Enhancement of DVRPC'S Travel Simulation Models

TASK 8

EXTERNAL-LOCAL TRIP DISTRIBUTION

PREPARED FOR
DELAWARE VALLEY REGIONAL PLANNING COMMISSION

BY
CAMBRIDGE SYSTEMATICS, INC.

JULY 1997

Delaware Valley Regional Planning Commission

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The Bourse Building
111 S. Independence Mall East
Philadelphia, PA 19106-2515

The report has been prepared by Cambridge Systematics, Inc., in partial fulfillment of the contract between the Delaware Valley Regional Planning Commission and Cambridge Systematics, Inc. to enhance DVRPC's travel simulation models. The preparation of this report was funded through federal grants from the U.S. Department of Transportation's Federal Highway Administration (FHWA) and the Pennsylvania and New Jersey Departments of Transportation. Cambridge Systematics, Inc. however is 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 for the 1990s is to emphasize technical assistance and services, and to conduct high priority studies for member state and local governments, while determining and meeting the needs of the private sector.

The DVRPC logo is adapted from the official seal of the Commission and is designed as a stylized image of the Delaware Valley. The outer ring symbolizes the region as a whole while the diagonal bar signifies the Delaware River flowing through it. The two adjoining crescents represent the Commonwealth of Pennsylvania and the State of New Jersey. The logo combines these elements to depict the areas served by DVRPC.

DELAWARE VALLEY REGIONAL PLANNING COMMISSION

Publication Abstract

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ABSTRACT

This report describes a revised method for modeling external-local travel in the DVRPC travel model system . The revised procedure consists of a roadway stratification scheme for external trips, revised trip generation model, and revised trip distribution model by roadway type. The external stations are classified as expressways, arterials near expressways, arterials not near expressways, and local roads. A different set of model parameters was estimated for each roadway category.

The model were estimated using data from the 1988-1989 cordon survey for the DVRPC region. The new models compare well against the survey data and will be implemented within the existing DVRPC model programs. No changes to DVRPC models other than trip generation and distribution are required to run the new models.

For More Information Contact:

Delaware Valley Regional Planning Commission
Regional Planning Division
The Bourse Building
111 South Independence Mall East
Philadelphia, PA 19106-2515
Telephone: (215) 592-1800 FAX: (215) 592-9125
e-mail: dvrpc@libertynet.org
website: http://www.libertynet.org/~dvrpc/

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Executive Summary

In the early days of travel models, external trips accounted for a negligible percentage of total regional trips. Now, however, regions have grown out to and beyond their cordon limits, and separate regions have grown together so that external traffic has become a significant trip component. It is obvious when looking at cordon data for various regions that travel characteristics vary significantly depending on the type of highway. The higher the classification of highway at the cordon, the longer its trips are likely to be.

The objective of this task is to develop and implement a plan for modeling trip distribution for external-local travel in the DVRPC travel model system. The existing DVRPC trip generation model treats external-local trips as a separate trip category. In the existing trip generation model, the number of external-local trips generated in each internal zone is based on the number of internal trips generated in the zone and the airline distance from the zone to the nearest external station. The existing external-local trip distribution model is a gravity model where the external end of each trip is treated as the production end and the internal end as the attraction end. The gravity model was calibrated using data from the 1988-1989 DVRPC cordon survey and is applied in TRANPLAN along with the distribution of internal and other trips.

Because the model enhancement project is not restructuring the overall trip generation and distribution framework of the DVRPC model system and because the existing procedures conform to the state of the practice and are working well, the existing framework for modeling external-local trips was not changed. The proposed analysis method for external-local trip modeling is therefore similar to the existing process, with the main difference being the stratification of external stations into more than the existing two categories. The development process for the revised procedure consisted of the following three steps:

1. Determination of roadway stratification scheme;

2. Development of revised trip generation models; and

3. Development of revised trip distribution models by roadway type.

The proposed roadway stratification scheme includes the following four classifications:

- Expressway;

- Arterial near expressway;

- Arterial not near expressway; and

- Local.

These categories are defined to be consistent with the functional classification definitions provided in a September 16, 1996 memorandum from DVRPC and not with the functional classifications used in the TRANPLAN model network. This scheme was chosen because the trip length frequencies are sufficiently different among the categories that they should be modeled separately.

It was decided to continue to use the existing functional form for the new trip generation model, estimating separate models for each external station type. The only change, other than the definitions of the external station types, was the substitution of the highway distance to the nearest external station of the given type, for the airline distance. The formula used in this task is linear in logarithms, and the models for the four station types were estimated using the 1988-1989 cordon survey for the DVRPC region using linear regression.

The trip generation models were validated by applying them using the base year internal trip generation totals and highway distance skims. The total number of generated trips for each station type was compared to the total of the base year volumes for the stations of that type.

To be consistent with the existing DVRPC methodology and the methodology for the internal and other trip types, the revised trip distribution models for the four categories are gravity models are based on highway time. These models were estimated using the 1988-1989 cordon survey for the DVRPC region, expanded to represent all external-local trips, using TRANPLAN. The estimated gravity models worked well in replicating the trip attractions and the trip length frequency distributions for each station type.

In summary, the new models compare well against the survey data. The new models will be implemented within the existing DVRPC model programs. No changes to DVRPC models other than trip generation and distribution are required to run the new models.

1.0 Introduction

In the early days of travel models, external trips accounted for a negligible percentage of total regional trips. Now, however, regions have grown out to and beyond their cordon limits, and separate regions have grown together so that external traffic has become a significant trip component. It is obvious when looking at cordon data for various regions that travel characteristics vary significantly depending on the type of highway. The higher the classification of highway at the cordon, the longer its trips are likely to be. For example, some roads, such as the turnpikes, carry a large number of long-distance trips. On average, a smaller percentage of the total length of trips on these roadways would be expected to occur in the DVRPC region, implying that travelers might be willing to travel farther within the DVRPC region once they cross the cordon. Other roads carry predominantly local traffic. Since local trips are generally short, there is a much greater likelihood that the local ends of these trips are near the cordon. Functional classification of the cordon highway, therefore, becomes a strong surrogate for other determinants of the types and kind of travel at the cordon.

The objective of this task is to develop and implement a plan for modeling trip distribution for external-local travel in the DVRPC travel model system. At present, the DVRPC model system uses a gravity model formulation to distribute external-local trips. This model distinguishes only between expressways and non-expressways.

■ Data Source

The main data source for the development of the revised external-local trip distribution models is the 1988-1989 cordon survey for the DVRPC region. The data set provided to Cambridge Systematics by DVRPC consists of information collected from a survey of drivers on 25 roadways at the cordon of the DVRPC model region. These roadways are shown in Table 1.1. The data items from this survey that are relevant to the work in Task 8 include:

- Trip origin or destination zone within the DVRPC region (depending on trip direction); and
- The roadway on which the driver was surveyed.

Trip origin/destination information was not available at a more detailed level than the DVRPC model zone. This was not a problem for the aggregate zone-level models being developed in Task 8. It was impossible to use the trip purpose data item from the survey since only the destination purpose was asked, and "home" was a possible response. This meant that identifying trip purpose consistent with those for internal trips in DVRPC's

Table 1.1 External Survey Roadways

Zone No.	Roadway
1399	I-95 (PA/DE line)
1401	PA 261
1402	U.S. 202 (PA/DE line)
1410	PA 41
1415	U.S. 1 (PA/MD line)
1422	U.S. 30 (Lancaster County line)
1433	PA 724
1434	U.S. 422
1443	PA 29
1447	PA 309
1450	PA 412
1451	PA 611
1453	Milford Bridge
1456	U.S. 202 (NJ)
1461	NJ 31
1470	U.S. 130 (north)
1476	I-195
1478	CR 524
1484	NJ 72
1489	U.S. 206
1493	Atlantic City Expressway
1492	CR 561
1495	U.S. 322
1503	NJ 77
1508	I-295

model system was impossible. Again, this was not a problem since disaggregating external-local trips by purpose was not envisioned in the revised models.

Trip distance within the DVRPC region was computed for each survey record by skimming the existing base year DVRPC highway network. The distance variable was appended to the survey data set for use in subsequent analyses.

Existing DVRPC External-Local Trip Modeling Procedures

Trip Generation

The existing DVRPC trip generation model treats external-local trips as a separate trip category. These trips are treated as being produced at the external station and attracted to the internal zone. The attractions generated by each internal zone are computed as a function of the total trip attractions and the distance from the nearest external station. The existing trip generation model for external-local trips has the form:

$$E_j = AT_jD_j^B \tag{1}$$

where:

E_j = external-local trips generated in zone j

T_j = internal trips generated in zone j

D_j = airline distance from zone j to the nearest external station

A, B = estimated parameters

The external-local trip attractions generated by this formula are subtracted from the total internal person trips generated for the zone.

Trip Distribution

The existing DVRPC external-local trip distribution model is a gravity model where the external end of each trip is treated as the production end and the internal end as the attraction end. The gravity model was calibrated using the 1988-1989 cordon survey and is applied in TRANPLAN along with the distribution of internal and other trips.

Analysis Method

Because the model enhancement project is not restructuring the overall trip generation and distribution framework of the DVRPC model system and because the existing procedures conform to the state of the practice and are working well, the existing framework for modeling external-local trips – modeling the trips as a separate purpose, basing trip generation for internal zones on the distance from the cordon, and applying a gravity model for trip distribution – was not changed.

The proposed analysis method for external-local trip modeling is therefore similar to the existing process, with the main difference being the stratification of external stations into more than the existing two categories. This, of course, required the reestimation of model parameters, including the trip generation parameters and the friction factors for the gravity model.

The development process for the revised procedure consisted of the following three steps:

Step 1. Determine Roadway Stratification Scheme

The cordon survey data was examined to determine an appropriate roadway stratification scheme. The major criterion for determining the stratification was the trip length frequency distributions within the DVRPC area for the external stations, as observed in the cordon survey. This process is documented in Section 2.0 of this report.

Step 2. Develop Revised Trip Generation Models

The external-local trip generation procedure was revised to take into account the external station stratification scheme developed in Step 1. External-local trip attraction equations were developed for each roadway stratification based on the cordon survey data. These formulas will be applied using base year trip attraction totals to obtain estimates of base year external-local trips by zone. This process is documented in Section 3.0 of this report.

Step 3. Develop Revised Trip Distribution Models by Roadway Type

Using the internal trip generation information developed in Step 2, the observed base year external station volumes, and data from the cordon survey, a gravity trip distribution model was developed for each roadway stratification. These models were validated using data from the cordon survey. This process is documented in Section 4.0 of this report.

2.0 Stratification of External Stations

The first step in the development of the revised external-local trip distribution models was to develop the external roadway stratification scheme. The existing DVRPC external-local trip distribution procedure uses a stratification of external roadways between freeway/expressway and all other roads. As this section will show, it is clear that other roadway characteristics besides functional classification can affect the type of travel, in terms of the local area origin or destination, that uses the road.

The following stratification schemes were considered for the revised models:

- Disaggregating freeway/expressway roads into toll versus non-toll roadways (on the assumption that toll road users are more likely to be making longer trips);
- Disaggregating non-freeway/expressway roads into arterial and local (on the assumption that local road users are more likely to be making shorter trips);
- Disaggregating non-freeway/expressway roads by whether the roadway is located near an expressway (on the assumption that users of such roadways are less likely to be making longer trips with a nearby expressway available); and
- Stratifying roadways by the distance from the external station to Center City Philadelphia. This stratification considers to some extent whether the roadway may be serving "suburbs" of a nearby large city such as Reading or Allentown.

In addition, cross-classifications of these categories were considered.

As it turned out, the external survey data set was unable to support stratification by the first scheme since only one toll road was surveyed. In addition, according to the roadway classifications from the model network, there was only one local road among the survey sites. Consequently, there were insufficient data to disaggregate the existing categories as desired.

This left three possible schemes:

1. Disaggregating non-freeway/expressway roads by whether the roadway is located near an expressway;
2. Stratifying roadways by the distance from the external station to Center City Philadelphia; and
3. Cross-classification of 1 and 2.

After examining the survey locations, it was decided that for schemes 2 and 3, stations should be classified into those within 35 miles of Center City, 35-45 miles away, and more than 45 miles away. Based on this determination, Table 2.1 shows the number of survey stations in each category. Table 2.2 shows the number of survey records for each category. (The row totals in both tables show the totals by category for scheme 2; the column totals for scheme 1). It should be noted that the nine categories shown for scheme 3 are considered to be too many for use in the revised models; however, the scheme was carried forward to see whether any categories could be combined to provide a reasonable number. (Obviously, the category for which no survey data were available would have to be combined with another.)

To determine which scheme provided the most information concerning external-local travel patterns, trip length frequencies were summarized from the survey data set by category. These are shown in Table 2.3. An examination of this table shows that any of the three schemes would result in categories between which trip lengths varied significantly.

Scheme 1 corresponds to the "All trips" rows in Table 2.3. The differences among the trip length frequencies are intuitive and significant. Expressways generally carry longer trips than either arterial category. Arterials near expressways carry significantly shorter trips than arterials not near expressways.

Scheme 2 corresponds to the "Total" column in Table 2.3. The differences among the trip length frequencies are once again intuitive and significant. Roadway locations closer to Center City generally carry longer trips than more distant locations. This likely reflects the fact that areas closer to Philadelphia probably send more trips into the city than more distant areas. The shorter trip lengths for the more distant locations also reflect the fact that areas which generate a significant number of trips from these locations are outside the modeling area, and the reported trip lengths include only the portions of trips within the modeling area.

Scheme 3 corresponds to the remainder of Table 2.3. The differences among the trip length frequencies are once again significant, but they are not always intuitive. For example, trip lengths on expressways are shortest for locations between 35 and 45 miles from Center City. However, the differences in all cases are significant and are intuitive in most cases. Unfortunately, the summaries do not imply any simple scheme for combining categories in scheme 3 to yield a more reasonable number of categories.

Given the summaries shown in Table 2.3, any of the three schemes could be used. After this analysis was completed, DVRPC provided, via a memorandum dated September 16, 1997, an alternate roadway classification scheme which allowed classification of non-expressways as arterial and local roads. This provided the following additional scheme:

4. Stratifying roadways by functional classification, including whether an arterial roadway is located near an expressway.

Table 2.1 Number of Survey Locations by Category

Category/Distance from Center City	Expressway	Arterial Near Expressway	Arterial Not Near Expressway	Total
< 35 miles	5	3	2	10
35-45 miles	2	4	3	9
> 45 miles	3	0	3	6
Total	**10**	**7**	**8**	**25**

Table 2.2 Number of Surveys by Category

Category/ Distance from Center City	Expressway	Arterial Near Expressway	Arterial Not Near Expressway	Total
< 35 miles	6,166	2,624	1,158	9,948
35-45 miles	1,898	3,436	2,570	7,904
> 45 miles	2,775	0	1,807	4,582
Total	**10,839**	**6,060**	**5,535**	**22,434**

Table 2.3 Trip Length Frequencies by Category

		Expressway		Arterial Near Expressway		Arterial not Near Expressway		Total	
Dist to CBD	Trip Distance	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
<35	<5	744	12.1	476	18.1	101	8.7	1,321	13.3
	5-10	851	13.8	572	21.8	56	4.8	1,479	14.9
	10-15	725	11.8	229	8.7	268	23.1	1,222	12.3
	15-20	758	12.3	455	17.3	102	8.8	1,315	13.2
	20-25	925	15.0	247	9.4	136	11.7	1,308	13.1
	25-30	644	10.4	186	7.1	170	14.7	1,000	10.1
	30-35	589	9.6	185	7.1	74	6.4	848	8.5
	35-40	384	6.2	135	5.1	138	11.9	657	6.6
	40-45	196	3.2	69	2.6	71	6.1	336	3.4
	45-50	148	2.4	31	1.2	22	1.9	201	2.0
	50-55	94	1.5	21	0.8	9	0.8	124	1.2
	55-60	53	0.9	8	0.3	6	0.5	67	0.7
	>=60	55	0.9	10	0.4	5	0.4	70	0.7
	Subtotal	**6,166**		**2,624**		**1,158**		**9,948**	
35-45	<5	130	6.8	1,385	40.3	449	17.5	1,964	24.8
	5-10	441	23.2	886	25.8	475	18.5	1,802	22.8
	10-15	365	19.2	389	11.3	387	15.1	1,141	14.4
	15-20	173	9.1	223	6.5	240	9.3	636	8.0
	20-25	229	12.1	168	4.9	158	6.1	555	7.0
	25-30	124	6.5	128	3.7	100	3.9	352	4.5
	30-35	96	5.1	84	2.4	194	7.5	374	4.7
	35-40	85	4.5	61	1.8	167	6.5	313	4.0
	40-45	115	6.1	52	1.5	148	5.8	315	4.0
	45-50	60	3.2	26	0.8	106	4.1	192	2.4
	50-55	43	2.3	25	0.7	60	2.3	128	1.6
	55-60	15	0.8	7	0.2	35	1.4	57	0.7
	>=60	22	1.2	2	0.0	51	2.0	75	0.9
	Subtotal	**1,898**		**3,436**		**2,570**		**7,904**	

Table 2.3 Trip Length Frequencies by Category (continued)

		Expressway		Arterial Near Expressway		Arterial not Near Expressway		Total	
Dist to CBD	Trip Distance	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
>45	<5	749	27.0	0	0.0	770	42.6	1,519	33.2
	5-10	448	16.1	0	0.0	407	22.5	855	18.7
	10-15	314	11.3	0	0.0	84	4.6	398	8.7
	15-20	222	8.0	0	0.0	80	4.4	302	6.6
	20-25	190	6.8	0	0.0	153	8.5	343	7.5
	25-30	124	4.5	0	0.0	44	2.4	168	3.7
	30-35	151	5.4	0	0.0	74	4.1	225	4.9
	35-40	110	4.0	0	0.0	74	4.1	184	4.0
	40-45	97	3.5	0	0.0	57	3.2	154	3.4
	45-50	123	4.4	0	0.0	42	2.3	165	3.6
	50-55	110	4.0	0	0.0	13	0.7	123	2.7
	55-60	40	1.4	0	0.0	5	0.3	45	1.0
	>=60	97	3.5	0	0.0	4	0.2	101	2.2
	Subtotal	**2,775**		**0**		**1,807**		**4,582**	
All trips	<5	1,623	15.0	1,861	30.7	1,320	23.8	4,804	21.4
	5-10	1,740	16.1	1,458	24.1	938	16.9	4,136	18.4
	10-15	1,404	13.0	618	10.2	739	13.4	2,761	12.3
	15-20	1,153	10.6	678	11.2	422	7.6	2,253	10.0
	20-25	1,344	12.4	415	6.8	447	8.1	2,206	9.8
	25-30	892	8.2	314	5.2	314	5.7	1,520	6.8
	30-35	836	7.7	269	4.4	342	6.2	1,447	6.5
	35-40	579	5.3	196	3.2	379	6.8	1,154	5.1
	40-45	408	3.8	121	2.0	276	5.0	805	3.6
	45-50	331	3.1	57	0.9	170	3.1	558	2.5
	50-55	247	2.3	46	0.8	82	1.5	375	1.7
	55-60	108	1.0	15	0.2	46	0.8	169	0.8
	>=60	174	1.6	15	0.2	60	1.1	249	1.1
	TOTAL	**10,839**		**6,060**		**5,535**		**22,434**	

The results of the test of this scheme are shown in Table 2.4. The basic conclusions are:

- There are sufficient survey data and external stations for each new subcategory to obtain significant conclusions about the differences in trip length frequencies among them; and
- The trip length frequencies are sufficiently different among the subcategories that they should be modeled separately.

Consequently, the final proposed categorization scheme includes the following four classifications:

- Expressway;
- Arterial near expressway;
- Arterial not near expressway; and
- Local.

These categories are defined to be consistent with the functional classification definitions provided in the September 23, 1996 memorandum from DVRPC and not with the functional classifications used in the TRANPLAN model network. Table 2.5 shows the category in which each of the external stations in the DVRPC model system falls, according to that memorandum.

Table 2.4 External Trip Length Frequency by Function Class – Scheme 4

Trip	All External Stations		Expressway		Arterial Near Expressway		Arterial Not Near Expressway		Local	
Distance	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
<5	4,804	21.41	489	7.16	1,652	26.86	1,073	18.40	1,590	43.91
5-10	4,136	18.44	1,062	15.55	1,170	19.02	1,020	17.49	884	24.41
10-15	2,761	12.31	819	11.99	694	11.28	826	14.16	422	11.65
15-20	2,253	10.04	707	10.35	795	12.92	556	9.53	195	5.39
20-25	2,206	9.83	999	14.63	557	9.06	459	7.87	191	5.27
25-30	1,520	6.78	665	9.74	393	6.39	331	5.68	131	3.62
30-35	1,447	6.45	665	9.74	316	5.14	401	6.88	65	1.80
35-40	1,154	5.14	443	6.49	260	4.23	395	6.77	56	1.55
40-45	805	3.59	327	4.79	147	2.39	288	4.94	43	1.19
45-50	558	2.49	265	3.88	68	1.11	202	3.46	23	0.64
50-55	375	1.67	174	2.55	64	1.04	125	2.14	12	0.33
55-60	169	0.75	84	1.23	19	0.31	61	1.05	5	0.14
>=60	246	1.10	131	1.92	16	0.26	95	1.63	4	0.11
Total	**22,434**	**100.00**	**6,830**	**100.00**	**6,151**	**100.00**	**5,832**	**100.00**	**3,621**	**100.00**

Table 2.5 External Station Types

Station Number	Roadway, Municipality	Type
1396	US 13, Marcus Hook	Arterial near expressway
1397	Ridge Rd., Lower Chichester	Arterial near expressway
1398	PA 491, Lower Chichester	Arterial near expressway
1399	I-95, Lower Chichester	Freeway/Expressway
1400	Carpenter Rd., Upper Chichester	Arterial not near expressway
1401	PA 261, Bethel	Collector/local
1402	US 202, Bethel	Arterial not near expressway
1403	Beaver Valley Rd., Birmingham	Collector/local
1404	Smith Bridge Rd., Birmingham	Collector/local
1405	Ridge Rd., Birmingham	Collector/local
1406	PA 100, Pennsbury	Arterial not near expressway
1407	PA 52, Pennsbury	Arterial not near expressway
1408	Old Kennett Rd., Kennett	Collector/local
1409	PA 82, Kennett	Collector/local
1410	PA 41, Kennett	Arterial not near expressway
1411	Limestone Rd., New Garden	Arterial not near expressway
1412	PA 896, London-Britain	Arterial not near expressway
1413	PA 841, Elk	Collector/local
1414	PA 272, East Nottingham	Arterial near expressway
1415	US 1, West Nottingham	Freeway/Expressway
1416	PA 272, West Nottingham	Arterial near expressway
1417	Forge Rd., Lower Oxford	Collector/local
1418	PA 472, Lower Oxford	Arterial not near expressway
1419	PA 896, Upper Oxford	Arterial not near expressway
1420	PA 372, West Sadsbury	Arterial not near expressway
1421	PA 41, West Sadsbury	Arterial not near expressway
1422	US 30, West Sadsbury	Arterial not near expressway
1423	PA 340, West Cain	Arterial not near expressway
1424	Beaver Dam Rd., Honey Brook	Collector/local
1425	US 322, Honey Brook	Arterial not near expressway
1426	PA 10, Honey Brook	Arterial near expressway
1427	Morgantown Rd., Honey Brook	Collector/local
1428	PA Tpk betw interchanges 22 and 23	Freeway/Expressway
1429	PA 23/401, Berks Co.	Arterial near expressway
1430	PA 82, Berks Co.	Collector/local

Table 2.5 External Station Types (continued)

Station Number	Roadway, Municipality	Type
1431	PA 345, Warwick	Collector/local
1432	Unionville Rd., North Coventry	Collector/local
1433	PA 724, North Coventry	Collector/local
1434	US 422, Douglass	Freeway/Expressway
1435	Benj. Franklin Hwy, Douglass	Arterial near expressway
1436	Pine Forge Rd., Douglass	Collector/local
1437	PA 562, Douglass	Arterial not near expressway
1438	PA 73, Colebrookdale	Arterial not near expressway
1439	PA 100, Colebrookdale	Arterial not near expressway
1440	Hoffmansville Rd. Douglass	Collector/local
1441	Niantic Rd. Douglass	Collector/local
1442	Philadelphia & Kutztown Rd. Upper Hanover	Collector/local
1443	PA 29, Upper Hanover	Arterial near expressway
1444	PA Tpk NE Ext betw interchanges 32 and 33	Freeway/Expressway
1445	Allentown Rd. Milford	Collector/local
1446	Old Bethlehem Pike, Springfield	Collector/local
1447	PA 309, Springfield	Arterial near expressway
1448	State Rd., Springfield	Collector/local
1449	Richlandtown Pike, Springfield	Collector/local
1450	PA 412, Springfield	Collector/local
1451	PA 611, Riegelsville	Arterial not near expressway
1452	Riegelsville Bridge, Riegelsville	Collector/local
1453	Milford Bridge, Bridgeton	Collector/local
1454	Frenchtown-Uhlerstown Bridge, Tinicum	Arterial not near expressway
1455	Stockton-Centre Bridge, Solebury	Arterial near expressway
1456	US 202, Solebury	Freeway/Expressway
1457	PA 179, New Hope	Arterial near expressway
1458	NJ 29, Hopewell	Freeway/Expressway
1459	CR 518, Hunterdon Co.	Arterial not near expressway
1460	CR 579, Hopewell	Arterial not near expressway
1461	NJ 31, Hopewell	Arterial not near expressway
1462	CR 607, Hopewell	Collector/local
1463	CR 518, Hopewell	Arterial not near expressway

Table 2.5 External Station Types (continued)

Station Number	Roadway, Municipality	Type
1464	CR 601, Princeton	Collector/local
1465	US 206, Somerset	Arterial not near expressway
1466	NJ 27, Mercer Co.	Arterial not near expressway
1467	US 1, Middlesex Co.	Arterial not near expressway
1468	CR 615, West Windsor	Collector/local
1469	CR 535, East Windsor	Arterial not near expressway
1470	US 130, East Windsor	Arterial near expressway
1471	CR 539, East Windsor	Arterial near expressway
1472	NJ Tpk betw interchanges 8 and 8A	Freeway/Expressway
1473	NJ 33, Middlesex Co.	Arterial near expressway
1474	CR 571, East Windsor	Collector/local
1475	CR 539, East Windsor	Arterial near expressway
1476	I-195, Washington	Freeway/Expressway
1477	CR 526, Washington	Arterial near expressway
1478	CR 524, Hamilton	Collector/local
1479	CR 664, North Hanover	Collector/local
1480	CR 537, North Hanover	Arterial not near expressway
1481	CR 528, North Hanover	Arterial not near expressway
1482	CR 528 Spur, North Hanover	Arterial not near expressway
1483	CR 530, Pemberton	Arterial not near expressway
1484	NJ 72, Woodland	Arterial not near expressway
1485	Stage Rd., Bass River	Collector/local
1486	CR 542, Bass River	Arterial not near expressway
1487	CR 563, Washington	Collector/local
1488	CR 542, Washington	Collector/local
1489	US 206, Shamong	Arterial not near expressway
1490	CR 536, Waterford	Arterial not near expressway
1491	US 30, Winslow	Arterial near expressway
1492	CR 561, Winslow	Collector/local
1493	Atlantic City Expy, Winslow	Freeway/Expressway
1494	CR 561 Spur, Winslow	Arterial near expressway
1495	US 322, Monroe	Arterial near expressway
1496	US 40, Atlantic Co.	Arterial not near expressway
1497	CR 555, Franklin	Arterial near expressway
1498	NJ 47, Franklin	Arterial near expressway

Table 2.5 External Station Types (continued)

Station Number	Roadway, Municipality	Type
1499	NJ 55, Franklin	Freeway/Expressway
1500	US 40, Franklin	Arterial near expressway
1501	CR 553, Franklin	Arterial not near expressway
1502	CR 604, Elk	Collector/local
1503	NJ 77, Elk	Collector/local
1504	CR 581, South Harrison	Arterial not near expressway
1505	NJ 45, South Harrison	Arterial not near expressway
1506	NJ Tpk betw interchange 1 and 2	Freeway/Expressway
1507	CR 551, Woolwich	Arterial near expressway
1508	I-295, Logan	Freeway/Expressway
1509	US 130. Logan	Arterial near expressway

3.0 Trip Generation

As discussed in Section 1.0, the existing DVRPC trip generation model for external-local trips has the form:

$$E_j = AT_jD_j^B \qquad (1)$$

where:

E_j = external-local trips generated in zone j

T_j = internal trips generated in zone j

D_j = airline distance from zone j to the nearest external station

A, B = estimated parameters

It was decided to continue to use this functional form for the new models, estimating separate models for each external station type. The only change, other than the definitions of the external station types, was the substitution of the highway distance to the nearest external station of the given type, H_j, for the airline distance. The formula used in this task is therefore given by:

$$E_{kj} = AT_jH_{kj}^B \qquad (2)$$

where:

E_{kj} = external-local trips for station type k generated in zone j

T_j = internal trips generated in zone j

H_{kj} = highway distance from zone j to the nearest external station of type k

A, B = estimated parameters

The models for the four station types were estimated using the 1988-1989 cordon survey for the DVRPC region. This was done by transforming Equation 2 using logarithms:

$$\log (E_{kj}) = \log (A + T_j) + B (\log (H_{kj})) \qquad (3)$$

This is a simple linear equation of the form y = A + Bx, and the parameters A and B were estimated easily using linear regression. The major purpose of the regression was to estimate the sensitivity B to the distance variable.

The models were validated by applying them using the base year internal trip generation totals and highway distance skims. The total number of generated trips for each station type was compared to the total of the base year volumes for the stations of that type. The constant term, A, for each model was revised as necessary to match the observed volumes.

The calibrated models are shown in Table 3.1, and the comparison of modeled and observed volumes for each external station type is shown in Table 3.2.

Table 3.1 Calibrated Trip Generation Models

Station Type	A	B
Freeway/Expressway	0.337	1.39
Arterial Near Expressway	0.343	1.69
Arterial Not Near Expressway	0.416	1.67
Collector/Local	0.154	1.76

Table 3.2 Comparison of Modeled and Observed Volumes

Station Type	Modeled Volume	Observed Volume
Freeway/Expressway	282,879	282,934
Arterial Near Expressway	199,740	199,887
Arterial Not Near Expressway	317,106	317,302
Collector/Local	81,175	81,079
Total	**880,900**	**881,202**

4.0 Trip Distribution

The final step in the process was to estimate gravity models for each of the four roadway types. This was a relatively straightforward process performed using the TRANPLAN function CALIBRATE GRAVITY MODEL. To be consistent with the existing DVRPC methodology and the methodology for the internal and other trip types, the revised gravity models are based on highway time. Terminal times remained unchanged from the existing DVRPC models.

This process consisted of the following steps:

1. Skim the DVRPC model highway network to obtain the base year highway travel time matrix.

2. Expand the 1988-1989 cordon survey for the DVRPC region to represent all external-local trips.

3. Estimate the external-local attractions for internal zones for each trip type using the models described in Section 3.0. The inputs for these models were the existing DVRPC person trip generation totals and the highway distance skims for the DVRPC model network, which had been previously created for use in the development of the trip generation models.

4. Enter the productions for external zones for each trip type as:

   - The external-internal auto volume if the external station is of the given type; or
   - Zero if the external station is of a different type.

5. Run the CALIBRATE GRAVITY MODEL module to estimate friction factors which match the trip length frequencies from the expanded survey data given the production and attraction totals from steps 3 and 4.

The estimated gravity models worked well in replicating the trip attractions and the trip length frequency distributions for each station type. These results are summarized in Table 4.1 and are shown graphically in Figures 4.1 through 4.4 for expressways, arterials near expressways, arterials not near expressways, and local roads respectively. Table 4.2 compares the average trip length for the model and survey.

Gravity model application setups were also developed and tested for the new external-local trip distribution models. Table 4.3 and Figure 4.5 show the final friction factors.

Table 4.1 Comparison of Observed and Modeled Trip Length Frequencies

	Percentage of Total Trips							
	Expressway		Arterial Near Expressway		Arterial Not Near Expressway		Local	
Time (min.)	Observed	Modeled	Observed	Modeled	Observed	Modeled	Observed	Modeled
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	3.72	3.69	11.68	11.40	11.51	10.82	23.62	23.05
15	7.73	7.66	28.87	26.55	14.23	12.75	26.52	25.27
20	9.01	8.36	4.05	4.06	7.97	6.89	10.35	10.10
25	9.87	8.86	10.16	9.81	10.99	10.47	10.16	11.29
30	6.42	6.40	4.36	6.19	9.75	9.29	5.49	6.53
35	5.88	5.64	7.80	7.51	8.17	9.75	4.49	4.84
40	6.28	6.78	4.76	5.02	5.34	7.79	2.72	2.58
45	6.22	6.33	4.70	4.88	4.15	5.33	3.72	3.40
50	4.97	5.54	3.23	3.60	5.23	5.71	2.11	2.23
55	5.34	5.61	3.06	3.21	3.12	3.69	1.52	1.57
60	4.68	5.38	3.06	2.93	2.91	3.03	0.90	1.31
65	3.82	4.56	1.43	1.77	2.40	2.48	1.39	1.42
70	2.95	2.67	1.48	1.55	2.34	1.88	2.16	1.77
75	2.52	2.57	1.65	1.79	2.28	1.71	1.25	0.97
80	2.60	3.63	2.52	2.22	2.09	1.57	0.73	0.93
85	5.10	3.90	2.08	2.04	1.46	1.36	0.62	0.59
90	2.97	2.38	1.46	1.58	1.87	1.27	0.46	0.47
95	2.18	2.53	0.75	0.96	1.41	0.84	0.63	0.52
100	1.93	1.69	0.82	0.77	0.45	0.63	0.19	0.41
105	1.12	1.32	0.44	0.59	0.52	0.60	0.31	0.27

Table 4.1 Comparison of Observed and Modeled Trip Length Frequencies (continued)

	Percentage of Total Trips							
	Expressway		Arterial Near Expressway		Arterial Not Near Expressway		Local	
Time (min.)	Observed	Modeled	Observed	Modeled	Observed	Modeled	Observed	Modeled
110	1.21	1.16	0.52	0.54	0.40	0.44	0.25	0.18
115	1.09	1.09	0.47	0.40	0.28	0.42	0.08	0.14
120	0.81	0.67	0.34	0.26	0.31	0.40	0.10	0.07
125	0.39	0.57	0.14	0.15	0.20	0.24	0.04	0.02
130	0.38	0.41	0.10	0.11	0.18	0.25	0.02	0.03
135	0.34	0.25	0.01	0.05	0.11	0.11	0.04	0.00
140	0.13	0.15	0.00	0.03	0.08	0.09	0.06	0.00
145	0.07	0.07	0.04	0.02	0.03	0.05	0.00	0.00
150	0.12	0.07	0.00	0.00	0.11	0.05	0.02	0.00
155	0.04	0.02	0.00	0.00	0.06	0.04	0.00	0.00
160	0.09	0.02	0.03	0.00	0.03	0.02	0.00	0.00
165	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00
170	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00
175	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
180	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
185	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
190	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
195	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00

Table 4.2 Comparison of Modeled and Survey Average Trip Lengths

	Average Trip Length (min.)	
Roadway Type	**Modeled**	**Survey**
Expressway	47.8	48.1
Arterial Near Expressway	32.5	33.3
Arterial Not Near Expressway	35.6	35.9
Local	24.3	24.4

Table 4.3 Gravity Model Friction Factors

Time (min.)	Expressway	Arterial Near Expressway	Arterial Not Near Expressway	Local
1	8246085	3306747	2640725	6487270
2	7143950	2829285	2354825	5484126
3	6203115	2426586	2103064	4648139
4	5398243	2086154	1881042	3949703
5	4708216	1797707	1684964	3364739
6	4115408	1552751	1511549	2873610
7	3605060	1344265	1357963	2460257
8	3164795	1166425	1221745	2111532
9	2784213	1014394	1100765	1816630
10	2454562	884146	993171	1566662
11	2168459	772321	897351	1354289
12	1919659	676110	811902	1173442
13	1702877	593161	735599	1019095
14	1513629	521496	667374	887070
15	1348103	459455	606292	773889
16	1203054	405637	551534	676650
17	1075711	358859	502383	592929
18	963709	318120	458209	520694
19	865020	282571	418458	458237
20	777905	251492	382642	404123
21	700871	224269	350334	357141
22	632633	200379	321153	316269
23	572081	179375	294765	280642
24	518258	160874	270876	249526
25	470335	144549	249222	222296
26	427596	130119	229572	198422
27	389416	117341	211720	177450
28	355255	106006	195483	158993
29	324640	95934	180699	142721

Table 4.3 Gravity Model Friction Factors (continued)

Time (min.)	Expressway	Arterial Near Expressway	Arterial Not Near Expressway	Local
30	297159	86970	167222	128347
31	272454	78977	154923	115628
32	250211	71840	143687	104354
33	230153	65456	133411	94343
34	212039	59736	124004	85439
35	195657	54604	115382	77505
36	180818	49992	107472	70424
37	167360	45840	100208	64094
38	155136	42098	93531	58426
39	144017	38719	87385	53343
40	133890	35665	81725	48777
41	124653	32899	76506	44669
42	116218	30391	71689	40968
43	108504	28114	67239	37628
44	101441	26043	63124	34609
45	94966	24158	59316	31878
46	89022	22439	55788	29402
47	83559	20869	52516	27154
48	78532	19434	49480	25112
49	73900	18121	46659	23252
50	69628	16917	44037	21558
51	65683	15812	41596	20011
52	62035	14797	39323	18598
53	58659	13863	37205	17305
54	55530	13003	35228	16119
55	52628	12209	33382	15032
56	49933	11477	31657	14034
57	47427	10799	30044	13115
58	45095	10173	28534	12269

Table 4.3 Gravity Model Friction Factors (continued)

Time (min.)	Expressway	Arterial Near Expressway	Arterial Not Near Expressway	Local
59	42923	9592	27119	11489
60	40896	9053	25793	10769
61	39005	8553	24549	10104
62	37238	8088	23380	9489
63	35584	7655	22282	8918
64	34036	7252	21249	8390
65	32585	6876	20277	7899
66	31224	6525	19362	7442
67	29945	6196	18499	7018
68	28744	5889	17685	6623
69	27613	5602	16916	6254
70	26548	5332	16190	5910
71	25545	5079	15504	5588
72	24598	4841	14855	5288
73	23703	4617	14241	5006
74	22858	4407	13658	4742
75	22058	4209	13106	4495
76	21300	4021	12583	4262
77	20582	3845	12086	4044
78	19901	3678	11614	3838
79	19254	3520	11165	3645
80	18639	3371	10738	3462
81	18054	3229	10331	3290
82	17497	3095	9944	3128
83	16966	2967	9575	2975
84	16459	2846	9223	2829
85	15975	2731	8887	2692
86	15512	2621	8567	2562
87	15070	2517	8260	2439

Table 4.3 Gravity Model Friction Factors (continued)

Time (min.)	Expressway	Arterial Near Expressway	Arterial Not Near Expressway	Local
88	14646	2417	7967	2322
89	14239	2322	7687	2210
90	13849	2231	7418	2105
91	13475	2144	7161	2005
92	13115	2061	6914	1909
93	12768	1982	6678	1818
94	12434	1906	6451	1732
95	12112	1832	6233	1649
96	11801	1762	6024	1571
97	11501	1695	5823	1496
98	11211	1630	5629	1424
99	10930	1568	5443	1356
100	10657	1508	5263	1290
101	10393	1451	5090	1228
102	10136	1395	4924	1168
103	9887	1342	4763	1111
104	9644	1290	4608	1057
105	9408	1240	4458	1005
106	9178	1192	4313	955
107	8953	1146	4173	907
108	8734	1101	4038	861
109	8520	1058	3907	817
110	8311	1016	3781	775
111	8106	975	3658	735
112	7905	936	3540	697
113	7708	898	3425	660
114	7515	861	3313	625
115	7326	826	3205	591
116	7140	791	3100	559

Table 4.3 Gravity Model Friction Factors (continued)

Time (min.)	Expressway	Arterial Near Expressway	Arterial Not Near Expressway	Local
117	6957	758	2999	528
118	6778	726	2900	499
119	6601	695	2804	471
120	6427	665	2711	444
121	6256	635	2621	418
122	6087	607	2533	394
123	5921	580	2448	370
124	5757	553	2365	348
125	5596	528	2284	327
126	5437	503	2206	307
127	5280	479	2130	287
128	5126	456	2056	269
129	4973	434	1983	252
130	4823	412	1913	235
131	4675	391	1845	220
132	4529	371	1779	205
133	4385	352	1714	191
134	4243	333	1652	177
135	4104	316	1591	165
136	3966	298	1531	153
137	3831	282	1474	142
138	3697	266	1418	131
139	3566	251	1363	121
140	3437	236	1310	112
141	3311	222	1259	103
142	3186	209	1209	95
143	3064	196	1160	88
144	2944	184	1113	80
145	2827	172	1067	74

Table 4.3 Gravity Model Friction Factors (continued)

Time (min.)	Expressway	Arterial Near Expressway	Arterial Not Near Expressway	Local
146	2712	161	1023	68
147	2599	151	980	0
148	2489	141	938	0
149	2381	131	897	0
150	2276	122	858	0
151	2174	114	820	0
152	2074	105	783	0
153	1976	98	748	0
154	1882	91	713	0
155	1790	84	680	0
156	1701	77	648	0
157	1614	71	617	0
158	1530	66	587	0
159	1449	60	558	0
160	1371	56	530	0
161	1295	0	503	0
162	1222	0	478	0
163	1152	0	453	0
164	1084	0	429	0
165	1019	0	406	0
166	957	0	384	0
167	898	0	363	0
168	841	0	342	0
169	786	0	323	0
170	734	0	305	0
171	0	0	287	0
172	0	0	270	0
173	0	0	254	0
174	0	0	238	0

Table 4.3 Gravity Model Friction Factors (continued)

Time (min.)	Expressway	Arterial Near Expressway	Arterial Not Near Expressway	Local
175	0	0	224	0
176	0	0	210	0
177	0	0	196	0
178	0	0	184	0
179	0	0	172	0
180	0	0	160	0
181	0	0	150	0
182	0	0	139	0
183	0	0	130	0
184	0	0	121	0
185	0	0	112	0
186	0	0	104	0
187	0	0	96	0
188	0	0	89	0
189	0	0	83	0
190	0	0	76	0
191	0	0	70	0
192	0	0	65	0

Figure 4.1 Comparison of Modeled and Observed Trip Length Frequencies
Expressways

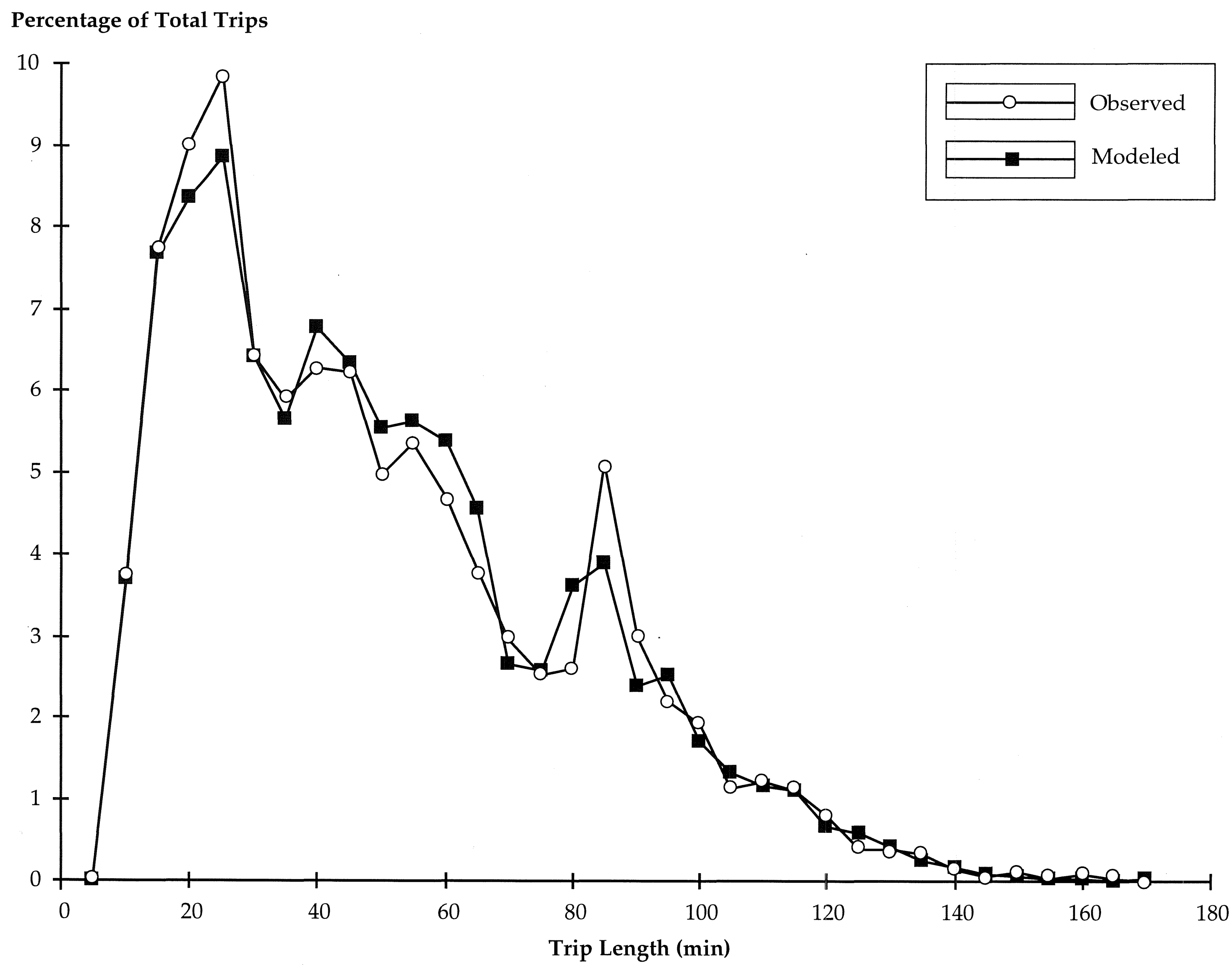


Figure 4.2 Comparison of Modeled and Observed Trip Length Frequencies
Arterials Near Expressways

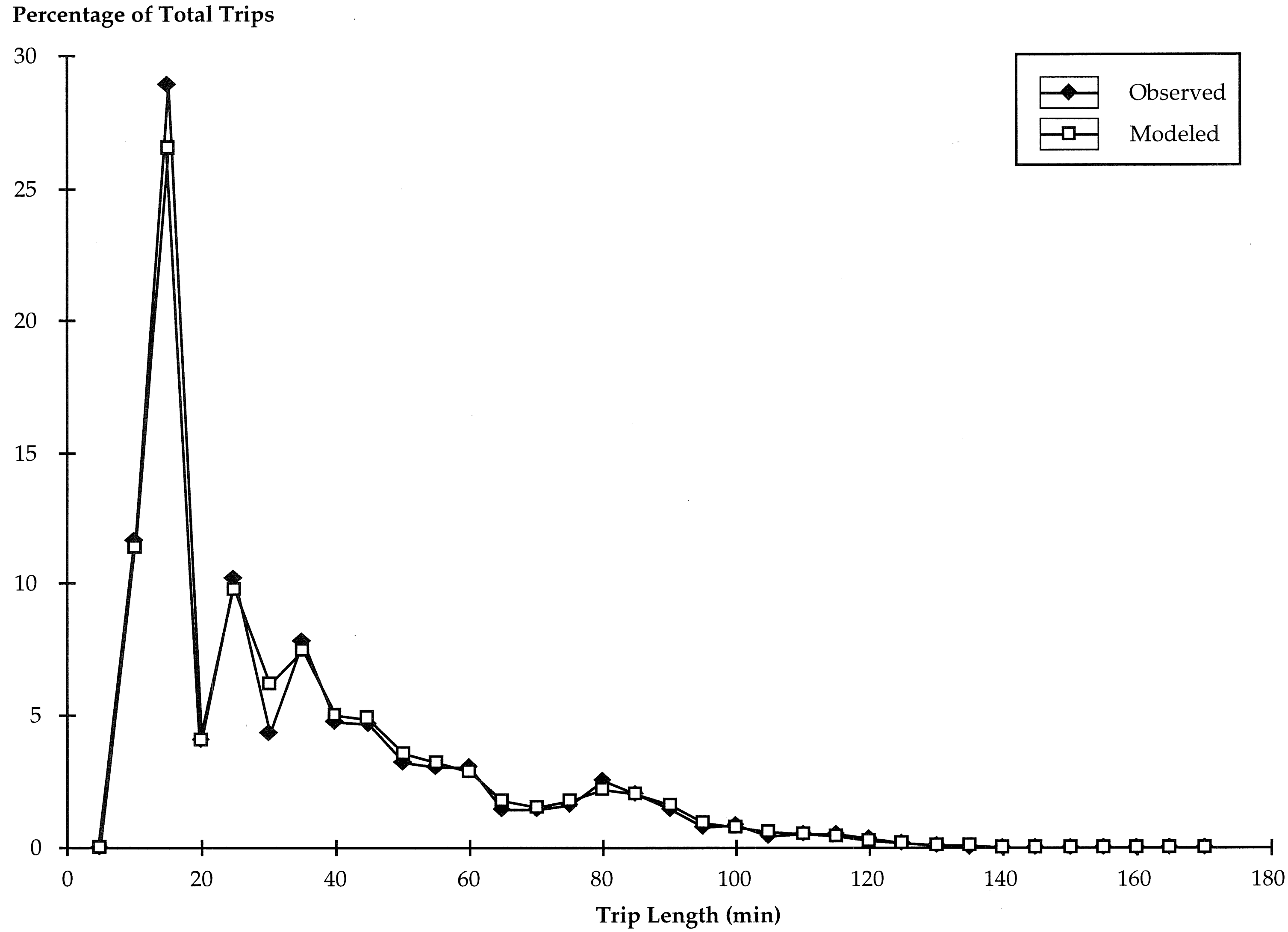


Figure 4.3 Comparison of Modeled and Observed Trip Length Frequencies
Arterials not Near Expressways

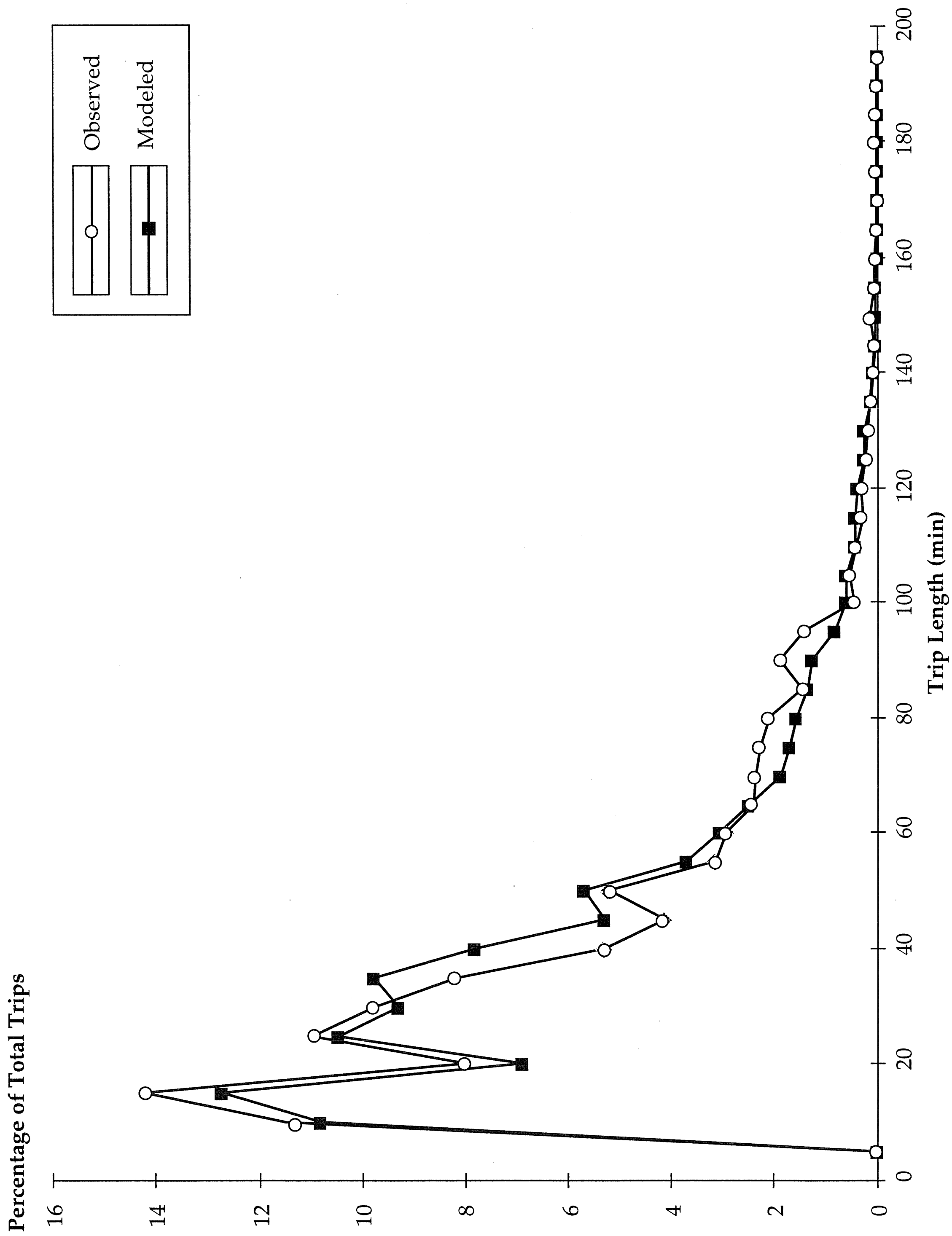


Figure 4.4 Comparison of Modeled and Observed Trip Length Frequencies
Local

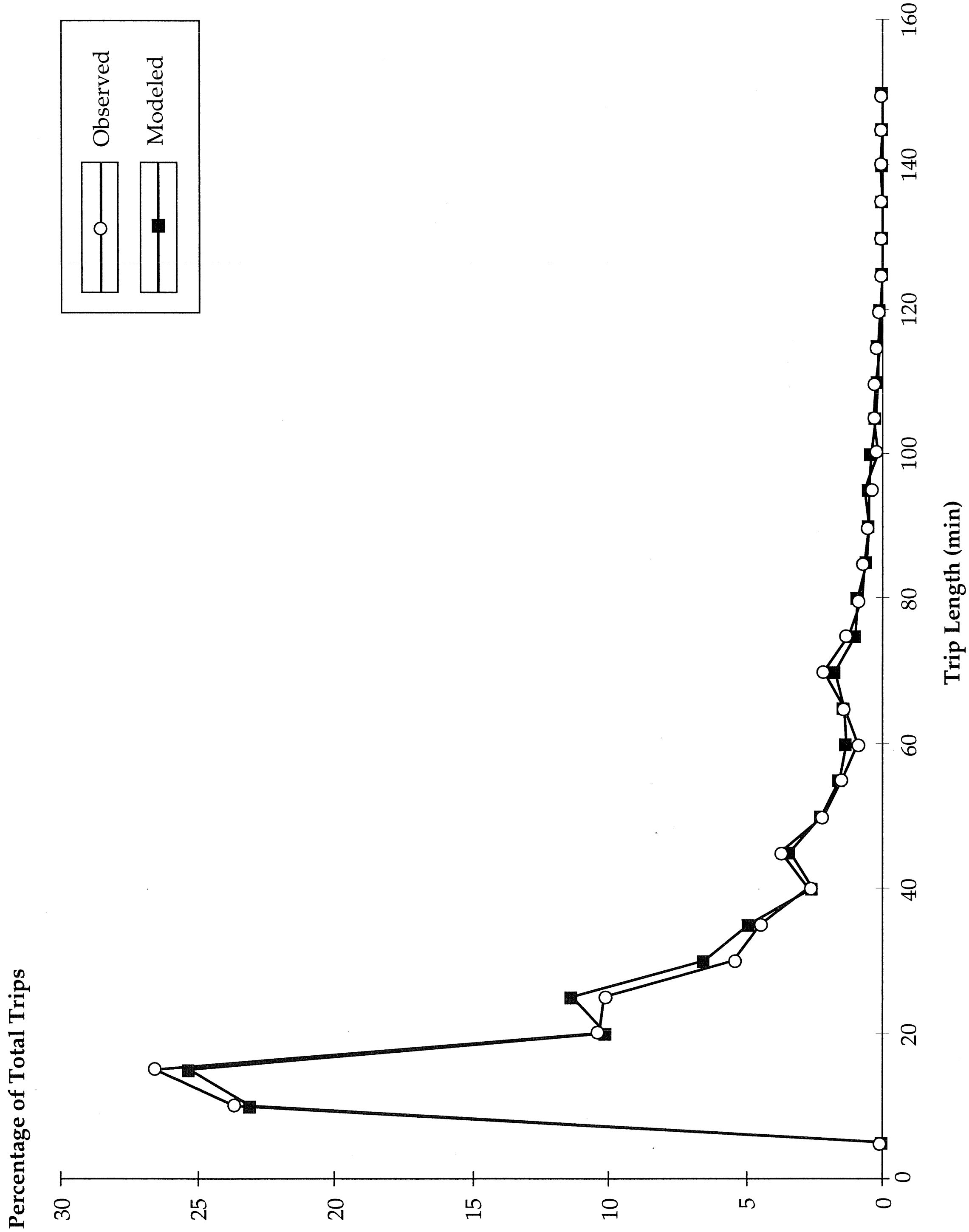


Figure 4.5a Friction Factors for Up to 60 Minutes

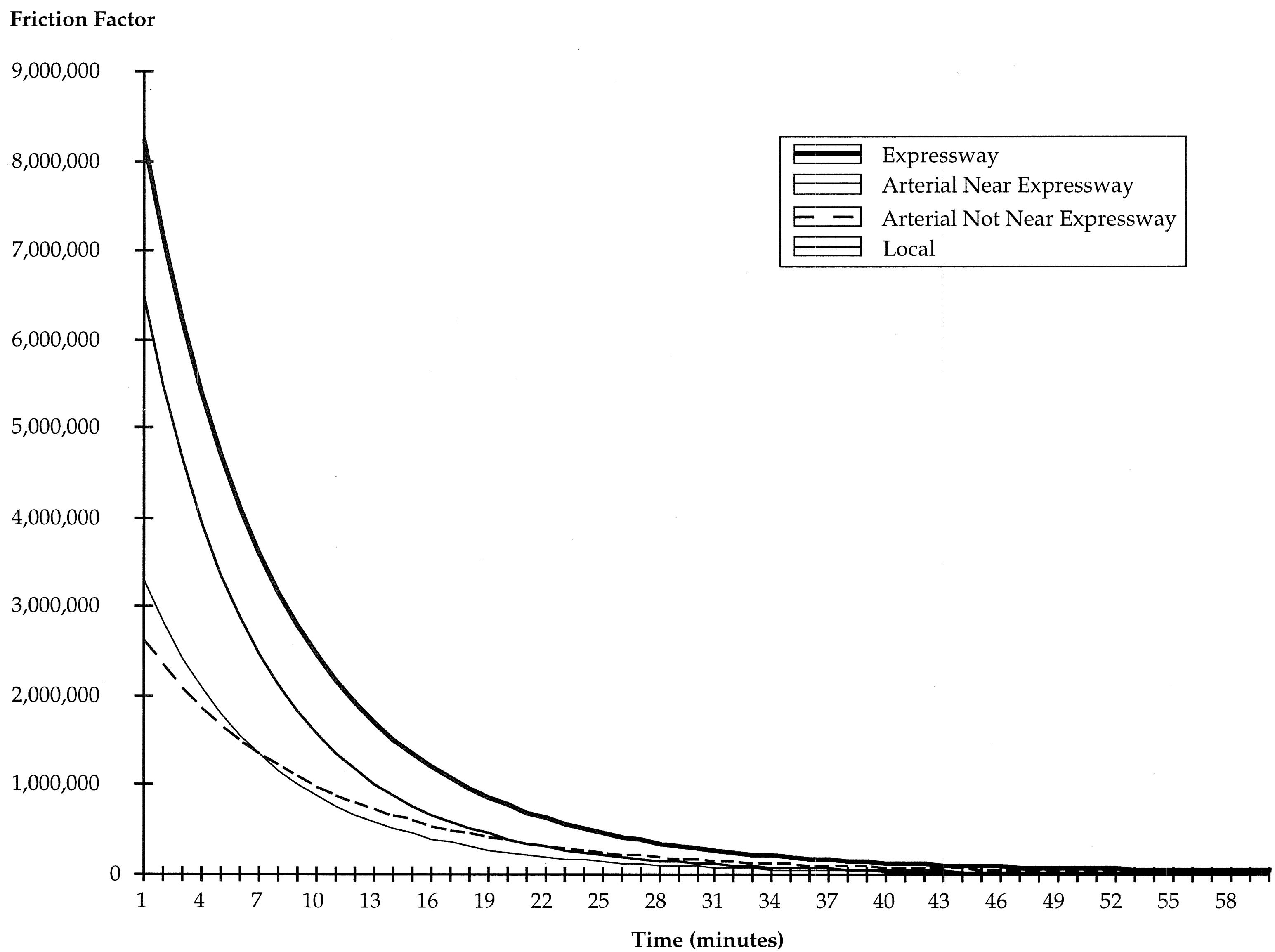
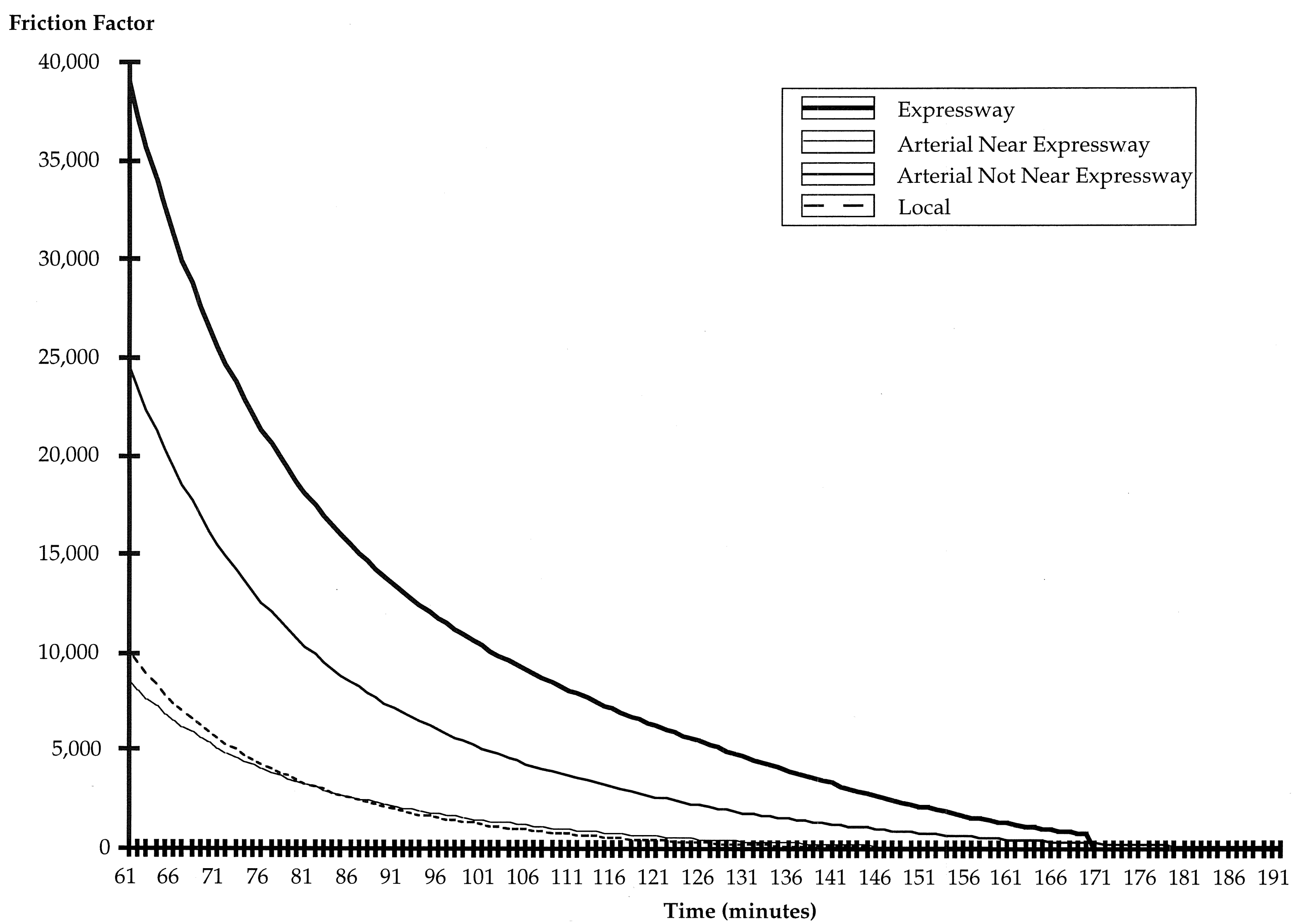


Figure 4.5b Friction Factors for 60 Minutes and Up



5.0 Summary

A new methodology for modeling external-local travel in the DVRPC travel model system has been developed and tested. This method consists of classifying external stations into four categories based on functional classification:

- Expressway;
- Arterial near expressway;
- Arterial not near expressway; and
- Local.

For each of these categories, new external-local trip generation and distribution models were developed. Each trip generation model for internal zones has a form that is linear in logarithms and is based on the number of internal trips generated and the highway distance from the nearest external station of the appropriate category. Each trip distribution model is a gravity model with its own set of friction factors. Both sets of models were calibrated using data from the 1988-1989 cordon survey for the DVRPC region. The new models compare well against the survey data.

The new models will be implemented within the existing DVRPC model programs. The trip generation models will be applied within the DVRPC trip generation programs. The trip distribution models will be applied as part of the TRANPLAN gravity model application programs, which are run simultaneously for all trip purposes. No changes to the mode choice, assignment, time of day, or vehicle availability processes are required.