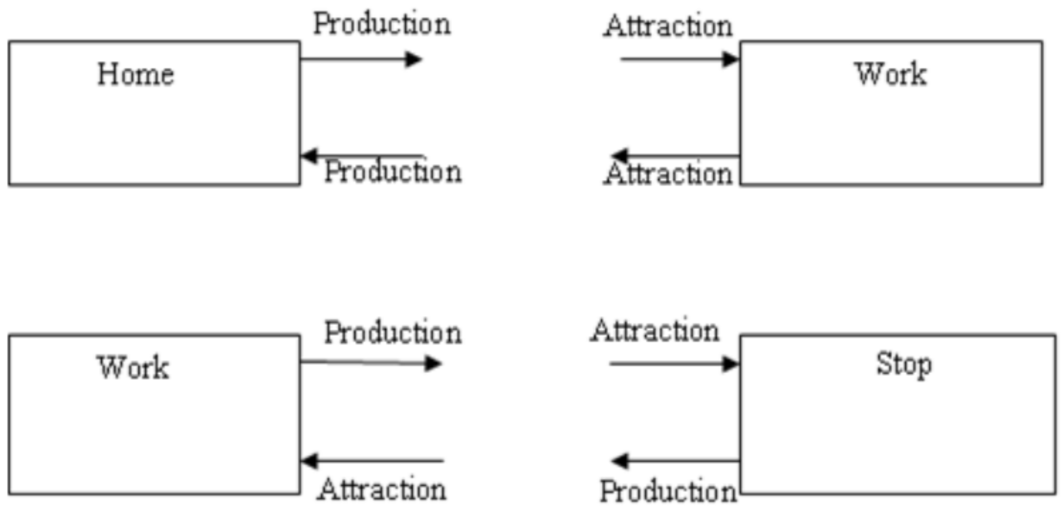
Trip Generation Model

Introduction

Trip Generation is the first step in the Sequential Demand Modelling arrangement which is also called as the Four Step Transportation Planning Process(FSTP) as mentioned earlier. In order to carry out modelling, the variable consists of total number of person-trips generated by a zone as a dependent variable and the independent variable consists of household and socio- economic factors which influence the trip making behaviour of the person. The data for the independent variable should be attained from an analyst. The output thus obtained consists of trip making or trip ends for each zone within a region.

In contemporary transportation planning language, A Trip is defined as a one way person movement by a mechanized mode of transport, having two trip ends. The start of the trip is called as origin and the end of trip is called as destination. Trip is classified as Production or Origin and Attraction or Destination. It should be note that the terminologies used are not identical. To understand with an example consider a single worker on a typical working day making a trip from his house which is in zone P to his office in Zone Q. Thus his trip origin will be zone P and trip destination will be zone Q. For the return trip from office to house his trip origin will be zone Q and trip Destination will be Zone P. Thus from the above Example it can be understood that the term Origin and Destination are defined in terms of direction of the trip while Production and Attraction in terms of land use associated with each trip end. Trip Production is the home end of home based trip and is the origin of trip of non- home based trip. Trip Attraction is the non- home end of home based trip and is the destination of a non-home based trip.



Classification of Trips

It has been found that better trip generation models can be obtained if the trips by different purpose are identified and modelled separately. The trips can be classified as given below:

1. Home Based Trip: One of the trip end is home.

Example: A trip from home to office.

Following are the list of home based trips that is trip purpose which are classified into five categories:

- Work Trips
- School Trips
- Shopping Trips
- Social- recreational Trips
- Other Trips

The first two trips are mandatory trips while other trips are discretional trips. The other trip class encompasses all the trips made for less routine purpose such as health bureaucracy etc.

2. Non Home based trips: None of the trip end is home.

Example: A trip from office to Shopping Mall.

3. Time based trips

The proportion of journey is different by different purposes usually varies with time of the day. Thus the classification is often given as Peak and Off Peak Period Trip.

Example

Time	Cars	Bus	Two Wheelers	Rickshaw
7:00 - 7:30	34	8	40	24
7:30 - 8:00	39	9	45	30
8:00 - 9:30	45	12	55	35

4. Person-type based trips

The travel behaviour of an individual is mainly dependent on its Socio-Economic attributes. Following are the categories which are usually employed.

- Income Level- Poor, Middle Class, Rich
- Car Ownership- 0,1,2,3
- Household Size- 1,2,3,4... etc.

Factors influencing Trip Production

- No. of workers in a household.
- No. of Students.
- Household size and composition.
- The household income.
- Some proxy of income such as number of cars etc.

Factors influencing Trip Attraction

- Floor area and number of employment opportunities in retail trade, service, offices manufacturing and wholesale areas.
- School and college enrolment
- Other activity centers like transport terminals, sports stadium, major recreational/ cultural/religious places

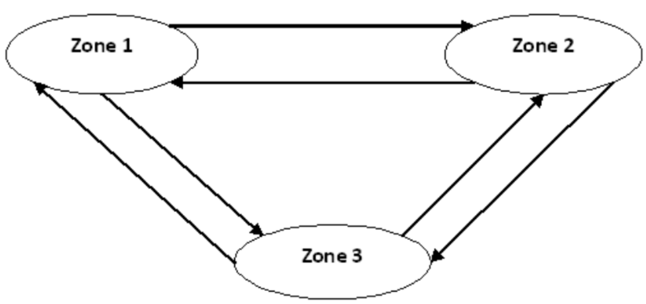
Table below represents base year data of Trip Production for exact zone.

Zone	Trips Produced	Home based trips(HBT)	Non Home based Trips(NHT)	Car Ownership(CO)
1	100	50	35	12
2	150	45	36	35
3	127	36	23	34
4	150	57	36	58
5	170	48	55	35

Similarly Trip Attraction Table is obtained with respect to its influencing variables.

Trip generation study typically involves the application of residential trip production which contains variable that defines the demographic makeup of zonal population and trip attraction that captures the activity of non-residential activities within the zone.

In the example given below the zones are connected by a two way link. Each zone will have its own demographic and non-residential characteristics depending on which the Trip Generation table is represented below.



Zone		Trips Production(P)	Trip Attraction(A)
1	2	20	34
2	2	25	25
2	1	35	55
2	3	67	70
3	2	55	75

The procedure to obtain the PA Table (shown above) from the base year condition of Trip Production and Attraction is explained in the next section call Modelling.

Modelling Trip Production

Modelling basically relates the dependent variable ie trips produced by a zone for aggregated model or household trip production rate for household based models to the corresponding Independent variables characterized by the whole zone or household characteristic respectively. Calibration is done based on the set of observations obtained corresponding to the zones for aggregate model and for disaggregate model employs a number of base year observations corresponding to an individual household in a sample of household drawn randomly from the region.

Thus we first need to identify what are the relevant variables:

- Home end
- Work end
- Shop end

The purpose of trip generation is to estimate the number of trip ends for each zones for the targeted year. The trip end is calculated for different travel purpose within the zone. These trips are represented as residential trip production obtained from household based cross classification tables or non-residential trip attractions which is obtained by projection of land use. Trip generation Models that are often used are Multiple Linear Regression Model or Cross Classification Model or involves combination of both.

Trip generation is the process of determining the number of trips that will begin or end in each traffic analysis zone within a study area. Since the trips are determined without regard to destination, they are referred to as trip ends. Each trip has two ends, and these are described in terms of trip purpose, or whether the trips are either produced by a traffic zone or attracted to a traffic zone. For example, a home-to-work trip would be considered to have a trip end produced in the home zone and attracted to the work zone. Trip generation analysis has two functions:

- To develop a relationship between trip end production or attraction and land use.
- To use the relationship to estimate the number of trips generated at some future date under a new set of land use conditions.

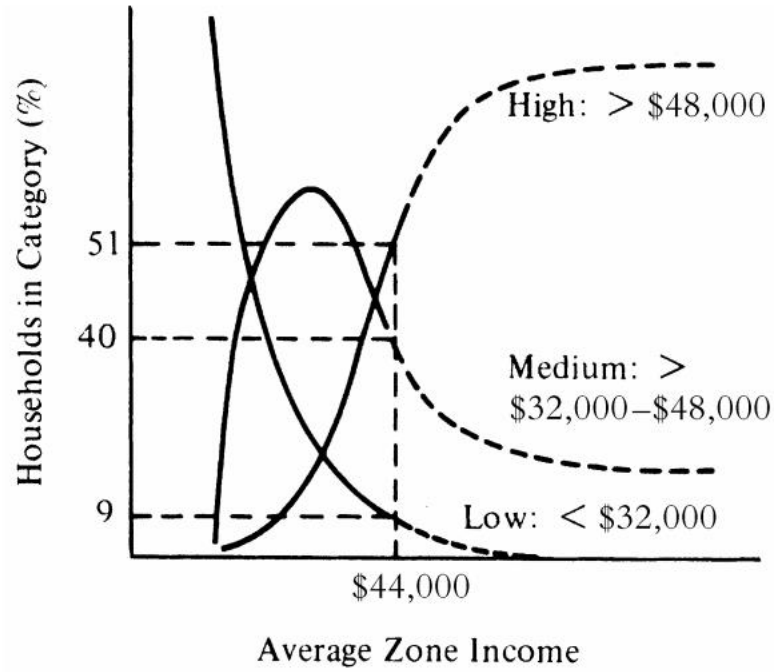
To illustrate the process, two methods are considered:

- Cross-classification and,
- Rates based on activity units.
- Another commonly used method is regression analysis, which has been applied to estimate both productions and attractions. This method is used infrequently because it relies on zonal aggregated data.

Trip generation methods that use a disaggregated analysis, based on individual sample units such as persons, households, income, and vehicle units, are preferred.

Cross-Classification

Cross-classification is a technique developed by the Federal Highway Administration (FHWA) to determine the number of trips that begin or end at the home. Home-based trip generation is a useful value because it can represent a significant proportion of all trips. The first step is to develop a relationship between socioeconomic measures and trip production. The two variables most commonly used are average income and auto ownership. Figure 1 illustrates the variation in average income within a zone. Other variables that could be considered are household size and stage in the household life cycle. The relationships are developed based on income data and results of O-D surveys.



Example: Developing Trip Generation Curves from Household Data

A travel survey produced the data shown in Table1. Twenty households were interviewed. The table shows the number of trips produced per day for each of the households (numbered 1 through 20), as well as the corresponding annual household income and the number of automobiles owned. Based on the data provided, develop a set of curves showing the number of trips per household versus income and auto ownership.

Solution:

Step 1. From the information in Table 1, produce a matrix that shows the number and percentage of households as a function of auto ownership and income grouping (see Table 2). The numerical values in each cell represent the number of households observed in each combination of income–auto ownership category. The value in Parentheses is the percentage observed at each income level. In actual practice, the sample size would be at least 25 data points per cell to ensure statistical accuracy. Figure 2 on page 596 illustrates how the data shown in Table 2 are used to develop relationships between the percent of households in each auto ownership category by household income.

Table 1 Survey Data Showing Trips per Household, Income, and Auto Ownership.

Household Number	*Trips Produced per Household*	*Household Income ($1000s)*	*Autos per Household*
1	2	16	0
2	4	24	0
3	10	68	2
4	5	44	0
5	5	18	1
6	15	68	3
7	7	38	1
8	4	36	0
9	6	28	1
10	13	76	3
11	8	72	1
12	6	32	1
13	9	28	2
14	11	44	2
15	10	44	2
16	11	52	2
17	12	60	2
18	8	44	1
19	8	52	1
20	6	28	1

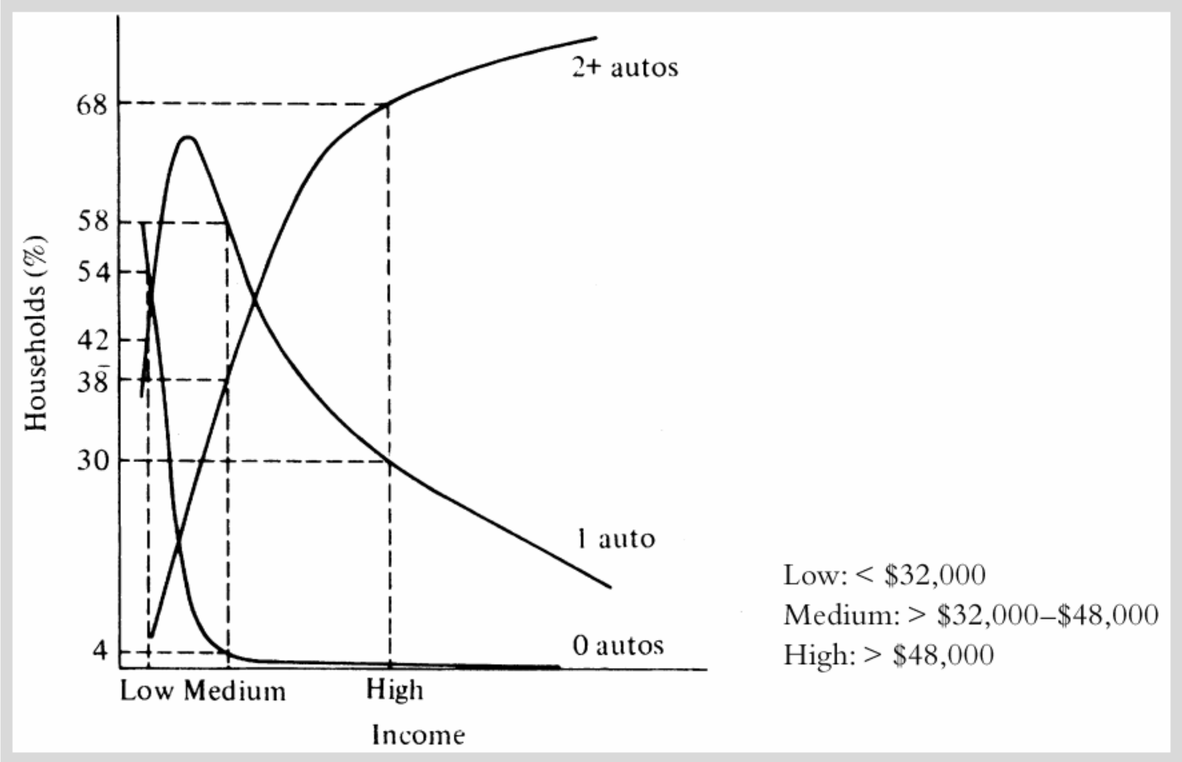


Fig. 2 Households by Automobile Ownership and Income Category**.**

Table 2 Number and Percent of Household in Each Income Category versus Car Ownership.

Income ($1000s)	*Autos Owned* 0	1	2+	*Total*
24	2(67)	1(33)	0(0)	3(100)
24–36	1(25)	3(50)	1(25)	5(100)
36–48	1(20)	2(40)	2(40)	5(100)
48–60	—	1(33)	2(67)	3(100)
>60	—	1(25)	3(75)	4(100)
Total	4	8	8	20

Note: Values in parentheses are percent of automobiles owned at each income range.

Step 2. A second table produced from the data in Table 1 shows the average number of trips per household versus income and cars owned. The results shown in Table 3 are illustrated in Figure 3, which depicts the relationship between trips per household per day by income and auto ownership. The table indicates that for a given income, trip generation increases with the number of cars owned. Similarly, for a given car ownership, trip generation increases with the rise in income.

Table 3 Average Trips per Household versus Income and Car Ownership.

	Autos Owned		
Income ($1000s)	*0*	*1*	*2+*
≤24	3	5	—
24–36	4	6	9
36–48	5	7.5	10.5
48–60	—	8.5	11.5
>60	—	8.5	12.7

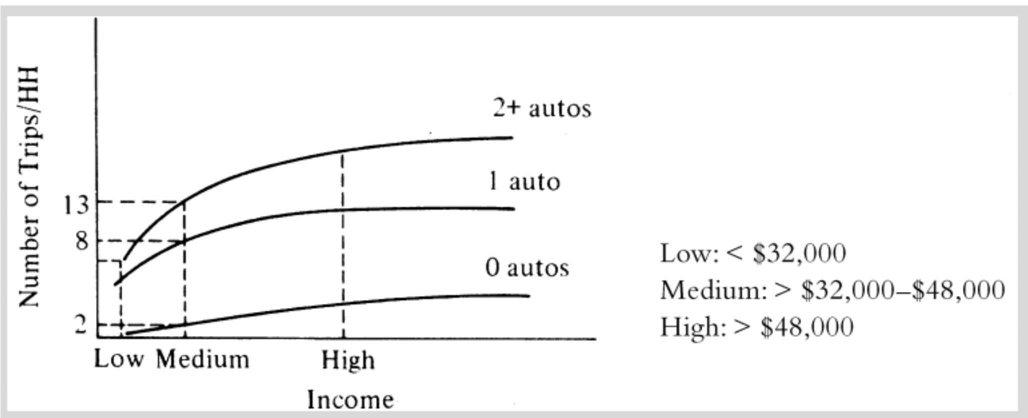


Figure 3 Trips per Household per Day by Auto Ownership and Income Category.

Step 3. As a further refinement, additional O-D data (not shown in Table 1) can be used to determine the percentage of trips by each trip purpose for each income category. These results are shown in Figure 4, wherein three trip purposes are used: home-based work (HBW), home-based other (HBO), and non-home-based (NHB). The terminology refers to the origination of a trip as either at the home or not at the home.

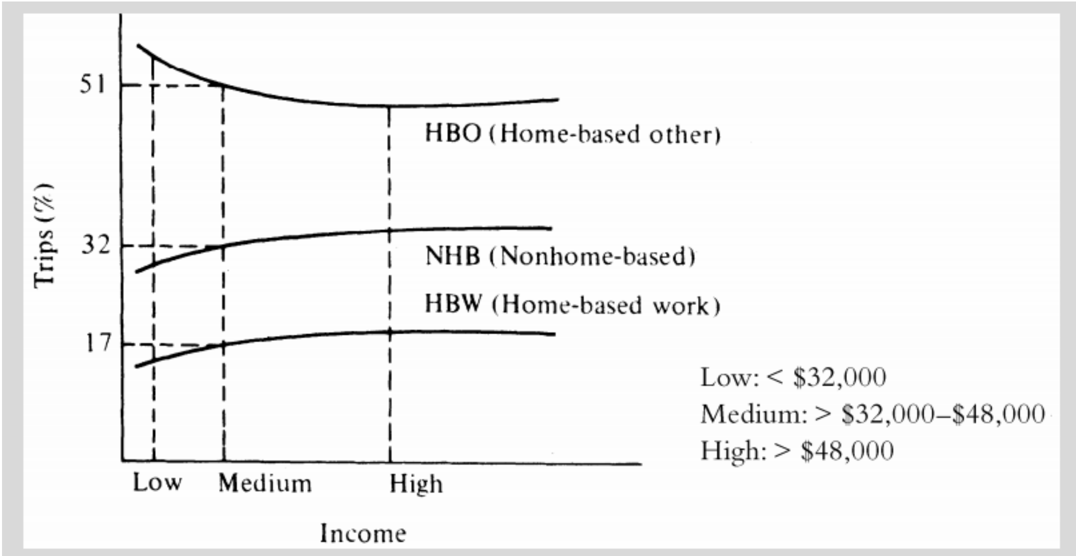


Figure 4 Trips by Purpose and Income Category.

The trip generation model that has been developed based on survey data can now be used to estimate the number of home- and non-home-based trips for each trip purpose.

Regression methods

The general form of a trip generation model is

$$T_i = f(x_1, x_2, x_3, ...x_i, ...x_k) \quad 1$$

Where x_i's are prediction factors or explanatory variable. The most common form of trip generation model is a linear function of the form

$$T_i = a_0 + a_1 x_1 + a_2 x_2 + \cdots + a_i x_i + \cdots + a_k x_k \quad 2$$

Where a_i's are the coefficient of the regression equation and can be obtained by doing regression analysis. The above equations are called multiple linear regression equation, and the solutions are tedious to obtain manually. However for the purpose of illustration, an example with one variable is given.

Example

Let the trip rate of a zone is explained by the household size done from the field survey. It was found that the household size are 1, 2, 3 and 4. The trip rates of the corresponding household is as shown in the table below. Fit a linear equation relating trip rate and household size.

Household size (x)

	1	2	3	4
Trips	1	2	4	6
per	2	4	5	7
day(y)	2	3	3	4
Σy	5	9	12	17

Solution The linear equation will have the form y = bx + a where y is the trip rate, and x is the household size, a and b are the coefficients. For a best fit, b is given by

$$
\begin{aligned}
b &= \frac{n\Sigma xy - \Sigma x \Sigma y}{n\Sigma x^2 - (\Sigma x)^2} \\
a &= \bar{y} - b\bar{x} \\
\Sigma x &= 3 \times 1 + 3 \times 2 + 3 \times 3 + 3 \times 4 = 30 \\
\Sigma x^2 &= 3 \times (1^2) + 3 \times (2^2) + 3 \times (3^2) + 3 \times (4^2) = 90 \\
\Sigma y &= 5 + 9 + 12 + 17 = 43 \\
\Sigma xy &= 1 \times 1 + 1 \times 2 + 1 \times 2 \\
&+ 2 \times 2 + 2 \times 4 + 2 \times 3 \\
&+ 3 \times 4 + 3 \times 5 + 3 \times 3 \\
&+ 4 \times 6 + 4 \times 7 + 4 \times 4 \\
&= 127 \\
\bar{y} &= 43/12 = 3.58 \\
\bar{x} &= 30/12 = 2.5 \\
b &= \frac{n\Sigma xy - \Sigma x \Sigma y}{n\Sigma x^2 - (\Sigma x)^2}
\end{aligned}
$$

$$
= \frac{((12 \times 127) - (30 \times 43))}{((12 \times 90) - (30)^2)} = 1.3
$$

$$
\begin{aligned}
a &= \bar{y} - b\bar{x} = 3.58 - 1.3 \times 2.5 = +0.33 \\
\bar{y} &= 1.3x - 0.33
\end{aligned}
$$

Growth factor modeling

Growth factor modes tries to predict the number of trips produced or attracted by a house hold or zone as a linear function of explanatory variables. The models have the following basic equation:

$$T_i = f_i t_i$$

Where

T_i is the number of future trips in the zone and و

t_i is the number of current trips in that zone and

f_i is a growth factor.

The growth factor f_i depends on the explanatory variable such as population (P) of the zone, average house hold income (I), average vehicle ownership (V). The simplest form of f_i is represented as follows

$$f_i = \frac{P_i^d \times I_i^d \times V_i^d}{P_i^c \times I_i^c \times V_i^c}$$

Where

The subscript d denotes the design year and the subscript c denotes the current year.

Example

A zone has 275 household with car and 275 household without car and let the average trip generation rates for each groups is respectively 5.0 and 2.5 trips per day. Assuming that in the future, all household will have a car, find the growth factor and future trips from that zone, assuming that the population and income remains constant.

Solution

- Current trip rate $t_i = 275 \times 2.5 + 275 \times 5.0 = 2062.5$ trips/day.
- Growth factor $F_i = \frac{V_i^d}{V_i^c} = \frac{550}{275} = 2.0$.
- Therefore, no. of future trips $T_i = F_i t_i = 2.0 \times 2062.5 = 4125$ trips/day.

The above example also shows the limitation of growth factor method. If we think intuitively, the trip rate will remain same in the future. Therefore, the number of trips in the future will be 550 households × 5 trips per day = 2750 trips per day. It may be noted from the above example that the actual trips generated is much lower than the growth factor method. Therefore, growth factor models are normally used for quick estimation and also in the prediction of external trips where no other methods are available. However, the regression methods are more suitable for internal trips and will be discussed in the following section.

Rates Based on Activity Units

The preceding section illustrated how trip generation is determined for residential zones where the basic unit is the household. Trips generated at the household end are referred to as productions, and they are attracted to zones for purposes such as work, shopping, visiting friends, and medical trips. Thus, an activity unit can be described by measures such as square feet of floor space or number of employees. Trip generation rates for attraction zones can be determined from survey data or are tabulated in some of the reference sources listed at the end of this chapter. Trip attraction rates are illustrated in Table 3.

Table 3 Trip Generation Rates by Trip Purpose and Employee Category.

	Attractions per Household	*Attractions per Nonretail Employee*	*Attractions per Downtown Retail Employee*	*Attractions per Other Retail Employee*
HBW	—	1.7	1.7	1.7
HBO	1.0	2.0	5.0	10.0
NHB	1.0	1.0	3.0	5.0

Example Computing Trips Generated in an Activity Zone.

A commercial center in the downtown contains several retail establishments and light industries. Employed at the center are 220 retail and 650 non-retail workers. Determine the number of trips per day attracted to this zone

Use the trip generation rates listed in Table 3.

HBW: $(220 \times 1.7) + (650 \times 1.7) = 1479$
HBO: $(220 \times 5.0) + (650 \times 2.0) = 2400$
NHB: $(220 \times 3.0) + (650 \times 1.0) = 1310$
Total $= 5189$ trips/day

Note that three trip purposes are given in Table 3: home-based work (HBW), home-based other (HBO), and non-home-based (NHB). For example, for HBO trips, there are 5.0 attractions per downtown retail employee (in trips/day) and 2.0 attractions per non-retail employee.

Balancing Trip Productions and Attractions

A likely result of the trip generation process is that the number of trip productions may not be equal to the number of trip attractions. Trip productions, which are based on census data, are considered to be more accurate than trip attractions. Accordingly, trip attractions are usually modified so that they are equal to trip productions. Table 4 illustrates how adjustments are made. The trip generation process has produced 600 home-based work productions for zones 1 through 3. However, the same process has produced 800 home-based work attractions. To rectify this imbalance, each attraction value for zones 1 through 3 is reduced by a factor equal to 600/800, or 0.75. The result is shown in Table 3 in the column “Balanced HBW Trips” Now both productions and attractions are equal. A similar procedure is used for HBO trips. An extra step is required for balancing NHB trips. This extra step is that after total productions and total attractions are equal, the productions for each zone are set equal to the attractions for each zone. For example, in Table 5, since there are 180 NHB attractions for zone 1 after balancing productions and attractions, then the number of NHB productions for zone 1 is also changed from 100 to 180. The rationale behind this extra step is that the true origin of non-home based trips is not provided by survey or census data, and thus the best estimate of the number of NHB trips produced in each zone is the number of NHB trips attracted to each zone.

Table 4 Balancing Home-Based Work Trips.

	Unbalanced HBW Trips		*Balanced HBW Trips*	
Zone	*Productions*	*Attractions*	*Productions*	*Attractions*
1	100	240	100	180
2	200	400	200	300
3	300	160	300	120
Total	600	800	600	600

Table 5 Balancing Non-Home-Based Trips.

	Unbalanced NHB Trips		*Balanced NHB Trips*	
Zone	*NHB Productions*	*NHB Attractions*	*NHB Productions*	*NHB Attractions*
1	100	240	180	180
2	200	400	300	300
3	300	160	120	120
Total	600	800	600	600