Because of the unique nature of the travel patterns associated with each location, there is no assurance that fine tuning of the mode choice utility will arrive at a satisfactory distribution of trip ends.

In order to circumvent this problem, public transportation services that are predominately intercity in nature (i.e., Amtrak rail service and privately furnished intercity bus services) are modeled in a separate transit network hereafter referred to as the shadow transit network. The shadow transit network identifies cordon stations, rail stations, and TAZs served by each route.

An external-internal and external-external trip distribution matrix was then determined for this network based on TAZ level and socio-economic activity measures as well as station activity and approximated cordon crossing levels as obtainable from the providers. For the remaining, local serving transit network, hereafter referred to as the main transit network, an external-internal trip distribution matrix was also prepared based on TAZ level internal transit tripends within predefined internal line service areas and approximated cordon crossing levels. The amount of intercity travel occurring on the SEPTA and NJ TRANSIT systems is thought to be minor, although a minor amount of transferring between the NJ TRANSIT Atlantic City line and Amtrak services is probably occurring at 30th Street Station.

Figure 5
1990 External Cordon Station Locations



C. Estimation of 1997 Through Travel Patterns

Determining the amount of through trips at each cordon station is insufficient when the effects of these trips on the region's roads and transit lines must be determined. A through trip table showing the demand for travel between individual points of entry into and departure from the region is also required. The procedure to generate the complete 1997 through trip matrices for all 114 regional cordon stations was as follows; Input the 1990 through trip matrix from the 1990 travel simulation and then fratar the 1990 through trip matrix to correspond to the 1997 through trip cordon station totals prepared by extrapolating the 1995 traffic counts.

V. INTERNAL TRIP GENERATION

The internal trip generation procedures were developed, for the most part, during earlier resimulation studies. Although several alternative methods were evaluated during these studies, the process that was selected is usually referred to as the "dwelling unit level" or disaggregate trip generation analysis. Internal trip productions, by zone, are established on the basis of trip rates per dwelling unit of a specified type, rather than by an equation that produces zonal aggregate data on the basis of the average characteristics of all dwelling units in the zone. At the end of the trip generation analysis, the trip data are summed to produce zone totals for input to the next phase of the process, the trip distribution models. These zonal totals are then used through the remainder of the process. There are 14 different categories of trip ends to be calculated for each zone or station. These do not include through trips and external-local vehicle driver trip productions, which were estimated from traffic counts using a different process that was discussed in Chapter IV of this report. These trip categories were also established during earlier studies and were not modified for this analysis.

The types of trip ends to be generated and the 1990 and 1997 regional total trip ends are shown in Table 10. The first six categories are internal-to-internal person-trips, and include trips by all significant modes of travel--auto driver, auto passenger, and transit passenger. They do not include truck passengers, taxi passengers, school bus passengers, walk trips, bicycle trips, motorcycle trips, etc. These types of trips are not currently included in the existing DVRPC travel simulation process. Categories 7 through 12 are truck and taxi vehicle trips on an origin-destination basis and are distributed with a separate set of trip distribution models. The last two categories represent external-local vehicle trip model attractions, for freeway/parkway and arterial/local cordon stations. All productions for external-local travel are assumed to occur on the nine-county cordon line and all corresponding attractions are allocated to internal traffic zones.

Table 10 also presents the trip end totals in each generation category for 1990 and the corresponding totals for 1997. These trip estimates reflect the output of the validated models for both model years. Overall, person trips have increased by 9.5 percent between 1990 and 1997. Work trips constitute 25 percent of total person trip ends in both 1990 and 1997, although the number of work trips has increased by more than 6.7 percent during the decade as a result of employment growth within the region. Home based non-work trips have increased by a greater than average rate (10.9 percent) and have increased slightly from 52.4 to 52.9 percent of regional person trips. Non-home based trips have grown by 10.1 percent This travel category in 1997 represents 22.8 percent of person trips.

Vehicle trips in total grew by 9.0 percent between 1990 and 1997. Arterial external-local travel is the fastest growing category of vehicle trips (10.8 percent over the seven year period). This resulted from the high residential and commercial land use growth rates in the vicinity of the nine-county cordon. Truck and taxi trips all grew at significant rates, with light trucks growing (9.5 percent) and heavy truck trips also growing (9.5 percent). Despite the differential growth rates, light truck trips still constitute a near majority of these vehicle trips (47.8 percent).

Table 10 : Trip Categories in the Modeling Process

Trip Category		Total 1990 Trip Ends	% of Total	Total 1997 Trip Ends	% of Total	1990-97 % Change
Internal-Internal Person-Trips						
1.	Home Based Work Person Trip Productions	3,964,641	12.4 %	4,231,546	12.1 %	6.7 %
2.	Home Based Work Person Trip Attractions	3,980,520	12.4	4,259,804	12.1	7.0
3.	Home Based Non-work Person Trip Productions	8,377,838	26.2	9,218,357	26.3	10.0
4.	Home Based Non-work Person Trip Attractions	8,402,884	26.2	9,322,258	26.6	10.9
5.	Non-home Based Person Trip Origins	3,649,608	11.4	4,018,014	11.5	10.1
6.	Non-home Based Person Trip Destinations	3,649,608	11.4	4,018,014	11.5	10.1
Total		**32,025,099**	**100.0 %**	**35,067,993**	**100.0 %**	**9.5 %**
Other Vehicle Trips						
7.	Light Truck Vehicle Trip Origins	1,212,291	23.8 %	1,327,750	23.9 %	9.5 %
8.	Light Truck Vehicle Trip Destinations	1,212,291	23.8	1,327,750	23.9	9.5
9.	Heavy Truck Vehicle Trip Origins	746,860	14.6	817,813	14.7	9.5
10.	Heavy Truck Vehicle Trip Destinations	746,860	14.6	817.813	14.7	9.5
11.	Taxi Vehicle Trip Origins	157,039	3.1	159,829	2.8	1.8
12.	Taxi Vehicle Trip Destinations	157,039	3.1	159,829	2.8	1.8
13.	Freeway/Expressway External-Local Vehicle Trip Attractions	349,456	6.9	375,973	6.8	7.6
14.	Arterial/Local External-Local Vehicle Trip Attractions	516,678	10.1	572,968	10.3	10.9
Total		**5,098,514**	**100.0 %**	**5,559,725**	**100.0 %**	**9.0 %**

The social and economic data for each internal zone required to calculate these various tripend estimates and the 1990 and 1997 regional and county totals are recorded in Tables 6 through 9 of Chapter II. These data are listed by zone in the report, "1997 Zonal Population and Employment Estimates", Delaware Valley Regional Planning Commission, January 1999. Notice that land use information, or acres of land by category, is not required for trip generation by this method. Income at the zone level is also not required, although it is necessary as a regional parameter for the mode choice model. For each trip category, the corresponding trip rates are applied to the socio-economic variables and the sum accumulated for each of the 1,395 internal zones. Some of the models are relatively simple and require only a few factors, while others are very complex and require multiple sets of socio-economic data.

Growth in these variables and decentralization of the associated land use patterns are the primary reasons for the growth in trips noted above. While there is an overall increase in the regional totals of both demographics and employment between 1990 and 1997, the magnitude of this increase varies significantly among individual variables. The total number of occupied dwelling units within the region increased by 2.3 percent during the seven years between 1990 and 1997. The growth rate varied significantly by vehicle ownership category, however, with 0 and 1 vehicle households declining by 0.7 and 0.3 percent, respectively, and 2 and 3+ vehicle households growing by 7.5 and 8.9 percent. This disproportionate growth in the higher ownership categories tends to increase trip making as multiple vehicle households have higher associated trip rates. Employed residents increased by 2.3 percent.

Total employment within the region increased by 2.2 percent during the interval between 1990 and 1997. The growth in employment, together with decentralization of the employment base into the suburbs also lead to significant increases in trip generation (9.5 percent).

Model Operations

To perform the trip generation calculations for the 1997 simulation, a series of four Fortran based computer programs were modified from previous versions. These programs take the estimated zonal demographic and employment data recorded on data cards and prepare the trip production and attraction input to the trip distribution models. All of these programs are executed on DVRPC's in-house simulation model computer network. Detailed description of the trip generation rates and adjustment parameters are given in the Chapter IV of the commissions report entitled " 1990 Validation of DVRPC Travel Simulation Models," October 1997.

TRIPGEN A - This first program of the series was converted from a previous version and is used to calculate the preliminary or "raw" trip productions and attractions for each internal zone. All trip purposes are calculated except external-local auto driver productions and attractions. The program reads the zonal demographic and employment data, a set of zonal area types, the trip rate cards (by area type, trip purpose, and independent variable), and a set of flag values that highlight any extreme values. It produces a computer file of the preliminary trip quantities and summarizes these values by analysis areas, by state, and for the total region. Special equivalency card images are used to specify the analysis areas to be summarized.

TRIPGEN B - This second program of the series is used to calculate a preliminary set of external-internal auto driver trip attractions. All of these trips are assumed to be produced at the external stations and attracted internally. During the 1990 model calibration process, this program was modified extensively to produce separate estimates of 1990 freeway/parkway and arterial/collector/local external-local attractions. These two roadway classes have significantly different trip length frequency distributions, with freeway/parkway being much longer. As in previous versions of this model, it was found that the number of external-local 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. First, the revised program computes the number of external-local auto driver trip attractions according to 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) and the airline distance from the centroid of the zone to the closest external station in miles.

In a second step, the percentage of external-local trip attractions allocatable to freeway/parkway is calculated as a function of distance from the cordon line, as the percentage of external-local attractions allocatable to the arterial/local trip distribution model is defined as the residual from the freeway/parkway equation. After the attractions calculated in step one are disaggregated into freeway/parkway and arterial/collector/local, the totals are normalized to the counted totals of productions.

For these calculations, TRIPGEN B reads a set of centroid and station X-Y coordinates (the same as those used for plotting the highway network), the trips generated by TRIPGEN A, and writes a new computer file containing the estimated external-local auto driver trip attractions. Some summaries are also produced in the process.

TRIPGEN C - This 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 (see Chapter III). In addition, the program reduces the number of internal person-trips by purpose by an equivalent amount. This feature was added to the simulation process for the 1977 simulation because of problems associated with those zones in the proximity of the cordon line producing excessive numbers of trips in previous simulation studies. 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. After balancing, or factoring, the estimated external-internal auto driver attractions by zone to the control values for productions, the program subtracts an equivalent number of internal person-trips from the file by trip purpose, assuming car occupancy values of:

Home based work	1.12
Home based non-work	1.54
Non-home based	1.41

These occupancies were taken from the 1987-88 Home Interview Survey. The program then writes a file containing zonal trip productions and attractions with printed trip summaries by trip purpose and county.

TRIPGEN D - This program makes the final adjustments to the zonal trip data, adds the external trip production and attraction records, and writes the data files that are required for the gravity models. Trips may be factored by trip purpose and by state (Pennsylvania or New Jersey) if required. The program is used to balance the trips to pre-established control values. Summary data are printed recording the total number of trips by purpose and by county.

VI. TRANSPORTATION NETWORK PREPARATION

A. *Highway Network*

The 1997 regional network was created by updating the 1990 network with major facilities that were constructed between 1990 and 1997. All facilities, minor arterial and above, open to traffic in 1997, were included. Significant new freeway facilities not included in the 1990 highway network were opened to traffic in late 1990 through 1994. These include the Mid-County and Vine expressways and Exton Bypass in Pennsylvania and the completion of I-295 in northern Burlington and Mercer counties. However, the completion of NJ 55 in Gloucester County was already included in the 1990 highway network as was the opening of the US 422 Expressway. The major facilities included in the 1997 highway update are as follows:

1. Mid-County Expressway (I-476) Completion
2. I-295 Completion in Burlington and Mercer Counties
3. Vine Street Expressway (I-676)
4. Exton Bypass (US 30)
5. Trenton Complex (NJ 29)
6. I-95 Center City/ Penns Landing Ramp Improvements
7. US 1 Brunswick Pike Improvements in Mercer County (US 1)
8. Trenton Freeway (US 1)/ New York Avenue Ramp Improvements
9. Swedesford Road widening in Chester County

Table 11 presents a comparison of the mileage by simulation functional classification of the facilities included in the 1990 and 1997 highway networks. Overall, freeway mileage within the region increased by about 51.8 directional miles (25.9 centerline miles; that is, both directions included in the tabulation). Overall, the 1997 network update increased the system mileage by about 120 one-way miles. The differences between the 1990 and 1997 totals by functional class also reflect re-evaluation of the facilities included in the highway network and the simulation functional classification system of existing links.

Table 11 : Comparison of 1990 and 1997 Regional Highway Network Mileage

DVRPC Functional Classification	Directional Route Miles 1990	Directional Route Miles 1997
Freeway	877.9	929.77
Parkway	220.8	216.87
Principal Arterial	3,278.3	3,315.40
Secondary Arterial	5,065.0	5,138.77
Collector / Local	4,073.5	4,422.87
Ramp	40.88	63.74
Total:	**13,568.5**	**13,688.0**

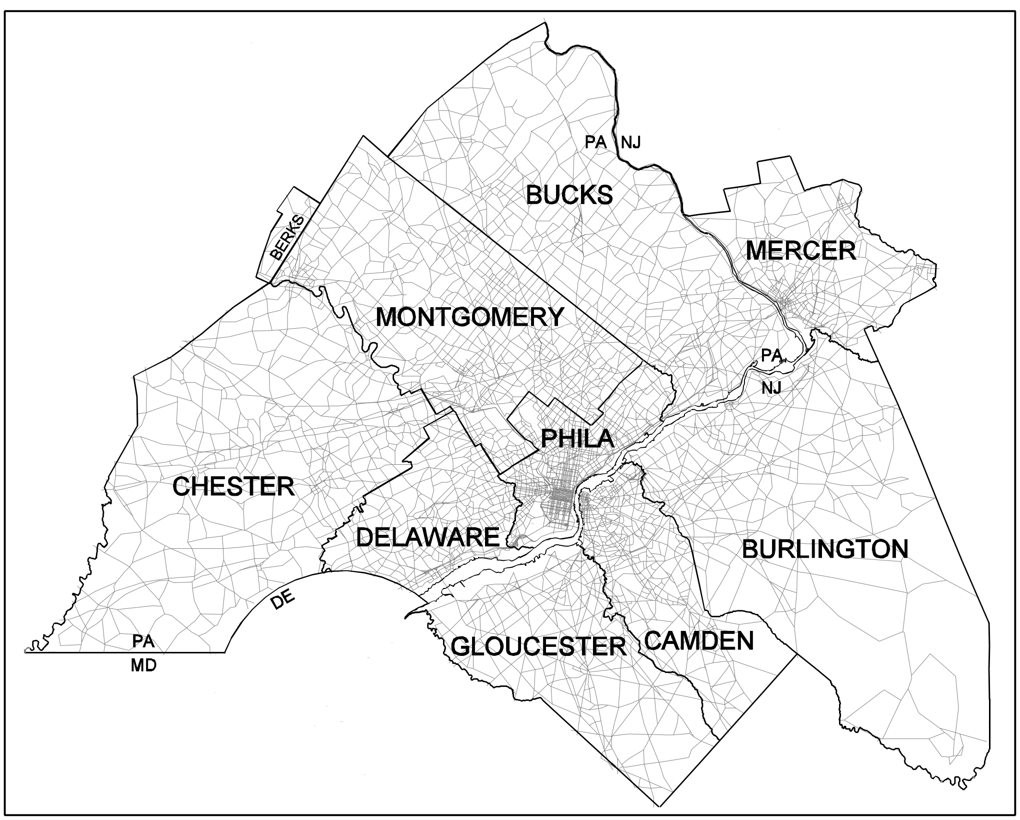
The coded network representing the 1997 regional highway system contains virtually every street segment of significance within the nine-county area. All freeways, parkways, principal arterials, secondary arterials, and many of the collector routes are included in the system. This represents about 36 percent of the 20,000 total miles of highway facilities that exist within the region and enables a very fine-grained regional traffic assignment that is adequate for most regional and some subarea design studies.

As it is now represented, the 1997 regional highway network contains:

1,510	centroids
13,304	nodes (including centroids)
40,149	link data cards
37,706	two-direction link data cards (each direction separately)
2,447	single-direction link data cards
13,688.0	one-way miles of highway system (both directions included)
537.0	center line miles of one-way streets (or freeways coded directionally)
6,575.5	center line miles of two-way streets
7,112.5	center line miles of total system

Figure 6 is a map of the resulting highway network showing every link in the system. It is evident from this illustration that the network is very comprehensive.

Figure 6
1997 Regional Highway Network



The validated (existing) DVRPC travel simulation model and enhanced Evans peak and off-peak models have significantly different link coding conventions. The procedures used in the existing model are documented in Chapter 5 of the commission report entitled, "1990 Validation of the DVRPC Travel Simulation Models," October 1997. The table look up speed and capacity tables as well as the toll coding conventions are also described in this document.

B. Transit Network

The 1997 nine-county regional transit network was created by updating the 1990 network. The update began with a complete review of all transit facilities included in the 1990 network with respect to additions, deletions or revisions of service by the operating agencies since that time. The traffic zone system to incorporates the new Traffic Analysis Zones (TAZ's) and zone revisions occasioned by the 1990 US Census. Finally, fares and morning peak headways on all routes were updated to 1997 values. The resulting network contains almost all regularly scheduled service within the nine-county area as it existed in the spring of 1997.

The principal transit service changes between 1990 and 1997 that were identified and used to modify the network were:

Principal Transit Service Changes 1990 to 1997

Canceled Routes:	**New Routes:**
69, 81, R 3 Shuttle, 50, 85, P, 4	199, 202
Abandoned Rail Stations:	**New Rail Stations:**
Logan, Tabor, Fulmor, Parkesburg, Coatesville, Fellwick, Mogees, Shawmont, Andalusia, Frankford Junction, Fishers, Westmoreland	University City

The nine operating companies in the transit system and the mode descriptions are shown in Table 12. For purposes of these statistics, route miles include all regularly-scheduled vehicle service patterns. For instance, if a bus route has two service patterns, one traversing the entire route and the other stopping at a turnback location, the common portion of this service will be counted twice. Bus routes which operate in both directions over a street will have this distance counted in both directions. Table 13 is a complete list of all public transit facilities included in the network, along with the mode and line card designations. Table 14 shows the transit station node number correspondences for all rail lines.

Table 12 : Transit System Operating Companies and Mode Descriptions

	Transit Companies		Modes
1	SEPTA City Transit Division	1	Walk
2	SEPTA Suburban Victory Division	2	Auto Penalty
3	SEPTA Suburban Frontier Division	3	Auto Connector
4	NJ Transit Mercer Division	4	Bus (Except NJ Transit)
6	PATCO Hi-Speedline (DRPA)	5	Bus (NJ Transit)
7	NJ Transit Southern Division	6	Subway-Elevated
8	NJ Transit Railroad Division	7	Commuter Rail
9	SEPTA Regional Rail Division	8	PATCO Line
14	Pottstown Urban Transit		

Table 13 : 1997 AM Peak Transit Line Card/Route # Correspondence by Company

Co. 1 - SEPTA City Transit Division

Route #	Mode	Line Cards
C	4	1,2,3
G	4	4,5,6,7
H	4	8
XH	4	9
J	4	10
K	4	11
L	4	12,13,14,15,16
R	4	17,18,19,20
Fox-Newt	4	21
1	4	22,23,24
2	4	25,26
3	4	27
5	4	28
6	4	29,30
7	4	31,32
8	4	33
9	4	34,35,36
10	4	37,38
11	4	39,40
12	4	41
13	4	42,43,44
14	4	45,46,47,48
15	4	49,50
17	4	51,52,53
18	4	54,55,56,57,58,59,60
19	4	61,62,63
20	4	64,65,66,67
21	4	68,69,70,71
22	4	72,73
23	4	74,75
24	4	76,77,78
25	4	79,80,81,
26	4	82,83,84,85
27	4	86,87,88,89,90,91
28	4	92
29	4	93
30	4	94
31	4	95,96
32	4	97,98,99,100
33	4	101,102,103,104
34	4	105,106
35	4	107
36	4	108,109,110
37	4	111,112,113
38	4	114
39	4	115
40	4	116
42	4	117,118,119
43	4	120,121
44	4	122,123,124
46	4	125
47	4	126
48	4	127,128,129
52	4	130,131,132,133
53	4	134
54	4	135,136
55	4	137,138,139,140
56	4	141,142
57	4	143,144,145
58	4	146,147,148,149,150
59	4	151
60	4	152
61	4	153,155,156
61 Exp	4	154
63	4	157
64	4	158
65	4	159,160
66	4	161,162,164,166
66 Exp	4	163,165
67	4	167,168
68	4	169
70	4	170,171,172
73	4	173
75	4	174
77	4	175

Co. 1 - SEPTA City Transit Division (Continued)

Route #	Mode	Line Cards	Route #	Mode	Line Cards
79	4	176	BSS	6	3,4,5
84	4	177,178,179	MFSE	6	6,7
88	4	180,181			
89	4	182			
90	4	183			
121	4	239,240,241			

Co. 2 - SEPTA Suburban Victory Division

101	4	200,201	111	4	222,223,224,225
102	4	202,203	112	4	226,227,228
103	4	204,205,206	113	4	229,230
104	4	207,208	114	4	231
105	4	209,210,211	115	4	232
106	4	212	116	4	233
107	4	213,214	117	4	234
108	4	215,216,217	118	4	235,236
109	4	218	119	4	237
110	4	219,220,221	120	4	238
100	6	1,2			

Co. 3 - SEPTA Suburban Frontier Division

92	4	184	124	4	242
93	4	185,186	125	4	243,244
94	4	187,188	127	4	245,246
95	4	189	128	4	247
96	4	190,191	129	4	248
97	4	192,193	130	4	249
98	4	194,195,196	202	4	250
99	4	197,198,199			

Co. 4 - New Jersey Transit Mercer Division

600	5	100,101	606	5	112,113,114,115, 116,117
601	5	102,103	607	5	118
602	5	104	608	5	119,120,121,121
603	5	105,106,107,108,109	609	5	123,124,125,126, 127,128
604	5	110	611	5	129
605	5	111			

Co. 6 - PATCO Hi-Speedline (DRPA)

Route #	Mode	Line Cards	Route #	Mode	Line Cards
Local	8	1,2	Wood. Local	8	4,5
Lind. Exp	8	3			

Co. 7 - New Jersey Transit Southern Division

313/315	5	1,2	450	5	66,67,68
317	5	3	451	5	69,70,71,72
400	5	4,5,6,7,8,9	452	5	73
401	5	10,11,12	453	5	74
402	5	13,14,15,16	454	5	75
403	5	17,18,19,20,21	455	5	76,77,78
404	5	22,23,24,25	457	5	79,80
405	5	26,27	459	5	81,82
406	5	28,29,30,31,32	463	5	83
407	5	33,34,35,36,37,38	551	5	84
408	5	39,40,41,42,43	554	5	85,86
409	5	44,45,46,47,48,49,50			
410	5	51,52,53,54			
412	5	55,56,57			
413	5	58,59,60,61,62,63			
419	5	64,65			

Co. 8 - New Jersey Transit Railroad Division

Corridor	7	50,51
Pr Jct	7	52,53
Atl Cty	7	54

Co. 9 - SEPTA Regional Rail Division

R1	7	1,2,3	R6	7	26,27,28,29,30
R2	7	4,5,6,7,8,9,10,11	R7	7	31,32,33,34
R3	7	12,13,14,15,16,17	R8	7	35,36,37,38,39
R5	7	18,19,20,21,22,23,24,25			

Co. 14 - Pottstown Urban Transit

Stw-San	5	200	N End Loop	5	201

Co. 15 - Krapf's Coaches

Route "A"	5	225	Coatesville Link	5	226

Table 14 : 1997 Transit Station Node Numbers

SEPTA Regional Rail Division

Trunk Lines

Node No.	Station	Node No.	Station
1910	North Philadelphia	1871	Temple University
1713	30th Street	1912	No. Broad St
1694	Suburban	2026	Wayne Junction
1696	Market East	2060	Fern Rock T.C.
		2109	Melrose Park
		2121	Elkins Park
		2132	Jenkintown / Wyncote
		2129	Glenside

R1 - Airport Line

Node No.	Station	Node No.	Station
3355	Airport Terminals	3357	University City
3356	84th Street (Future)		

R2 - Wilmington Line

Node No.	Station	Node No.	Station
2498	Marcus Hook	3770	Prospect Park
2629	Highland Ave	2879	Norwood
2628	Lamokin St	2531	Glenolden
2516	Chester T.C.	2635	Folcroft
2522	Eddystone	2536	Sharon Hill
2625	Crum Lynne	2632	Curtis Park
4436	Ridley Park	2633	Darby

R2 - Warminster Line

Node No.	Station	Node No.	Station
2823	Warminster	2178	Crestmont
2141	Hatboro	4440	Roslyn
2139	Willow Grove	2127	Ardsley

SEPTA Regional Rail Division (Continued)

R3 - Media - West Chester Line

Node No.	Station	Node No.	Station
2170	Elwyn	2124	Primos
2544	Media	2661	Clifton Heights
2548	Moylan-Rose Valley	2651	Gladstone
4443	Wallingford	2593	Lansdowne
2557	Swarthmore	2685	Fernwood-Yeadon
1640	Morton	1805	Angora
2561	Secane	1888	49th Street

R3 - West Trenton Line

Node No.	Station	Node No.	Station
2710	West Trenton	2189	Forest Hills
2519	Yardley	2188	Philmont
2517	Woodbourne	2145	Bethayres
2514	Langhorne	2167	Meadowbrook
2510	Neshaminy Falls	2164	Rydal
2945	Trevose	2133	Noble
2146	Somerton		

R5 - Parkesburg - Paoli Line

Node No.	Station	Node No.	Station
2960	Downingtown	1743	Radnor
2962	Whitford	2634	Villanova
4438	Exton	2771	Rosemont
2959	Malvern	2799	Bryn Mawr
2282	Paoli	2827	Haverford
2255	Daylesford	2856	Ardmore
2254	Berwyn	2608	Wynnewood
2226	Devon	2889	Narberth
2712	Strafford	2890	Merion
2357	Wayne	2891	Overbrook
2760	St. Davids		

SEPTA Regional Rail Division (Continued)

R5 - Lansdale - Doylestown Line

Node No.	Station	Node No.	Station
2857	Doylestown	2895	Pennbrook
2855	Delaware Valley College	2894	North Wales
2854	New Britain	2893	Gwynedd Valley
2902	Chalfont	2499	Penllyn
2901	Link Belt	2745	Ambler
2899	Colmar	2125	Fort Washington
2898	Fortuna	4437	Oreland
2896	Lansdale	2126	North Hills

R6 - Norristown Line

Node No.	Station	Node No.	Station
2797	Elm Street	4446	Ivy Ridge
1630	Main Street	1633	Manayunk
1631	Norristown T.C.	1944	Wissahickon T.C.
2647	Conshohocken	1880	East Falls
1632	Spring Mill	1937	Allegheny
1643	Miquon		

R6 - Cynwyd Line

Node No.	Station	Node No.	Station
4441	Cynwyd	1899	Wynnefield Ave
1903	Bala		

R7 - Trenton Line

Node No.	Station	Node No.	Station
2520	Trenton	2077	Torresdale
2506	Levittown	2073	Holmesburg Junction
2504	Bristol	2154	Tacony
2503	Croydon	2153	Wissinoming
2859	Eddington	1986	Bridgesburg
2501	Cornwells Heights		

SEPTA Regional Rail Division (Continued)

R7 - Chestnut Hill East Line

Node No.	Station	Node No.	Station
2014	Chestnut Hill East	2047	Sedgewick
2017	Gravers	2045	Stenton
2019	Wyndmoor	2043	Washington La
1741	Mount Airy	2023	Germantown
		1740	Wister

R8 - Fox Chase Line

Node No.	Station	Node No.	Station
2101	Fox Chase	2131	Cheltenham
2098	Ryers	2137	Lawndale
		2036	Olney

R8 - Chestnut Hill West Line

Node No.	Station	Node No.	Station
2012	Chestnut Hill West	2009	Upsal
2159	Highland	2008	Tulpehocken
2158	St. Martins	2006	Chelten Ave
2157	Allen Lane	2104	Queen Lane
2156	Carpenter		

SEPTA Subway-Elevated System

Market-Frankford Line

Node No.	Station	Node No.	Station
3244	69th Street	1680	5th Street
4773	Millbourne	1679	2nd Street
1818	63rd Street	1724	Spring Garden
1819	60th Street	1853	Girard
1820	56th Street	1874	Berks
1821	52nd Street	1878	York-Dauphin
1822	46th Street	1916	Huntingdon
1823	40th Street	1922	Somerset
1889	34th Street	1923	Allegheny
1712	30th Street	1928	Tioga
1686	15th Street/City Hall	1949	Erie-Torresdale
1683	13th Street	1958	Church St
1682	11th Street	2015	Margaret-Orthodox
1681	8th Street	2067	Bridge-Pratt

SEPTA Subway-Elevated System (Continued)

Broad Street Subway Line

Node No.	Station	Node No.	Station
2059	Fern Rock Terminal	1748	Fairmount
2040	Olney	1718	Spring Garden
2030	Logan	1699	Race-Vine
2028	Wyoming	1684	City Hall
2000	Hunting Park	1702	Walnut-Locust
1971	Erie	1654	Lombard-South
1935	Allegheny	1730	Ellsworth-Federal
1911	North Philadelphia	1788	Tasker-Morris
1891	Susquehanna-Dauphin	1778	Snyder
1869	Columbia-Temple U.	1761	Oregon
1848	Girard	4267	Pattison

Broad Ridge Spur Line

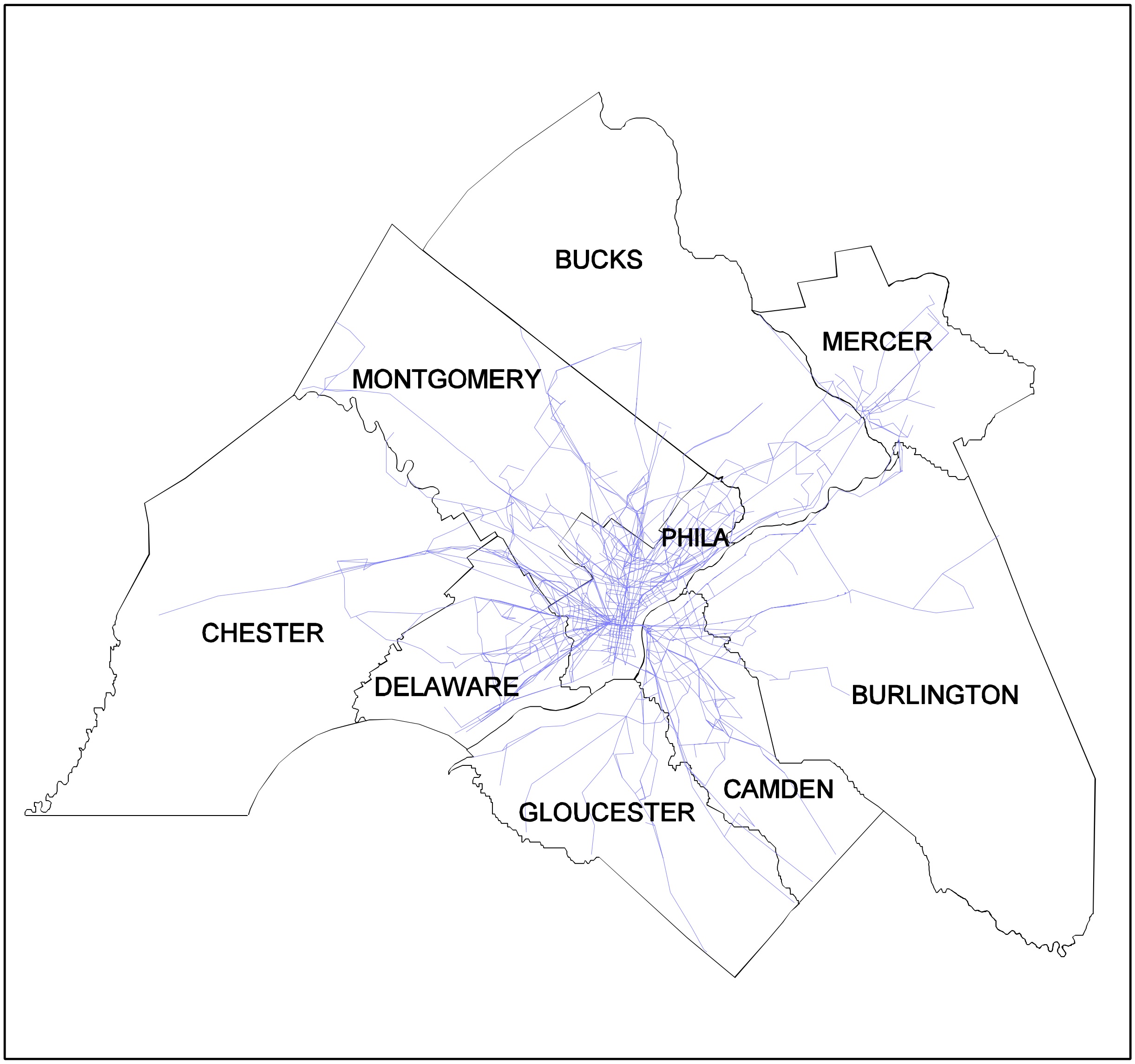
1719	Spring Garden	1681	8th & Market
1698	Chinatown		

PATCO Hi-Speedline (DRPA)

1701	15th-16th Sts	4054	Collingswood
1703	12th-13th Sts	4053	Westmont
1704	9th-10th Sts	4052	Haddonfield
4061	8th & Market Sts	4060	Woodcrest
4057	City Hall, Camden	4051	Ashland
4056	Broadway, Camden T.C.	4050	Lindenwold
4055	Ferry Ave		

The transit network is a literal description of the morning peak period transit system that is operating on a regularly scheduled basis within the nine-county region in 1997. A map of the system without approach links is shown as Figure 7.

Figure 7
1997 Regional Transit Network



VII. TRIP DISTRIBUTION

Trip distribution is the process whereby the zonal trip ends established in the trip generation analysis are linked together to form origin and destination patterns in trip table format. It is not sufficient to know only how many trips will originate or be destined to a zone on a daily basis. It is necessary to know between what pairs of zones these trips will occur. That is the function of the distribution models.

The basic premise of the gravity-type distribution models is that the trips between a pair of zones will be proportional to the number of trips generated in the production zone, times the number of trips attracted to the destination zone, and inversely proportional to the physical separation between the zones to some exponential power. The formulation of the equation and a discussion of the theory is available in Urban Transportation Networks, by Yosef Sheffi, Prentice-Hall, 1985, pp.180-81.

The gravity model is, by far, the most common of the trip distribution models. Their calibration and application is well documented and the computer routines that perform the calculations are readily available. The accuracy of the models in calculating the trip distributions is commensurate with the other models that are included in the sequence.

For the simulation of 1997 travel demands, a series of eight gravity-type distribution models were applied. These eight gravity models were divided into two basic types. The first three models were used to distribute the internal person trips by all modes of travel, and models 4 through 8 were used to distribute certain vehicular trips by autos, trucks, and taxis. As reported in Chapter IV, the through vehicle trip distribution was prepared manually and did not require an application of a distribution model. The individual models are as follows:

Model Number	Description
1	Internal Home-Based Work Person Trips
2	Internal Home-Based Non-work Person Trips
3	Internal Non-home-Based Person Trips
4	External-Local Auto Driver Trips, All Purposes, Freeway Cordon Stations
5	External-Local Auto Driver Trips, All Purposes, All Other Cordon Stations
6	All Light Truck Trips (including external-local)
7	All Heavy Truck Trips (including external-local)
8	All Taxi Trips

In the 1990 model validation effort, the person trip models were recalibrated with trip length frequency data from the 1987-88 Home Interview Survey and the external-local models recalibrated with data from the 1988-89 cordon line O-D survey. No truck or taxi survey data was available to recalibrate these trip distribution models. These successful applications of the models in previous model validation studies supported their continued use in the 1997 travel simulation.

In the above list, the term "internal" refers to the internal traffic zones and does not include external station travel. In this case, both ends of the trips must be within the study area. External-local trips are those that have one end inside the study area and the other beyond the cordon line (nine-county boundary). The term "all" is a combination of these and includes both the internal and external-local travel. It does not include external-external or through travel, however.

The reference to "person trips" as opposed to "vehicle trips" means that all common modes of travel are included such as auto driver, auto passengers, and transit passengers. It does not include walk trips, school bus or truck and taxi passenger trips. Vehicle trips represent the driver of the vehicle only and do not include any passengers. These are autos, trucks, and taxis and are loaded directly on the highway networks.

The term "home-based" means that one end of the trip is made to or from the residence of the individual. Conversely, non-home-based means that neither end of the trip is at home. The home-based trips are in trip production-attraction format, where all trips originate at the home end and are attracted to the non-home end regardless of their direction of travel. Unless specified as "home-based," all trips are on an origin destination basis and the origins and destinations are the true starting and ending places of the trips.

To execute these eight trip distribution models, several sets of input data are required. Each model requires the number of trip productions and attractions (or origins and destinations) to be distributed for each zone (or station), a measure of impedance to travel between all zones and stations which is usually referred to as a "skim tree," and a set of "friction factors" which relate the propensity to travel with respect to the impedance value. For person trip distributions a preliminary distribution based on highway skims was made.

This preliminary distribution was adjusted for highway bias using a correction curve which related the bias to the relative highway/transit service levels. This bias correction was executed as a first step in the modal split model computer program model, just prior to calculating the transit and highway trip tables. The vehicle trip models used highway times to measure intra-zonal impedances. When the model runs were completed, the trip tables were passed to the mode split procedure, which then created the final trip tables for loading on the highway or transit networks.

As the modal split impedance difference was used, it was convenient to execute this adjustment process in modal split computer program MSPLIT. This adjustment was applied to the person trip interchanges immediately before applying the simulated modal split to the preliminary person trip interchanges. In general, where good transit service exists, the person trips are increased and, where no service or very poor service was offered, the person trips are slightly reduced. This tended to remove the bias within the person trip model output.

The data in Table 15 record the pertinent summary statistics for each model as run for the 1997 simulation. These data are taken directly from the model output tabulations and represent the final status of the models after the third iteration of attraction balancing.

Table 15 : General Trip Distribution Model Attributes

Model Number	Trip Category	Total Trips	Average Trip Length* (Minutes)	Standard Deviation of ATL* (Minutes)
Person Trip Models				
1	Home Based Work	4,231,546	28.9	19.0
2	Home Based Non-work	9,218,357	17.6	14.3
3	Non-home Based	4,018,014	16.6	13.6
	(Subtotal)	**17,467,917**	**20.1**	**15.3**
Vehicle Trip Models				
4	External-Local Fwy/Expwy	409,928*	58.2	32.2
5	External-Local Arterial/Local	557,921	43.0	33.2
6	Light Trucks	1,351,320	10.6	10.5
8	Taxis	159,829	15.2	10.7
	(Subtotal)	**2,478,998**	**28.5**	**22.7**

Note* : The interzonal travel times that are used in the calculation of average trip length, and the standard deviation of the average trip length include terminal time at both ends of the trip as well as the system travel time. Interzonal travel times consist of assumed interzonal time plus twice the terminal time for the zone.

The data in this table were evaluated for reasonableness by comparing the statistics with the results of previous simulations. Of critical importance is the average trip length, which is a good parameter to compare with previous runs and the percentage of intrazonal trips, as this can vary substantially with adjustments to the terminal and intrazonal travel time assumptions. All of the results shown in Table 15 appear to be within a reasonable range for the 1997 simulation.

Almost 17.5 million regional internal trips were distributed by the three person trip gravity models, and almost 2.4 million vehicular trips with the four vehicle gravity models. The individual trip tables produced by the person trip models then became the input to the modal split operation, and the vehicular trip tables were later incorporated with other model output and loaded on the 1997 highway network. The modal split model application is discussed in the next chapter.

VIII. MODAL SPLIT MODEL APPLICATION

The function of the mode choice, or modal split process, is to allocate the internal person trips that were developed by the trip distribution model to either the highway or the transit systems. The auto occupancy analysis further subdivides the highway oriented trips into auto drivers and auto passengers. Those trips that are allocated to the transit system are then prepared for assignment to the transit network. The auto driver trips are added to the truck, taxi and external vehicle trips in preparation for assignment to the highway network. This modal split was subjected to an extensive validation/recalibration effort using home-interview and 1990 Census data. See chapter VIII of the commission report entitled, "1990 Validation of the DVRPC travel Simulation Models," October 1997 for a detailed description of the model validation results and a description of the recalibrated model.

The mode choice models do not determine the submode (commuter rail, subway-elevated, or surface bus) of travel for the transit trips; they determine only the total number of transit-oriented trips that will be allocated to the transit system. The minimum impedance traces through the transit network determine the submode of travel for each interzonal movement and the mode choice model then estimates the number of transit trips, given the transit submode of travel. In this process, the actual allocation of the transit trips to a particular submode is done during the transit path building and assignment process.

This method of determining the mode of travel (highway or transit) is defined as a post-distribution or trip interchange modal split model. Some studies prefer to allocate the trips to either the transit or the highway system during the trip generation phase of the process before the trip distributions are made. That method, known as the pre-distribution procedure, usually has very limited sensitivity to the quality of transportation service by mode of travel and was, therefore, not used.

The two models, mode choice and auto occupancy, will be described separately in this section of the report, even though they are actually performed within the same computer operation. The mode choice model is, by far, the more complex of the two.

A. Mode Choice Model

The mode choice model operates on each person trip interchange volume in the trip tables and computes the trips to be allocated to the highway and transit systems. The model computes the proportion (percentage) of the total trip volume to be allocated to transit, and the residual difference is allocated to the highway system.

The calculation of the proportion of trips to transit is a complex mathematical process that actually computes a "standard score" value which is then converted to a percentage of transit through a reference table. The model computes this standard score value by a series of 18 stratified diversion curves, each curve relating the percent by transit for a stratum to the impedance difference between transit and highway. In general, the greater the impedance difference (poor transit) the lower the standard score and the lower the percent allocated to transit. This type of modal split model is sometimes described by the term binary probit; "Binary"because a two way split (higher versus time out) is considered and "Probit" because standard score (normal distribution) weight utilities are used.

The following combinations of trip purpose, transit submode, and auto ownership form the stratums for the eighteen diversion curves:

Trip Purpose (3)

Home based work
Home based non-work
Non-home based

Transit Submode (3)

Commuter Rail
Subway-elevated
Surface bus/trolley

Auto Ownership (2)

Trip interchanges by autoless households
Trip interchanges by car-owning households

These eighteen stratifications, in addition to the parameters included in the formulation of the model and the coding of the networks, insure that the model is stable with respect to geographic areas and time periods, and that it is both accurate and policy sensitive. The factors considered in computing the amount of travel allocated to the two modes are transit-user characteristics, trip characteristics, land use characteristics, quality of transit service, and quality of highway service.

Transit-user characteristics are expressed through car ownership considerations: autoless and car-owning households. Trip characteristics are reflected in the three generalized trip purposes. 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, and by adjustment of the travel impedance by type of area. The quality of transit service is measured by transit travel time, fare, and submode of travel. The transit fares used in the simulation are those that existed in 1997.

Finally, the quality of highway service is measured by considering the travel cost by highway in addition to the travel time. Highway travel cost is the perceived operating cost , including gas, oil, tires, maintenance and insurance together with a time impedance representative of the out-of-vehicle, or "excess", travel time. Parking charges are assessed based on the zone of trip attraction and toll charges are in the existing DVRPC model are assessed by equivalent time penalties incorporated into the highway network.

The major determinants of mode choice are the differences in travel time and cost between the highway and transit systems. Most of the other parameters in the equation are used to modify this basic relationship.

B. Auto Occupancy Model

After the mode choice is calculated for each individual trip interchange by the appropriate mode split equation, a secondary model is employed to determine the proportion of the highway-oriented travel that would be auto drivers and, thus, the number of vehicles on the system. This is done by calculating an auto occupancy which is then applied to the highway-oriented person-trips. Previous investigations have found the principal determinants of auto occupancy to be trip length and trip purpose. The procedures developed during that analysis were recalibrated using Home Interview and CTPP data. DVRPC's auto occupancy model is based on linear equations which relate the number of occupants per vehicle to trip length. Separate equations are included for HBW, HBNW, and NHB trips. The 1990 validated report cited above contains a description of the Auto Occupancy model in Chapter VIII.

C. Model Application Results

The trip distribution models passed 17,467,917 person trips to the mode choice analysis. The highway/transit bias adjustment increased this number of trips to 17,528,370. Of these, 12,051,640 trips were defined as auto driver trips, 4,675,785 as auto passenger trips, and 800,945 as transit trips. Thus 4.6 percent of the 1997 regional internal person trips were transit-oriented, down from 5.1 percent in 1990.

Table 16 shows the percent of trip productions made by transit by trip purpose for each county planning area and for the region as a whole. The regional total percentage of transit trips ranges from 11.3 percent for home based work trips to 1.4 percent for non-home based trips.

The percent transit for trip attractions is shown in Table 17. The highest percentages of transit trips occur in the central part of the region. (The business district has 21.6 percent for total productions and 45.1 percent for total attractions.) Generally, the percent of transit trips decreases as the distance from the Philadelphia CBD increases; several outlying planning areas in Chester, Mercer, and Burlington counties have almost no transit trips.

Table 16 : 1997 Travel Simulation: Percent of Daily Person Trip Production Made by Transit By Trip Purpose and County Planning Area

CPA	Home-Based Work Trips Person Trips	Home-Based Work Trips Transit Trips	Home-Based Work Trips Percent Transit	Home-Based Non-Work Trips Person Trips	Home-Based Non-Work Trips Transit Trips	Home-Based Non-Work Trips Percent Transit	Non-Home-Based Trips Person Trips	Non-Home-Based Trips Transit Trips	Non-Home-Based Trips Percent Transit	Total Trips Person Trips	Total Trips Transit Trips	Total Trips Percent Transit
Philadelphia												
1	25,442	9,006	35.4	44,629	11,822	26.5	113,074	18,811	16.6	183,138	39,639	21.6
2	104,137	42,990	41.3	134,473	30,329	22.6	69,830	3,861	5.5	308,445	77,180	25.0
3	51,747	18,396	35.5	64,695	10,023	15.5	37,267	901	2.4	153,709	29,320	19.1
4	137,145	57,815	42.2	183,178	40,143	21.9	80,472	8,074	10.0	400,777	106,032	26.5
5	69,496	33,636	48.4	95,568	27,682	29.0	66,661	5,897	8.8	231,721	67,215	29.0
6	49,378	21,460	43.5	63,740	14,563	22.8	33,849	1,719	5.1	146,972	37,742	25.7
7	54,027	21,634	40.0	79,230	15,051	19.0	38,488	1,841	4.8	171,741	38,526	22.4
8	34,212	7,004	20.5	67,079	3,920	5.8	22,425	380	1.7	123,720	11,304	9.1
9	75,430	19,037	25.2	119,927	11,066	9.2	43,913	962	2.2	239,274	31,065	13.0
10	122,693	37,917	30.9	161,094	21,402	13.3	39,874	1,635	4.1	323,656	60,954	18.8
11	158,100	45,534	28.8	260,901	28,887	11.1	95,899	2,711	2.8	514,898	77,132	15.0
12	126,464	16,645	13.2	290,127	6,249	2.2	110,207	566	0.5	526,803	23,460	4.5
TOTAL	**1,008,271**	**331,074**	**32.8**	**1,564,641**	**221,137**	**14.1**	**751,959**	**47,358**	**6.3**	**3,324,854**	**599,569**	**18.0**
Delaware												
13	66,154	4,618	7.0	121,929	1,113	0.9	42,933	156	0.4	231,019	5,887	2.5
14	71,976	6,588	9.2	171,869	1,560	0.9	77,268	358	0.5	321,114	8,506	2.6
15	115,071	20,844	18.1	221,727	8,222	3.7	65,604	1,115	1.7	402,399	30,181	7.5
16	82,970	8,596	10.4	200,196	2,821	1.4	88,858	549	0.6	372,021	11,966	3.2
17	33,500	2,103	6.3	83,511	475	0.6	42,142	168	0.4	159,151	2,746	1.7
18	17,800	410	2.3	42,422	35	0.1	25,003	39	0.2	85,226	484	0.6
TOTAL	**387,471**	**43,159**	**11.1**	**841,654**	**14,226**	**1.7**	**341,808**	**2,385**	**0.7**	**1,570,930**	**59,770**	**3.8**
Chester												
19	58,065	1,525	2.6	151,017	129	0.1	102,612	151	0.1	311,692	1,805	0.6
20	34,023	976	2.9	88,663	277	0.3	23,067	32	0.1	145,754	1,285	0.9
21	22,654	40	0.2	62,204	14	0.0	10,932	3	0.0	95,790	57	0.1
22	50,373	957	1.9	124,292	116	0.1	68,745	71	0.1	243,411	1,144	0.5
23	74,442	1,198	1.6	175,288	181	0.1	71,273	96	0.1	321,004	1,475	0.5
24	25,564	46	0.2	58,258	3	0.0	17,089	1	0.0	100,912	50	0.0
25	34,430	945	2.7	84,696	226	0.3	29,923	45	0.2	149,049	1,216	0.8
26	27,716	189	0.7	73,180	49	0.1	17,965	4	0.0	118,861	242	0.2
27	18,770	20	0.1	48,551	8	0.0	9,989	1	0.0	77,309	29	0.0
28	12,308	415	3.4	31,358	102	0.3	8,019	17	0.2	51,684	534	1.0
29	14,893	0	0.0	35,145	0	0.0	11,700	0	0.0	61,738	0	0.0
TOTAL	**373,238**	**6,311**	**1.7**	**932,652**	**1,105**	**0.1**	**371,314**	**421**	**0.1**	**1,677,204**	**7,837**	**0.5**

Table 16 : 1997 Travel Simulation: Percent of Daily Person Trip Production Made by Transit By Trip Purpose and County Planning Area (Continued)

	Home-Based Work Trips			Home-Based Non-Work Trips			Non-Home-Based Trips			Total Trips		
CPA	Person Trips	Transit Trips	Percent Transit	Person Trips	Transit Trips	Percent Transit	Person Trips	Transit Trips	Percent Transit	Person Trips	Transit Trips	Percent Transit
Montgomery												
30	63,620	1,631	2.6	152,861	215	0.1	75,006	76	0.1	291,487	1,922	0.7
31	37,124	1,345	3.6	91,082	163	0.2	47,024	112	0.2	175,231	1,620	0.9
32	100,540	8,006	8.0	250,128	2,263	0.9	102,108	484	0.5	452,781	10,753	2.4
33	35,540	1,870	5.3	81,932	374	0.5	57,752	148	0.3	175,228	2,392	1.4
34	85,564	7,450	8.7	202,447	2,373	1.2	144,739	900	0.6	432,750	10,723	2.5
35	73,099	2,423	3.3	168,201	422	0.3	78,289	134	0.2	319,586	2,979	0.9
36	64,534	945	1.5	172,932	174	0.1	58,079	37	0.1	295,546	1,156	0.4
37	111,950	2,040	1.8	265,649	210	0.1	140,846	184	0.1	518,438	2,434	0.5
38	26,675	3	0.0	69,388	0	0.0	20,673	0	0.0	116,736	3	0.0
39	41,006	730	1.8	91,772	288	0.3	38,660	49	0.1	171,435	1,067	0.6
TOTAL	**639,652**	**26,443**	**4.1**	**1,546,392**	**6,482**	**0.4**	**763,176**	**2,124**	**0.3**	**2,949,218**	**35,049**	**1.2**
Bucks												
40	27,435	0	0.0	70,900	0	0.0	20,988	0	0.0	119,323	0	0.0
41	14,539	0	0.0	40,484	0	0.0	7,961	0	0.0	62,984	0	0.0
42	39,177	0	0.0	105,394	0	0.0	32,987	0	0.0	177,558	0	0.0
43	50,372	1,001	2.0	129,280	145	0.1	50,067	80	0.2	229,717	1,226	0.5
44	21,826	204	0.9	62,458	28	0.0	14,226	5	0.0	98,508	237	0.2
45	8,568	104	1.2	22,336	17	0.1	8,133	5	0.1	39,038	126	0.3
46	90,196	1,586	1.8	211,499	162	0.1	77,742	58	0.1	379,434	1,806	0.5
47	26,555	197	0.7	69,479	32	0.0	21,341	3	0.0	117,376	232	0.2
48	69,792	3,278	4.7	164,358	377	0.2	88,875	159	0.2	323,019	3,814	1.2
49	44,912	1,341	3.0	105,062	136	0.1	62,539	53	0.1	212,516	1,530	0.7
50	73,549	1,967	2.7	181,478	269	0.1	59,290	70	0.1	314,314	2,306	0.7
51	56,896	2,512	4.4	128,733	275	0.2	50,704	107	0.2	236,332	2,894	1.2
TOTAL	**523,817**	**12,190**	**2.3**	**1,291,461**	**1,441**	**0.1**	**494,853**	**540**	**0.1**	**2,310,119**	**14,171**	**0.6**
Berks												
72	11,174	5	0.0	24,641	1	0.0	7,603	0	0.0	43,416	6	0.0
TOTAL	**11,174**	**5**	**0.0**	**24,641**	**1**	**0.0**	**7,603**	**0**	**0.0**	**43,416**	**6**	**0.0**
PA TOTAL	**2,943,623**	**419,182**	**14.2**	**6,201,441**	**244,392**	**3.9**	**2,730,713**	**52,828**	**1.9**	**11875741**	**716,402**	**6.0**

Table 16 : 1997 Travel Simulation: Percent of Daily Person Trip Production Made by Transit By Trip Purpose and County Planning Area (Continued)

	Home-Based Work Trips			Home-Based Non-Work Trips			Non-Home-Based Trips			Total Trips		
CPA	Person Trips	Transit Trips	Percent Transit	Person Trips	Transit Trips	Percent Transit	Person Trips	Transit Trips	Percent Transit	Person Trips	Transit Trips	Percent Transit
Mercer												
52	59,883	5,581	9.3	86,605	2,010	2.3	57,939	484	0.8	204,433	8,075	3.9
53	58,867	1,577	2.7	127,691	322	0.3	93,770	104	0.1	280,327	2,003	0.7
54	82,873	1,744	2.1	188,232	465	0.2	67,398	65	0.1	338,506	2,274	0.7
55	17,500	110	0.6	43,370	3	0.0	12,438	6	0.0	73,308	119	0.2
56	36,441	423	1.2	76,490	22	0.0	31,267	16	0.1	144,199	461	0.3
57	40,355	730	1.8	76,834	59	0.1	56,045	80	0.1	173,235	869	0.5
TOTAL	**295,919**	**10,165**	**3.4**	**599,222**	**2,881**	**0.5**	**318,857**	**755**	**0.2**	**1,214,008**	**13,801**	**1.1**
Burlington												
58	101,560	2,286	2.3	241,781	426	0.2	114,670	81	0.1	458,019	2,793	0.6
59	168,465	5,661	3.4	408,619	1,015	0.2	167,146	194	0.1	744,233	6,870	0.9
60	61,187	125	0.2	125,429	13	0.0	43,858	3	0.0	230,473	141	0.1
61	38,434	405	1.1	114,493	98	0.1	32,859	8	0.0	185,785	511	0.3
62	15,767	0	0.0	42,531	0	0.0	10,470	0	0.0	68,768	0	0.0
TOTAL	**385,413**	**8,477**	**2.2**	**932,853**	**1,552**	**0.2**	**369,003**	**286**	**0.1**	**1,687,278**	**10,315**	**0.6**
Camden												
63	88,448	12,600	14.2	168,121	5,018	3.0	84,390	954	1.1	340,970	18,572	5.4
64	99,871	6,415	6.4	241,959	1,285	0.5	140,662	426	0.3	482,494	8,126	1.7
65	102,363	9,371	9.2	241,714	2,422	1.0	80,876	378	0.5	424,957	12,171	2.9
66	48,084	2,686	5.6	126,508	741	0.6	45,496	71	0.2	220,090	3,498	1.6
67	88,548	7,342	8.3	209,474	1,731	0.8	60,218	194	0.3	358,238	9,267	2.6
TOTAL	**427,314**	**38,414**	**9.0**	**987,776**	**11,197**	**1.1**	**411,642**	**2,023**	**0.5**	**1,826,749**	**51,634**	**2.8**
Gloucester												
68	70,805	2,849	4.0	169,451	784	0.5	84,670	120	0.1	324,927	3,753	1.2
69	30,836	331	1.1	82,410	51	0.1	30,590	4	0.0	143,836	386	0.3
70	70,715	2,473	3.5	158,418	523	0.3	53,965	61	0.1	283,101	3,057	1.1
71	40,992	1,232	3.0	106,978	348	0.3	24,757	17	0.1	172,730	1,597	0.9
TOTAL	**213,348**	**6,885**	**3.2**	**517,257**	**1,706**	**0.3**	**193,982**	**202**	**0.1**	**924,594**	**8,793**	**1.0**
NJ TOTAL	**1,321,994**	**63,941**	**4.8**	**3,037,108**	**17,336**	**0.6**	**1,293,484**	**3,266**	**0.3**	**5,652,629**	**84,543**	**1.5**
REGION TOTAL	**4,265,617**	**483,123**	**11.3**	**9,238,549**	**261,728**	**2.8**	**4,024,197**	**56,094**	**1.4**	**17528370**	**800,945**	**4.6**

Table 17 : 1997 Travel Simulation: Percent of Daily Person Trip Attraction Made by Transit By Trip Purpose and County Planning Area

CPA	Home-Based Work Trips Person Trips	Home-Based Work Trips Transit Trips	Home-Based Work Trips Percent Transit	Home-Based Non-Work Trips Person Trips	Home-Based Non-Work Trips Transit Trips	Home-Based Non-Work Trips Percent Transit	Non-Home-Based Trips Person Trips	Non-Home-Based Trips Transit Trips	Non-Home-Based Trips Percent Transit	Total Trips Person Trips	Total Trips Transit Trips	Total Trips Percent Transit
Philadelphia												
1	462,684	248,271	53.7	240,020	95,987	40.0	115,797	24,771	21.4	818,513	369,029	45.1
2	95,715	19,459	20.3	135,841	18,971	14.0	70,905	2,879	4.1	302,506	41,309	13.7
3	39,147	4,683	12.0	83,474	5,281	6.3	37,703	609	1.6	160,314	10,573	6.6
4	133,304	38,877	29.2	160,285	24,528	15.3	81,463	5,944	7.3	375,052	69,349	18.5
5	118,006	45,893	38.9	125,568	31,737	25.3	68,205	7,462	10.9	311,809	85,092	27.3
6	48,390	12,507	25.8	65,883	10,772	16.4	34,492	1,636	4.7	148,725	24,915	16.8
7	52,046	11,162	21.4	78,441	9,933	12.7	39,223	1,569	4.0	169,717	22,664	13.4
8	19,102	2,266	11.9	48,875	1,761	3.6	22,757	229	1.0	90,700	4,256	4.7
9	45,352	7,808	17.2	94,080	7,211	7.7	44,658	742	1.7	184,111	15,761	8.6
10	35,494	8,759	24.7	84,718	10,772	12.7	40,603	1,476	3.6	160,831	21,007	13.1
11	109,426	20,599	18.8	199,884	19,361	9.7	97,755	2,508	2.6	407,092	42,468	10.4
12	85,062	3,801	4.5	260,661	3,139	1.2	112,223	201	0.2	457,946	7,141	1.6
TOTAL	**1,243,728**	**424,085**	**34.1**	**1,577,730**	**239,453**	**15.2**	**765,784**	**50,026**	**6.5**	**3,587,316**	**713,564**	**19.9**
Delaware												
13	47,085	1,669	3.5	92,869	551	0.6	42,211	114	0.3	182,163	2,334	1.3
14	59,220	1,142	1.9	178,302	382	0.2	77,057	133	0.2	314,595	1,657	0.5
15	58,271	5,519	9.5	143,715	3,396	2.4	65,954	892	1.4	267,943	9,807	3.7
16	81,659	2,394	2.9	205,636	998	0.5	89,560	294	0.3	376,849	3,686	1.0
17	39,868	1,289	3.2	91,512	280	0.3	41,682	116	0.3	173,047	1,685	1.0
18	20,969	102	0.5	54,663	1	0.0	24,486	20	0.1	100,120	123	0.1
TOTAL	**307,072**	**12,115**	**3.9**	**766,697**	**5,608**	**0.7**	**340,950**	**1,569**	**0.5**	**1,414,717**	**19,292**	**1.4**
Chester												
19	104,600	859	0.8	242,928	72	0.0	103,804	73	0.1	451,316	1,004	0.2
20	19,973	344	1.7	52,138	134	0.3	22,774	27	0.1	94,898	505	0.5
21	6,042	10	0.2	26,998	6	0.0	10,444	1	0.0	43,481	17	0.0
22	57,114	427	0.7	159,119	27	0.0	68,720	37	0.1	284,967	491	0.2
23	66,084	670	1.0	153,588	132	0.1	70,890	94	0.1	290,562	896	0.3
24	18,067	0	0.0	46,920	0	0.0	16,144	0	0.0	81,132	0	0.0
25	25,683	38	0.1	72,745	3	0.0	28,550	5	0.0	126,976	46	0.0
26	13,962	1	0.0	44,242	0	0.0	17,004	0	0.0	75,209	1	0.0
27	8,237	0	0.0	30,390	0	0.0	9,250	0	0.0	47,881	0	0.0
28	7,070	0	0.0	22,570	0	0.0	7,297	0	0.0	36,937	0	0.0
29	9,342	0	0.0	35,084	0	0.0	11,243	0	0.0	55,659	0	0.0
TOTAL	**336,174**	**2,349**	**0.7**	**886,722**	**374**	**0.0**	**366,120**	**237**	**0.1**	**1,589,018**	**2,960**	**0.2**

Table 17 : 1997 Travel Simulation: Percent of Daily Person Trip Attraction Made by Transit By Trip Purpose and County Planning Area (Continued)

	Home-Based Work Trips			Home-Based Non-Work Trips			Non-Home-Based Trips			Total Trips		
CPA	Person Trips	Transit Trips	Percent Transit	Person Trips	Transit Trips	Percent Transit	Person Trips	Transit Trips	Percent Transit	Person Trips	Transit Trips	Percent Transit
Montgomery												
30	82,134	646	0.8	188,013	110	0.1	75,835	45	0.1	345,983	801	0.2
31	50,855	634	1.2	115,937	68	0.1	47,545	70	0.1	214,329	772	0.4
32	84,881	2,802	3.3	241,436	959	0.4	103,638	283	0.3	429,939	4,044	0.9
33	60,627	1,052	1.7	132,688	334	0.3	58,556	72	0.1	251,880	1,458	0.6
34	152,507	6,071	4.0	325,316	1,935	0.6	147,235	533	0.4	625,057	8,539	1.4
35	80,455	1,148	1.4	176,811	301	0.2	79,284	101	0.1	336,545	1,550	0.5
36	48,857	156	0.3	135,183	26	0.0	57,227	8	0.0	241,274	190	0.1
37	130,331	897	0.7	321,359	75	0.0	139,972	136	0.1	591,632	1,108	0.2
38	16,834	0	0.0	50,041	0	0.0	19,611	0	0.0	86,489	0	0.0
39	34,185	527	1.5	94,368	245	0.3	36,931	48	0.1	165,483	820	0.5
TOTAL	**741,666**	**13,933**	**1.9**	**1,781,152**	**4,053**	**0.2**	**765,834**	**1,296**	**0.2**	**3,288,611**	**19,282**	**0.6**
Bucks												
40	21,088	0	0.0	56,561	0	0.0	19,775	0	0.0	97,422	0	0.0
41	4,614	0	0.0	24,449	0	0.0	7,097	0	0.0	36,151	0	0.0
42	30,856	0	0.0	84,956	0	0.0	31,740	0	0.0	147,552	0	0.0
43	44,783	510	1.1	115,684	53	0.0	49,251	75	0.2	209,726	638	0.3
44	11,981	10	0.1	36,116	0	0.0	13,660	0	0.0	61,756	10	0.0
45	5,440	7	0.1	19,312	0	0.0	7,580	1	0.0	32,324	8	0.0
46	65,956	249	0.4	182,502	30	0.0	77,979	26	0.0	326,449	305	0.1
47	19,376	93	0.5	50,172	17	0.0	21,066	2	0.0	90,610	112	0.1
48	71,466	627	0.9	212,445	114	0.1	89,765	75	0.1	373,655	816	0.2
49	42,182	256	0.6	149,779	43	0.0	62,773	28	0.0	254,730	327	0.1
50	42,414	190	0.4	143,640	19	0.0	59,235	23	0.0	245,280	232	0.1
51	44,726	590	1.3	117,009	69	0.1	50,931	73	0.1	212,667	732	0.3
TOTAL	**404,882**	**2,532**	**0.6**	**1,192,625**	**345**	**0.0**	**490,852**	**303**	**0.1**	**2,088,322**	**3,180**	**0.2**
Berks												
72	10,858	19	0.2	17,504	0	0.0	7,214	0	0.0	35,579	19	0.1
TOTAL	**10,858**	**19**	**0.2**	**17,504**	**0**	**0.0**	**7,214**	**0**	**0.0**	**35,579**	**19**	**0.1**
PA TOTAL	**3,044,380**	**455,033**	**14.9**	**6,222,430**	**249,833**	**4.0**	**2,736,754**	**53,431**	**2.0**	**12003563**	**758,297**	**6.3**

Table 17 : 1997 Travel Simulation: Percent of Daily Person Trip Attraction Made by Transit By Trip Purpose and County Planning Area (Continued)

	Home-Based Work Trips			Home-Based Non-Work Trips			Non-Home-Based Trips			Total Trips		
CPA	Person Trips	Transit Trips	Percent Transit	Person Trips	Transit Trips	Percent Transit	Person Trips	Transit Trips	Percent Transit	Person Trips	Transit Trips	Percent Transit
Mercer												
52	99,190	8,441	8.5	98,998	2,489	2.5	58,304	683	1.2	256,513	11,613	4.5
53	91,388	1,223	1.3	192,920	276	0.1	94,634	36	0.0	378,941	1,535	0.4
54	51,261	254	0.5	144,140	83	0.1	67,569	11	0.0	262,966	348	0.1
55	9,658	9	0.1	25,278	0	0.0	12,253	1	0.0	47,196	10	0.0
56	29,696	58	0.2	66,724	0	0.0	30,351	5	0.0	126,777	63	0.0
57	74,437	1,052	1.4	109,502	80	0.1	55,662	36	0.1	239,567	1,168	0.5
TOTAL	**355,630**	**11,037**	**3.1**	**637,562**	**2,928**	**0.5**	**318,773**	**772**	**0.2**	**1,311,960**	**14,737**	**1.1**
Burlington												
58	85,545	715	0.8	261,058	282	0.1	113,259	40	0.0	459,882	1,037	0.2
59	151,337	986	0.7	421,505	358	0.1	167,322	74	0.0	740,160	1,418	0.2
60	38,351	4	0.0	93,379	0	0.0	41,309	1	0.0	173,045	5	0.0
61	35,454	261	0.7	78,838	53	0.1	31,875	6	0.0	146,156	320	0.2
62	7,111	0	0.0	31,480	0	0.0	9,712	0	0.0	48,306	0	0.0
TOTAL	**317,798**	**1,966**	**0.6**	**886,260**	**693**	**0.1**	**363,477**	**121**	**0.0**	**1,567,549**	**2,780**	**0.2**
Camden												
63	117,162	9,355	8.0	182,669	5,131	2.8	85,609	1,176	1.4	385,447	15,662	4.1
64	130,770	1,719	1.3	354,097	989	0.3	142,674	186	0.1	627,530	2,894	0.5
65	57,224	805	1.4	201,765	680	0.3	81,777	181	0.2	340,736	1,666	0.5
66	37,101	200	0.5	118,886	41	0.0	45,140	20	0.0	201,137	261	0.1
67	42,652	574	1.3	151,640	365	0.2	60,425	60	0.1	254,747	999	0.4
TOTAL	**384,909**	**12,653**	**3.3**	**1,009,057**	**7,206**	**0.7**	**415,625**	**1,623**	**0.4**	**1,809,597**	**21,482**	**1.2**
Gloucester												
68	75,271	1,542	2.0	200,885	686	0.3	84,140	90	0.1	360,308	2,318	0.6
69	29,350	70	0.2	71,347	11	0.0	29,378	1	0.0	130,063	82	0.1
70	40,195	656	1.6	140,998	324	0.2	52,664	49	0.1	233,839	1,029	0.4
71	18,084	166	0.9	70,010	47	0.1	23,386	7	0.0	111,491	220	0.2
TOTAL	**162,900**	**2,434**	**1.5**	**483,240**	**1,068**	**0.2**	**189,568**	**147**	**0.1**	**835,701**	**3,649**	**0.4**
NJ TOTAL	**1,221,237**	**28,090**	**2.3**	**3,016,119**	**11,895**	**0.4**	**1,287,443**	**2,663**	**0.2**	**5,524,807**	**42,648**	**0.8**
REGION TOTAL	**4,265,617**	**483,123**	**11.3**	**9,238,549**	**261,728**	**2.8**	**4,024,197**	**56,094**	**1.4**	**17528370**	**800,945**	**4.6**

IX. HIGHWAY ASSIGNMENT

DVRPC's highway assignment model uses the equilibrium technique, starting with table lookup link speeds and capacities by functional class and area type. The network is heavily congested and fifteen iterations are needed to achieve a reasonable level of convergence on travel times.

The assignment of 1997 vehicle trip demands to the 1997 street and highway network required two basic inputs: a loading trip table and a network description. The trip table was prepared during the modal split-car occupancy process as described in Chapter VIII. The 1997 highway network was a result of the coding operations explained in Chapter VI. In addition to these two basic inputs, the 1995 traffic counts throughout the region were assembled for approximate verification of the 1997 assignment procedures.

This traffic assignment was performed by assigning the trip table to the network. The network was restrained with fifteen iterations of capacity restraint using the equilibrium highway assignment process included in TRANPLAN program EQUILB. The restrained volumes were then compared to the 1995 traffic counts and further checked by a screenline-cutline analysis.

A. Highway Assignment Process

Each iteration of the traffic assignment consists of building a network description from the link data cards and building a set of minimum travel time paths (vines) through the network. Normally, one vine is constructed for each zone centroid in the system, including the external stations. In this case, 1,510 vines were prepared for each traffic assignment.

After the network and vines have been constructed, the trip table is loaded and accumulated on the individual links of the system and a "loaded network" is produced that is stored in the load history file memory in a convenient form as an interim product of the assignment. For this assignment 15,146,665 trips were loaded on the highway network, representing the 1997 average daily auto driver, truck, and taxi vehicle trips.

All of the trips loaded on the 1997 network, including the through trips, were synthetically generated. As part of the modal split operations, the internal person-trip tables that were allocated to highway-oriented travel were converted into vehicular travel by the car occupancy model. To these internal-to-internal vehicle trips from the modal split models were added the external-local auto driver trips, light and heavy truck trips, and taxi trips from the vehicular distribution models.

The 1997 external-to-external travel (through trips) for autos, light trucks, and heavy trucks were then combined with the other trip tables to form the total vehicle trip table. One of the final steps in the modal choice operation was to "square" the trip table in preparation for the traffic assignment process.

This trip table is a square trip table (1,510 x 1,510) and contains a total of 15,146,665 vehicular trips. Of this total, 3,339,464 are intra-zonal trips which are not loaded on the highway system. The total number of trips actually assigned to the network, then, was 11,807,201. By comparison, 10,934,173 vehicular trips were loaded on the 1990 highway network. This represents a 8 percent increase in the total number of vehicle trips assigned to the network.

As with the other models used in this study, several trial loadings were made to insure that the network was properly coded and that the various assumptions concerning initial speeds, link capacities, and total impedances were correct. After each trial assignment, the vehicle-miles and vehicle-hours of travel were evaluated and a screenline and cutline comparison analysis was performed. Certain critical links in the system were also carefully examined. The trial loading process was repeated until the network was considered error-free.

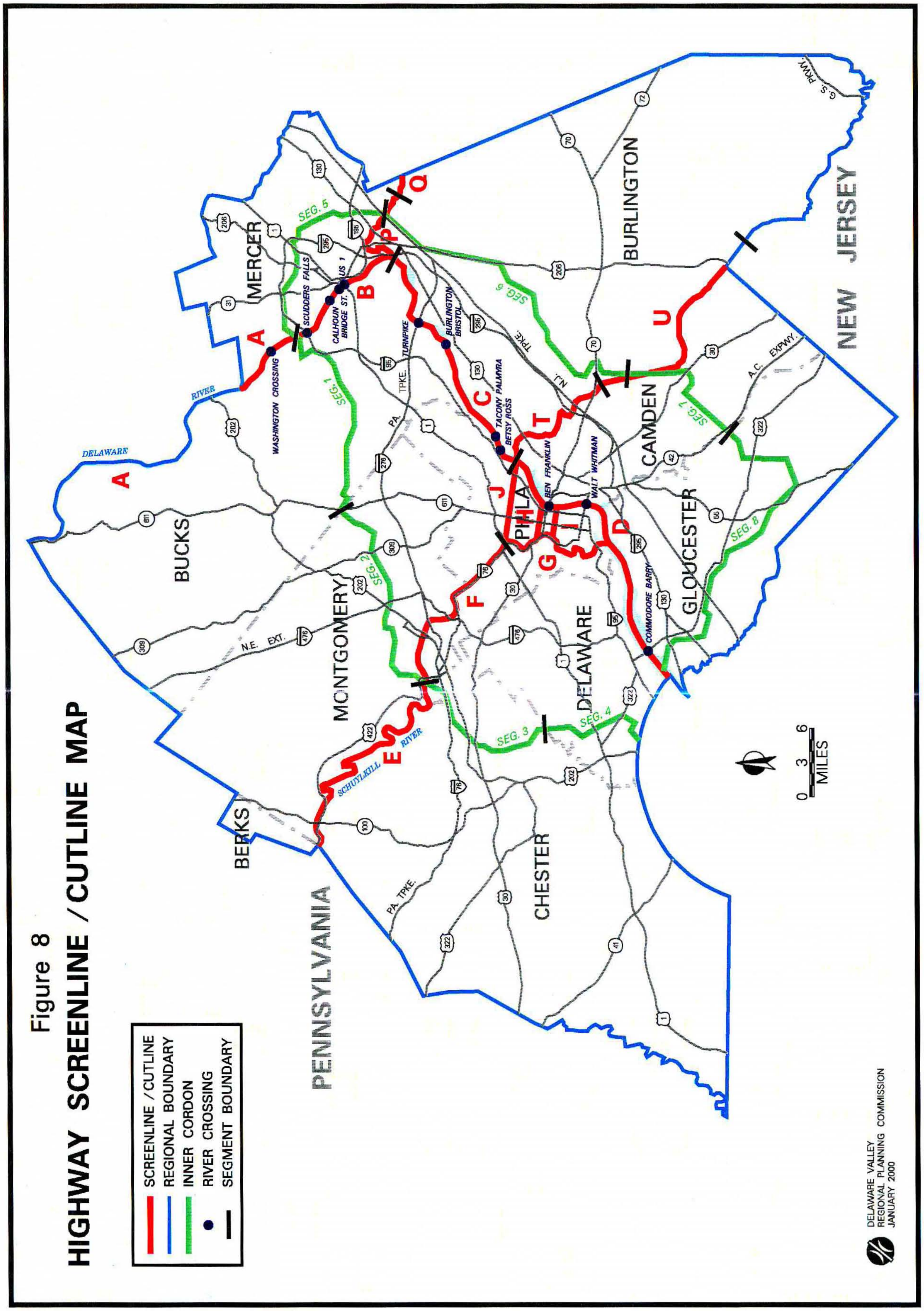
B. Screenline-Cutline Crossing Analysis

As a principle check of the assignment, a series of screenlines and cutlines have been established to afford a comparison of the assigned vehicle trips crossing the lines to the traffic counts. These screenlines and cutlines are illustrated in Figure 8. For the most part they are equivalent to the screenlines that were used in the 1990 model validation effort.

An important screenline is the line surrounding the Philadelphia Central Business District (labeled GHI). Its northern and southern boundaries are at Vine and South streets, with the Delaware and Schuylkill rivers forming the eastern and western boundaries. The Conrail freight right-of-way across North Philadelphia also provides a convenient highway screenline (J) because it is grade separated and only a limited number of streets cross it. For the remainder of the region, rivers or county boundaries form the screenlines. The Delaware (ABCD) and Schuylkill rivers (EFG) are traditionally used as screenlines as are the Burlington/Mercer (Crosswicks Creek PQ) and Camden/Burlington (TU) county boundaries in New Jersey. In total, 180 highway facilities cross the various screenlines.

Figure 8

HIGHWAY SCREENLINE / CUTLINE MAP



The "inner cordon line" serves as a convenient cutline to gauge the changes in travel patterns and to check the results of travel simulations. It is summarized by eight segments representing Bucks, Montgomery, Chester, Delaware, Mercer, Burlington, Camden, and Gloucester Counties, respectively. This line is also shown on Figure 8 and contains 172 crossings of primary and secondary highways. During 1995, there was an inventory of traffic counts collected at all 172 inner cordon and 180 screenline locations which provided a base for comparing the 1997 travel simulation. These count data were factored to represent an estimate of 24-hour annual average daily traffic (AADT), which includes Saturdays and Sundays. It should be noted that the 1995 screenline volumes do not reflect the changes in traffic volumes that occurred between 1995 and 1997. Therefore, the screenline statistics given the Tables 19 and 20 cannot be interpreted as errors, although the differences between 1995 and 1997 traffic counts should be less than 10 percent. The differences vary by area of the region, being positive in growing suburban and rural areas and stable to declining in some older urbanized areas.

According to the data in Table 18, the total 1995 traffic count across all of the screenlines and cutlines is 6,381,600 daily vehicle trips. This represents a 29.9 percent increase in the value of 5,681,000 that was reported in 1990. The comparable 1997 existing model-assigned volume for all lines was 6,471,700,--slightly over-assigned by a volume of 90,100 (1.4 percent). The overall R^2 between 1997 predicted and 1995 actual traffic volumes on the screenlines and cordon lines was 0.83, an acceptable correspondence.

The 1995 crossings of the Delaware River (screenline segments A,B,C, and D) totaled 554,600, a 5 percent increase over the 1990 crossings. The 1997 comparable simulated volume crossing the Delaware River was 582,800--an apparent over-assignment of about 4.6 percent.

The Center City Philadelphia Cordon Line is another important screenline for monitoring travel and evaluating simulation results. In 1990, 806,600 daily crossings were reported for this cordon. The 1995 ground counts indicate that this has increased to 977,500 or about 21.2 percent, much higher than most screenlines. The 1997 simulation assigned 895,000 trips across this cordon for an apparent under assignment of 8.4 percent. These discrepancies are within a reasonable tolerance for the total screenline crossings.

As seen in Table 18, the Inner Cordon in Delaware County (Seg. 4) screenline shows the most severe discrepancy with an apparent over assignment of about 13.4 percent. Although technically over the 10 percent standard for FHWA validation, this discrepancy is not significant because the screen line is rather short and traffic volumes in the vicinity of his screenline may have grown between 1995 and 1997. The coefficients of correlation appear to be within acceptable limits for each of the screenlines, according to the data in Table 18.

Table 18 : 1997 Regional Highway Assignment Existing Model Summary of Screenlines

Screenline	Number of Crossings	1995 Counted Volume (000)	1997 Simulated Volume (000)	Percent Diff.	R^2
Inner Cordon Seg. 1 (Bucks County)	21	259.4	276.4	6.6%	0.69
Inner Cordon Seg. 2 (Montgomery Co.)	34	508.5	542.1	6.6	0.84
Inner Cordon Seg. 3 (Chester Co.)	14	214.3	235.7	10.0	0.88
Inner Cordon Seg. 4 (Delaware Co.)	17	209.8	237.9	13.4	0.98
Inner Cordon Seg. 5 (Mercer Co.)	26	415.0	409.1	-1.4	0.79
Inner Cordon Seg. 6 (Burlington Co.)	28	311.7	323.0	3.6	0.96
Inner cordon Seg. 7 (Camden Co.)	11	150.9	147.9	-2.0	0.82
Inner Cordon Seg. 8 (Gloucester Co.)	21	223.3	215.6	-3.4	0.90
Delaware River (ABCD)	18	554.6	582.8	5.1	0.83
Schuylkill River (EFG)	40	1,331.2	1,331.6	0.0	0.69
Center City Phila. (GHI)	60	977.5	895.0	-8.4	0.81
N. Phila. RR (J)	26	491.6	511.5	4.0	0.93
Crosswicks Creek (PQ)	7	220.3	205.9	-6.5	0.75
Camden-Burlington Co. Boundary (TU)	32	513.7	557.2	8.5	0.83
Total	**355**	**6,381.8**	**6,471.7**	**1.4**	**0.83**

C. Focused Travel Simulation Model

The regional highway assignment even with equilibrium assignment techniques does not always give accurate volume estimates, 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 those additional roads, a special enhanced assignment technique, focused on a specific detailed study area, is used.

The focused simulation process has several characteristics which made it desirable for use in these studies:

- It can provide link and turning volumes for nearly all streets and intersections within the detailed study area.
- It allows the use of DVRPC regional simulation models without recalibration.
- 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 requires 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.

A successful highway traffic assignment also requires a buffer area to allow a smooth transition between the coarser-grained regional travel simulation network and the very detailed network inside the study area. Areas far from the study area are maintained at the census tract level to accurately load the freeways, highways, streets, and transit lines carrying traffic into and through the study area. This refinement to the highway and transit networks required that existing links be split in the study area, with approach links added for the new block-level centroids. Additional streets or transit lines may need to be added to the network in or near the detailed study area.

Three steps are required to produce the focused travel simulation model.

They are:

- 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.

- Split down the traffic zone estimates of population, households, auto ownership, employed residents and employment 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.

- 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 subzone 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.

As can be seen from the data in Table 19, the focusing process effectively reduces the regional simulation error by about 50 percent. These error reductions are most pronounced for links that carry between 3,000 and 50,000 vehicles per day. Error in the under 3,000 vehicles per day range is increased by the focusing process. This occurs primarily because of the large number of local streets that are added to the focused network. These links are greatly affected by approach link volume discontinuities.

Average link error statistics are significantly smaller than the RMS statistics. This is because of the tendency of RMS error to emphasis the contributions of outliers, which have large errors. Overall, average errors for most facilities considered in traffic studies show errors in the range between 8 and 16 percent.

Table 19 : Percent Root Mean Squared Average Error as a Function of Counted Roadway Volume Group

Volume Group (Veh/day)	1990 Regional Simulation*	Selected Recent Focused Simulations**	
	RMS Error	RMS Error	Average Error
<3,000	155.6%	171.6%	116.5%
3,000 - 5,000	123.5%	69.6%	52.2%
5,000 - 10,000	47.3%	34.6%	27.3%
10,000 - 15,000	43.2%	29.3%	23.9%
15,000 - 20,000	39.7%	26.0%	20.0%
20,000 - 30,000	32.6%	22.2%	16.0%
30,000 - 50,000	29.1%	15.0%	11.7%
>50,000	14.0%	10.3%	8.5%

* The use of 1995 screenline traffic counts to validate the 1997 travel simulation prohibited calculation of regional simulation RMS error statistics. For this reason, 1990 values from the 1990 Model Validation Report have been substituted. The 1997 traffic simulation has very similar error statistics to the 1990 validation and the values remain representative for the 1997 regional traffic assignment.

* * Error data from a number of focused simulation models must be pooled together to get enough observations to calculate the volume group error statistics. The selected simulations include: US 322 (1999), US 202 sections 100 and 300 (1998-9), Philadelphia Airport (1998), I-95/PA Turnpike Interchange (1999), and Chester County Simulation (1999).

X. PUBLIC TRANSIT ASSIGNMENT

The transit assignment procedure accomplishes two major tasks. First, the transit person trip table produced by the modal split model is "unlinked" to include any transfers that occur either between transit trips or between auto approaches and transit lines. Second, the unlinked transit trips are associated with specific transit facilities to produce line, link, and station volumes. These tasks are accomplished simultaneously with TRANPLAN program TRLOAD, which assigns the transit trip matrix to the minimum impedance paths built through the transit network. There is no capacity restraining procedure for a transit assignment. The detailed methodology use to execute the transit assignment is described in Chapter X of the 1990 simulation model validation report.

A. Transit Network Assignment Process

After the transit network description was constructed from the link and line cards, a set of minimum impedance paths was calculated through the network using the composite impedance values. The statistics pertaining to each of the minimum impedance paths were then passed to the mode choice models for preparation of the transit trip table.

A total of 800,545 daily transit trips were allocated to the transit system. This total transit trip table was then assigned to the minimum impedance paths. The results were then summarized by link, line, station, intersection, and transfer volumes.

The 800,545 daily transit trips loaded on the network are "linked" trips and represent the total travel between pairs of zones. As these trips may be assigned to more than one submode or facility on the minimum path routing, the assignment reports "unlinked" trips or those assigned to each of the various facilities in the network.

The total volume of "unlinked" trips reported by the assignment to the network was 1,245,974, which indicated a considerable amount of transferring between routes or modes within the system. Unlike the highway network traffic assignment procedure, the transit network is not restrained in the loading process.

An important aspect of the mode choice and transit assignment procedures is that the allocation of trips by transit submode is done by the minimum path selection process as they are constructed through the network. 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, used by the mode choice model to select the appropriate diversion curve. The trips that are returned from the mode choice procedure are then assigned on the submode selected originally by the minimum impedance path calculations.

B. Transit Assignment Results

The number of assigned passengers from the existing model by submode is compared to counted transit passenger data in Table 20. The counted passenger data are the most reliable estimates available for this analysis. The percentage differences by submode and for the total passenger count are very close with no particular bias toward any submode. The total assigned passenger volumes, and volumes for all submodes are less than 7 percent different from those estimated from available passenger counts for 1997. All three submodes were over assigned with the commuter rail having the least simulation error (4.1 percent). Surface bus and trolley and subway-elevated were overstated by 6.0 and 6.8 percent respectively, for a total assignment error of 6.1 percent.

Table 20 : Comparison of 1997 Passenger Counts and Existing Simulated Volumes by Transit Submode

Submode	1997 Simulated Volumes	1997 Passenger Counts	Percent Difference
Commuter Rail	88,740	85,269	4.1%
Sub-Elevated / High Speed Rail	385,578	361,152	6.8
Bus and Trolley	735,964	694,534	6.0
Total	**1,210,282**	**1,140,955**	**6.1 %**

Table 21 presents a more detailed breakdown of transit assignment error statistics by transit operator and submode. Again, there is a close correspondence between assigned and reported ridership for virtually all transit operators within the region. The simulated line volumes on the principle elements of the transit system are well within a reasonable range of accuracy.

Table 21 : Comparison of 1997 Passenger Counts and Existing Model Assigned Volumes by Transit Operating Company

Company/Division	Submode	1997 Assigned Volumes	1997 Passenger Counts	% Difference
SEPTA City Transit	Subway-Elevated	327,438	314,193	4.2%
	Bus & Trolley	644,454	602,455	7.0
		971,892	**916,648**	**6.0%**
SEPTA Suburban				
Victory Division	Bus & High Speed Line	41,055	46,090	-10.9
Frontier Division	Bus	9,555	9,589	-0.4
		50,610	**55,679**	**-9.1%**
SEPTA Regional Rail	Commuter Rail	88,740	85,269	4.1
Total SEPTA		**1,111,242**	**1,057,596**	**5.1%**
NJT Southern Division	Bus	35,633	29,000	22.9%
NJT Mercer Division	Bus	14,542	15,100	-3.7
Total NJT		**50,175**	**44,100**	**13.8%**
DRPA	High Speed Rail	48,865	39,259	24.5%
Grand Total		**1,210,282**	**1,140,955**	**6.1%**

XI. DVRPC'S ENHANCED SIMULATION MODELS

The existing DVRPC travel simulation model is a classic implementation of the four step modeling process (see Figure 1, Page 4) in Chapter I. Trip generation is based on constant trip rates imbedded in a cross-classification structure. Trip distribution uses a doubly constrained gravity model, stratified into three person (HBW, HBNW, and NHB) and four vehicle trip purposes. Modal split utilizes a binary probit-like formulation stratified by trip purpose, transit submode, and auto ownership. The highway assignment is based on the equilibrium method using minimum travel time paths. Initial highway speeds are input through a table lookup stratified by functional class and density of development (area type). The transit assignment is unrestrained. It uses minimum paths based on the modal split model definition of impedance. All aspects of the existing model produce estimates of daily travel. While this existing model has produced reasonable and accurate forecasts for many years, it did not meet the new federal requirements which require separate peak and off peak models that operate within an iterative (Evans Algorithm) structure with respect to highway travel time.

A. Implementation of the DVRPC Iterative Travel Simulation Process

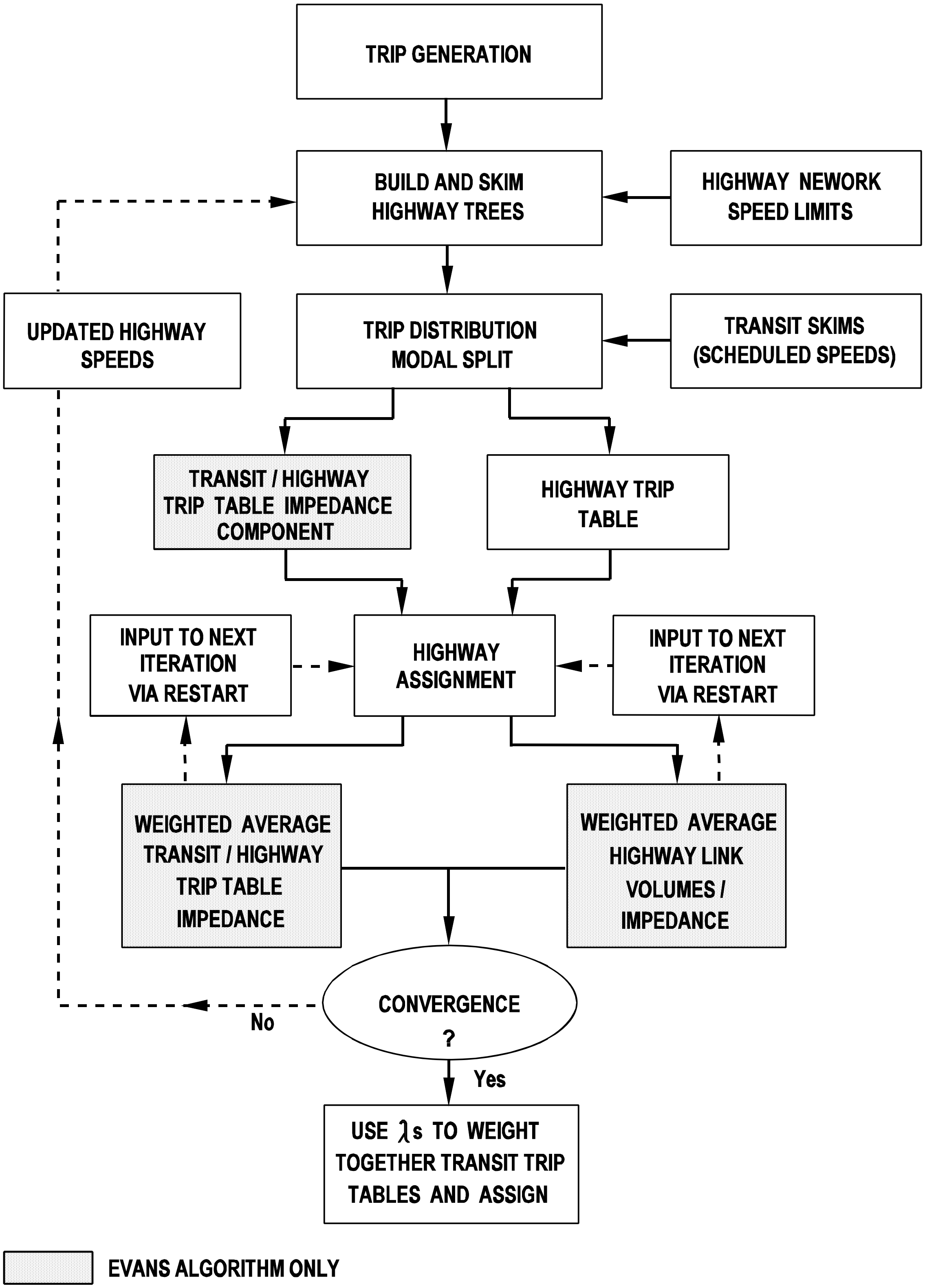
The Evans Algorithm is not difficult to implement in a four-step travel simulation model that includes a highway assignment model based on the Equilibrium Method. Evans re-executes the gravity and modal split models after each iteration of highway assignment and assigns a weight (λ), to each iteration. Therefore, a restart procedure must be available in the highway assignment program to access the weighted average highway link volumes from the previous iteration, load the network for the current iteration, calculate the weight for the current iteration (λ) and prepare a convex combination of the link volumes for the current iteration and previous weighted average. This is not a fundamental departure from the way things are normally done in the equilibrium assignment, and Urban Systems was retained by DVRPC to prepare a special extended version of TRANPLAN with the Evans restart procedure.

The second required extension is to include the impedance implications of the highway and transit trip tables into the gradient calculation that is used to determine λ (see Figure 9). This requires an estimate of transit impedance and off-network highway impedance (terminal times and parking charges) for the trip tables of the current iteration and the weighted average of the previous iterations. Transit impedance is assumed to be independent of the highway link restraining process and is calculated as the sum of the products of interzonal transit impedances and transit volumes. It may be theoretically desirable to also include the effect of highway congestion on bus and trolley travel times. However, this enhancement requires extensive changes to the highway assignment computer program and is beyond the scope of this study. In any case, only about four percent of the region's total travel is made by transit.

In this implementation, it is assumed that weighted average totals of transit and off-network highway impedance are linear in λ and can be calculated directly from the system totals for the current and weighted average of the previous iterations. The alternative would be to calculate a new λ-weighted trip table and multiply this new table by the interzonal impedance matrix. This simplification has little effect on the accuracy of the calculation. It greatly reduces the

Figure 9

EVANS ITERATIVE TRAVEL SIMULATION PROCESS



computational effort in the search routine that is used to determine λ and the complexity of the required program code changes. For the current iteration, the system total for both the highway off-network and transit impedance are calculated in the modal split model and passed in a scratch file to the highway assignment for inclusion in the gradient calculation. Similarly, the final weighted transit and off-network highway impedance calculated in the highway assignment is passed from iteration to iteration in a scratch file.

In the Evans Algorithm, trip tables are weighted together from iteration to iteration using λ-based successive averages in exactly the same way as highway link volumes. Thus, the transit trip table must be calculated with this method before assignment to the transit network.

Disaggregation Into Separate Peak and Off-peak Models

The enhanced DVRPC travel simulation models are disaggregated into separate peak period (combined AM and PM) and off-peak (the remainder of the day) time periods. This disaggregation begins in trip generation where factors are used to separate daily trips into peak and off peak travel. The enhanced process then utilizes completely separate model chains for peak and off-peak travel simulation runs. The separation of the models into two time periods proved to be relatively straight forward with few changes to the models or their parameters required. However, time of day sensitive inputs to the models such as daily highway capacities and transit service levels were disaggregated to be reflective of peak and off-peak conditions. The changes to the models and the inputs required for time of day modeling are documented in the following sections of this chapter.

Incorporating Free Flow Highway Speeds Into the Simulation Model

The existing DVRPC model has a fundamental problem that prevents it from being used directly in an iterative framework. Input highway speeds are unrealistically low, particularly on freeways. Furthermore, the output speeds from the assignment (via the BRP restraining curve) are even more unrealistic, perhaps half the true average daily highway operating speeds. This is common in simulation models developed during the 1970's. Although these speeds cannot be used for emissions calculations, they generally improve the accuracy of the highway assignment which responds favorably to a bias against freeways and severe capacity restraint.

The most straightforward way to correct this problem is to insert actual congested speeds into the highway network through a revised speed lookup table. However, the results of this substitution were not acceptable. The use of actual speeds increased the total volume error for all screenline counts from 2.2 percent to almost 20 percent and prevented the model from achieving screenline validation for purposes of conducting traffic studies and Plan/TIP conformity analyses.

Clearly, a more sophisticated method is needed to incorporate actual operating speeds into the travel simulation model. It was always obvious that some of the values in the original highway speed lookup table were not real speeds, but rather a crude form of impedance. The phenomenon being addressed was that drivers consider distance (or operating cost) as well as travel time when choosing routes. Freeways move faster than arterials, but there is a limit to the route circuity that drivers will accept to achieve travel time savings. The modal split model already had a highway impedance measure that considered both highway time and operating cost. A theoretically appealing way to incorporate actual congested speeds is to extend this impedance measure to the gravity model and highway assignment as well. The entire simulation model would then be based on a uniform definition of impedance. This impedance definition is similar to the one found in most disutility-based modal split models, and is calculated as:

$$Z = k_1\, ET + k_2\, RT + k_3\, C$$

Where:

Z = Impedance for a given travel mode.
ET = Excess or out-of-vehicle time. Terminal time for highway, sum of walk and wait time for transit. Transit impedance also includes a supplemental transfer penalty.
RT = Running or in-vehicle time.
C = Monetary Cost. Fare for transit; out of pocket operating cost plus tolls and parking for highway.
k_1, k_2, and k_3 are calibration constants.

In order to test this approach, highway trees were built using the modal split impedance definition with actual congested times in the lookup table. The resulting impedance skims were found to be perfectly collinear with the minimum time skims from the original speed lookup table. Only a simple scale factor was required to make these impedance skims usable with the original gravity model friction factor curves, terminal and intrazonal times, etc. Highway assignment path building was also based on this impedance definition. The capacity restraint calculation was limited to the travel time portion of the impedance.

Several additional changes were required to produce reasonably accurate estimates of highway traffic volumes and operating speeds directly from the highway assignment model. The number of functional classes in the highway link capacity lookup table was increased from 9 to 27 to better account for detailed design capacity variations within the general functional class designations (freeway, parkway, principal arterial, etc.). The initial highway network speeds were modified to reflect free-flow speeds (speed limits or measured operating speeds, which ever is higher). And finally, a formal toll plaza queing model was implemented to better model the toll collection congestion and delay on the Turnpikes and Toll Bridges withing the region. These changes improved the accuracy of the highway link volumes produced by the Evans process and brought the model into compliance with federal requirements that require free flow highway speeds be used in the initial iteration of the travel simulation process.

B. Disaggregation of *Trip Generation into Separate Peak and Off-Peak*

The enhanced DVRPC travel simulation models are disaggregated into separate model chains for the Peak (combined AM and PM) and Off-Peak (the remainder of the day) periods for the trip distribution, modal split, and travel assignment phases of the process. This disaggregation assumes that the peak period is from 7:00 AM to 9:00 AM and from 3:00 PM to 6:00 PM. It is based on the series of peak period factors given below. These factors represent the percentage of daily trips that occur during peak periods. They were prepared by Cambridge Systematics, DVRPC's model enhancement consultants, and are taken from the commission report entitled, "Task 6/7 Peak/Off-Peak Period Modeling," March 1998.

Peak Period Trip Generation Percentages

Trip Purpose	Percent of Travel During Peak Periods
Home Based Work	52.8%
Home Based Non-work	31.4%
Non-home Based	26.7%
Light Truck	32.4%
Heavy Truck	32.4%
Taxi	32.4%

External-local productions at the nine-county cordon stations were disaggregated into peak and off-peak components using percentages derived from the temporal distribution of traffic counts taken at each cordon station. These percentages are documented in the Commission report cited above. The Peak/Off-peak disaggregation was accomplished in a new trip generation computer program named TRIPGEN E.

C. Highway Network Coding Procedures

The validated (existing) DVRPC travel simulation model and enhanced Evans peak and off-peak models have significantly different link coding conventions.

The principal differences between the existing and enhanced highway network coding procedures involve:

1. Expansion of the functional class system from 9 to 27 individual categories.
2. Refining highway capacity lookup table to better reflect real world variation in specific roadway designs.

3. Updating the speed lookup table to reflect free flow speed limits (or measured speed whichever is higher) rather than assignment speeds.
4. Modifying the network capacities to reflect peak and off-peak hours of the day rather than daily values.
5. Implementation of new turnpike and bridge toll coding procedures.
6. Development of a formal queuing model to simulate congestion and delays at toll plazas.

Refined Speeds and Capacities for Highway Look-up Table

The enhanced travel simulation models employ three "per lane hourly capacities" for each functional class, corresponding to a high, medium, and low value. 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 by simply varying capacity with functional class and area type. Employing three values for each functional classification and area type allows for easier and more accurate model calibration.

Note that the "high" and "low" values do not necessarily correspond to absolute maximum and minimum values, but rather to capacities that are representative of very favorable or very poor conditions for the given functional class and area type.

For the most part, the "high" capacity values were taken from "Enhancement of DVRPC's Travel Simulation Models: Task 1. Highway Network and Assignment Revisions" and the "medium" values were carried forward from DVRPC's existing simulation model speed-capacity table. Exceptions include Parkways and Ramps. For Parkways, the existing values were used for the "low" range and the Task 1 values were used as the "medium" capacity; for Ramps, the existing values were also used for the low range, but the Task 1 values were used as the "high" capacity.

The remaining table entries were calculated in the following manner: "low" values for Freeways and Principal Arterials and "high" values for Parkways were determined by employing the methods proscribed by the 1994 Highway Capacity Manual (HCM) and assuming conditions appropriate for the given functional class, area type, and capacity range. "Low" values for Secondary Arterials were taken as 70 percent of the Principal Arterial "low" value, consistent with the relationships between the "high" and "medium" ranges of these two functional classes. "Low" values for Collector/Local facilities were assumed to be 80 percent of the "medium" value; "medium" capacities for Ramps were taken as the average of the "high" and "low" values.

Table 22 summarizes the high, medium, and low capacities employed by the enhanced travel simulation models.

Table 22: Per Lane Hourly Capacities Assuming "E" Service Level

Functional Classification			CBD (1)	Fringe (2)	Area Type Urban (3)	Suburban (4)	Rural (5)
1	Freeway	High	2,315	2,315	2,332	2,431	2,493
		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	1,035	1,035	1,096	1,266	1,453
		Low	960	960	960	960	1,120
3	Principal Arterial	High	761	805	1,031	1,278	1,489
		Medium	600	640	820	950	1,100
		Low	460	540	690	810	910
4	Secondary Arterial	High	552	606	755	937	1,165
		Medium	410	460	570	680	800
		Low	320	380	480	570	640
6	Collector / Local	High	558	632	702	843	981
		Medium	400	450	500	600	750
		Low	320	360	400	480	600
8	Ramps	High	585	613	698	810	910
		Medium	460	490	540	680	800
		Low	325	365	390	540	680

These hourly capacities are converted to peak and off-peak period capacities through factors which are analogous to "2KD" factors, which convert between hourly and daily capacity. These factors are given in the following Tables 23 and 24 .

Table 23: Peak Period (7:00 - 9:00 AM and 3:00 - 6:00 PM) Conversion Factors

Functional Classification			Peak "2KD" Conversion Factors CBD (1)	Fringe (2)	Urban (3)	Suburban (4)	Rural (5)
1	Freeway	High	0.243	0.243	0.252	0.261	0.282
		Medium	0.243	0.243	0.252	0.261	0.282
		Low	0.243	0.243	0.252	0.261	0.282
2	Parkway	High	0.243	0.243	0.276	0.282	0.288
		Medium	0.243	0.243	0.276	0.282	0.288
		Low	0.243	0.243	0.276	0.282	0.288
3	Principal Arterial	High	0.249	0.249	0.252	0.258	0.270
		Medium	0.249	0.249	0.252	0.258	0.270
		Low	0.249	0.249	0.252	0.258	0.270
4	Secondary Arterial	High	0.255	0.255	0.282	0.294	0.300
		Medium	0.255	0.255	0.282	0.294	0.300
		Low	0.255	0.255	0.282	0.294	0.300
6	Collector / Local	High	0.228	0.267	0.267	0.342	0.360
		Medium	0.228	0.267	0.267	0.342	0.360
		Low	0.228	0.267	0.267	0.342	0.360
8	Ramps	High	0.174	0.204	0.225	0.246	0.267
		Medium	0.174	0.204	0.225	0.246	0.267
		Low	0.174	0.204	0.225	0.246	0.267

Table 24: Off-peak Period Conversion Factors

Functional Classification			Off-Peak "2KD" Conversion Factors CBD (1)	Fringe (2)	Urban (3)	Suburban (4)	Rural (5)
1	Freeway	High	0.125	0.125	0.129	0.134	0.145
		Medium	0.125	0.125	0.129	0.134	0.145
		Low	0.125	0.125	0.129	0.134	0.145
2	Parkway	High	0.125	0.125	0.141	0.145	0.148
		Medium	0.125	0.125	0.141	0.145	0.148
		Low	0.125	0.125	0.141	0.145	0.148
3	Principal Arterial	High	0.128	0.128	0.129	0.132	0.138
		Medium	0.128	0.128	0.129	0.132	0.138
		Low	0.128	0.128	0.129	0.132	0.138
4	Secondary Arterial	High	0.131	0.131	0.145	0.151	0.154
		Medium	0.131	0.131	0.145	0.151	0.154
		Low	0.131	0.131	0.145	0.151	0.154
6	Collector / Local	High	0.117	0.137	0.137	0.175	0.185
		Medium	0.117	0.137	0.137	0.175	0.185
		Low	0.117	0.137	0.137	0.175	0.185
8	Ramps	High	0.089	0.105	0.115	0.126	0.137
		Medium	0.089	0.105	0.115	0.126	0.137
		Low	0.089	0.105	0.115	0.126	0.137

The new model uses free-flow speeds as inputs in the speed-capacity table. Free-flow speeds are taken to be the larger of the posted speed limit or the measured speeds from the travel time survey. Free flow speeds are as follows:

Table 25: Free Flow Speeds (mph)

	Free-Flow Speeds (mph)				
	CBD (1)	Fringe (2)	Urban (3)	Suburban (4)	Rural (5)
Freeway	50.0	55.0	55.0	55.0	60.0
Parkway	45.0	45.0	50.0	60.0	55.0
Principal Arterial	30.0	30.0	35.0	40.0	50.0
Secondary Arterial	25.0	25.0	30.0	35.0	45.0
Collector / Local	15.0	15.0	20.0	35.0	35.0
Ramp	20.0	35.0	40.0	45.0	45.0

New Bridge and Turnpike Coding Procedures

The TRANPLAN equilibrium highway assignment program (EQUILB) contains procedures for modeling the effects of toll charges and queuing delay at bridge and turnpike toll booths. The TRANPLAN setups used to execute the highway assignment and the highway network were modified to include the toll charges as part of the highway cost trace variable described in the introduction of this report. The existing DVRPC model had included toll charges as equivalent time. The highway network coding procedure modifications primarily involved removing this equivalent time from the dummy link representing the toll plaza. The actual toll charges assumed in this run are documented in Chapter V of the 1990 model validation report cited above.

Toll Booth Queuing Model

TRANPLAN also 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 was originally developed for the Florida Turnpike Authority. Some customization of the TRANPLAN computer program was required to adapt the Florida model for DVRPC's use. This principally involved adding a peak hour factor field to the toll data record and the internal logic of the computer program. The toll queuing model assumes a hourly traffic volume, while the DVRPC model assigns multi-hour traffic (peak or off-peak) volumes. The peak hour factor is used to estimate a hourly traffic volume for purposes of calculating toll booth delay.

D. Transit Network Coding Procedures

The existing DVRPC model uses the AM Peak transit service as a proxy for the daily service levels required to estimate daily transit ridership. The enhanced model is stratified into separate peak and off-peak time periods. In the new model AM Peak service is used as a proxy for the peak period and mid-day transit service for the off-peak. Both existing and enhanced models use the transit network coding conventions given in Chapter VI of the 1990 validation report. Separate transit networks were coded for the AM Peak and Midday (off peak) time periods.

As it is now coded, the 1997 regional transit network includes 8,008.6 miles of scheduled transit service patterns in the peak period and 5,534.9 during midday hours. The breakdown of this service by transit submode follows:

1997 Transit Service Miles

Submode	Peak	Midday
Commuter Rail	1,406.8	779.0
Subway-elevated	204.1	115.8
Surface	6,397.7	4640.1
Total	**8,008.6**	**5,534.9**

During the peak period there are 1406.8 miles of scheduled commuter rail service, 204.1 miles of subway-elevated systems (including the PATCO Hi-Speedline) and 6,397.7 one-way miles of surface trolley and bus lines. The corresponding midday totals are 779.0, 115.8, and 4,640.1 miles, respectively, primarily as a result of the off-peak transit service reductions. The correspondence between peak period line card and transit facility is given in Table 13 of Chapter VI. The Midday line card correspondance with transit facility is given below in Table 26.

Table 26 : 1997 Mid-Day Transit Line Card/Route # Correspondence by Company

Co. 1 - SEPTA City Transit Division

Route #	Mode	Line Cards	Route #	Mode	Line Cards
C	4	1,2	34	4	55
G	4	3,4	35	4	56
H	4	5	36	4	57
XH	4	6	37	4	58,59
J	4	7	38	4	60
K	4	8	39	4	61
L	4	9,10,11	40	4	62
R	4	12,13	42	4	63,64
Fox-Newt	4	14	43	4	65
2	4	15	44	4	66
3	4	16	46	4	67
5	4	17	47	4	68,69
6	4	18	47 M	4	70
7	4	19	48	4	71
8	4	20	52	4	72
9	4	21	53	4	73
10	4	22	54	4	74
11	4	23	55	4	75,76
12	4	24	56	4	77
13	4	25	57	4	78,79
14	4	26,27	58	4	80,81,82
15	4	28	59	4	83
17	4	29,30	60	4	84
18	4	31	61	4	85,86
19	4	32,33	63	4	87
20	4	34,35	64	4	88
21	4	36,37	65	4	89
22	4	38,39	66	4	90,91
23	4	40	67	4	92,93
24	4	41,42	68	4	94
25	4	43	70	4	95,96
26	4	44,45	73	4	97
27	4	46,47,48	75	4	98
28	4	49	76	4	99
29	4	50	77	4	100
30	4	51	79	4	101
31	4	52	84	4	102
32	4	53	88	4	103,104
33	4	54	89	4	105

Co. 1 - SEPTA City Transit Division (Continued)

Route #	Mode	Line Cards	Route #	Mode	Line Cards
90	4	106	BSS	6	2,3
			MFSE	6	4

Co. 2 - SEPTA Suburban Victory Division

101	4	116	111	4	128
102	4	117	112	4	129,130
103	4	118	113	4	131
104	4	119	114	4	132
105	4	120,121	115	4	133
106	4	122	116	4	134
107	4	123	117	4	135
108	4	124	118	4	136
109	4	125	119	4	137
110	4	126,127	120	4	138
100	6	1			

Co. 3 - SEPTA Suburban Frontier Division

92	4	107	124	4	139
93	4	108	125	4	140
94	4	109	127	4	141
95	4	110	128	4	142
96	4	111	129	4	143
97	4	112	130	4	144
98	4	113	202	4	145
99	4	114,115			

Co. 4 - New Jersey Transit Mercer Division

600	5	100	606	5	107,108
601	5	101	607	5	109
602	5	102	608	5	110
603	5	103,104	609	5	111,112,113
604	5	105	611	5	114
605	5	106			

Co. 6 - (DRPA) PATCO Hi-Speedline

Route #	Mode	Line Cards
Local	8	1

Co. 7 - New Jersey Transit Southern Division

Route #	Mode	Line Cards	Route #	Mode	Line Cards
313/315	5	1,2	450	5	25
317	5	3	451	5	26
400	5	4,5,6	452	5	27
401	5	7	453	5	28
403	5	8,9,10,11	455	5	29
404	5	12	457	5	30,31
405	5	13	459	5	32
406	5	14,15	463	5	33
407	5	16	551	5	34
408	5	17	554	5	35
409	5	18,19			
410	5	20,21			
412	5	22			
413	5	23			
419	5	24			

Co. 8 - New Jersey Transit Railroad Division

Corridor	7	50
Pr Jct	7	51,52
Atl Cty	7	53

Co. 9 - SEPTA Regional Rail Division

			Route #	Mode	Line Cards
R1	7	1,2	R6	7	8
R2	7	3	R7	7	9
R3	7	4,5	R8	7	10,11
R5	7	6,7			

Co. 14 - Pottstown Urban Transit

Stw-San	5	200	Coventry Mall	5	202
N End Loop	5	201			

Co. 15 - Krapf's Coaches

Route "A"	5	225	Coatesville Link	5	226

E. Enhanced Gravity Model Procedures

The gravity model procedures employed by the enhanced simulation models represent a significant departure from the existing DVRPC model in several ways. First, separate peak and off peak distributions are executed and trips are distributed on the basis of a travel impedance that includes highway operating costs, transit fares, and highway parking charges as well as the highway and transit travel times used in the existing model. Further, the gravity model is incorporated within an iterative equilibrium process (Evans) as a starting point using highway free-flow speeds. The Evans equilibrium process uses sophisticated optimization techniques (Frank-Wolf decomposition) to input congestion effects into the trip distribution model through the highway capacity constrained congested speeds as the Evans process approaches equilibrium. This tends to equilibrate transportation facility supply and demand to a much greater extent than the previous DVRPC model which used what amounts to a fixed transportation demand matrix.

Table 27 compares the general trip distribution model attributes for the peak and off-peak model runs. The trip length estimates given in Table 27 have been recentered to be comparible with the validated model results in Table 15. Overall, the average trip lengths for individual purposes do not vary significantly between the peak and off-peak simulation runs. However, because of the different distribution of travel by trip purpose in the peak and off-peak periods, the weighted average person trip length is about 2.5 minutes longer in the peak period. This difference resulted primarily from more work trips and greater congestion levels in the peak period.

F. Enhanced Modal Split Model Application

The validated modal split model described above was also used in the enhanced model runs described in this report. However, some changes in the model were made to accommodate certain requirements of the enhanced travel simulation model process.

1. Peak and off-peak time periods were executed in separate model runs.

2. The modal splits output from the model for the off-peak modal split time period were reduced by 20 percent to account for the variation in transit service between mid-day and evening. The off-peak transit network was based on Midday service patterns thereby introducing an upward bias in off-peak modal split. Much of the person trip activity occurs during evening hours, when less transit service is available.

3. Highway times input to the model were generated by the iterative simulationprocess starting with free flow speeds, rather than the table lookup highway speeds in the validated model.

The modal split model outputs from the enhanced model runs are summarized for the peak, off-peak, and total daily trip productions by county and county planning area in Table 28 and for trip attractions in Table 29. The total daily production and attraction summaries in Tables 28 and 29 are comparible in pattern and magnitude to the corresponding columns in Tables 16 and 17.

Table 27 : General Trip Distribution Model Attributes for the Enhanced Model

Model Number	Trip Category	PEAK PERIOD Total Trips	PEAK PERIOD Average Trip Length* (Impedance)	OFF PEAK PERIOD Total Trips	OFF PEAK PERIOD Average Trip Length* (Impedance)
Person Trip Models					
1	Home Based Work	2,234,266	28.4	1,997,279	28.5
2	Home Based Non-work	2,894,872	17.5	6,324,465	17.5
3	Non-home Based	1,072,803	16.6	2,945,240	16.6
	(Subtotal)	**6,201,941**	**21.1**	**11,266,984**	**18.6**
Vehicle Trip Models					
4	External-Local Fwy/Expwy	90,964**	57.8	184,460**	56.2
5	External-Local Arterial/Local	204,854	38.8	355,046	39.4
6	Light Trucks	438,567	10.7	912,424	10.6
8	Taxis	51,793	14.4	108,036	14.4
	(Subtotal)	**786,178**	**24.2**	**1,559,966**	**23.7**

Note* : The interzonal travel impedances that are used in the calculation of average trip length, include terminal time at both ends of the trip as well as the system travel time cost and tolls. Interzonal travel impedances consist of assumed interzonal impedance plus twice the terminal impedance for the zone. Impedance have been rescaled by a factor of 0.2740 to make the values comparable with the times in Table 15.

** Pennsylvania and New Jersey Turnpike cordon station external-local trips have been removed from the gravity model and incorporated into the highway through matrix.

Table 28: 1997 Enhanced Model Travel Simulation: Percent of Total Person Trip Productions Made by Transit By Time Period and County Planning Area

CPA	Peak Period Productions Person Trips	Peak Period Productions Transit Trips	Peak Period Productions Percent Transit	Off-Peak Productions Person Trips	Off-Peak Productions Transit Trips	Off-Peak Productions Percent Transit	Total Daily Productions Person Trips	Total Daily Productions Transit Trips	Total Daily Productions Percent Transit
Philadelphia									
1	57,782	13,953	24.1	123,883	20,305	16.4	181,665	34,258	18.9
2	110,367	35,007	31.7	186,463	33,214	17.8	296,830	68,221	23.0
3	57,152	15,693	27.5	96,679	13,669	14.1	153,831	29,362	19.1
4	144,890	48,831	33.7	241,151	49,147	20.4	386,041	97,978	25.4
5	80,100	29,641	37.0	141,490	30,560	21.6	221,590	60,201	27.2
6	52,432	16,729	31.9	88,782	15,561	17.5	141,214	32,290	22.9
7	61,756	17,539	28.4	105,536	16,059	15.2	167,292	33,598	20.1
8	43,970	6,554	14.9	76,744	4,652	6.1	120,714	11,206	9.3
9	89,934	16,639	18.5	152,144	13,199	8.7	242,078	29,838	12.3
10	122,487	31,454	25.7	192,616	24,890	12.9	315,103	56,344	17.9
11	189,281	38,891	20.5	319,345	32,372	10.1	508,626	71,263	14.0
12	181,523	12,140	6.7	331,744	9,527	2.9	513,267	21,667	4.2
TOTAL	**1,191,674**	**283,071**	**23.8**	**2,056,577**	**263,155**	**12.8**	**3,248,251**	**546,226**	**16.8**
Delaware									
13	84,197	3,461	4.1	146,414	2,595	1.8	230,611	6,056	2.6
14	109,672	4,485	4.1	204,651	3,560	1.7	314,323	8,045	2.6
15	145,476	16,431	11.3	250,977	13,726	5.5	396,453	30,157	7.6
16	129,654	6,904	5.3	242,266	5,493	2.3	371,920	12,397	3.3
17	55,401	1,482	2.7	105,142	1,194	1.1	160,543	2,676	1.7
18	29,246	199	0.7	56,230	162	0.3	85,476	361	0.4
TOTAL	**553,646**	**32,962**	**6.0**	**1,005,680**	**26,730**	**2.7**	**1,559,326**	**59,692**	**3.8**
Chester									
19	105,901	1,775	1.7	208,728	1,565	0.7	314,629	3,340	1.1
20	50,205	564	1.1	90,921	417	0.5	141,126	981	0.7
21	34,401	0	0.0	62,002	4	0.0	96,403	4	0.0
22	84,170	702	0.8	161,288	672	0.4	245,458	1,374	0.6
23	112,232	1,205	1.1	206,640	1,026	0.5	318,872	2,231	0.7
24	35,996	0	0.0	64,646	0	0.0	100,642	0	0.0
25	51,905	371	0.7	95,506	317	0.3	147,411	688	0.5
26	42,070	127	0.3	76,682	111	0.1	118,752	238	0.2
27	27,593	0	0.0	49,596	0	0.0	77,189	0	0.0
28	18,085	0	0.0	32,736	0	0.0	50,821	0	0.0
29	21,903	0	0.0	39,957	0	0.0	61,860	0	0.0
TOTAL	**584,461**	**4,744**	**0.8**	**1,088,702**	**4,112**	**0.4**	**1,673,163**	**8,856**	**0.5**

Table 28: 1997 Enhanced Model Travel Simulation: Percent of Total Person Trip Productions Made by Transit By Time Period and County Planning Area

CPA	Peak Period Productions Person Trips	Peak Period Productions Transit Trips	Peak Period Productions Percent Transit	Off-Peak Productions Person Trips	Off-Peak Productions Transit Trips	Off-Peak Productions Percent Transit	Total Daily Productions Person Trips	Total Daily Productions Transit Trips	Total Daily Productions Percent Transit
Montgomery									
30	101,714	1,278	1.3	191,298	966	0.5	293,012	2,244	0.8
31	60,372	819	1.4	114,387	760	0.7	174,759	1,579	0.9
32	157,007	6,034	3.8	292,305	4,801	1.6	449,312	10,835	2.4
33	60,804	1,372	2.3	117,664	971	0.8	178,468	2,343	1.3
34	142,677	6,462	4.5	273,765	6,270	2.3	416,442	12,732	3.1
35	112,432	1,573	1.4	208,712	1,098	0.5	321,144	2,671	0.8
36	107,621	701	0.7	204,169	580	0.3	311,790	1,281	0.4
37	180,707	1,090	0.6	341,900	1,018	0.3	522,607	2,108	0.4
38	41,221	0	0.0	75,608	0	0.0	116,829	0	0.0
39	60,125	259	0.4	109,988	193	0.2	170,113	452	0.3
TOTAL	**1,024,680**	**19,588**	**1.9**	**1,929,796**	**16,657**	**0.9**	**2,954,476**	**36,245**	**1.2**
Bucks									
40	41,736	0	0.0	76,517	0	0.0	118,253	0	0.0
41	22,262	0	0.0	40,327	0	0.0	62,589	0	0.0
42	61,753	0	0.0	114,329	0	0.0	176,082	0	0.0
43	80,392	614	0.8	149,976	536	0.4	230,368	1,150	0.5
44	34,776	120	0.3	64,002	106	0.2	98,778	226	0.2
45	13,688	67	0.5	25,530	53	0.2	39,218	120	0.3
46	132,978	1,052	0.8	243,119	540	0.2	376,097	1,592	0.4
47	41,355	136	0.3	76,106	10	0.0	117,461	146	0.1
48	111,514	2,247	2.0	211,292	1,787	0.8	322,806	4,034	1.2
49	72,439	947	1.3	138,200	633	0.5	210,639	1,580	0.8
50	111,150	1,181	1.1	203,440	859	0.4	314,590	2,040	0.6
51	82,860	1,432	1.7	151,140	1,171	0.8	234,000	2,603	1.1
TOTAL	**806,903**	**7,796**	**1.0**	**1,493,978**	**5,695**	**0.4**	**2,300,881**	**13,491**	**0.6**
Berks									
72	16,020	0	0.0	28,364	0	0.0	44,384	0	0.0
TOTAL	**16,020**	**0**	**0.0**	**28,364**	**0**	**0.0**	**44,384**	**0**	**0.0**
PA TOTAL	4,177,384	348,161	8.3	7,603,097	316,349	4.2	11,780,481	664,510	5.6

Table 28: 1997 Enhanced Model Travel Simulation: Percent of Total Person Trip Productions Made by Transit By Time Period and County Planning Area

	Peak Period Productions			Off-Peak Productions			Total Daily Productions		
CPA	Person Trips	Transit Trips	Percent Transit	Person Trips	Transit Trips	Percent Transit	Person Trips	Transit Trips	Percent Transit
Mercer									
52	75,453	4,779	6.3	131,812	4,206	3.2	207,265	8,985	4.3
53	95,656	1,096	1.1	184,160	851	0.5	279,816	1,947	0.7
54	118,830	1,381	1.2	215,357	1,151	0.5	334,187	2,532	0.8
55	26,006	70	0.3	47,294	67	0.1	73,300	137	0.2
56	50,948	267	0.5	92,191	238	0.3	143,139	505	0.4
57	60,184	487	0.8	112,976	550	0.5	173,160	1,037	0.6
TOTAL	**427,077**	**8,080**	**1.9**	**783,790**	**7,063**	**0.9**	**1,210,867**	**15,143**	**1.3**
Burlington									
58	156,846	1,350	0.9	293,349	750	0.3	450,195	2,100	0.5
59	259,336	3,768	1.5	481,241	2,988	0.6	740,577	6,756	0.9
60	80,654	61	0.1	143,993	40	0.0	224,647	101	0.0
61	64,152	430	0.7	120,135	116	0.1	184,287	546	0.3
62	24,159	0	0.0	44,090	0	0.0	68,249	0	0.0
TOTAL	**585,147**	**5,609**	**1.0**	**1,082,808**	**3,894**	**0.4**	**1,667,955**	**9,503**	**0.6**
Camden									
63	119,037	9,014	7.6	215,039	9,010	4.2	334,076	18,024	5.4
64	165,931	4,316	2.6	318,040	4,394	1.4	483,971	8,710	1.8
65	148,916	6,257	4.2	270,966	6,782	2.5	419,882	13,039	3.1
66	75,703	1,159	1.5	141,412	1,374	1.0	217,115	2,533	1.2
67	126,882	4,484	3.5	228,870	4,404	1.9	355,752	8,888	2.5
TOTAL	**636,469**	**25,230**	**4.0**	**1,174,327**	**25,964**	**2.2**	**1,810,796**	**51,194**	**2.8**
Gloucester									
68	112,251	2,115	1.9	211,277	1,346	0.6	323,528	3,461	1.1
69	49,631	253	0.5	93,092	44	0.0	142,723	297	0.2
70	100,829	1,324	1.3	182,045	707	0.4	282,874	2,031	0.7
71	60,816	482	0.8	110,151	297	0.3	170,967	779	0.5
TOTAL	**323,527**	**4,174**	**1.3**	**596,565**	**2,394**	**0.4**	**920,092**	**6,568**	**0.7**
NJ TOTAL	**1,972,220**	**43,093**	**2.2**	**3,637,490**	**39,315**	**1.1**	**5,609,710**	**82,408**	**1.5**
REGION TOTAL	**6,149,604**	**391,254**	**6.4**	**11,240,587**	**355,664**	**3.2**	**17,390,191**	**746,918**	**4.3**

Table 29 : 1997 Enhanced Model Travel Simulation: Percent of Daily Person Trip Attractions Made by Transit By Time Period and County Planning Area

CPA	Peak Period Attractions Person Trips	Peak Period Attractions Transit Trips	Peak Period Attractions Percent Transit	Off-Peak Period Attractions Person Trips	Off-Peak Period Attractions Transit Trips	Off-Peak Period Attractions Percent Transit	Total Daily Attractions Person Trips	Total Daily Attractions Transit Trips	Total Daily Attractions Percent Transit
Philadelphia									
1	327,562	201,285	61.4	428,960	183,346	42.7	756,522	384,631	50.8
2	113,090	15,656	13.8	196,536	14,410	7.3	309,626	30,066	9.7
3	58,527	4,429	7.6	108,715	4,280	3.9	167,242	8,709	5.2
4	144,188	35,693	24.8	239,854	33,218	13.8	384,042	68,911	17.9
5	112,988	33,186	29.4	183,527	31,509	17.2	296,515	64,695	21.8
6	53,973	9,828	18.2	92,999	9,397	10.1	146,972	19,225	13.1
7	61,469	8,867	14.4	106,960	8,254	7.7	168,429	17,121	10.2
8	30,901	1,840	6.0	59,147	1,413	2.4	90,048	3,253	3.6
9	67,385	6,895	10.2	124,815	5,950	4.8	192,200	12,845	6.7
10	59,884	8,953	15.0	114,165	8,886	7.8	174,049	17,839	10.2
11	146,398	17,847	12.2	264,234	15,620	5.9	410,632	33,467	8.2
12	160,037	3,067	1.9	309,888	2,507	0.8	469,925	5,574	1.2
TOTAL	**1,336,402**	**347,546**	**26.0**	**2,229,800**	**318,790**	**14.3**	**3,566,202**	**666,336**	**18.7**
Delaware									
13	65,323	1,153	1.8	118,740	959	0.8	184,063	2,112	1.1
14	104,555	627	0.6	201,434	504	0.3	305,989	1,131	0.4
15	93,422	4,173	4.5	176,170	3,577	2.0	269,592	7,750	2.9
16	128,288	2,051	1.6	242,418	1,570	0.6	370,706	3,621	1.0
17	60,045	725	1.2	111,780	541	0.5	171,825	1,266	0.7
18	35,216	5	0.0	66,312	6	0.0	101,528	11	0.0
TOTAL	**486,849**	**8,734**	**1.8**	**916,854**	**7,157**	**0.8**	**1,403,703**	**15,891**	**1.1**
Chester									
19	154,959	871	0.6	288,860	768	0.3	443,819	1,639	0.4
20	32,634	142	0.4	61,021	117	0.2	93,655	259	0.3
21	15,639	0	0.0	31,161	2	0.0	46,800	2	0.0
22	97,653	293	0.3	185,781	278	0.1	283,434	571	0.2
23	99,983	550	0.6	186,379	504	0.3	286,362	1,054	0.4
24	28,531	0	0.0	51,821	0	0.0	80,352	0	0.0
25	44,812	167	0.4	84,585	140	0.2	129,397	307	0.2
26	26,867	2	0.0	51,186	7	0.0	78,053	9	0.0
27	16,279	0	0.0	30,836	0	0.0	47,115	0	0.0
28	12,727	0	0.0	23,860	0	0.0	36,587	0	0.0
29	18,646	0	0.0	35,584	0	0.0	54,230	0	0.0
TOTAL	**548,730**	**2,025**	**0.4**	**1,031,074**	**1,816**	**0.2**	**1,579,804**	**3,841**	**0.2**

Table 29 : 1997 Enhanced Model Travel Simulation: Percent of Daily Person Trip Attractions Made by Transit By Time Period and County Planning Area (Continued)

	Peak Period Attractions			Off-Peak Period Attractions			Total Daily Attractions		
CPA	Person Trips	Transit Trips	Percent Transit	Person Trips	Transit Trips	Percent Transit	Person Trips	Transit Trips	Percent Transit
Montgomery									
30	118,459	476	0.4	218,720	248	0.1	337,179	724	0.2
31	71,444	427	0.6	133,288	313	0.2	204,732	740	0.4
32	143,030	1,728	1.2	273,692	1,317	0.5	416,722	3,045	0.7
33	85,336	855	1.0	159,177	438	0.3	244,513	1,293	0.5
34	183,144	4,668	2.5	337,028	3,586	1.1	520,172	8,254	1.6
35	115,677	756	0.7	215,522	385	0.2	331,199	1,141	0.3
36	112,569	92	0.1	210,094	61	0.0	322,663	153	0.0
37	204,926	508	0.2	382,937	405	0.1	587,863	913	0.2
38	31,169	0	0.0	58,528	0	0.0	89,697	0	0.0
39	57,254	207	0.4	105,445	174	0.2	162,699	381	0.2
TOTAL	**1,123,008**	**9,717**	**0.9**	**2,094,431**	**6,927**	**0.3**	**3,217,439**	**16,644**	**0.5**
Bucks									
40	34,677	0	0.0	63,299	0	0.0	97,976	0	0.0
41	12,365	0	0.0	24,122	0	0.0	36,487	0	0.0
42	52,520	0	0.0	97,008	0	0.0	149,528	0	0.0
43	74,521	267	0.4	137,669	230	0.2	212,190	497	0.2
44	22,962	11	0.0	42,607	5	0.0	65,569	16	0.0
45	11,046	6	0.1	21,076	0	0.0	32,122	6	0.0
46	114,288	125	0.1	216,459	66	0.0	330,747	191	0.1
47	32,489	36	0.1	60,273	0	0.0	92,762	36	0.0
48	125,347	393	0.3	241,105	313	0.1	366,452	706	0.2
49	83,354	129	0.2	163,383	105	0.1	246,737	234	0.1
50	84,719	76	0.1	165,190	72	0.0	249,909	148	0.1
51	72,720	277	0.4	137,275	236	0.2	209,995	513	0.2
TOTAL	**721,008**	**1,320**	**0.2**	**1,369,466**	**1,027**	**0.1**	**2,090,474**	**2,347**	**0.1**
Berks									
72	13,535	0	0.0	22,732	0	0.0	36,267	0	0.0
TOTAL	**13,535**	**0**	**0.0**	**22,732**	**0**	**0.0**	**36,267**	**0**	**0.0**
PA TOTAL	4,229,532	369,342	8.7	7,664,357	335,717	4.4	11,893,889	705,059	5.9

Table 29 : 1997 Enhanced Model Travel Simulation: Percent of Daily Person Trip Attractions Made by Transit By Time Period and County Planning Area (Continued)

CPA	Peak Period Attractions Person Trips	Peak Period Attractions Transit Trips	Peak Period Attractions Percent Transit	Off-Peak Period Attractions Person Trips	Off-Peak Period Attractions Transit Trips	Off-Peak Period Attractions Percent Transit	Total Daily Attractions Person Trips	Total Daily Attractions Transit Trips	Total Daily Attractions Percent Transit
Mercer									
52	95,706	6,303	6.6	152,095	5,712	3.8	247,801	12,015	4.8
53	131,477	928	0.7	242,227	582	0.2	373,704	1,510	0.4
54	91,096	251	0.3	174,778	216	0.1	265,874	467	0.2
55	16,553	16	0.1	31,525	10	0.0	48,078	26	0.1
56	44,543	42	0.1	81,675	42	0.1	126,218	84	0.1
57	84,367	850	1.0	146,837	669	0.5	231,204	1,519	0.7
TOTAL	**463,742**	**8,390**	**1.8**	**829,137**	**7,231**	**0.9**	**1,292,879**	**15,621**	**1.2**
Burlington									
58	153,242	451	0.3	295,439	231	0.1	448,681	682	0.2
59	251,003	770	0.3	473,847	448	0.1	724,850	1,218	0.2
60	65,011	5	0.0	121,489	5	0.0	186,500	10	0.0
61	52,705	142	0.3	94,960	67	0.1	147,665	209	0.1
62	16,475	0	0.0	31,784	0	0.0	48,259	0	0.0
TOTAL	**538,436**	**1,368**	**0.3**	**1,017,519**	**751**	**0.1**	**1,555,955**	**2,119**	**0.1**
Camden									
63	138,242	7,160	5.2	239,325	7,425	3.1	377,567	14,585	3.9
64	210,482	1,982	0.9	397,017	1,904	0.5	607,499	3,886	0.6
65	115,475	1,138	1.0	227,564	1,413	0.6	343,039	2,551	0.7
66	71,256	94	0.1	135,407	87	0.1	206,663	181	0.1
67	90,000	453	0.5	176,626	324	0.2	266,626	777	0.3
TOTAL	**625,455**	**10,827**	**1.7**	**1,175,939**	**11,153**	**0.9**	**1,801,394**	**21,980**	**1.2**
Gloucester									
68	123,401	962	0.8	232,223	607	0.3	355,624	1,569	0.4
69	47,101	10	0.0	86,946	5	0.0	134,047	15	0.0
70	82,558	313	0.4	158,969	179	0.1	241,527	492	0.2
71	39,379	42	0.1	75,497	21	0.0	114,876	63	0.1
TOTAL	**292,439**	**1,327**	**0.5**	**553,635**	**812**	**0.1**	**846,074**	**2,139**	**0.3**
NJ TOTAL	**1,920,072**	**21,912**	**1.1**	**3,576,230**	**19,947**	**0.6**	**5,496,302**	**41,859**	**0.8**
REGION TOTAL	**6,149,604**	**391,254**	**6.4**	**11,240,587**	**355,664**	**3.2**	**17,390,191**	**746,918**	**4.3**

Transit shares are highest in the central, densely urbanized portion of the region, but decline significantly with distance from the Philadelphia Central Business District to very small values in the suburban and rural portions of the region. Most suburban counties have overall transit shares on the order of one percent or less. The proportion of transit person trip attractions is much higher than for person trip productions in the central business district (50.8 versus 18.9 percent), but lower in the remainder of the region because of the importance of employment density in making a commercial area attractive to transit riders. Generally, peak period modal splits are about twice as high as the comparible off-peak values. However, it is interesting to note that off-peak person trips are much more numerous than peak period trips --19 hours of the day versus 5 hours for the peak period). Taken together, these two phenomena almost compensate for each other and about 48 percent of all transit trips occur during off-peak hours of the day. This corresponds closely to current transit counts for all modes and companies which show that about 52 percent of total daily transit boardings occur during the off-peak.

Work continues on completing the off-peak period implementation of the enhanced nested modal split model within the Evans Iterative process. The off-peak period may be disaggregated into separate midday and evening time periods to eliminate the need for the adhoc 20 percent transit adjustment in the off-peak simulation runs.

G. Enhanced Highway Assignment Model

The Evans travel simulation process embeds the model chain from trip distribution through highway assignment within the Frank-wolf decomposition so that the effect of capacity restraint is included in trip distribution and modal split. Following an initial 15 iterations of traditional assignment, seven iterations of Evans capacity restraint are executed for a total of 22 iterations. In addition, separate travel simulation processes are executed for peak and off-peak time periods (a total of 44 iterations). The enhanced model assignment screenline results reported below are for the sum of the peak and off-peak simulations. Further description of the enhanced assignment process are beyond the scope of this report, but will be included in a forthcoming supplement to the 1990 validation report.

Table 30 presents the same screenline results for the enhanced travel simulation model. For the most part, the screenline statistics for the new model and existing model (see Table 18) are comparable, although the new model may produce slightly lower assignments in urban areas because the capacity constraint applies to the trip table preparation as well as the highway assignment. The volumes shown in Table 30 were prepared as part of the development of the travel simulation model for Chester County. The Chester County portion of the enhanced model output were subjected to a detailed county-wide validation based on more then three hundred traffic counts. The new model was found to be significantly more accurate than the existing model when simulating current volumes on significant roadways in Chester County.

Table 30 : 1997 Regional Highway Assignment Preliminary Enhanced Model Summary of Screenlines

Screenline	1995 Number of Crossings	1995 Counted Volume (000)	1997 Simulated Volume (000)	Percent Diff	R^2
Inner Cordon Seg. 1 (Bucks County)	21	259.4	249.0	-4.0%	0.71
Inner Cordon Seg. 2 (Montgomery Co.)	34	508.5	474.7	-6.6	0.89
Inner Cordon Seg. 3 (Chester Co.)	14	214.3	238.2	11.2	0.82
Inner Cordon Seg. 4 (Delaware Co.)	17	209.8	237.8	13.3	0.94
Inner Cordon Seg. 5 (Mercer Co.)	26	415.0	377.5	-9.0	0.75
Inner Cordon Seg. 6 (Burlington Co.)	28	311.7	326.6	4.8	0.93
Inner cordon Seg. 7 (Camden Co.)	11	150.9	146.6	-2.8	0.88
Inner Cordon Seg. 8 (Gloucester Co.)	21	223.3	226.2	1.3	0.88
Delaware River (ABCD)	18	554.6	516.4	-6.9	0.93
Schuylkill River (EFG)	40	1,318.0	1,192.5	-9.5	0.70
Center City Phila. (GHI)	60	977.5	927.0	-5.2	0.80
N. Phila. RR (J)	26	491.6	463.9	-5.6	0.92
Crosswicks Creek (PQ)	7	220.3	235.4	6.9	0.80
Camden-Burlington Co. Boundary (TU)	32	513.7	518.8	1.0	0.84
Total	**355**	**6,368.6**	**6,130.6**	**-3.7%**	**0.84**

H. Enhanced Model Transit Assignment

The enhanced transit assignment process uses the methodology described above except the transit assignment is conducted separately for peak and off-peak time periods. The results shown below represent the sum of the peak and off-peak time periods. The transit loading matrix for each time period was created by weighting together the trip table from each Evans iteration using the Frank-wolf lambda values used in the highway assignment iterations.

Tables 31 and 32 present the same statistics from the enhanced travel simulation model output as provided in the existing model in Tables 20 and 21 by submode, the enhanced model produced slightly more accurate totals, particularly for bus and trolley and subway-elevated. Overall, the enhanced model predicted total transit boardings within one percent error. The error statistics by transit company and submode shown in Table 31 for the enhanced model are for the most part comparable to those of the existing model.

Table 31 : Comparison of 1997 Passenger Counts and Enhanced Model Simulated Volumes by Transit Submode

Submode	1997 Simulated Volumes	1997 Passenger Counts	Percent Difference
Commuter Rail	88,105	85,269	3.3 %
Sub-Elevated / High Speed Rail	350,724	361,152	-2.9
Bus and Trolley	699,294	694,534	0.7
Total	**1,138,123**	**1,140,955**	**-0.2%**

Table 32 : Comparison of 1997 Passenger Counts and Enhanced Model Assigned Volumes by Transit Operating Companies

Company/Division	Submode	1997 Assigned Volumes	1997 Passenger Counts	% Difference
SEPTA City Transit	Subway-Elevated	297,150	314,193	-5.4%
	Bus & Trolley	606,995	602,455	0.8
Total		**904,145**	**916,648**	**-1.4%**
SEPTA Suburban				
Victory Division	Bus & High Speed Line	54,510	46,090	18.3%
Frontier Division	Bus	6,085	9,589	-36.5
Total		**60,595**	**55,679**	**8.8%**
SEPTA Regional Rail	Commuter Rail	88,105	85,269	3.3%
Total SEPTA		**1,052,845**	**1,057,596**	**-0.4%**
NJT Southern Division	Bus	26,427	29,000	-8.9%
NJT Mercer Division	Bus	13,341	15,100	-11.6
Total NJ TRANSIT		**39,768**	**44,100**	**-9.8%**
DRPA	High Speed Rail	45,510	39,259	15.9
Grand Total		**1,138,123**	**1,140,955**	**-0.25%**

H. Validation Results of the 1997 Travel Simulatin

The extensive comparisons of the simulated and actual link and facility volumes contained in this report clearly show that both the existing and enhanced models produce sufficently accurate results for all ongoing short and long range travel forecasts, plan and congestion management evaluations, facility level design data projections, air quality/conformity evaluations, etc. At present, the existing model is used for most facility level evaluations, while the ISTEA/conformity rule compliant enhanced model is being used for air quality/conformity evaluations and for county wide planning studies. In the near future, the DVRPC will change over the the enhanced model for all travel forecasting applications. This report clearly shows that the existing and enhanced models produce comparable facility level volumes and levels of accuracy. This comparability will allow transitioning to the new model with little or no disruption to DVRPC's ongoing planning activities and work programs.