Modeling Commercial Vehicle Travel

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A new Commercial trip forecasting model has been developed for the Baltimore Metropolitan Council (BMC). BMC has included trucks in its regional modeling for many years. However, it has not included an important category of non-personal travel using passenger cars, light trucks, and other vehicles not included in the "Truck" model. These trips include light-duty delivery vehicles, taxis, government vehicles, service personnel, craftsmen, tradesmen, and similar vehicles. BMC recently revised its Medium and Heavy Truck trip models. As part of that project, a new Commercial vehicle trip model was also developed.

In this model, "Commercial" refers to those trips that are business-oriented and are not personal transportation, but do not involve a Medium or Heavy Truck. This includes a wide range of vehicles: pickups, vans, minivans, and sport-utility vehicles (SUVs), and passenger cars used for business purposes. Light trucks, vans, and SUVs used for personal transportation are not included.

This is a new category of trip that has not been commonly recognized in regional travel demand models but which is becoming the focus of attention in several urban areas. It includes package delivery vehicles, postal vehicles, couriers, equipment repair and service technicians, craftsmen (carpenters, plumbers, etc.), government workers, taxis, and many other types of light-duty vehicles. Planners are beginning to realize that business-related travel is very poorly identified in home-interview surveys. The difficulty in identifying the travel patterns of such trips has doubtless kept many planners from including them in the modeling process. In some other urban areas, the Commercial category includes Medium Trucks, making this an even more important group. Since the BMC model already estimates Medium Trucks separately, Commercial trips are defined differently than elsewhere.

Observation of the traffic stream on any roadway will reveal that Commercial trips represent a category of travel that is too large to ignore. Exclusion of these trips will result in either underestimating traffic volumes, or (perhaps worse) implicitly incorporating their volume within some other category, most likely non-home-based travel. Since Commercial trips obviously have different travel characteristics than most personal travel, accounting for these trips in a separate category will improve the accuracy of the model.

Since much of this category consists of delivery people and others who spend much of their workday either outdoors or in their vehicle, capturing their travel pattern data is a particular challenge. A workplace survey might identify some of these trips, but the authors believe that a comprehensive Commercial trip survey is probably not feasible. Thus, an alternative method has been developed to estimate the model parameters.

This method relies on a procedure that works "backwards" to develop a trip table from count data. There are many such procedures available; the consultant author has developed a relatively simple one called “adaptable assignment”. This procedure assigns a starting trip table, systematically compares the resulting assigned link volumes to the counts, and adjusts the trips so as to produce a closer match between assigned volumes and counts. The starting trip table is usually based on a model borrowed from another urban area. Adaptable assignment produces a set of trip table adjustments. Examination of these adjustments can identify areas in which the starting model can be improved and the process re-applied.

The Commercial model developed in this study consists of a trip generation and distribution model, external and X/X table procedures, and a calibration adjustment table that is carried into the forecasting phase.

The basic methodology of this study relies on developing a trip table from counts. However, counts of Commercial traffic are not commonly available. Worse, obtaining such counts is complicated by the difficulty in defining Commercial vehicles in a manner that is suitable for traffic counting. The consultant author developed a procedure that leverages the relatively large database of classification counts conducted by the Maryland Department of Transportation (MDOT). These counts identify volumes stratified by the 13 FHWA categories based on the size and type of vehicle. These counts were available at approximately 550 locations throughout the BMC modeled area for 2000.

The BMC author conducted new counts of Commercial traffic at 113 of those locations. For these counts, “Commercial” was defined as any vehicle that displays text, logo, or trademark, or that is transporting equipment of an obviously commercial nature. This definition was coordinated with the FHWA category descriptions so as to avoid duplication with the BMC Medium and Heavy Truck categories.

The counts were conducted in early 2002, at a variety of locations around the BMC modeled area. BMC staff obtained a sample of links stratified by functional class group and area type. Counts were conducted for 30 minutes at a time, between 10 AM and 3 PM. Test counts indicated that 30 minutes’ worth of this kind of data should be sufficiently representative of a typical weekday’s activity. In addition, a total vehicle count was made at the same time. This permits the calculation of a “percent Commercial” value for each link. Additional data were assembled from the MDOT classification data and the coded network, including daily counts for vehicle types F1 – F13, jurisdiction, speed class, capacity class, functional type, area type, number of lanes, weekday count, and directionality.

These data were used to develop a model of the percent Commercial traffic. For each observation, the dependent variable is the percent Commercial traffic and the independent variables are as described above. Such a model could be applied to the approximately 550 classification count links, producing a count database that could be used in the adaptable assignment process.

Since the dependent variable is a fraction (0.0 to 1.0), the logit structure was selected. This function is $p = 1/(1+e^U)$, where p is the percent Commercial and U is the “utility” of Commercial traffic, expressed as a linear function of the independent variables, plus a constant term (“bias coefficient”), which varies by jurisdiction and facility type and area type. Although logit models are most commonly developed using discrete choice data, it is possible to estimate coefficients using aggregate data such as in this case.

The best model had a 25% RMSE, 0.43 r^2, 0.59 ρ^2 with respect to zero, and 0% total error. Table 1 shows the model.

According to the utility equation in Table 1, the percent Commercial increases as the capacity class decreases, the speed class increases, the number of lanes increases, the percent bus increases, the daily F1 or F11 count decreases, and the daily F7 or F12 count increases. The city center has a higher Commercial share, while Rural and Suburban areas have lower shares. Freeways have a slightly lower share than other roadways. It makes sense that Commercial traffic is higher on downtown arterial and collector streets, since much of this traffic is probably relatively short trips between business establishments. The synthesized Commercial count is simply the Commercial share times the weekday total count.

Table 1
Commercial Count Model

$$\text{Percent Commercial} = 1/(1 + e^{U})$$

$$U = cJur + cFD + 0.0042*CAPCLASS - 0.0058*SPDCLASS - 0.0111*LANES - 0.0472*pBus + 0.0004*F1 - 0.00015*F7 + 0.0005*F11 - 0.0005*F12$$

where:
CAPCLASS = network capacity class
SPDCLASS = network speed class
LANES = number of lanes (each way)
pBus = percent of traffic count that is buses
F1 = classification count (motorcycle), both directions
F7 = classification count (4 axle, single unit truck), both directions
F11 = classification count (5 axle, multiple unit truck), both directions
F12 = classification count (6 axle, multiple unit truck), both directions

cJur = bias coefficient by jurisdiction

Baltimore City	-0.32
Anne Arundel Co	-0.02
Baltimore Co	0.15
Carroll Co	0.06
Harford Co	-0.06
Howard Co	-0.01
Washington area	0.00

cFD = bias coefficient by facility group and area type

Facility Group	Rural	Suburban	Urban	City Ctr.
Freeway	2.62	2.62	2.68	2.30
Arterial	2.52	2.62	2.68	2.43
Collector	2.41	2.65	2.71	2.19

The starting generation model was borrowed from the Lehigh Valley in Pennsylvania. For distribution, the new BMC Medium Truck distribution model's F factors were used. The starting model also accounts for zones in which there is strong reason to believe that the Commercial trip activity is higher than the standard trip rates would indicate. The most important zones are few enough in number that they can be identified individually and classified in a way that allows the starting model to account for them. Although no data are available to specifically determine the increase in Commercial trips for such areas, a reasonable estimate can be made and confirmed in the adaptable assignment process.

Six types of zones have been identified and within these types, the zones are further divided as to their relative scale: smaller vs. larger. The BMC author determined that the level of 300 truck trips per day would be used to distinguish smaller from larger facilities. Although these classifications are rather simplistic, the authors believe that this is a reasonable trade-off against the need to maintain and forecast this data item. The truck zone types are defined below:

- Business District: core area of central business districts, major retail areas, college campuses
- Warehouse/Manufacturing: manufacturing and processing facilities, industrial parks
- Intermodal Transfer: facilities where freight transfers between trucks and another mode – mainly the port areas
- Airport: Baltimore-Washington International (BWI -- a special category)
- Institutional/Other: landfills, quarries
- Delivery/Medium Truck: facilities that process mail or express delivery packages

The external trip model assumes that the generation model estimates total trip ends. The external share of the total trip ends is modeled as a function of the zone's distance to the model's cordon, along the highway network. The external share model is shown in Figure 1, the equation of which is: Percent External = $0.468 * D^{-1.2}$, where D is the distance to the nearest external station in miles. The external trip ends at the internal zones are balanced to match the total external trip ends at the external stations. Thus, the cordon volumes are preserved.

At the external stations, Commercial trips were split into external vs. through (X/X), based on 2000 total weekday volumes posted on the network and a total X/X trip table provided by BMC. First, the percentage of total X/X trips by station was determined, using a look-up table to estimate the external trip share (= 100% - through trip share) for each station.

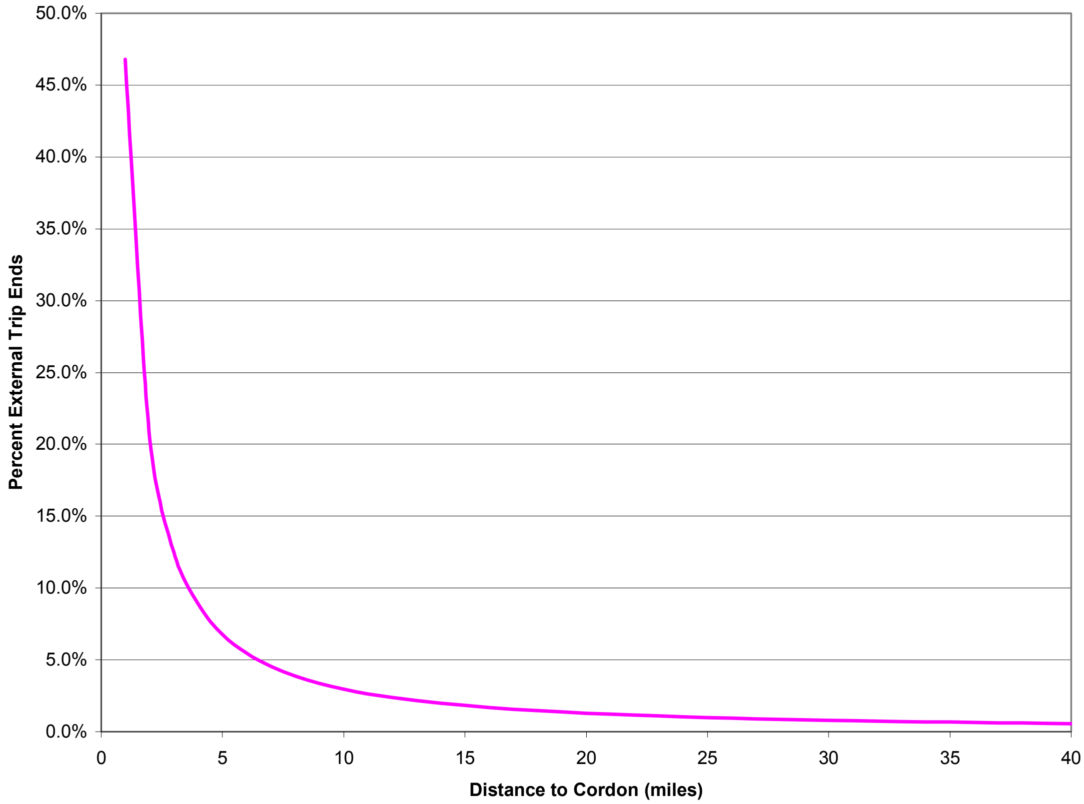
Due to the different sizes of network and modeled area, and other differences, it is not feasible to transfer the Lehigh Valley Commercial distribution model. However, Commercial trips should be similar enough to Medium Truck trips that it should be feasible to use the BMC Medium Truck F factors. The Medium Truck model uses a gamma function to define its F factors, as follows:

$$F = \alpha * t^{\beta} * e^{(\gamma t)}$$

where:
t = travel time, minutes
α, β, γ = calibrated coefficients

The Medium Truck coefficients of e^{14} for α, -2.95 for β, and 0.0 for γ were used. (The gamma value of zero effectively converts this into an exponential model.) The same F factors were applied to I/I and external trips. Figure 2 shows the resulting F factor curve. The starting model's estimated trip length is 16.2 min, which seemed reasonable.

Figure 1
External Share Model



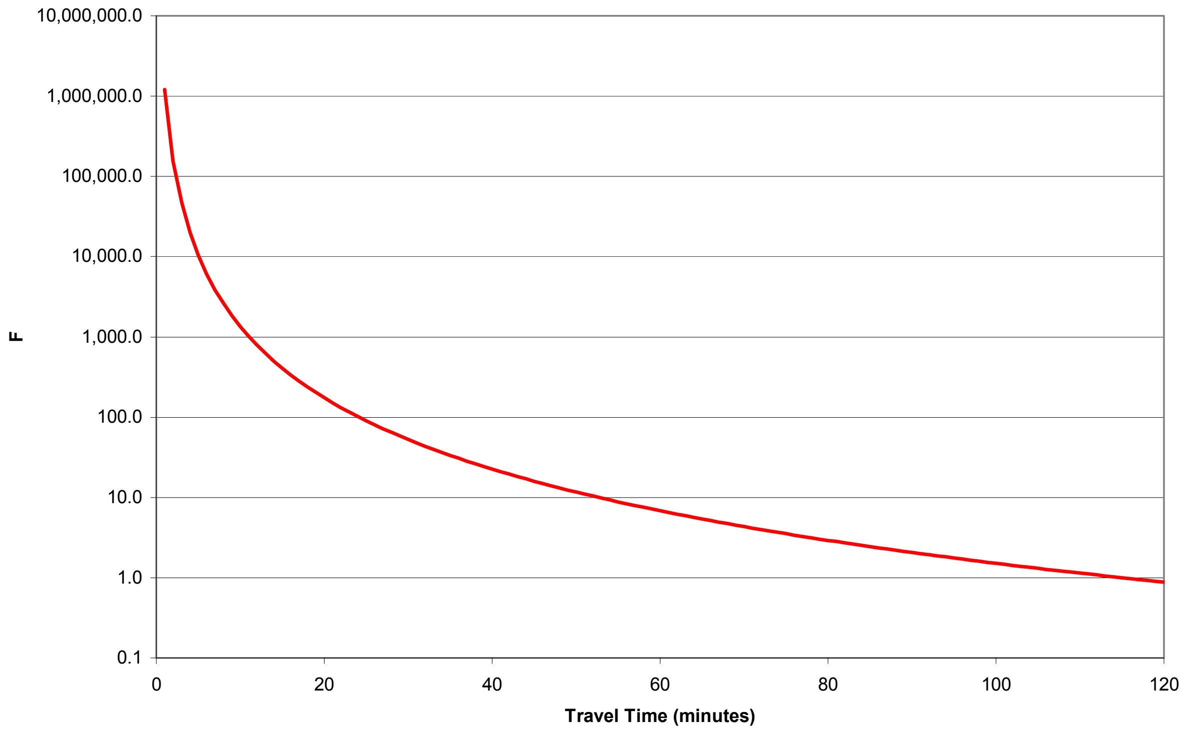
For X/X trip patterns, the consulting author examined the external stations where X/X Commercial trips should be expected. By making assumptions about likely X/X patterns, the consultant developed an "X/X pattern file". This was used to create a seed matrix, which was then Fratared to match the estimated number of daily X/X Commercial trip ends at each station. The final X/X 2000 daily Commercial total is 4,229. This volume is not significant in the context of the entire model, but it is more important for analyses that focus on the major through roadways in the region.

This model was applied to year 2000 conditions. The total error was +8.7% and the percent root-mean-square error (%RMSE) was 70%. These figures represent a worse-than-average degree of accuracy and it was clear that this could be improved upon. The resulting trip tables were used as the starting point for the adaptable assignment process.

The nature of the adaptable assignment process requires that it is iterated several times until a balance has been achieved and little additional assignment accuracy can be expected. The best results were achieved by using 10 iterations. The new trip table is Fratared after the 5^{th} and 10^{th} iterations, so that the external station totals will match the counts. Links in the Baltimore region are given a higher priority than Washington area links, so as to try to match those counts more closely.

The adaptable assignment process produces a new trip table. The ratio of this table to the starting trip table is called the "delta table". This table is an O/D matrix of calibration adjustments that, when multiplied by the starting trip table, produces a table that matches

Figure 2
Commercial F Factors



the counts fairly closely. The trip ends of the final-minus-starting table were compared to the land use data to see if there were any systematic employment- or household-based adjustments that would improve the model. None was found. Next, the consulting author cross-tabulated the delta trip ends and the starting model trip ends by various factors, including truck zone type, jurisdiction, and density code. This analysis indicated a number of modifications to the truck zone factors, as well as a need for jurisdiction- and density code-based adjustment factors.

After several iterations of this analysis, several adjustments were developed for the starting generation model. The revised model is shown in Table 3. This version incorporates adjustments based on the area type and jurisdiction of the zone. These adjustments reduce the number of trips in the city center. Since those areas have many more employees, it would make sense that the Commercial trip rate per employee might be less there. The final truck zone factors suggest that only in the larger Business District and Delivery/Medium Truck zones are the Commercial trips per employee higher than elsewhere. In both those cases, the factors for the "Larger" zones exceed those for the "Smaller" zones, which is logical.

The revised interim model estimates 1,124,000 total Commercial trips (1,038,000 I/I, 82,000 external, 4,000 X/X).

Although adaptable assignment identified a number of changes that make the starting model more accurate, the resulting accuracy is still not as good as one would like. As described above, adaptable assignment can be used to "inform" a model, presumably making it more accurate. This should make the adjustment factors smaller, but they will never be zero.

Table 3
Final Generation Model

COM = 0.80 * (0.454 * INDEMP + 0.501 * RETEMP + 0.454 * OFFEMP + 0.146 * HH)

Factor for truck zone type:

Type	Larger	Smaller
Business District	1.2	1.0
Warehouse/Mfgr.	1.0	1.0
Intermodal Transfer	1.0	1.0
Airport	1.0	N/A
Institutional/Other	1.0	1.0
Delivery/Medium Truck	3.0	2.5

Factor for area type:

Rural	0.8
Suburban	1.0
Urban	1.5
City Center	0.7

Factor for jurisdiction:

Baltimore City	1.0
Anne Arundel	1.5
Baltimore County	1.2
Carroll	1.7
Harford	2.1
Howard	1.2
D.C.	0.5
Montgomery	0.7
Prince George's	1.2
Frederick	0.6

This adjustment table then becomes an integral part of the model. It is always multiplied by the model output, to become the "final" trip table for assignment. From experience in other studies, the consulting author believes that this method of highway assignment calibration is superior to other techniques and produces results that are not only more accurate in the base year, but more credible in the forecast years.

The final "difference" table (final minus starting) totals 55,077 trips. The most desirable characteristic of a delta trip table is that it is small, relative to the starting table. The total delta is 5% of the starting trip table, which is very acceptable. The relative delta should also be consistent across the region. In this case, the relative delta is a little high in Baltimore City and Carroll County. No explanation could be found for this.

An interesting characteristic of this process is that the new trip table has a shorter average trip length than the original table. Mechanically, this is because adaptable assignment factors the starting trips to match the counts, and the majority of the trips from any zone tend to go to nearby zones. Thus, the process tends to magnify these close trips. However, this may make some rational sense, since very short trips tend to be undercounted in trip surveys. Here, including the delta table reduced the average trip length from 15.4 mi. to 14.3. Since the original value was not calibrated to any observed data, this is of no great concern.

As the final step in the development of this model, the table from the revised starting model was multiplied by the adjustment table and the resulting table was assigned to the BMC 2000 network. This procedure used the new BMC Truck assignment procedure, so as to:

1) maintain Medium and Heavy Truck volumes separately by link,
2) prevent Medium and Heavy Trucks from using truck-prohibited links, and
3) factor Medium Truck volumes by 1.5 and Heavy Truck volumes by 2.0, for the purposes of the V/C calculation

The resulting assigned volumes were compared to the synthesized Commercial counts, producing the report shown in Table 4. The total error is -1.9%, while the %RMSE value is 13%. This is a *substantial* improvement over the starting model. BMC and the consultant considered these results acceptable.

There is little difference in the estimated/observed ratio, when stratified by the various fields shown in these reports. The %RMSE values tend to be better (lower) for the higher-type, higher-volume facilities, but this is to be expected.

The adaptable assignment process is at least as valid as the count data. The result of this process is a model that both matches the counts and displays reasonable sensitivity to changes. The new model's coefficients and the inclusion of special factors for truck zones produces logical and defensible trip patterns.

Most other regional travel models do not specifically account for Commercial vehicle trips. In most cases, these trips are counted as Truck or NHB trips. Counting them as Truck trips is incorrect, since the trip patterns and average trip lengths are so different. Counting them as NHB is incorrect, since Commercial trips are not personal travel and are not subject to changes in mode choice. Counting these trips in this new category of travel represents an improvement in accuracy and credibility, compared to the old model.

A model is not complete until it has been used to make a forecast. As the final step in the development of the Commercial model, it was used to forecast 2025 trips. The results are shown in Table 5. These figures reflect a fairly modest growth in Commercial travel to 2025. Most of this is due to an increase in total Commercial trips, while some is due to increased trip length. These estimates do not appear unreasonable.

Table 4
Assignment Report

County	Count	Vol	Est/Obs	%RMSE	Links	Obs VMT	Est VMT
External	90472	83633	0.92	0.19	84	27138	25089
BaltCity	133376	133739	1.00	0.13	111	34515	34767
AnnArndl	409880	399052	0.97	0.14	209	343244	336454
BaltmrCo	545202	543956	1.00	0.12	288	345769	340274
Carroll	39864	39421	0.99	0.05	70	42184	41832
Harford	132616	128452	0.97	0.16	144	175273	167454
Howard	226280	223248	0.99	0.09	110	176891	173480
Montgomery	114159	113015	0.99	0.12	38	112201	109490
PG	228631	222362	0.97	0.06	60	287201	277825
Frederick	27124	24287	0.90	0.16	22	71970	63656

Vol Class	Count	Vol	Est/Obs	%RMSE	Links	Obs VMT	Est VMT
<= 999	260935	260205	1.00	0.23	539	185446	182292
1000-2499	542055	538528	0.99	0.12	341	349070	340215
2500-4999	613740	603638	0.98	0.08	173	603590	587671
5000-9999	530874	508794	0.96	0.08	83	478280	460143

Area Type	Count	Vol	Est/Obs	%RMSE	Links	Obs VMT	Est VMT
Rural	656429	634338	0.97	0.16	539	752272	720063
Suburban	1171150	1155918	0.99	0.11	515	831522	817617
Urban	79314	80781	1.02	0.13	62	26578	26743
City Ctr	40711	40128	0.99	0.06	20	6014	5898

Roadway Type	Count	Vol	Est/Obs	%RMSE	Links	Obs VMT	Est VMT
Freeway	1231181	1199476	0.97	0.08	339	1229499	1188380
>2 Ln Div	113233	115083	1.02	0.07	78	65425	65753
2WCLTL	31640	31517	1.00	0.03	28	21586	21390
Undivided	70628	72234	1.02	0.25	60	36622	37057
Arterial	210696	213030	1.01	0.14	175	61969	62671
Rural Hwy	65067	64819	1.00	0.07	101	69841	68883
Substndrd	84746	82936	0.98	0.25	188	73876	71864
Local	39728	40953	1.03	0.25	76	26370	26236
Ramp 1	2326	2647	1.14	0.15	2	744	834
Ramp 2	6455	3928	0.61	0.43	3	3001	1964
Ramp 5	1432	909	0.63	0.36	2	315	200
Cent Conn	90472	83633	0.92	0.19	84	27138	25089

Totals:

Count	1947604.000
Assigned Vol	1911165.000
Est/Obs Vol	0.981
RMS Error	52581053.000
Avg RMS Error	215.142
% RMS Error	0.125488
Links	1136.000
Obs. VMT	1616386.000
Est. VMT	1570321.000
Est/Obs VMT	0.972
Corr Coef R	0.996
Coef Var Rsq	0.992589

Table 5
2025 Forecast Summary

	2000	2025	% Change
Commercial Trips	1,179,800	1,545,600	31%
Avg. Trip Length	7.2	8.4	17%
Commercial VMT (000)	8,479.7	13,011.6	53%

Includes calibration adjustment.

The development of this model focused mainly on daily trips. Since the BMC model assigns trips by time period, time of day factors were needed to split the trips by period. Factors to accomplish this were obtained from the literature, as shown in Table 6.

Table 6
Commercial Time of Day Factors

Period	Trip Share
Night (12 M – 6 AM)	4.5%
AM Peak (6 – 10)	25.1
Midday (10 AM – 3 PM)	28.9
PM Peak (3 – 7)	29.4
Evening (7 PM – 12 M)	12.1

The final Commercial trip model includes the following components:

- trip generation model (Table 3)
- trip distribution model (F factors as shown in Figure 2)
- procedure to calculate external trips (Figure 3)
- base year through trip table
- calibration adjustment factor table
- time of day splits (Table 6)