CHAPTER 5

EXTERNAL TRAVEL ESTIMATION

INTRODUCTION

External trips are trips that have at least one end outside the study area defined by an encircling cordon line. When both the origin and destination of a trip are outside the cordon line, the trip is termed a through trip or external-external trip. When one trip end is outside the study area, the trip is classified as an external-internal or internal-external trip. The point on the roadway where the area cordon is crossed is referred to as an external station. Figure 10 displays the various types of external travel.

Because of the small proportion of external travel relative to total travel, the effort on measuring and modeling external travel has been less intensive than for internal travel. However, while the percentage of total travel that is external may be small, decisions regarding improvements to facilities that carry high percentages of external trips must be made with some degree of confidence in the estimate of external travel behavior. Very little is known about the population and employment characteristics at the end of the trip that is outside the internal study area. Travel is measured in vehicle trips instead of person trips, and transit trips from outside the region are often ignored. Future-year external travel is typically growth factored, using an average annual growth rate.

Historically, the most popular method for collecting external travel data is to conduct a roadside intercept survey at the regional cordon. Very few roadside surveys have been conducted in recent years, primarily because of the concern that stopping vehicles on the highway would be perceived as an unacceptable intrusion on the motorist. Poorly conducted roadside surveys have resulted in unnecessary delays and extended queues of vehicles. Alternative, nonintrusive survey methods have been used to collect external survey data. These include the following:

- The recording of license plate numbers (either through the use of video tape, direct reading of the plates into a tape recorder, or direct entry into a notebook computer by a survey recorder) and matching plate numbers at the cordon to obtain through trip tables; or
- The recording of license plate numbers (using one of the above methods), matching the number with Department of Motor Vehicle registration, and mailing out a survey form to the registered owner of the vehicle.

The first method provides data only on through travel and does not allow for the estimation of observed external-internal or internal-external travel. The second method, although providing data on all external travel, has the disadvantage of a definite time lag between the time the trip is actually made and the time the survey form is received by the driver. Even with direct entry of the plate number into a computer and overnight matching of numbers to registrant, it is at least 3 days (and more likely 4 to 5) before the registrant receives the survey forms. The registrant may not recall exactly where the trip was made or in some cases was not the driver of the vehicle. For these reasons, the roadside intercept is still the most cost-effective method for obtaining external travel data.

Techniques for estimating the number of trips generated within an area were discussed in Chapter 3. Depending on the size and geography of the study area, a majority of these trips will take place completely within the study area. The larger the study area's geographic limits, the less impact that external travel has on total travel.

This chapter presents a method for estimating external travel in a study area where an external survey is not available or possible. This step is typically done before trip distribution because the external-internal trips are distributed using the same procedure as internal trips. Through trips are needed before a traffic assignment can be performed. As will be noted in the next section, the procedure for estimating external travel is applicable only to smaller sized urban areas.

BASIS FOR DEVELOPMENT

In most regional or large-area studies, an external cordon survey is a required input to the travel modeling process. An external survey can provide accurate information on trip interchanges, particularly for through trips. In addition to the trip origin and destination, a number of other variables are needed to model external travel. The following information is typically asked during a roadside survey of vehicles entering the study area:

1. *Vehicle Class*. Vehicle class is important from several points of view. The vehicle's impact on the highway varies by size and weight, as does its impact on capacity and air quality. The minimum number of categories

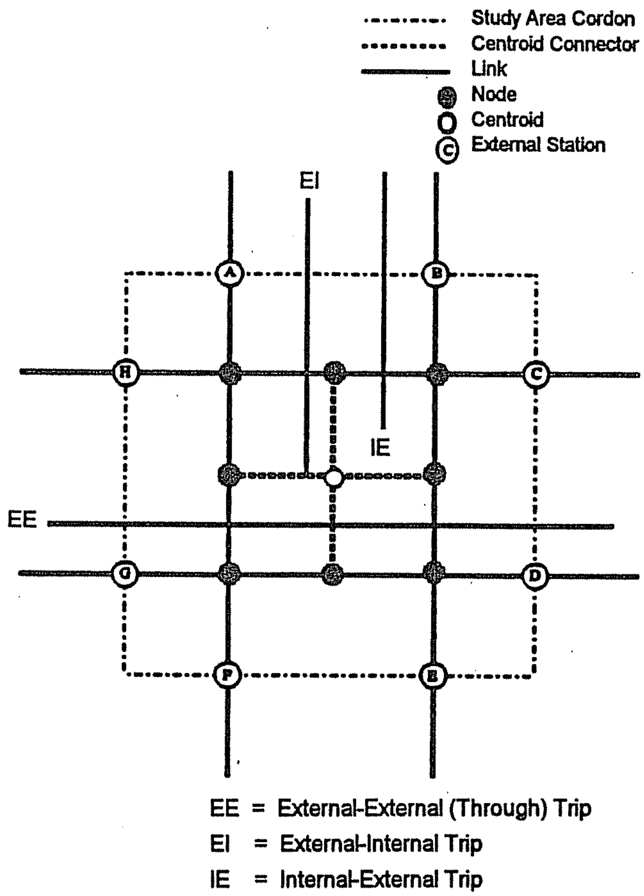

Figure 10. External travel diagram.

would seem to be cars, vans, and pickups as a group and trucks as a group. Some argument might be made for dividing trucks into light, medium, and heavy, and combining light trucks with automobiles, vans, and pickups to yield three strata. Of course, each added stratum imposes additional base year data requirements and methodological requirements.

2. *Trip Purpose.* The major person-trip purposes are work, shop, and school. The work trips typically have a longer trip length than do the shop trips. A minimum stratification probably should include work and other. No stratification of truck trips by trip purposes seems necessary.
3. *Resident Status.* The resident status for persons is simply whether they reside in the region, and for trucks, where they are garaged; i.e., if a truck is garaged in the study area normally, it is considered a resident.

The smaller area- and sketch-planning studies for which this report has been designed may not have the resources to conduct a survey of external travel. An alternative method for estimating external travel is required and presented in this chapter.

The trip rates presented in Chapter 3 represent all trips made by residents, including trips in which one end of the trip is outside the study area. These internal-external trips are part of the total productions for a zone. To create a trip table of internal-external movements, the relative attractiveness of each exit route or external station is needed.

The estimation of external trips assumes that counts of the average daily traffic (ADT) on each of the major highways entering the study area at the cordon line are available. The sum of the counts for all stations, representing total cordon crossings, is greater than the total number of external trips because through trips cross the cordon twice. If possible, classification counts should be conducted to determine the split between autos and trucks.

The following steps are required for developing internal-external, external-internal, and external-external volumes:

- Estimation of through trips at each station,
- Distribution of through trips between stations,
- Estimation of external-internal trip productions and attractions, and
- Distribution of internal-external and external-internal trips between internal zones and external stations.

The procedure presented below produces reasonable results for small urban areas, particularly those with populations of 50,000 or less. For interstates and principal arterials, the rates appear to be reasonable for areas with a population up to about 100,000. For areas with populations greater than 100,000, the method produces through trip percentages that are less than zero, an illogical conclusion. The research conducted in this project yielded very little in the treatment of external travel behavior. The characteristics of external travel are much more a function of the unique geographic location and character of each urban area and, as such, the opportunity for transferring external travel characteristics between urban areas is limited. The procedures presented below should be applied with extreme caution and the reasonableness of the results must be thoroughly reviewed.

ESTIMATION OF THROUGH TRIPS AT EXTERNAL STATIONS

The first step in the process will be to estimate through trips at the external stations. Previous research has shown that the percent of through trips at and between stations is related to the functional classification of the external highway, the connectivity of each external station pair, the average daily volume at the station, the relative size of the station, the size of the population of the study area, and the vehicle composition at the external station.

Through trips as a percent of all external trips vary from place to place. Data for selected cities are shown in Table 16.

TABLE 16 Through trips as a percent of external trips

Place	1990 Population	External - Internal Internal - External	External - External (Through)	Total
Chicago	6,070,000	95%	5%	100%
Twin Cities	2,464,000	93	7	100
San Diego	2,498,000	88	12	100
Phoenix	2,122,000	86	14	100
Reno	255,000	87	13	100
Wausau	37,000	80	20	100

Through trips as a percent of total external trips range from 5 percent in the largest region, Chicago, to 20 percent in the smallest region, Wausau.

D.G. Modlin, Jr., working with the State of North Carolina,[1,2] developed a model for estimating through trip ends at a station on the cordon of a study area. The model used functional classification of the highway, the ADT at the external station, the percentage of trucks (excluding vans and pickups), the percentage of vans and pickups, and the population of the study area.

The equation for estimating the percent through trips at an external station is

$$\begin{aligned} Y_i = {} & 76.76 + 11.22 \times I - 25.74 \times PA \\ & - 042.18 \times MA + 0.00012 \times ADT_i + 0.59 \\ & \times PTKS_i - 0.48 \times PPS_i - 0.000417 \times POP \end{aligned} \qquad (5\text{-}1)$$

where

Y_i = percentage of the ADT at external station i, that are through trips,
I = interstate (0 or 1),
PA = principal arterial (0 or 1),
MA = minor arterial (0 or 1),
ADT_i = average daily traffic at external station i,
$PTKS_i$ = percentage of trucks excluding vans and pickups at external station i,
PPS_i = percentage of vans and pickups at external station i, and
POP = population inside the cordon area.

In equation 5-1, an external station can be only one of the three functional classifications. For that classification, the value of the variable is 1; for the other two, the value will be 0 (i.e., functional class is a dummy variable).

[1]David G. Modlin, Jr. *Synthesis of Through Trip Patterns in Small Urban Areas*, Department of Civil Engineering, North Carolina State University, Raleigh (1971).
[2]David G. Modlin, Jr., "Synthesized Through-Trip Table for Small Urban Areas," *Transportation Research Record 842*, Transportation Research Board, National Research Council, Washington, DC (1982).

For illustration, given a route with ADT of 7,000, 6 percent heavy and medium trucks (excluding vans and pickups), and 10 percent vans and pickups, the following through trips percentages shown in Table 17 would be predicted by functional class using equation 5-1.

Because total through-trip percentages can vary substantially, it is important that the overall through trips be reasonable and the total should be checked after application of the equation. Regression models are particularly susceptible to error when used outside of the range of data used for the initial fitting or calibration.

If classification counts are not available at the cordon, the percentage of trucks at the external stations must be estimated. In *NCHRP Report 187*, total areawide truck trips were presented as a percent of areawide vehicle trips. At the time that report was released, truck traffic represented anywhere from 27 percent of total trips in areas with less than 100,000 population to 16 percent of total trips in the largest urbanized areas. Recent studies suggest that trucks are a smaller portion of the total vehicles on the road now, because of the increase in personal nonwork trips. A truck percentage between 5 percent and 15 percent of the total trips might be more realistic.

Once the percent of through trips crossing the cordon is estimated, the number of through trips can be calculated by station.

Using the example problem from Table 17, assume that an area with a population of 25,000 had a minor arterial with counts of 3,600 inbound and 3,400 outbound for a total of 7,000 ADT. The total through trips at the station would equal 24 percent of 7,000 or 1,680 crossings. This would be split into 864 through trips entering the area and 816 through trips leaving the area. The remaining 5,320 crossings have a trip end in the study area.

DISTRIBUTION OF THROUGH TRIPS BETWEEN STATIONS

The distribution of the estimated through-trip ends from an external station to each of the other external stations is the next step in obtaining a matrix of through trips among sta-

TABLE 17 Alternative through-trip percentages

Functional Class	Population 25,000	Population 50,000	Population 100,000
Interstate	77%	67%	46%
Principal Arterial	40	30	9
Minor Arterial	24	13	0 [2]

[1] Example problem assumes the following:

ADT = 7,000
Heavy and Medium Trucks = 6%
Vans and Pickup Trucks = 10%

[2] Computed value less than 0%, therefore use 0%

tions. If an area had 10 external stations, then the resulting vehicle trip table would be a matrix with 10 origins and 10 destinations.

Modlin developed equations, one for each functional class, to estimate the distribution of through trips that enter the analysis area at an origin external station (i) to each of the destination stations (j). For estimation of each interchange, the functional class of the destination station dictates which equation is to be used.

Interstate:

$$Y_{ij} = -2.70 + 0.21 \times PTTDES_j + 67.86 \times RTECON_{ij} \quad (5\text{-}2)$$

Principal Arterial:

$$Y_{ij} = -7.40 + 0.55 \times PTTDES_j + 24.68 \times RTECON_{ij} + 45.62 \times \frac{ADT_j}{\sum_{j=1}^{n} ADT_j} \quad (5\text{-}3)$$

Minor Arterial:

$$Y_{ij} = -0.63 + 86.68 \times \frac{ADT_j}{\sum_{j=1}^{n} ADT_j} + 30.04 \times RTECON_{ij} \quad (5\text{-}4)$$

where

Y_{ij} = percentage distribution of through-trip ends from origin station i to destination station j,

$PTTDES_j$ = percentage through-trip ends at destination station j,

$RTECON_{ij}$ = route continuity between stations i and j: 1 = Yes, 0 = No, and

ADT_j = average daily traffic at the destination station j.

Station-to-station trip movements also can be estimated using a simple factoring procedure which uses an external station's portion of the total through trips. However, because the geographic characteristics of the study area often determine the likely connections between stations, some effort should be made to ascertain the existing through movement patterns either by reference to earlier studies of the area or by general observations. The likely movements can be set using control totals.

Example of Through-Trip Table Estimation

To illustrate the application of through-trip procedures, a simple five-station external example is presented. Assume that the data in Table 18 have been observed at the external stations.

In this example, stations 101 and 103 are two points on a continuous route, and stations 102 and 104 are two points on another continuous route.

The estimated through trips for each station are computed using the equation:

$$Y_i = 76.76 + 11.22 \times I - 25.74 \times PA - 42.18 \times MA + 0.00012 \times ADT_i + 0.59 \times PTKS_i - 0.48 \times PPS_i - 0.000417 \times POP$$

For example, the percent through trips for station 101 would be:

TABLE 18 Example data for through-trip estimation

Station	Functional Classification	ADT	Percent Trucks	Percent Vans and Pickups
101	Principal Arterial	15,000	5	10
102	Interstate	25,000	10	10
103	Principal Arterial	10,000	7	10
104	Interstate	20,000	10	10
105	Minor Arterial	5,000	3	10
Total		75,000		

$$Y_{101} = 76.76 + 11.22 \times 0 - 25.74 \times 1 - 42.18 \times 0 + 0.00012 \times 15{,}000 + 0.59 \times 5 - 0.48 \times 10 - 0.000417 \times 50{,}000 = 30$$

The resulting through trips are presented in Table 19. The trips have been rounded to the nearest 100 trips.

The next step is to estimate the distribution of the through trips between the external stations. The equations presented previously are used and the results are normalized in order for the sum of the distribution percentages to be equal to 100 percent. For example, the distribution of trips from station 101 to the other four stations is presented in Table 20.

The through-trip distributions are computed for each of the four remaining external stations. Table 21 contains the normalized percentages of through trip distributions among the five stations. The percentages sum to 100 percent down each column.

TABLE 19 Through trips

Station	ADT	Percent Through	Through Trips	E-I and I-E Trips
101	15,000	30	4,500	10,500
102	25,000	71	17,800	7,200
103	10,000	31	3,100	6,900
104	20,000	71	14,100	5,900
105	5,000	11	600	4,400
Total	75,000		40,100	34,900

TABLE 20 Distribution of through trips for external station 101

Origin Station	Destination Station	Calculated Percent	Normalized Percent
101	102	12%	18%
	103	40	58
	104	12	17
	105	5	7
	Total	70	100

TABLE 21 **Through-trip distribution percentages**

Destination Station	Origin Station 101	102	103	104	105
101	—	15	59	16	31
102	18	—	17	67	21
103	58	13	—	13	27
104	17	67	17	—	21
105	7	4	7	4	—
Total	100	100	100	100	100

The percentages presented in Table 21 are applied to the through trips presented in Table 19 for each external station. Table 22 contains the initial through-trip table.

Note that the row totals of trips do not equal the desired number of trips for each external station and that the table is not symmetrical about the intrastation diagonal. For example, the trips from 101 to 102 equal 2,736 trips while the trips from 102 to 101 equal 790. Because the trips represent average daily trips, the table should be symmetrical. The trip table is averaged to produce a table symmetrical about the diagonal. This symmetrical trip table is presented in Table 23.

At this step in the process, the row and column totals are equal; however, they are not equal to the desired number of through trips at each external station. This difference is presented in Table 24.

The most common procedure for adjusting a trip table to match desired row and column totals is the matrix balancing or Fratar technique. Many of the travel demand software packages have programs for applying this technique. The major use of the technique is to produce future-year trip tables that are growth factored. Table 25 contains the balanced or "Fratared" external through-trip table.

The resulting through-trip table is saved for later use in traffic assignment. The station-to-station vehicles are added to the total vehicle trips and assigned using the standard highway assignment procedures. Although the through trips are a minor portion of total vehicle trips in a region, the external-external volumes have a significant impact on facilities crossing the cordon line and passing entirely through the study area.

ESTIMATION OF EXTERNAL-INTERNAL TRIP PRODUCTIONS AND ATTRACTIONS

The estimation of external-internal trip productions and attractions is needed as part of the trip generation process. In Chapter 3, the section on balancing productions and attractions specified the need for external travel information in developing regional control totals by purpose. In fact, the approach for developing external productions and attractions is determined by whether or not the external trips made by

TABLE 22 **Initial through-trip table**

Destination Station	Origin Station 101	102	103	104	105	Total
101	—	2,736	1,837	2,165	188	6,926
102	790	—	524	9,483	126	10,924
103	2,595	2,329	—	1,843	160	6,927
104	782	11,965	519	—	125	13,391
105	332	770	220	609	—	1,932
Total	4,500	17,800	3,100	14,100	600	40,100

TABLE 23 Averaged through-trip table

Destination Station	Origin Station 101	102	103	104	105	Total
101	—	1,763	2,216	1,474	260	5,713
102	1,763	—	1,426	10,724	448	14,362
103	2,216	1,426	—	1,181	190	5,013
104	1,474	10,724	1,181	—	367	17,746
105	260	448	190	367	—	1,266
Total	5,713	14,362	5,013	13,746	1,266	40,100

residents of the region are included in the trip generation rates by trip purpose. If external trips are not included with the home-based work, home-based other, or non-home-based trips, the external trips could be treated as a separate purpose. The approach outlined in this report assumes that external trips are included in the trip rates by purpose.

The first part of this step will be to summarize the through-trip matrix by direction and station and subtract these totals from the station counts. The remainders represent the overall control totals by station for external-internal trips. While the counts conducted at the external stations might show differences in the number of vehicles traveling into and out of the study area on a particular route, the directional differences are ignored. This assumption, that the total trips entering the study area equals the total trips leaving the study area on a typical day, simplifies the process used to estimate external-internal travel.

The next step involves separating the external trips by purpose and resident status. The resident totals by purpose become the attractions at each station. Nonresident totals by purpose become the productions at each station.

If an external survey has been conducted, information on the purpose and residency status of trips could be used directly to estimate productions and attractions. External truck trips could be treated separately in determining the residency status based on the garage location. However, when basic information on external travel is not available, it will be necessary to apply typical factors by station. These factors are applied to the two-way ADT by station.

While the external travel characteristics of cities and metropolitan areas can vary significantly, a few common variables exist. Earlier it was stated that the size of the study area affects the percentage of through trips. The size of a region (in area), its socioeconomic characteristics, and proximity to other urbanized and suburban areas are other factors that affect the purpose and residency status of external-internal trips. The existence of a strong employment center within the study area will tend to pull more nonresidents into the region to seek employment. In areas where trip attractions such as employment and shopping are distributed more evenly between the areas inside and outside the cordon, the split between resident and nonresident trips at the cordon becomes relatively equal. Alternatively, a region that is mostly suburban may have a shortage of overall employment opportunities and a surplus of service and retail employment. In such a community, the flow of trips across the cordon could reflect a net export of work trips and a net import of other trips.

TABLE 24 Difference between calculated and desired external station through trips

External Station	Calculated Trips	Desired Trips	Ratio Desired/ Calculated
101	5,713	4,500	0.79
102	14,342	17,800	1.24
103	5,013	3,100	.63
104	13,746	14,100	1.03
105	1,266	600	.47
Total	40,100	40,100	

TABLE 25 Balanced through-trip table

Destination Station	Origin Station 101	102	103	104	105	Total
101	—	2,781	974	662	83	4,500
102	2,781	—	1,684	12,952	383	17,800
103	974	1,684	—	397	45	3,100
104	662	12,952	397	—	89	14,100
105	83	383	45	89	—	600
Total	4,500	17,800	3,100	14,100	600	40,100

Tables 26 and 27 show the split of internal-external trip totals by purpose and resident status for an area with a centralized activity center—San Juan, Puerto Rico—and an area with a more even distribution of activities on either side of the cordon—San Diego, California. These are presented to show the variation possible when planning regions have strong central activity centers or more diffuse employment.

These examples also demonstrate another characteristic of traffic across cordons: the number of work trips across the cordons is greater than the regional share of work trips. Two obvious reasons can be used to explain this phenomenon: (1) auto occupancy for work trips is generally lower than for all other purposes, so the share of vehicle trips that are carrying work trips is higher than the share of person trips that are work trips; and (2) average trip lengths for work trips are generally longer than average trip lengths for other trip purposes so work trips tend to be more likely to pass between regions than trips made for other purposes. If no data are available to estimate the distribution of inter-regional vehicle trips, local knowledge should be used to estimate the values from the following ranges: home-based work—25 to 50 percent of total vehicle trips across the cordon; home-based other—30 to 50 percent; non-home-based—15 to 25 percent. These default values for external travel should be used cautiously, however, and external surveys are highly recommended.

Returning to the example in Table 19 in which through trips were estimated, the external-internal trip productions and attractions also can be estimated. It was noted that 34,900 of the crossings represented external-internal or internal-external trips. The 10,500 external-internal trips for station 101 could be split as follows: 3,675 home-based work (35%); 4,200 home-based other (40%); and 2,625 non-home based (25%).

The next step in the process is to translate the vehicle trips into productions and attractions. External station productions are trips whose home base is outside of the region, and external station attractions are trips whose home is within the region. The task of splitting the vehicle trips is therefore dependent on a basic level of knowledge of the general land use and travel patterns in and around the study area. Suppose that the study area in the preceding example is primarily a suburban area 20 miles away from a major urban area. Suppose also that the primary attractions in the study area are a major university and several regional shopping centers. If local knowledge tells us that the

TABLE 26 External trip purpose/residency factors for centralized areas[1]

Trip Purpose	Resident	Non-Resident	Total
Home-Based Work	12%	34%	46%
Home-Based Other	9	23	32
Non-Home-Based	11	11	22
Total	32	68	100

[1] San Juan, Puerto Rico 1990 External Cordon Survey.

TABLE 27 External trip purpose/residency factors for evenly distributed areas[1]

Trip Purpose	Resident	Non-Resident	Total
Home-Based Work	15%	10%	25%
Home-Based Other	27	23	50
Non-Home-Based	8	17	25
Total	50	50	100

[1] San Diego Region.

predominant flow of traffic during the a.m. peak period flows from out of the study area at the ratio of 3 to 1, we could make the following assumptions: 75 percent of external-internal home-based work trips have productions within the study area; 40 percent of the home-based other trips have productions within the study area; and (by definition) 50 percent of the non-home based trips have productions within the study area. The following table would summarize the 10,500 external-internal trips associated with station 101:

Trip Purpose	Productions	Attractions	Total
Home-Based Work	919	2,756	3,675
Home-Based Other	2,520	1,680	4,200
Non-Home Based	1,312	1,313	2,625
Total	4,751	5,749	10,500

The trip attractions would equal 5,749 vehicles and the trip productions would equal 4,751 vehicles at external station number 101. These vehicle trips need to be converted to person trips using the automobile occupancy rates presented in Chapter 7 before they can be included in the final steps of the trip generation process.

DISTRIBUTION OF INTERNAL-EXTERNAL AND EXTERNAL-INTERNAL TRIPS

After the external productions (nonresident trips) and attractions (resident trips) have been estimated for each station and purpose, they are used in the standard modeling process to reflect trips between internal zones and external stations. In trip generation, control totals of trip productions can be calculated using the external totals to balance productions and attractions. While attractions should be normalized to productions for internal trips, the external station attractions should be held constant, because they represent actual counts of the base year. This was shown in Equation 3-1 in Chapter 3. Trip distribution of internal-external and external-internal trips follows the conventional gravity model approach described in Chapter 4, Trip Distribution.

CASE STUDY

As has been discussed previously, external trips can be divided into two categories: external-external trips, which pass completely through the region without having a trip-end within the region, and external-internal trips, which have one trip-end within the region and one trip-end outside of the region. The external-internal trips are converted to person trip-ends and incorporated into the regional trip generation model, while the external-external trips are expressed as a separate trip table that is added to the other vehicle-trip tables before assignment.

The procedures used to estimate external travel for the Asheville case study are listed below. All of the calculations were performed with the aid of a computer spreadsheet program.

Classification of External Stations

Average daily traffic (ADT) counts were collected for 16 facilities crossing the external cordon around the Asheville region. These ADT counts were collected at each location where significant traffic volumes flow into or out of the Asheville region. Each of these external stations was classified as either a minor arterial, a principal arterial, or an interstate facility. In addition, external station pairs that were linked by a continuous facility were noted because they would be expected to carry a statistically significant share of external-external traffic. The most notable of these pairs in the Asheville region are stations 109 and 117, which are connected by the Route 19/23 bypass and Interstate 26, and stations 114 and 121, which are connected by Interstate 40.

Estimation of Through-Trip Percentages

The synthetic procedures outlined previously in this chapter for estimating the share of external cordon trips that are likely to be through trips are only appropriate for urbanized areas with less than 50,000 in population. Therefore, local experience must be relied upon to estimate the through-trip-making potential for the Asheville region. This experience was used to classify four facilities, those carrying ADT volumes of greater than 20,000, as interstates, each of which was estimated to contribute 30 percent of its traffic to the external-external trip table. Another two facilities, designated as principal arterials, were estimated to have a 10 percent through-trip share each. The remainder of the external stations were designated as minor arterials and were assumed to contribute a negligible share of their ADT volumes to the through-trip table.

Table 28 displays the external station volumes including the estimated number of through trips and internal-external trips. All of the data in this table reflect vehicle trips, because the data are based upon existing traffic count data.

Distribution of Through Trips to External-External Trip Table

The distribution of through trips between stations is estimated using Equations 5-2, 5-3, and 5-4. The relative shares were first calculated as in the following example for the interchange between external stations 109 and 117, which represent the eastern and western extremities of I-40 within the study area:

$$Y_{ij} = -2.70 + 0.21 \times PTTDES_j + 67.86 \times RTECON_{ij}.$$
$$= -0.70 + 0.21 \times 30 + 67.86 \times 1 = 71.46$$

TABLE 28 External station through-trip summary

Station Number	Description	1989 ADT	Classification	Percent Through	External-External	Internal-External
108	Route 251	1,800	Minor	0	0	1,800
109	Routes 19 & 23 Bypass	27,700	Interstate	30	8,310	19,390
110	Routes 19 & 23 Business	7,000	Minor	0	0	7,000
111	BRP (N)	2,850	Minor	0	0	2,850
112	Snope Creek Road	2,000	Minor	0	0	2,000
113	Route 70	16,100	Principal	10	1,610	14,490
114	I-40 (E)	24,700	Interstate	30	7,410	17,290
115	Route 74	11,000	Minor	0	0	11,000
116	Route 25	12,450	Minor	0	0	12,450
117	I-26	33,100	Interstate	30	9,930	23,170
118	Routes 191 & 280	7,400	Minor	0	0	7,400
119	BRP (S)	970	Minor	0	0	970
120	Route 151	1,550	Minor	0	0	1,550
121	I-40 (W)	27,500	Interstate	30	8,250	19,250
122	Leicester Highway	14,000	Principal	10	1,400	12,600
123	Bear Creek Road	3,940	Minor	0	0	3,940

where

Y_{iy} = percentage distribution of through-trip ends from origin station i to destination station j,
i = 109,
j = 117,
$PTTDES_j$ = percentage through trip ends at destination station j, and
$RTECON_{ij}$ = 1 = route continuity flag for stations i and j.

The calculations for the other external station pairs are displayed in Appendix Table B-4.

The relative shares for each of the possible destinations from a cordon station are added together and the result is used to normalize the raw data. Table 29 displays the raw shares and the normalized shares for each of the potential destinations for through trips entering the region at each of the six external stations.

Next, the normalized shares were used to distribute the through trips originating at those stations to the other five external stations expected to contribute a significant number of through trips to the external-external trip table. For station 109, the adjusted shares were used to distribute the 8,310 through trips originating at that station to the other five stations. The same procedure was used to distribute the through trips associated with the other five interstate and principal external stations. The results of this process are displayed in Table 30. Note that, for intuitive reasons, there are no *intrazonal* trips within the external zones, and that there are no trips allowed between stations 113 and 114, which are proximate, parallel facilities unlikely to attract trips from one another.

Given that the values arrived at in Table 26 are not symmetrical (i.e., the number of trips from station i to j is not equal to the number of trips from j to i) the next step is to average the ij and ji values to produce a symmetrical trip table. For example, given that the estimated value from station 109 to station 117 is 7,031, and the value from station 117 to 109 is 8,402, the average value between stations 109

TABLE 29 Through-trip distribution—raw and normalized percentages

	Origin Station					
Destination Station	109	113	114	117	121	122
Raw Percentages						
109	—	3.60	3.60	71.46	3.60	3.60
113	3.23	—	—	3.23	3.23	3.23
114	3.60	—	—	3.60	71.46	3.60
117	71.46	3.60	3.60	—	3.60	3.60
121	3.60	3.60	71.46	3.60	—	3.60
122	2.56	2.56	2.56	2.56	2.56	—
Total	84.46	13.36	81.22	84.46	84.46	17.63
Norm. Factor	1.184	7.483	1.231	1.184	1.184	5.671
Normalized Percentages						
109	—	26.94	4.43	84.61	4.26	20.42
113	3.83	—	—	3.83	3.83	18.33
114	4.26	—	—	4.26	84.61	20.42
117	84.61	26.94	4.43	—	4.26	20.42
121	4.26	26.94	87.98	4.26	—	20.42
122	3.03	19.18	3.16	3.03	3.03	—
Total	100	100	100	100	100	100

TABLE 30 Through-trip table—asymmetrical

Destination Station	Origin Station 109	113	114	117	121	122	Total
109	—	434	328	8,402	352	286	9,802
113	318	—	—	380	316	257	1,271
114	354	—	—	423	6,981	286	8,044
117	7,031	434	328	—	352	286	8,431
121	354	434	6,519	423	—	286	8,016
122	252	309	234	301	250	—	1,347
Total	8,310	1,610	7,410	9,930	8,250	1,400	36,910

and 117 is 7,717. The results of this exercise are displayed in Table 31, the symmetrical trip table.

The result of this latest maneuver, however, is a trip table in which the row totals and column totals are not equal to the through volumes estimated in Table 28. The recommended solution to this problem is to apply the Fratar technique to the symmetric trip table, using the through trip volumes in Table 28 as the row and column targets. The ultimate result of the Fratar process is the final external-external vehicle trip table, as displayed in Table 32.

Conversion of Internal-External Trips to Person-Trip Productions and Attractions

In order to estimate the internal-external vehicle trip totals, the through-trip totals were subtracted from the external station totals as shown in Table 28. Next the external trip purpose factors were applied to the external-internal totals. Local knowledge of the region is used to estimate that the traffic crossing the external cordon is composed of 40 percent home-based work trips, 40 percent home-based other trips, and 20 percent non-home-based trips. Local experience is then used to further estimate that the Asheville area is a net importer of work trips, by a ratio of 70 to 30, and that the region is a net importer of other home-based trips by a ratio of 60 to 40. The non-home-based trips are assumed to be balanced between productions and attractions. Finally, auto-occupancy factors (from Chapter 7) of 1.11 persons per vehicle for home-based work trips, 1.67 persons per vehicle for home-based other trips, and 1.66 persons per vehicle for non-home-based trips were used to convert the vehicle trips to person trips. The resulting estimates of trip productions and attractions for external stations in the Asheville region are

TABLE 31 Through-trip table—symmetrical

Destination Station	Origin Station 109	113	114	117	121	122	Total
109	—	376	341	7,717	353	269	9,056
113	376	—	—	407	375	283	1,440
114	341	—	—	376	6,750	260	7,727
117	7,717	407	376	—	387	294	9,180
121	353	375	6,750	387	—	268	8,133
122	269	283	260	294	268	—	1,373
Total	9,056	1,440	7,727	9,180	8,133	1,373	36,910
Target	8,310	1,610	7,410	9,930	8,250	1,400	36,910
Adj. Factor	0.918	1.118	0.959	1.082	1.014	1.020	

TABLE 32 Through-trip table—after the Fratar adjustment

Destination Station	Origin Station 109	113	114	117	121	122	Total
109	—	222	167	7,526	243	152	8,310
113	222	—	—	676	439	273	1,610
114	167	—	—	515	6,521	207	7,410
117	7,526	676	515	—	746	467	9,930
121	243	439	6,521	746	—	301	8,250
122	152	273	207	467	301	—	1,400
Total	8,310	1,610	7,410	9,930	8,250	1,400	36,910

summarized in Table 33. This table shows that the estimated 157,150 external-internal vehicle trips crossing the cordon around the Asheville region carried 226,925 person trips, including 137,915 productions (from locations outside the region) and 89,010 attractions (to locations outside the region).

SUMMARY

This is a review of steps required to estimate external travel. The key is knowing the ADT by direction for trucks and autos at each external station.

TABLE 33 External-internal person-trip productions and attractions

Station Number	Productions			Attractions		
	HBW	HBO	NHB	HBW	HBO	NHB
108	559	721	298	239	480	298
109	6,026	7,771	3,218	2,582	5,181	3,218
110	2,175	2,805	1,162	932	1,870	1,162
111	885	1,142	473	379	761	473
112	621	801	332	266	534	332
113	4,503	5,807	2,405	1,930	3,871	2,405
114	5,373	6,929	2,870	2,303	4,619	2,870
115	3,418	4,408	1,826	1,465	2,939	1,826
116	3,869	4,989	2,066	1,658	3,326	2,066
117	7,201	9,286	3,846	3,086	6,191	3,846
118	2,299	2,965	1,228	985	1,977	1,228
119	301	388	161	129	259	161
120	481	621	257	206	414	257
121	5,982	7,715	3,195	2,564	5,143	3,195
122	3,916	5,050	2,091	1,678	3,366	2,091
123	1,224	1,579	654	524	1,052	654
Total Person Trips	48,842	62,985	26,086	20,932	41,990	26,086

1. Collect classification counts at each cordon station.
2. Estimate percentage of through trips (E-E) at each cordon station.
3. Take through trips and distribute to create the E-E trip table. This vehicle trip table will be used in the traffic assignment step.
4. Subtract through trips from total ADT at each station to get E-I/I-E totals.
5. Apply the trip purpose and residence (direction) factors to two-way ADT by station. Resident totals by purpose correspond to attractions at each external station. Nonresident totals by purpose correspond to productions at each external station.
6. Convert external-internal vehicle-trip productions and attractions to person trips (Chapter 7) and complete balancing of Ps and As by purpose as shown in Chapter 3.
7. Distribute the E-I and I-E trips using the gravity model by trip purpose (i.e., HBW, HBO, and NHB) as shown in Chapter 4.