APPENDIX E

The Travel Forecasting Model Set
For the Atlanta Region
2010 Documentation

July 2011

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1. Introduction

The Atlanta Regional Commission (ARC) travel demand model is designed to, at a minimum, represent the state of the practice in travel demand modeling and to meet all modeling requirements in the US EPA Transportation Conformity Rule (40 CFR Parts 51 and 93). Since 1990, a full consultation process, peer review and the ARC strategic travel demand model enhancement program have guided all modifications to the travel demand model. As a result, all elements of the travel demand model are designed to support all technical and policy decisions that are required in developing a comprehensive, multimodal transportation plan and program in accordance with the Intermodal Surface Transportation Equity Act of 1991 (ISTEA), the 1990 Clean Air Act Amendments (CAAA) and the Transportation Conformity Rule and the 2005 Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). Model improvements over the past decade and a half have generally been incremental approaches designed to produce a travel demand model that successfully addresses all federal planning and air quality requirements and sufficiently represents all transportation modes in the Atlanta region.

This report documents the trip based travel demand model developed for the Atlanta region. The trip based travel demand models consist of a series of sub-models which estimate travel patterns throughout the region and use these travel patterns to estimate the travel on the highway and transit transportation links in the region. The model boundary area originally consisted of 13 counties in order to be consistent with air quality conformity requirements for the ozone nonattainment areas.

On December 17, 2004, the United States Environmental Protection Agency (USEPA) designated 20 whole counties and two partial counties within the metropolitan Atlanta area as nonattainment under the fine particulate matter (PM2.5) standard. The PM2.5 nonattainment area encompasses the 13-county one-hour ozone maintenance area plus seven additional "ring" counties: Carroll, Bartow, Hall, Barrow, Walton, Newton, and Spalding counties; and parts of Heard and Putnam counties. As a result of this nonattainment designation, the Atlanta Regional Commission (ARC) expanded the current travel demand model boundary from 13 to 20 counties in order to meet the federal requirements for performing conformity analysis. The model was not expanded to include the two partial counties of Heard and Putnam counties.

The main data source for the calibration of the travel demand models was a household travel survey of eight thousand households conducted for the Atlanta Regional Commission (ARC) from April 2001 through April 2002. In addition, the ARC had an On-Board transit survey conducted in late 2001 and early 2002 which was used in developing the travel demand models and a survey of air passengers at Hartsfield International Airport conducted in 2001. Extensive speed studies were conducted to assist with the development of the network speeds. Over 5,000 daily traffic counts were utilized to perform the highway assignment validation. Vehicle classification counts were also collected to develop a new commercial vehicle and truck model.

The household survey data was the main source of data for developing the trip generation and distribution model. The trip generation model is a fairly unique trip based model in that it estimated the frequency a person will make trips, by the purpose of the trip, and then applies this frequency to individual persons to determine the total amount of travel made by the residents of the region. This model was structured to make maximum use of the household survey data. The model was calibrated using a logit structure and used the program ALOGIT for this purpose. The distribution model was a gravity model which used both highway time and transit time as measures of travel impedance. The distribution model also used the 2000 journey to work census data as much as possible. Since the models were developed in early 2003, it was only possible to use the county to county census data work “flows”.

The mode choice model also used the household survey data but, in addition, it also used the transit on-board survey. The mode choice model is a nested logit model, calibrated using the program ALOGIT. The air passenger survey was used to develop an air-passenger model. This model is also a nested logit model, which estimates the non-airport location of air passengers and the mode which the air passengers used to the airport.

Additional model refinements have been incorporated into the ARC model structure in 2005-2006 in addition to the expansion of the model boundary. During 2005, the mode choice model was re-evaluated to improve the performance of the model performance on suburban intra-county trips. The purpose of this effort was to examine the existing mode choice model and improve its ability to predict travel mode of trips in the Atlanta region. The review of the market segments in the model was conducted and revised. Various model specifications were explored and tested. In addition, an attraction share model was incorporated into the regional modeling process to improve the model performance. As a result of this effort, refinements were made to the trip generation, trip distribution and mode choice models. In addition, a new commercial vehicle and truck model was developed to improve traffic assignment and to provide for the analysis of truck only toll (TOT) lanes. These changes have significantly changed the model structure and formats of output files from previous versions of the ARC travel demand model set.

The report has ten sections, including the Introduction. The second section describes the trip generation model while the third section discusses the trip distribution model. The mode choice model is the subject of the fourth section while the external model is described in section five. Section six documents the development of the commercial vehicle and truck models. Section seven describes the air passenger model while the section eight discusses the highway assignment model and the results of applying the entire model chain to obtain daily highway volumes on all the highway links. Section nine provides a description of the network specifications. Section ten describes the ITS Methodologies and strategies. Please refer to the *User's Guide* for detailed information on how to run the travel demand model set. The *User's Guide* also specifies the input data files and describes the format of the model output files.

2. Trip Generation

The trip generation model was refined as part of the effort to refine the mode choice model in 2005. The refinements consisted of revising the trip productions by purpose to be stratified by the new market segments necessary for the revised mode choice model and revising the attraction model component to include an attraction share model. This section documents the calibration of the trip generation model including both the initial calibration efforts and the new refinements.

The trip generation model estimates trip ends for a typical weekday. A production trip end is where a trip begins from the home of the trip maker. An attraction trip end is where a trip ends. For example, a person who made two trips in a day, one from home to work and one from work to home, would generate two productions at the home end and two work attractions at the work end. Trips which neither begin nor end at the traveler's home are called non-home based trips and the trip ends are called origins and destinations – with the origin being the beginning or the trip and the destination being the end of the trip. The trips used in the development of the trip generation model were the total person trips, which includes walking and bicycling trips.

The trip generation models develop trip ends by purpose. The ARC models are stratified into six purposes:

1. <u>Home Based Work</u>: Trips made for the purpose of work and which either begin or end at the traveler's home. This is a typical trip purpose that is obviously related to the employment and the income of the traveler or the household.

2. <u>Home Based Shopping</u>: Trips made for any type of shopping that begin or end at the traveler's home. This trip purpose is obviously related to socioeconomic and land-use characteristics; e.g. Retail employment, income, and household size.

3. <u>Home Based Grade School</u>: Any trip between an elementary or high school and the home. Characteristics of these trips were determined from the home interview survey. If the age of the traveler was under 19 years, the trip was classified as a grade school trip.

4. <u>Home Based University</u>: All school travel made to a university with one end being at the traveler's home. Characteristics of these trips were determined from the home interview survey. If the age of the traveler was 19 years or older, the trip was classified as a university trip.

5. <u>Home Based Other</u>: Any trip made with one end at the home except for the purpose of work, shopping, or school. This includes trips made for social visits, recreational trips, or personal-business.

6. <u>Non-Home Based</u>: Any trip that neither begins nor ends at home.

The trip generation model consists of a number of sub-models. There is a model to estimate the trip productions, by purpose and a model to estimate the trip attractions by purpose. There is also a model to estimate the types of households in each traffic analysis zone and a model to estimate which productions are non-motorized productions and which are motorized productions. Non-motorized productions are those productions which represent trips made by walking or by bicycling. Motorized productions are those productions which represent trips made by using an automobile or by using transit.

2.1. Trip Production Model

The trip production model was developed by using the 2000 home interview survey. This survey of approximately 8,000 households consisted of identifying the travel patterns for each member of the household for two consecutive days. Because of the two day survey and the large number of households there were a substantial number of trip records; approximately 100,000.

The new trip production model is structured completely different than the previous trip production model. The previous trip production model was designed as a cross-classification model which estimated trips, by purpose, for a household based on the number of persons in the household and the number of automobiles owned by the household, and the number of workers in the household. The cross classification model was chosen because it was the best model structure given the amount of data available at the time. The data was from the 1990 household survey consisting of a one day survey of about 2,300 households and 20,000 trips.

The new trip production model is structured as a logit model estimating the daily trip frequency a person (not a household) would make. This is a fairly unique model structure. The reasons this model structure was chosen because the logit structure: (1) allows more independent variables to be used; (2) allows continuous independent variables to be used, rather than only classification variables; and (3) allows statistical measures to be made measuring the significance of the independent variables and the entire equation. The logit model structure was possible for this modeling effort due to the large number of observed data records. Although the trip production model was refined in 2005 to export trips by the new market segments, the initial calibration of the production model was unchanged.

The approach is to use a set of logit models, stratified by trip purpose and person type, to estimate the probability of a person making no trips, 1 trip, 2 trips, etc. These probabilities are then used to calculate the effective net trip rate per person, by person type. Those rates are then used to calculate the overall trip rate for the household (HH), by purpose, and summed to the traffic analysis zone level.

The trip purposes are: home-based work (HBW), home-based shop (HBShop), home-based university (HBU), home-based school (HBSch), home-based other (HBO), and non-home-based (NHB). HBU trips are defined as school trips made by people over the age of 18. HBSch trips are primary/secondary school trips made by people aged 18 and younger.

The person types are: adult worker (age 16 or older, with a full- or part-time job -- WKR), non-working adult (NWA), and child (age 15 or younger -- CHL). There is a model for each person type for each purpose, except where the person type and the purpose are not compatible. For example, there is no HBW model for non-working adults.

The socio-economic independent variables, specified as information for the household, are as follows:

- HH size (1, 2, 3, 4+)
- HH income group (under $20K, $20 – 50K, $50 – 100K, over $100K)
- Number of workers (0, 1, 2, 3+)
- Number of children (0, 1, 2, 3+)
- Number of autos (0, 1, 2, 3+)

For the calibration of the model, each household in the survey data set has a value for each of these five socio-economic variables. In the application of the model for a future year, the ARC land use model estimates households by household size and income group. Using these households, a set of models is then used to estimate the number of households, actually the proportion, for each of the other three socio-economic variables. These models are described in section 2.2.

Since fractional households are used in this calculation, it may be more accurate to think of the fractions as the probability of a Household being in each category, multiplied by the total number of Households in the zone. Since the number of persons, by type, is known in each “cell” of this 5-way stratification, the trip rates per person can be combined to compute the net trip rate for the Household.

The model is a logit formulation, structured as follows:

$$p_{x,y}(n) = \frac{e^{U_{x,y}(n)}}{\sum e^{U_{x,y}(n)}}$$

Where:
$p_{x,y}(n)$ = probability of a person of type x making n trips of purpose y, n = 0, 1, 2, …
$U_{x,y}(n)$ = utility of n trips for person type x and purpose y

The utility of making no trips (U (0)) is, by convention, defined to be zero for all models. The utility of the other numbers of trips is a linear function of various known attributes of the HH, including income, size, autos, and location.

There are 15 separate models, numbered as shown in Table 2.1. By definition, only Workers can make HBW trips, and Children cannot make HBU trips.

The calibration of this model consists of estimating the coefficients for the 15 models. One of the first calculations is to determine the number of utility equations for each model. That is, which numbers of integer trip choices should be modeled in each model? The trip estimation file was examined and the choices were determined such that, in general, the last choice comprised about 2% of the total number of trips. Table 2.2 shows the number of choices for each model and the average number of trips for the last choice.

Table 2.1
Trip Model Numbers

Purpose	Worker	Non-working Adult	Child
HB Work	#1		
HB Shop	#2	#3	#4
HB University	#5	#6	
HB School	#7	#8	#9
HB Other	#10	#11	#12
Non-Home-Based	#13	#14	#15

Table 2.2
Trip Choices by Model

Purpose	Worker	Non-working Adult	Child
HB Work	4 / 4.12		
HB Shop	3 / 3.51	4 / 4.32	2 / 2.15
HB University	1 / 1.66	1 / 2.07	
HB School	1 / 1.79	1 / 1.90	3 / 3.80
HB Other	4 / 4.62	4 / 4.75	4 / 4.40
Non-Home-Based	7 / 8.11	5 / 6.24	4 / 4.59

Legend: xx / yy: xx = highest trip category, yy = average trips/person for the highest category
So, for example, in the model of Home Based Shopping trips by Non-working Adults, the choice set consists of:

0 trips
1 trip

2 trips
3 trips
4+ trips (the average of this category is 4.32 trips/person)

These choices are assumed to be independent of each other. While that might not strictly be true, it greatly simplifies the analysis and was thus judged acceptable.

The internal-internal trip generation model developed trip end estimates for twenty-one trip purposes. For each of the five home-based trip purposes (work, other, shop, school and university) there were four individual income groups resulting in twenty home-based trip purposes. Non-home based trips were maintained as a single trip purpose. The initial challenge in the development of the trip distribution models was to determine if separate distribution models were required for the individual income groups within each of the home-based trip purposes.

The second challenge was the development of a spatial separation variable that recognized that transit service between traffic analysis zone pairs is perceived by travelers as increasing traffic analysis zone pair accessibility. A methodology that has been used in other areas is to develop a composite time (combination of highway and transit time). The formulation of the composite time includes the combining of the highway and transit travel times between traffic analysis zone pairs to reflect a single (composite) time. It is acknowledged that it is not logical that both the highway and transit times should receive equal weight, i.e., the composite time should be weighted more heavily to the highway travel time. The trip distribution model can be calibrated using this new spatial separation variable, composite time.

2.1.1. Selection of Income Group Stratifications by Trip Purpose

The stratification of income groups within a trip purpose was carried out using two criteria. First, there was a determination of the number of survey samples available within each trip purpose and income group. If there were not sufficient samples in an income group for statistical reliability, the income groups within a trip purpose were combined to have a minimum of 400 sample records in a particular group. Table 2.3 shows the allocation of survey records by purpose and income group.

As can be seen in Table 2.3 for university trips there were a total of only 1,029 survey sample records with the individual income groups stratified as follows:

Income Group 1 – 181;
Income Group 2 – 299;
Income Group 3 - 416; and
Income Group 4 – 133.

Based upon the lack of sufficient survey samples in an individual income group, university trips were combined into a single income group purpose.

2.1.2. Calibration File

The file used to estimate this model was based on the 2000 Home Interview Survey. This survey file was used to create a file with one record per person, per day (some people were surveyed across one day; some, across two days). The trips per person were summarized on each record. The number of records is: 16,967 Workers, 8,179 non-workers, and 4,542 Children for a total of 29,688 records. Table 2.3 shows the trip totals and average per person by purpose and type.

Table 2.3
Trip Totals and Averages

Purpose	Worker	Non-working Adult	Child
HB Work	20,480 / 1.21		
HB Shop	8,168 / 0.48	5,907 / 0.72	1,015 / 0.22
HB University	761 / 0.04	673 / 0.08	
HB School	351 / 0.02	967 / 0.12	6,049 / 1.33
HB Other	12,679 / 0.75	9,266 / 1.13	3,136 / 0.69
Non-Home-Based	22,040 / 1.30	6,766 / 0.83	2,323 / 0.51

Legend: xx / yy: xx = number of trips, yy = average daily trips/person

The calibration file includes several Household attributes, including number of persons by type, Household income group, auto ownership, relationship of autos to workers, the zone area type the household was in, and various accessibility measures. The accessibility measures are computed by zone, as follows:

$$A(i) = \sum_j \frac{S(j)}{T_{i,j}^2}$$

where:
A(i) = accessibility for zone i
S(j) = a measure of activity in zone j: population, employment, or population plus employment
$T_{i,j}$ = impedance separating zones i and j: either total transit travel time (AM peak, walk-to-local), or highway time (AM peak), or highway distance.

This accessibility measure incorporates urban form (number of persons or jobs "close" to a household) and the transit and highway access (more transit and / or faster highways will have more persons or jobs "close" to a household. The highway distance accessibility represents the accessibility for walking trips. The formulation, shown above, is such that the variable is continuous but produces very low values for high travel times.

The trips represent total trips on a weekday, including walk/bike trips. A weighting factor is included on each record, for the purpose of adjusting each record so that the entire sample is representative of the region, according to the 2000 Census. Several of the variables are dummy variables. For example, HH auto ownership is described using four dummy variables: CAR0, CAR1, CAR2, and CAR3. For any person, only one of these is true (value = 1); the others are false (value = 0). CAR3 represents 3 or more autos in the HH. In the "cars < workers" dummy variable, the value is set to True (1) if autos = 0, even if workers = 0. Persons whose trips were surveyed on two different days are included in the survey as two records. Again, these observations are not necessarily independent of each other, but that issue was not examined further in the interest of saving time. Table 2.4 shows the structure of the calibration file.

2.1.3. Calibration Procedure

The ALOGIT program, version 3F/2, was used to estimate the coefficients for each model. The calibration file was initially prepared in DBF format. The first step was to convert the data to ASCII for use in ALOGIT. This involved selecting the records for each person type, "capping" the number of trips for the selected purpose, as shown in Table 2.2, and adding 1 to each trip total. This meant that zero trips is represented by "1", one trip is a "2", etc. This is necessary because the value zero is not accepted by ALOGIT to define a choice.

Once the file was prepared, the next step was to hypothesize an equation for the utility of each number of trips in the choice set. ALOGIT was applied, the results examined, and a new equation was tested. The general approach for each model was to begin with a relatively simple model – usually one consisting only of the income group dummy variables. Next, various measures of family composition were examined (size, presence of children, number of workers, etc.). Next, descriptors of the number of autos were tested (total autos, autos vs. workers). Finally, attributes which indicated the density of the area around the Household's location were tested (area type and accessibility).

This process continued in iterative fashion until the analysts felt that the following criteria were met as much as possible:

1. all coefficients had logical signs
2. the included variables were logically related to the trip choice (more of a true cause-and-effect, rather than just a statistical correlation)
3. coefficient values seemed reasonable
4. variables had acceptable t scores (2.0 or higher, as much as possible), indicating a 95+% probability that the coefficient value was indeed different from zero
5. for models of each trip purpose, an attempt was made to use a consistent set of variables if at all possible (e.g., all three HBO models by person type look similar)
6. achieving the highest feasible rho-squared value, indicating the overall explanatory power of the independent variables

Most of the ALOGIT runs were made without using the weighting factors. The few runs that did use them did not indicate any significant difference or improvement, so they were omitted from the analysis.

2.1.4. Calibration Results

This section will discuss, for each for the 15 individual production models, the variables used in the selected model. The specific model specifications, including coefficients and statistical tests are shown on Tables 2.5 to 2.19.

2.1.4.1 Home Based Work Productions by Workers

The final model is shown in Table 2.5. This was a difficult model to estimate because the factors that influence a worker to go to work on any particular day are not closely related to the variables available for this calibration. The final model says that the worker is somewhat more likely to go to work if the HH is of higher income. But the worker is less likely to go to work if the Household is in a low density area, if there are fewer cars than workers, or there are any children in the Household. Low density may relate to the different nature of employment in suburban and rural areas. Car ownership speaks to a general level of mobility. The presence of children in the HH means the worker may have to stay home sometimes to care for them.

2.1.4.2 Home Based Shopping by Workers

The final model is shown in Table 2.6. Income clearly plays a role – higher income means a higher probability of travel. Larger Household size means a lower probability of the worker making a shop trip. This makes sense, since there are other persons in the Household who can also do shopping. The influence of household size is significant but is not linear and therefore the size of the household was entered into the model as a series of dummy income size variables. Being in a high density area means a greater chance of making 3+ shop trips, but its influence on the other trip categories was statistically insignificant. Workers in low density areas are less likely to make shop trips, which may relate to the difficulty of trip chaining in such areas.

Table 2.4
Model Calibration File Structure

FIELD_NAME	TYPE	WIDTH	Field Description	Data Table	Note
HHID	Integer	8	Household ID		
PERSONID	Integer	3	Person ID		
DAYID	Integer	2	Day ID		
MAINACTIVI	Integer	2	Person Main Activity	Person	1=full-time worker, 2=part-time worker, 3=full-time school, 4=full-time worker&school, 5=part-time worker&school, 6=non-school&non-worker
NPERSONTYP	Integer	2	New Person Type	Person	1=adult worker, 2=child (age<16), 3=adult non-worker
CHILDINHH	Integer	2	Number of Children in HH	Household	
WORKERINHH	Integer	2	Number of Workers in HH	Household	
NONWORKERI	Integer	2	Number of Non-workers in HH	Household	
LOWINC	Integer	2	Low Income Dummy ($0~19999)	Household	
LOWMEDINC	Integer	2	LowMed Income Dummy ($20000~49999)	Household	
HIGHMEDINC	Integer	2	HighMed Income Dummy ($50000~99999)	Household	
HIGHINC	Integer	2	High Income Dummy ($100000~)	Household	
USEIMPUTEI	Integer	2	Use of Imputed Income	Household	1=used, 0=not used
CAR0	Integer	2	Zero Car Dummy	Household	
CAR1	Integer	2	One Car Dummy	Household	
CAR2	Integer	2	Two Car Dummy	Household	
CAR3	Integer	2	Three+ Car Dummy	Household	
CARLWORKER	Integer	2	Cars less than Workers Dummy	Household	
CAREWORKER	Integer	2	Cars equal to Workers Dummy	Household	
CARGWORKER	Integer	2	Cars more than Workers Dummy	Household	
CHILDDUMMY	Integer	2	Children (Age<16) in HH Dummy	Household	1=there are children in HH, 0=no child in HH
NW1CHILD0	Integer	2	HH with non-worker & no child Dummy	Household	
NW1CHILD1	Integer	2	HH with non-worker & child Dummy	Household	
NW0CHILD1	Integer	2	HH with no non-worker & child Dummy	Household	
FINALWEIGH	Integer	8	Final Weight for HH * 10000	Household	
TAZCENTROI	Integer	5	TAZ Centroid of HH	Zone	
AREATYPE	Integer	3	Area Type of TAZ	Zone	
EMPHWY	Integer	6	Employment Highway Access Measure	Zone	
EMPTRN	Integer	6	Employment Transit Access Measure	Zone	
POPHWY	Integer	6	Population Highway Access Measure	Zone	
POPTRN	Integer	6	Population Transit Access Measure	Zone	
EMPPOPHWY	Integer	6	Employment&Population Highway Access Measure	Zone	
EMPPOPTRN	Integer	6	Employment&Population Transit Access Measure	Zone	
EMPDIST	Integer	6	Employment Distance Access Measure	Zone	
POPDIST	Integer	6	Population Distance Access Measure	Zone	
EMPPOPDIST	Integer	6	Employment&Population Distance Access Measure	Zone	
HBW	Integer	3	Number of Home Based Work Trips	Trip	
HBSCH	Integer	3	Number of Home Based School Trips	Trip	
HBU	Integer	3	Number of Home Based University Trips	Trip	
HBSHOP	Integer	3	Number of Home Based Shopping Trips	Trip	
HBO	Integer	3	Number of Home Based Other Trips	Trip	
NHB	Integer	3	Number of Non-Home Based Trips	Trip	

2.1.4.3 Home Based Shopping by Non-Workers

The final model is shown in Table 2.7. Here, income plays even a larger role, especially between incomes 1 and 2 and between 2 and 3. Larger HH size means a lower probability of the NWA making a shop trip, again, because there are others in the HH that can do that. Here, the effect is linear with increasing size. The presence of any children means a greater chance of a shop trip, which makes sense, since children create a greater need for shopping. Having fewer (or the same) cars than workers results in a lower level of mobility that reduces shopping probability.

2.1.4.4 Home Based Shopping by Children

The final model is shown in Table 2.8. The results are similar to the shopping by non-work model: higher HH income means more shopping, larger HH size means a lower chance that this child will go shopping. Low density also means a lower chance that the child will go shopping, possibly due to the longer distances involved. But if there is an adult non-worker in the household, the chance that the child will make 2+ shop trips increases, probably because the child can travel with the non-worker.

2.1.4.5 Home Based University by Workers

The final model is shown in Table 2.9. In this case, the worker is less likely to make a Home Based University trip if the household has a higher income. This makes sense, since higher income Households tend to have workers who already went to college. Probably, most of the Workers who go to college are younger people with somewhat lower household incomes. There is a higher chance of making a Home Based University trip if there are any children or any other workers in the Household or if the Household is in a high density area and a lower chance if the Household is in a low density area. It makes sense that many student workers live in multi-worker Households. The density factor probably relates to residential proximity to a college campus. The effect of the presence of children is difficult to explain.

2.1.4.6 Home Based University by Non-working Adults

The final model is shown in Table 2.10. In this case, a Household income group dummy is used instead of a single bias coefficient, but the coefficient on income doesn't vary much by income group. There is a slightly greater chance of making a Home Based University trip if the household is a low income household, suggesting that this may represent "households" consisting of college-age people. There is also a greater chance of making a trip if there are more people in the household, which seems to make sense. Density of the surrounding area also plays a role: high density means more trips, low density means fewer trips. Again, this may relate to proximity to campuses.

2.1.4.7 Home Based School by Workers

The final model is shown in Table 2.11. Only a very few workers make a Home Based School trip. These are most likely 16-18 year-olds with a part-time job. The likelihood is increased if the household is a lower income household, the more (other) adults in the household, and the more cars there are in the household.

2.1.4.8 Home Based School by Non-working Adults

The final model is shown in Table 2.12. This is similar to the Home Based School by Workers model. The chance of making a Home Based School trip increases if the household is a higher income household, as there are more other adults in the household, as the number of cars increases, and if there is a child in the Household. The income function works the opposite of the Home Based School by Worker model, for reasons that are not clear. The "other adults" and "any child" variables may suggest that there is a greater chance this person is a 16-18 year-old, and thus should be going to school.

2.1.4.9 Home Based School by Children

The final model is shown in Table 2.13. As with work trips by workers, it is difficult to determine why a child may go to school or not on any particular day. Perhaps many of the trips which would normally be classified "home-to-school" are instead classified as "home-to-other", if the child (or the parent transporting him) makes a stop on the way to school. The chance of the child making a school trip increases if there are more cars in the HH, which is interesting. The chance decreases if there is any Adult Non-workers in the Household. That most likely correlates with the child's being younger than school age. The propensity for school travel does not vary by income, which seems appropriate.

2.1.4.10 Home Based Other by Workers

The final model is shown in Table 2.14. Income clearly plays a major role, with higher income households associated with more trip making. The chance of making a Home Based Other trip (actually, an increasing number of trips) increases if there are any children in the household, which is logical. The chance that the worker will make a Home Based Other trip decreases if there are any other adults in the household, which makes sense, since the other adult could make any necessary trips.

2.1.4.11 Home Based Other by Non-working Adults

The final model is shown in Table 2.15. Again, income is a major influence, and logically so. As with the Home Based Other by workers model, trips go up if there is a child in the household and go down if there are other adults available to make the trip. Also, trips go up if there are more cars than workers, indicating the influence of mobility on what is largely discretionary travel.

2.1.4.12 Home Based Other by Children

The final model is shown in Table 2.16. Trips increase with increasing income, but the relationship is not as clear as with the other models. Trips increase if there are more cars than workers, but this probably relates to the similarly greater Home Based Other trip making by non-working adults, who then take the child along for the ride. This theory is further supported by the decrease in trips with fewer adults in the household.

2.1.4.13 Non-Home Based by Workers

The final model is shown in Table 2.17. This category has the largest number of choices: 0 through 7+ trips per day. Income plays an important role, especially the "low" vs. "non-low" comparison. Non-home Based trip making decreases if there are other adults in the household and if there are fewer cars than workers (reduced mobility), but increases if there are any children.

2.1.4.14 Non-Home Based by Non-working Adults

The final model is shown in Table 2.18. This is very similar to the Non-Home Based by workers, except that "fewer cars than workers" is replaced with "more cars than workers", and the effect is reversed. More cars than workers increase Non-Home Based trips by Non-working Adults.

2.1.4.15 Non-Home Based by Children

The final model is shown in Table 2.19. Again, "low" vs. "non-low" income is the most important segmentation. The only other variable that produced usable results was the number of adults in the household, which reduces Non-Home Based trip making by children. This suggests that when there are Non-Home Based trips to be made by the household, the priority is for the adults to make them, which makes sense.

2.1.5. Conclusions for the Trip Production Model

This work has shown that it is readily possible to extend trip-based trip generation models beyond the standard income/size based cross-classification approach. Doing so with a set of logit models makes it possible to consider many other variables and relationships that would otherwise not be tractable. Although this approach still falls short of the newly emerging tour-based micro-simulation approach, it is a reasonable mid-point between them and trip-based cross-classification models and was able to be calibrated in a much shorter time frame, which was critical in this project.

The results of this work largely support decades of prior research that have shown that household income is an extremely important determinant of household trip making. Income provides the resources both for consumption of goods and services and for trip making, so it should logically be a strong influence on travel. However, this work also suggests that a closer look at household size was worthwhile. In most of these 15 models, total number of persons is not a key variable. For adult trip-makers, total size has largely been replaced with the "number of other adults" and the "presence of any children". This suggests that the number of children in a household is not a strong determinant of travel – it doesn't matter much whether there is one child or four. But the presence of even one child makes a huge difference over the presence of none, as every new parent will readily attest.

It is also interesting that the number of cars, or the relationship between cars and workers, was important for many of the "discretionary" trip models. This influence is over and above that of income. This may suggest that the effect of "induced travel" comes indirectly from households locating in areas where transit and walking are not viable options, thus causing greater car ownership, and thus creating more trips.

The density and accessibility variables were not very important. The researchers had theorized that high density or accessibility might relate to less trip making, since car ownership could be less and more trips could be combined. This did not prove to be the case, however. The accessibility variables were statistically too weak. In those few models which used high density (area types 5, 6, 7) or low density (area types 1, 2), the propensity was for slightly more travel in high density areas and slightly less travel in low density areas.

Table 2.5
Model 1: Home Based Work Trips by Workers

PURPOSE: **HOME BASED WORK TRIPS**
TYPE OF PERSON: **WORKER**

		<---- Coefficients on Trip Frequency ------->			
Variables	Description	1 Trip	2 Trips	3 Trips	4+ Trip
Inc 1	Dummy Variable - low Income	-0.7697	0.3264	-3.2480	-3.0880
Inc 2	Dummy Var. Medium low income	-0.1436	0.6020	-2.5340	-2.3420
Inc 3	Dummy Var. Medium High Income	-0.1004	0.5619	-2.8080	-2.1940
Inc 4	Dummy Variable - High Income	-0.2047	0.4045	-2.6650	-2.6570
Any Child	Dummy variable 1 if HH has any children	-0.1887	-0.3540	-0.2418	-0.6892
Cars < Workers	Dummy Variable cars less than workers=1	-0.7281	-0.2171	-0.9196	-0.9408
Low Density	Dummy Variable 1 if area type is 5, 6, or 7	-0.1141	-0.0902	-0.4191	-0.3266

		<----- T Value on Trip Frequency ----->			
Variables	Description	1 Trip	2 Trips	3 Trips	4+ Trip
Inc 1	Dummy Variable - low Income	7.2	4.3	9.2	9.2
Inc 2	Dummy Var. Medium low income	2.6	13.1	16.4	16.7
Inc 3	Dummy Var. Medium High Income	2.2	14.5	20.6	19.8
Inc 4	Dummy Variable - High Income	3.5	8.1	15.8	16.0
Any Child	Dummy variable 1 if HH has any children	4.1	9.1	1.6	4.9
Cars < Workers	Dummy Variable cars less than workers=1	8.5	3.6	3.0	3.4
Low Density	Dummy Variable 1 if area type is 5, 6, or 7	2.5	2.3	3.0	2.7

Number of observations (person days)	16,967	Trips / Person	Number	Percent
Number of Trips	20,480	0	5,334	31.4%
Initial Log Likelihood	-27,307	1	3,677	21.7%
Final Log Likelihood	-20,003	2	7,415	43.7%
Rho-squared	0.2675	3	229	1.3%
Average of 4+ trips	4.12	4+	312	1.8%
		total	16,967	100.0%

Note: A negative sign on the coefficient signifies that the probability of making the trip frequency decreases. A positive sign signifies that the probability increases.

Table 2.6
Model 2: Home Based Shopping Trips by Workers

PURPOSE: **HOME BASED SHOPPING TRIPS**
TYPE OF PERSON: **WORKER**

Variables	Description	1 Trip	2 Trip	3+ Trip
		<- Coefficients on Trip Frequency -->		
Inc 1	Dummy Variable - low Income	-1.6230	-1.9820	-3.3400
Inc 2	Dummy Var. Medium low income	-1.0820	-1.6880	-3.1060
Inc 3	Dummy Var. Medium High Income	-0.8936	-1.4590	-2.7720
Inc 4	Dummy Variable - High Income	-0.9642	-1.4190	-2.5300
2 person	Dummy Variable (1 if 2 persons / household)	-0.4694	-0.1251	-0.0310
3 person	Dummy Variable (1 if 3 persons / household)	-0.6923	-0.3513	-0.2270
4+ person	Dummy Variable (1 if 4+ persons / household)	-0.8421	-0.3874	-0.4312
High Density	Dummy Variable (1 if area type 1 or 2)	N/A	N/A	0.5120
Low Density	Dummy Variable (1 if area type is 5, 6, or 7)	-0.0182	-0.1665	-0.3045

Variables	Description	1 Trip	2 Trip	3+ Trip
		<----- ABS(T Value) on Trip Frequency ----->		
Inc 1	Dummy Variable - low Income	14.4	15.7	13.9
Inc 2	Dummy Var. Medium low income	18.1	22.8	21.4
Inc 3	Dummy Var. Medium High Income	14.6	19.5	19.4
Inc 4	Dummy Variable - High Income	12.7	16.0	15.6
2 person	Dummy Variable (1 if 2 persons / household)	7.7	1.7	0.2
3 person	Dummy Variable (1 if 3 persons / household)	9.6	4.0	1.5
4+ person	Dummy Variable (1 if 4+ persons / household)	12.1	4.7	2.8
High Density	Dummy Variable (1 if area type 1 or 2)	N/A	N/A	3.3
Low Density	Dummy Variable (1 if area type is 5, 6, or 7)	0.4	3.2	3.0

			Trips / Person	Number	Percent
Number of observations (persons days)	16,967				
Number of Trips	8,168		0	11,965	70.5%
Initial Log likelihood	-23,521		1	2,621	15.4%
Final Log likelihood	-14,841		2	1,860	11.0%
Rho-squared	0.369		3+	521	3.1%
Average of 3+ trips	3.51	Total		16,967	100.0%

Table 2.7

Model 3: Home Based Shopping Trips by Non-working Adults

PURPOSE: **HOME BASED SHOPPING TRIPS**
TYPE OF PERSON: **NON-WORKING ADULT**

		<--------Coefficients on Trip Frequency ------->			
Variables	Description	1 Trip	2 Trip	3 Trip	4+ Trip
Inc 1	Dummy Variable - low Income	-1.2860	-0.8486	-3.5080	-2.8450
Inc 2	Dummy Var. Medium low income	-0.7616	-0.4775	-2.6200	-2.0270
Inc 3	Dummy Var. Medium High Income	-0.4832	-0.3340	-1.9460	-1.5310
Inc 4	Dummy Variable - High Income	-0.3592	-0.0740	-1.6630	-1.3880
Household Size	Number of people per household (1 to 6)	-0.3394	-0.2989	-0.3143	-0.3877
Any Child	Dummy variable 1 if HH has any children	0.6351	0.2628	0.6337	0.2186
Cars <= Workers	Dummy Variable cars less than or equal to workers = 1	-0.8990	-0.8468	-0.7976	-1.4200

		<----- ABS(T Value) on Trip Frequency ----->			
Variables	Description	1 Trip	2 Trip	3 Trip	4+ Trip
Inc 1	Dummy Variable - low Income	10.5	8.2	11.4	10.7
Inc 2	Dummy Var. Medium low income	7.3	5.1	12.1	10.2
Inc 3	Dummy Var. Medium High Income	4.6	3.5	9.4	7.6
Inc 4	Dummy Variable - High Income	2.6	0.6	6.5	5.4
Household Size	Number of people per household (1 to 6)	8.0	7.9	3.7	4.6
Any Child	Dummy variable 1 if HH has any children	5.6	2.5	2.9	1.0
Cars <= Workers	Dummy Variable cars less than or equal to workers = 1	7.9	8.6	3.3	4.9

Number of observations (person days)	8,179
Number of Trips	5,907
Initial Log likelihood	-13,163
Final Log likelihood	-8,610
Rho-squared	0.3458
Average of 4+ trips	4.32

Trips / Person		Number	Percent
	0	5,113	62.5%
	1	1,108	13.5%
	2	1,442	17.6%
	3	239	2.9%
	4+	277	3.4%
Total		8,179	100.0%

Table 2.8
Model 4: Home Based Shopping by Children

PURPOSE: **HOME BASED SHOPPING TRIPS**
TYPE OF PERSON: **CHILD**

Variables	Description	Coefficients on Trip Frequency 1 Trip	 2+ Trip
Inc 1	Dummy Variable - low Income	-1.3870	-2.0440
Inc 2	Dummy Var. Medium low income	-1.0430	-1.8310
Inc 3	Dummy Var. Medium High Income	-0.8509	-1.5670
Inc 4	Dummy Variable - High Income	-0.7379	-1.3230
Household Size	Number of people per household (1 to 6)	-0.2667	-0.2436
Any NWA	Dummy Variable (1 if any adult non-worker in HH)	N/A	0.3928
Low Density	Dummy Variable 1 if area type is 5, 6, or 7	-0.2408	-0.3030

Variables	Description	<----- ABS(T Value) on Trip Frequency -----> 1 Trip	 2+ Trip
Inc 1	Dummy Variable - low Income	5.1	6.1
Inc 2	Dummy Var. Medium low income	4.5	6.2
Inc 3	Dummy Var. Medium High Income	3.7	5.5
Inc 4	Dummy Variable - High Income	3.1	4.6
Household Size	Number of people per household (1 to 6)	5.3	3.8
Any NWA	Dummy Variable (1 if any adult non-worker in HH)	N/A	3.0
Low Density	Dummy Variable 1 if area type is 5, 6, or 7	2.1	2.2

Number of observations (person days)	4,542
Number of Trips	1,015
Initial Log likelihood	-4,990
Final Log likelihood	-2,390
Rho-squared	0.5209
Average of 2+ trips	2.15

Trips / Person	Number	Percent
0	3,838	84.5%
1	433	9.5%
2+	271	6.0%
Total	4,542	100.0%

Table 2.9
Model 5: Home Based University by Workers

PURPOSE: **HOME BASED UNIVERSITY TRIPS**
TYPE OF PERSON: **WORKER**

		Coefficients on Trip Frequency
Variables	Description	1+ Trip
Inc 1	Dummy Variable - low Income	-2.9850
Inc 2	Dummy Var. Medium low income	-3.9520
Inc 3	Dummy Var. Medium High Income	-4.2140
Inc 4	Dummy Variable - High Income	-4.3270
Any Child	Dummy variable 1 if HH has any children	0.2962
High Density	Dummy Variable (1 if area type is 1 or 2)	0.5256
Low Density	Dummy Variable (1 if area type is 5, 6, or 7)	-0.2058
Other Worker	Dummy Variable (1 if 2 workers in household)	0.6141

		<----- ABS(T Value) on Trip Frequency ----->
Variables	Description	1+ Trip
Inc 1	Dummy Variable - low Income	18.3
Inc 2	Dummy Var. Medium low income	28.0
Inc 3	Dummy Var. Medium High Income	30.1
Inc 4	Dummy Variable - High Income	25.0
Any Child	Dummy variable 1 if HH has any children	2.9
High Density	Dummy Variable (1 if area type is 1 or 2)	3.1
Low Density	Dummy Variable (1 if area type is 5, 6, or 7)	1.9
Other Worker	Dummy Variable (1 if 2 workers in household)	5.5

Number of observations (person days_	16,967
Number of Trips	761
Initial Log likelihood	-11,760
Final Log likelihood	-2,048
Rho-squared	0.8258
Average of 1+ trips	1.66

Trips / Person		Number	Percent
	0	16,508	97.3%
	1+	459	2.7%
Total		16,967	100.0%

Table 2.10
Model 6: Home Based University by Non-Working Adults

PURPOSE: **HOME BASED UNIVERSITY TRIPS**
TYPE OF PERSON: **NON-WORKING ADULT**

		Coefficients on Trip Frequency
Variables	Description	1+ Trip
Inc 1	Dummy Variable - low Income	-3.0570
Inc 2	Dummy Var. Medium low income	-3.5760
Inc 3	Dummy Var. Medium High Income	-3.5460
Inc 4	Dummy Variable - High Income	-3.6780
Household Size	Number of people per household (1 to 6)	0.2004
High Density	Dummy Variable (1 if area type is 1 or 2)	0.5331
Low Density	Dummy Variable (1 if area type is 5, 6, or 7)	-0.4707

		<----- ABS(T Value) on Trip Frequency ----->
Variables	Description	1+ Trip
Inc 1	Dummy Variable - low Income	17.8
Inc 2	Dummy Var. Medium low income	20.4
Inc 3	Dummy Var. Medium High Income	21.3
Inc 4	Dummy Variable - High Income	15.6
Household Size	Number of people per household (1 to 6)	4.8
High Density	Dummy Variable (1 if area type is 1 or 2)	2.5
Low Density	Dummy Variable (1 if area type is 5, 6, or 7)	3.8

			Trips / Person	Number	Percent
Number of observations (person days)	8,179				
Number of Trips	673		0	7,854	96.0%
Initial Log likelihood	-5,669		1+	325	4.0%
Final Log likelihood	-1,339		Total	8,179	100.0%
Rho-squared	0.7638				
Average of 1+ trips	2.07				

Table 2.11
Model 7: Home Based School Trips by Workers

PURPOSE: **HOME BASED SCHOOL TRIPS**
TYPE OF PERSON: **WORKER**

Variables	Description	Coefficients on Trip Frequency 1+ Trip
Inc 1	Dummy Variable - low Income	-6.5360
Inc 2	Dummy Var. Medium low income	-6.8240
Inc 3	Dummy Var. Medium High Income	-6.9030
Inc 4	Dummy Variable - High Income	-7.0330
Other Adults	Number of Adults in household, less 1	0.6849
Number of Cars	Number of cars in household	0.5403

Variables	Description	<----- ABS(T Value) on Trip Frequency -----> 1+ Trip
Inc 1	Dummy Variable - low Income	18.8
Inc 2	Dummy Var. Medium low income	24.7
Inc 3	Dummy Var. Medium High Income	24.9
Inc 4	Dummy Variable - High Income	22.3
Other Adults	Number of Adults in household, less 1	11.1
Number of Cars	Number of cars in household	5.8

Number of observations (person days)	16,967
Number of Trips	351
Initial Log likelihood	-11,760
Final Log likelihood	-955
Rho-squared	0.9188
Average of 1+ trips	1.79

Trips / Person	Number	Percent
0	16,771	98.8%
1+	196	1.2%
Total	16,967	100.0%

Table 2.12
Model 8: Home Based School Trips by Non-Working Adults

PURPOSE: **HOME BASED SCHOOL TRIPS**
TYPE OF PERSON: **NON-WORKING ADULT**

Variables	Description	Coefficients on Trip Frequency 1+ Trip
Inc 1	Dummy Variable - low Income	-5.4640
Inc 2	Dummy Var. Medium low income	-5.2460
Inc 3	Dummy Var. Medium High Income	-4.8060
Inc 4	Dummy Variable - High Income	-4.6420
Other Adults	Number of Adults in household, less 1	1.0260
Number of Cars	Number of cars in household	0.1294
Any Child	Dummy variable 1 if HH has any children	0.9509

Variables	Description	<----- ABS(T Value) on Trip Frequency -----> 1+ Trip
Inc 1	Dummy Variable - low Income	25.4
Inc 2	Dummy Var. Medium low income	29.7
Inc 3	Dummy Var. Medium High Income	28.3
Inc 4	Dummy Variable - High Income	22.1
Other Adults	Number of Adults in household, less 1	20.5
Number of Cars	Number of cars in household	2.3
Any Child	Dummy variable 1 if HH has any children	9.5

Number of observations (person days)	8,179
Number of Trips	967
Initial Log likelihood	-5,669
Final Log likelihood	-1,535
Rho-squared	0.7292
Average of 1+ trips	1.9

Trips / Person	Number	Percent
0	7,670	93.8%
1+	509	6.2%
Total	8,179	100.0%

Table 2.13
Model 9: Home Based School Trips by Children

PURPOSE: **HOME BASED SCHOOL TRIPS**
TYPE OF PERSON: **CHILD**

		Coefficients on Trip Frequency	
Variables	Description	1 Trip	2+ Trip
Bias	Bias Coefficient	-0.5677	0.6252
Any NWA	Dummy Variable (1 if any adult non-worker in HH)	-0.8466	-0.2891
Cars	Number of cars in household	0.1749	0.1293

		<----- ABS(T Value) on Trip Frequency ----->	
Variables	Description	1 Trip	2+ Trip
Bias	Bias Coefficient	4.6	7.0
Any NWA	Dummy Variable (1 if any adult non-worker in HH)	8.6	4.2
Cars	Number of cars in household	3.4	3.5

Number of observations (person days)	4,542
Number of Trips	6,049
Initial Log likelihood	-4,989
Final Log likelihood	-4,317
Rho-squared	0.1348
Average of 2+ trips	2.05

Trips / Person	Number	Percent
0	1,235	27.2%
1	698	15.4%
2+	2609	57.4%
Total	4,542	100.0%

Table 2.14
Model 10: Home Based Other trips by Workers

PURPOSE: **HOME BASED OTHER TRIPS**
TYPE OF PERSON: **WORKER**

		<---- Coefficients on Trip Frequency ------->			
Variables	Description	1 Trip	2 Trip	3 Trip	4 Trip
Inc 1	Dummy Variable - low Income	-1.6080	-1.7050	-3.4590	-3.5810
Inc 2	Dummy Var. Medium low income	-1.3250	-1.4550	-3.1180	-3.0720
Inc 3	Dummy Var. Medium High Income	-1.1260	-1.4810	-2.9230	-3.0230
Inc 4	Dummy Variable - High Income	-0.9980	-1.5230	-2.7910	-2.7320
Other Adults	Number of Adults in household, less 1	-0.3021	-0.1655	-0.2373	-0.2340
Any Child	Dummy Variable 1 if HH has any children	0.4891	0.6685	0.9783	1.4360

		<----- ABS(T Value) on Trip Frequency ----->			
Variables	Description	1 Trip	2 Trip	3 Trip	4 Trip
Inc 1	Dummy Variable - low Income	15.8	17.2	16.2	17.6
Inc 2	Dummy Var. Medium low income	25.9	28.0	29.4	31.1
Inc 3	Dummy Var. Medium High Income	24.9	31.1	31.4	33.5
Inc 4	Dummy Variable - High Income	16.6	23.1	23.4	25.1
Other Adults	Number of Adults in household, less 1	10.3	5.8	4.1	4.4
Any Child	Dummy Variable 1 if HH has any children	10.5	14.1	11.3	18.1

		Trips / Person	Number	Percent
Number of observations (person days)	16,967			
Number of Trips	12,679	0	10,519	62.0%
Initial Log likelihood	-27,307	1	2,704	15.9%
Final Log likelihood	-18,600	2	2,433	14.3%
Rho-squared	0.3188	3	585	3.4%
Average of 4+ trips	4.62	4+	726	4.3%
		total	16,967	100.0%

Table 2.15
Model 11: Home Based Other Trips by Non-working Adults

PURPOSE: **HOME BASED OTHER TRIPS**
TYPE OF PERSON: **NON-WORKING ADULT**

		<---- Coefficients on Trip Frequency ------->			
Variables	Description	1 Trip	2 Trip	3 Trip	4+ Trip
Inc 1	Dummy Variable - low Income	-2.0530	-1.5070	-4.2070	-3.3450
Inc 2	Dummy Var. Medium low income	-1.6890	-1.3840	-3.5460	-2.5320
Inc 3	Dummy Var. Medium High Income	-1.2070	-1.0890	-3.0130	-2.1160
Inc 4	Dummy Variable - High Income	-1.0700	-0.9071	-2.8860	-1.7020
Other Adults	Number of Adults in household, less 1	-0.2824	-0.2623	-0.5266	-0.4814
Any Child	Dummy Variable 1 if HH has any children	0.0348	0.2272	0.7896	1.4540
Cars > workers	Dummy Variable 1 if cars greater than workers	0.4933	0.6879	1.3710	0.9050

		<----- ABS(T Value) on Trip Frequency ----->			
Variables	Description	1 Trip	2 Trip	3 Trip	4+ Trip
Inc 1	Dummy Variable - low Income	16.6	15.3	14.9	19.2
Inc 2	Dummy Var. Medium low income	13.7	13.4	13.3	16.2
Inc 3	Dummy Var. Medium High Income	9.4	10.0	11.0	12.9
Inc 4	Dummy Variable - High Income	6.5	6.5	9.2	8.9
Other Adults	Number of Adults in household, less 1	6.2	7.0	6.1	8.3
Any Child	Dummy Variable 1 if HH has any children	0.4	3.1	6.2	17.0
Cars > workers	Dummy Variable 1 if cars greater than workers	4.7	7.9	5.7	6.8

		Trips / Person	Number	Percent
Number of observations (person days)	8,179			
Number of Trips	9,266	0	4,292	52.5%
Initial Log likelihood	-13,163	1	1,056	12.9%
Final Log likelihood	-10,114	2	1,687	20.6%
Rho-squared	0.2317	3	342	4.2%
Average of 4+ trips	4.75	4+	802	9.8%
		total	8,179	100.0%

Table 2.16
Model 12: Home Based Other Trips by Children

PURPOSE: **HOME BASED OTHER TRIPS**
TYPE OF PERSON: **CHILD**

		<---- Coefficients on Trip Frequency ------->			
Variables	Description	1 Trip	2 Trip	3 Trip	4+ Trip
Inc 1	Dummy Variable - low Income	-0.9732	-0.2050	-3.1440	-3.7910
Inc 2	Dummy Var. Medium low income	-0.5500	-1.1870	-2.4970	-2.9520
Inc 3	Dummy Var. Medium High Income	-0.1051	-0.7754	-2.1130	-2.6490
Inc 4	Dummy Variable - High Income	-0.0821	-0.6540	-1.8760	-2.5240
Cars > workers	Dummy Variable 1 if cars greater than workers	N/A	0.1876	0.4367	0.7729
Total Adults	Number of total adults	-0.5719	-0.1847	-0.5390	-0.4210

		<----- ABS(T Value) on Trip Frequency ----->			
Variables	Description	1 Trip	2 Trip	3 Trip	4+ Trip
Inc 1	Dummy Variable - low Income	5.1	9.6	6.8	7.2
Inc 2	Dummy Var. Medium low income	3.2	7.6	6.7	7.5
Inc 3	Dummy Var. Medium High Income	0.6	4.9	5.4	6.5
Inc 4	Dummy Variable - High Income	0.4	3.9	4.6	5.9
Cars > workers	Dummy Variable 1 if cars greater than workers	N/A	2.3	2.3	3.8
Total Adults	Number of total adults	7.1	2.7	3.1	2.4

		Trips / Person	Number	Percent
Number of observations (person days)	4,542			
Number of Trips	3,136	0	2,838	62.5%
Initial Log likelihood	-7,310	1	662	14.6%
Final Log likelihood	-4,770	2	807	17.8%
Rho-squared	0.3474	3	124	2.7%
Average of 4+ trips	4.40	4+	111	2.4%
		total	4,542	100.0%

Table 2.17
Model 13: Non-Home Based Trips by Workers

PURPOSE: **NON HOME BASED TRIPS**
TYPE OF PERSON: **WORKER**

		<----------------- Coefficients on Trip Frequency ----------------->						
Variables	Description	1 Trip	2 Trip	3 Trip	4 Trip	5 Trip	6 Trip	7+ Trip
Inc 1	Dummy Variable - low Income	-1.3750	-1.5840	-2.0930	-2.5850	-3.5530	-3.8640	-3.4520
Inc 2	Dummy Var. Medium low income	-0.9691	-1.1000	-1.5810	-1.9730	-2.7780	-3.2770	-2.8850
Inc 3	Dummy Var. Medium High Income	-0.6505	-0.8395	-1.2210	-1.7630	-2.5670	-2.8190	-2.6470
Inc 4	Dummy Variable - High Income	-0.6145	-0.7348	-1.1830	-1.6070	-2.2770	-2.8160	-2.6210
Cars < Workers	Dummy Variable 1 if cars less than workers	-0.3614	-0.3989	-0.3590	-0.1670	-0.3461	N/A	N/A
Number of Other Adults	Number of Adults in household, less 1	-0.2799	-0.3539	-0.4707	-0.4643	-0.4779	-0.5017	-0.4769
Any Child	Dummy Variable 1 if HH has any children	0.2009	0.2415	0.2812	0.3394	0.4506	0.6048	N/A

		<------------ ABS(T Value) on Trip Frequency ------------>						
Variables	Description	1 Trip	2 Trip	3 Trip	4 Trip	5 Trip	6 Trip	7+ Trip
Inc 1	Dummy Variable - low Income	13.2	13.6	13.9	14.1	12.2	12.3	13.2
Inc 2	Dummy Var. Medium low income	18.7	19.7	22.8	24.0	23.3	22.8	23.6
Inc 3	Dummy Var. Medium High Income	14.3	16.8	19.8	23.3	23.5	22.5	23.4
Inc 4	Dummy Variable - High Income	10.0	11.0	14.2	16.1	16.5	16.7	17.0
Cars < Workers	Dummy Variable 1 if cars less than workers	4.2	4.1	2.9	1.2	1.6	N/A	N/A
Number of Other Adults	Number of Adults in household, less 1	9.7	10.9	10.9	8.9	6.3	5.7	6.2
Any Child	Dummy Variable 1 if HH has any children	4.3	4.7	4.4	4.5	4.2	5.0	N/A

Number of observations (person days)	16,967
Number of Trips	22,040
Initial Log likelihood	-35,281
Final Log likelihood	-25,484
Rho-squared	0.2777
Average of 7+ trips	8.11

Trips / Person	Number	Percent
0	8,408	49.6%
1	2,907	17.1%
2	2,316	13.7%
3	1,372	8.1%
4	884	5.2%
5	411	2.4%
6	300	1.8%
7+	369	2.2%
total	16,967	100.0%

Table 2.18
Model 14: Non-Home Based Trips by Non-working Adults

PURPOSE: **NON HOME BASED TRIPS**
TYPE OF PERSON: **NON-WORKING ADULT**

Variables	Description	<------- Coefficients on Trip Frequency -------> 1 Trip	2 Trip	3 Trip	4 Trip	5+ Trip
Inc 1	Dummy Variable - low Income	-2.3450	-2.8760	-3.8520	-4.2640	-3.6380
Inc 2	Dummy Var. Medium low income	-1.9421	-2.6260	-3.3420	-3.7800	-3.0360
Inc 3	Dummy Var. Medium High Income	-1.5220	-2.0370	-3.1840	-3.4110	-2.3480
Inc 4	Dummy Variable - High Income	-1.3870	-1.7430	-2.9260	-2.9680	-2.1780
Cars > Workers	Dummy Variable 1 if cars greater than workers	0.5928	0.7435	1.2560	1.0920	0.2636
Number of Other Adults	Number of Adults in household, less 1	-0.1991	-0.3976	-0.3465	-0.3815	-0.5378
Any Child	Dummy variable 1 if HH has any children	0.1863	0.3079	0.3518	0.3230	0.5909

Variables	Description	<----- ABS(T Value) on Trip Frequency -----> 1 Trip	2 Trip	3 Trip	4 Trip	5+ Trip
Inc 1	Dummy Variable - low Income	19.2	18.2	16.4	14.6	15.1
Inc 2	Dummy Var. Medium low income	16.2	14.9	14.6	13.3	13.5
Inc 3	Dummy Var. Medium High Income	12.2	12.7	13.3	11.6	10.1
Inc 4	Dummy Variable - High Income	9.0	9.1	10.6	9.0	7.6
Cars > Workers	Dummy Variable 1 if cars greater than workers	5.8	5.6	6.0	4.3	1.4
Number of Other Adults	Number of Adults in household, less 1	4.7	7.0	4.7	4.1	5.7
Any Child	Dummy variable 1 if HH has any children	2.4	3.3	2.9	2.2	4.3

		Trips / Person	Number	Percent
Number of observations (person days)	8,179			
Number of Trips	6,766	0	5,248	64.2%
Initial Log likelihood	-14,654	1	1,221	14.9%
Final Log likelihood	-9,273	2	749	9.2%
Rho-squared	0.3672	3	421	5.1%
Average of 5+ trips	6.24	4	261	3.2%
		5+	279	3.4%
		total	8,179	100.0%

Table 2.19
Model 15: Non-Home Based Trips by Children

PURPOSE: **NON HOME BASED TRIPS**
TYPE OF PERSON: **CHILD**

Variables	Description	<--- Coefficients on Trip Frequency ---> 1 Trip	2 Trip	3 Trip	4+ Trip
Inc 1	Dummy Variable - low Income	-1.1690	-1.6980	-4.0920	-3.3920
Inc 2	Dummy Var. Medium low income	-0.8698	-1.0680	-1.7810	-2.7250
Inc 3	Dummy Var. Medium High Income	-0.3137	-0.9809	-1.6880	-2.1240
Inc 4	Dummy Variable - High Income	-0.1489	-0.7965	-1.5600	-2.8610
Total Adults	Number of adults	-0.4456	-0.5585	-0.6797	-0.5273

Variables	Description	<--- ABS(T Value) on Trip Frequency ---> 1 Trip	2 Trip	3 Trip	4+ Trip
Inc 1	Dummy Variable - low Income	6.3	6.7	5.5	6.3
Inc 2	Dummy Var. Medium low income	5.4	5.0	5.3	6.5
Inc 3	Dummy Var. Medium High Income	1.9	4.3	4.6	4.9
Inc 4	Dummy Variable - High Income	0.9	3.3	4.0	5.6
Total Adults	Number of adults	6.1	5.5	4.0	2.7

		Trips / Person	Number	Percent
Number of observations (person days)	4,542			
Number of Trips	2,323	0	3,175	69.9%
Initial Log likelihood	-7,310	1	777	17.1%
Final Log likelihood	-4,175	2	367	8.1%
Rho-squared	0.4289	3	133	2.9%
Average of 4+ trips	4.59	4+	90	2.0%
		total	4,542	100.0%

2.2. Non-Motorized Trips

The trip production model estimates productions for all travel including travel by automobile, by transit, by walking and by bicycling. The later models in the travel demand model chain only handle trips by the motorized modes of automobile and transit. It is therefore important for the trip generation model to separate out the motorized productions from the non-motorized productions of walking and bicycling. The section describes the model which allows this separation.

There were very few non-motorized trips in the home interview survey as shown in the below table.

Purpose	Number of Non-motorized Trips	Percent Non-Motorized of all trips
Home Based Work	463	2.22%
Home Based Shopping	583	3.86%
Home Based Other	1,460	5.82%
Home Based School	438	5.32%
Home Based University	180	12.55%
Non-Home Based	1,937	6.22%

Most of these non-motorized trips were walk trips with very few bicycle trips; too few bicycle trips to allow any reasonable statistical modeling procedure for bicycle trips. Therefore walk and bicycle trips were merged into a single mode – non-motorized trips.

For the non-motorized model, the same calibration file, used in the production model calibration, was used. The independent variables used in the model are shown on Table 2.20. There were essentially three independent variables. The income of the household of the traveler; specified as four dummy variables – that is, a 1 if the household was in the income group represented by the variable. The density of the area of the household of the traveler was the second type of measure. This measure was represented by the zone area type of the household. This measure was represented by three dummy variables – one for a high density area, one for a medium dense area and one for a low density area. The final type of measure was the accessibility measure described in section 2.1.2. These accessibility measures used the highway distance, not including freeways, as the impedance variable and the used three measures of activity (population, employment, and population plus employment).

The model used in the calibration was a logit formulation, as described in section 2.1, with the dependent variable being the probability that the trip would be a non-motorized trip. Again the ALOGIT program, version 3F/2, was used and the criteria, used to select the best model, were the same as described in section 2.1.3.

2.2.1. Calibration Results

This section will discuss for each of the six models, the variables used in the selected model and the statistical measures for each model. The specific model specifications, including coefficients and statistical tests are shown on Tables 2.21 to 2.26.

2.2.1.1. Home Based Work Trips

The final model is shown on Table 2.21. As was expected the persons from the higher income households had a smaller proportion of non-motorized trips – the coefficient on income becoming increasing negative as income increases. The accessibility measure used in this model was the employment / distance measure and as this measure increased (more employment close to the household of the traveler) the proportion of non-motorized trips increased. The final independent measure was the three density measures. The high and medium density measures had positive coefficients (increasing the proportion of non-motorized trips) while the low density measure had a negative coefficient (decreasing the proportion of non-motorized trips). All the independent variables in this model had “T” values of greater than 2.5, meaning they were statistically significant.

2.2.1.2. Home Based Shopping Trips

The final model is shown on Table 2.22. This model was very similar to the home based work model. The proportion of non-motorized trips decreases as income increases. The accessibility measure was employment and the coefficient on the measure was positive as similar to the home based work coefficient. The coefficients on the density measures were all positive, but the “T” value for the low density measure was less than 2.5 – meaning it was not significantly different from a coefficient of zero. All the other coefficients had a “T” value of greater than 2.5.

2.2.1.3. Home Based School Trips

The final model is shown on Table 2.23. This model used only income and the population distance accessibility measure. As with the other models the proportion of non-motorized trips decreases as income increases. The population distance accessibility measure is very strong (a “T” value of 11.0) and shows the proportion of non-motorizing trips increasing with increasing population density. Again all “T” values were greater than 2.5.

2.2.1.4. Home Based University Trips

The final model is shown on Table 2.24. This model used income and the density measures. As with the other models the proportion of non-motorized trips decreases as income increases. The proportion of non-motorizing trips increased as the zones became denser, although the “T” value for the low density variable was insignificant – that is statistically it could have been zero. With the exception of the low density measure, all the “T” values were greater than 2.5.

2.2.1.5. Non-Home Based Trips

The final model is shown on Table 2.25. This model used income, the density measures, and the employment plus population accessibility measure. As with the other models the proportion of non-motorized trips decreases as income increases. The proportion of non-motorizing trips increased as the zones became denser. The high and medium density zones, though, had a very similar coefficient. The population-employment accessibility measure coefficient was positive – showing that the proportion of non-motorized trips increase as more employment and population are within walking distance. All the “T” values were greater than 2.5, except the low density measure which had a “T” value of 2.4.

2.2.1.6. Home Based Other Trips

The final model is shown on Table 2.26. This model used income, the density measures, and the employment plus population accessibility measure. As with the other models the proportion of non-motorized trips decreases as income increases. The proportion of non-motorizing trips increased as the zones became denser. The high and medium density zones had a very similar coefficient and the low density coefficient had a ”T” value of 1.6 (that is it could have been zero). The population-employment accessibility measure coefficient was positive –showing that the proportion of non-motorized trips increase as more employment and population are within walking distance. All the “T” values were greater than 2.5, except the low density measure which had a “T” value of 1.6.

2.2.2. Conclusions for the Non-Motorized Model

This work showed that it is possible to estimate the proportion of non-motorized trips using information on the wealth of the traveler, the urban form in terms of density, and the availability of opportunities in terms of the number of jobs and people within a reasonable distance. While the number of non-motorized trip records was very small (ranging from two thousand to two hundred), it was possible to develop a statistically significant model by using disaggregate modeling procedures. That is logit calibration and estimating proportions rather than trips.

Table 2.20
Descriptions of Variables Used in Non-motorized Model

Variable Description

Variable	Description
Inc1dum	Low Income Dummy, 1 if Inc<=19999
Inc2dum	Low Med. Inc Dummy, 1 if 20000<=Inc<=49999
Inc3dum	High Med Inc Dummy, 1 if 50000<=Inc<=99999
Inc4dum	High Income Dummy, 1 if Inc>=100000
EmpDis *	Employment Distance Access Measure
PopDis *	Population Distance Access Measure
EPDis *	Emp + Pop Distance Access Measure
HighDen	High Density Dummy, 1 if Area Type = 1 or 2
MedDen	Medium Density Dummy, 1 if Area Type = 3
LowDen	Low Density Dummy, 1 if Area Type = 5 or 6 or 7

*Note
$EmpDis = Sum_j (Employment_j / Distance_{ij}^2)$
$PopDis = Sum_j (Population_j / Distance_{ij}^2)$
$EPDis = Sum_j ((Employment_j + Population_j) / Distance_{ij}^2)$

Table 2.21
Non-Motorized Model for Home Based Work Trips

ARC Non-Motorized Model
Purpose: Home Based Work
Distance Access Measure: Employment

Number of Observations (Trips) = 20889

Number of non-motorized trips = 463

Likelihood with Zero Coefficients = -14479.1515

Likelihood with Constants only = -2221.5137

Initial Likelihood = -14479.1515

Final value of Likelihood = -1938.5833

"Rho-Squared" w.r.t. Zero = .8661

"Rho-Squared" w.r.t. Constants = .1274

	inc1dum	inc2dum	inc3dum	inc4dum	EMPDis	HighDen
Estimate	-3.274	-3.641	-4.363	-5.039	.2379E-05	1.497
Std. Error	.196	.155	.155	.220	.380E-06	.183
"T" Ratio	-16.7	-23.5	-28.1	-22.9	6.3	8.2

	MedDen	LowDen
Estimate	.6534	-.4745
Std. Error	.175	.166
"T" Ratio	3.7	-2.9

Note: A negative sign on the coefficient means that the percent of non-motorized trips decrease, with the highest (furthest from zero) negative value having the least percent of non-motorized trips. A positive sign means that the percent of non-motorized trips increase.

Table 2.22
Non-Motorized Model for Home Based Shopping Trips

ARC Non-Motorized Model
Purpose: Home Based Shopping
Distance Access Measure: Employment

Number of Observations (Trips) = 15090

Number of non-motorized trips = 583

Likelihood with Zero Coefficients = -10459.5910

Likelihood with Constants only = -2468.4390

Initial Likelihood = -10459.5910

Final value of Likelihood = -2162.8956

"Rho-Squared" w.r.t. Zero = .7932

"Rho-Squared" w.r.t. Constants = .1238

	inc1dum	inc2dum	inc3dum	inc4dum	EMPDis	HighDen
Estimate	-2.909	-3.908	-4.582	-4.489	.3000E-05	1.633
Std. Error	.180	.171	.169	.191	.706E-06	.216
"T" Ratio	-16.1	-22.9	-27.1	-23.6	4.3	7.6

	MedDen	LowDen
Estimate	1.800	.3092
Std. Error	.175	.171
"T" Ratio	10.3	1.8

Table 2.23
Non-Motorized Model for Home Based School Trips

ARC Non-Motorized Model
Purpose: Home Based School
Distance Access Measure: Population

Number of Observations (Trips) = 4115

Number of non-motorized trips = 438

Likelihood with Zero Coefficients = -2852.3006

Likelihood with Constants only = -1395.0123

Initial Likelihood = -2852.3006

Final value of Likelihood = -1142.6458

"Rho-Squared" w.r.t. Zero = .5994

"Rho-Squared" w.r.t. Constants = .1809

	Inc1dum	inc2dum	inc3dum	inc4dum	PopDis
Estimate	-1.564	-2.847	-3.815	-4.037	.2397E-04
Std. Error	.176	.141	.141	.194	.219E-05
"T" Ratio	-8.9	-20.2	-27.1	-20.8	11.0

Table 2.24
Non-Motorized Model for Home Based University Trips

ARC Non-Motorized Model
Purpose: Home Based University

Number of Observations (Trips) = 1434

Number of non-motorized trips = 180

Likelihood with Zero Coefficients = -993.9731

Likelihood with Constants only = -541.7461

Initial Likelihood = -993.9731

Final value of Likelihood = -419.3346

"Rho-Squared" w.r.t. Zero = .5781

"Rho-Squared" w.r.t. Constants = .2260

	inc1dum	inc2dum	inc3dum	inc4dum	HighDen	MedDen
Estimate	-2.585	-3.538	-3.953	-4.607	3.001	1.862
Std. Error	.533	.524	.530	.690	.538	.540
"T" Ratio	-4.8	-6.7	-7.5	-6.7	5.6	3.4

	LowDen
Estimate	.7417
Std. Error	.532
"T" Ratio	1.4

Table 2.25
Non-Motorized Model for Non-Home Based Trips

ARC Non-Motorized Model
Purpose: Non-Home Based
Distance Access Measure: Employment + Population

Number of Observations (Trips) = 31129

Number of non-motorized trips = 1937

Likelihood with Zero Coefficients = -21576.9786

Likelihood with Constants only = -7254.4927

Initial Likelihood = -21576.9786

Final value of Likelihood = -6989.0985

"Rho-Squared" w.r.t. Zero = .6761

"Rho-Squared" w.r.t. Constants = .0366

	inc1dum	inc2dum	Inc3dum	inc4dum	EPDis	HighDen
Estimate	-2.760	-3.264	-3.457	-3.368	.4384E-05	.4378
Std. Error	.107	.851E-01	.794E-01	.888E-01	.380E-06	.127
"T" Ratio	-25.8	-38.3	-43.5	-37.9	11.5	3.5

	MedDen	LowDen
Estimate	.5334	.1872
Std. Error	.917E-01	.770E-01
"T" Ratio	5.8	2.4

Table 2.26
Non-Motorized Model for Home Based Other Trips

ARC Non-Motorized Model
Purpose: Home Based Other
Distance Access Measure: Employment + Population

Number of Observations (Trips) = 25081

Number of non-motorized trips = 1460

Likelihood with Zero Coefficients = -17384.8244

Likelihood with Constants only = -5568.4205

Initial Likelihood = -17384.8244

Final value of Likelihood = -5209.4163

"Rho-Squared" w.r.t. Zero = .7003

"Rho-Squared" w.r.t. Constants = .0645

	inc1dum	inc2dum	inc3dum	inc4dum	EPDis	HighDen
Estimate	-2.719	-3.276	-3.551	-3.952	.4412E-05	.8133
Std. Error	.115	.985E-01	.932E-01	.114	.449E-06	.146
"T" Ratio	-23.7	-33.2	-38.1	-34.6	9.8	5.6

	MedDen	LowDen
Estimate	.7389	.1463
Std. Error	.106	.907E-01
"T" Ratio	7.0	1.6

2.3. School Bus Trips

The trip production model includes home based school trips which are made by school bus. Since the provision of school bus service is a local policy decision, no mathematical model was used to estimate school bus usage. Instead the present school bus usage was determined, from the home interview survey, and used as the basis for "removing" the school bus trips from the home based school productions. Very close to half of all school trips are made by school buses, ranging from 39 percent in the city of Atlanta to 54 percent in the outlying counties of the ARC region. Because of the small number of school bus trips by county, especially the outlying counties, the percent of school bus trips was grouped by counties with similar school bus usage. The following school bus proportions were used in the model:

1. City of Atlanta – 38.0%
2. Rest of Fulton County – 48.8%
3. Dekalb County – 47.1%
4. Cobb County – 52.0%
5. Gwinnett County – 55.4%
6. All other counties – 53.5%

2.4. Socio-Economic Model

The trip production model requires a great deal of information about the characteristics of the households in the region. The ARC staff develops forecasts of households by family size and four income group for each traffic analysis zone. For the travel demand models developed from the 2000 home interview survey, these four income groups are as follows:

Income Group	Income range (2000 dollars)	Percent of households
1 Low	0 to $19,999	14.3%
2. Low Medium	$20,000 to $49,999	31.9%
3. High Medium	$50,000 to $99,999	35.2%
4. High	$100,000 or more	18.5%

The New Dram / Empal model, being prepared by the ARC staff, will actually estimate the households by six income groups and the travel demand model procedures will aggregate the second and third Dram / Empal group to the Low Medium group and the fourth and fifth Dram / Empal group to the High Medium group. There are six family size ranges which are 1 person per household, 2 persons per household, 3 persons per household, 4 persons per household, 5 persons per household, and six or more persons per household.

Using the households stratified by size and income group, the travel demand procedures use models to further stratify the households. These stratifications are by number of workers in the household, number of children in the household, and number of automobiles owned by the household. There are four stratifications of workers (0, 1, 2, and 3+) and six stratifications of children (0, 1, 2, 3, 4, and 5+). There are also four stratifications of automobile ownership (0, 1, 2 and 3+). Given these stratifications there are two thousand, three hundred and four possible combinations of households – not all of these combinations are physically feasible. In fact there are only one thousand and seventy logical combinations.

This section discusses the three socio-economic models required to develop these household classifications. These models are: (1) a model to estimate the number of workers per household; a model to estimate the number of children in a household; and (3) a model to estimate the number of automobiles owned by a household. Each of these models is designed to estimate the probability (or percent) of households with an integer number of workers, children and / or automobiles. To determine the number of households by each category the households by income group and family size are multiplied by these probabilities. Given the fairly small number of households in a traffic analysis zone (TAZ) and the large number of combinations, it is obvious that estimates of integer (i.e. whole numbers) households cannot be made for each category and the estimates will be made using partial households (real values). These partial households will be kept in the computer memory, during the trip generation application, and the trip produced by these households will be aggregated at the zone level, only by income level, for output data to be used by the distribution model.

2.4.1. Worker Model

The first model in the socio-economic estimation chain is the Worker model, which estimates the number of households by 0, 1, 2 and 3 or more workers. This model uses information from the census data to estimate the percent of households by these worker categories given the family size and income of the household[1]. The model consists of two tables. The first is a cross-classification table which contains the average workers per household stratified by income and family size. The second table is a single dimension table which contains the percent of households by each worker category given the average workers per household. The first cross classification table was developed from the 1990 census data[2]. This cross tabulation is as follows:

Regional Average Workers per Household by Size and Household Income Quartile

	Income Quartile				
Persons	1	2	3	4	Subtotal
1	0.282	0.803	0.847	0.809	0.571
2	0.509	1.177	1.559	1.567	1.303
3	0.782	1.453	1.945	2.003	1.683
4	0.837	1.594	1.984	2.190	1.846
5	1.000	1.689	2.150	2.232	1.931
6+	0.949	1.876	2.592	3.468	2.312
Subtotal	0.460	1.212	1.764	1.912	1.360

The single dimension table is shown on table 2-27. The use of these two tables allows the trip generation procedures to estimate a unique percent of households by worker for each income group and household size group combination.

2.4.2. Child Model

Once the households are estimated by income group, family size and number of workers, the next step is to estimate the number of households, in each of the income, size, and worker categories, by the number of children, from no children to 5 or more children. The procedure to estimate these households was also developed using the 1990 PUMS census data. The model development used the same technique as was used for the worker model. In this case, though, the initial households were stratified by three variables instead of two. The final model combined the average children per household with the probability of a household with 0, 1, 2, 3, 4 or 5 or more children to produce a combined table showing the probability of households by each child category for each income, size, and worker category. This combined table is shown on Table 2-28.

[1] A description of the previous worker model can be found on page 5-14 of "Transportation Solutions for a New Century, Appendix 4, Model Documentation", Atlanta Regional Commission, August 28, 2002.
[2] The 2000 census data, required by this cross classification table, was not available at the time of this analysis.

Table 2.27
Worker Distribution Model

Average workers/HH	Percent No Workers	Percent One Worker	Percent Two Workers	Percent 3+ Workers
0.0	100.00%	0.00%	0.00%	0.00%
0.1	90.00%	10.00%	0.00%	0.00%
0.2	80.50%	19.00%	0.50%	0.00%
0.3	71.63%	26.74%	1.63%	0.00%
0.4	64.00%	33.38%	1.94%	0.68%
0.5	58.00%	37.04%	3.46%	1.50%
0.6	51.84%	40.21%	6.05%	1.90%
0.7	47.08%	41.57%	8.55%	2.80%
0.8	41.96%	43.45%	10.99%	3.60%
0.9	37.07%	44.64%	14.00%	4.29%
1.0	32.60%	45.61%	16.51%	5.28%
1.1	28.53%	45.49%	19.85%	6.13%
1.2	24.75%	43.77%	25.00%	6.48%
1.3	21.10%	42.31%	29.50%	7.09%
1.4	17.85%	40.45%	33.81%	7.89%
1.5	13.87%	39.81%	37.75%	8.57%
1.6	10.65%	38.95%	40.50%	9.90%
1.7	8.35%	37.05%	43.00%	11.60%
1.8	5.90%	35.50%	45.25%	13.35%
1.9	4.88%	33.07%	46.01%	16.04%
2.0	3.51%	30.63%	47.47%	18.39%
2.1	3.00%	27.67%	48.00%	21.33%
2.2	2.20%	25.52%	47.90%	24.38%
2.3	1.75%	23.59%	46.78%	27.88%
2.4	1.40%	21.40%	45.85%	31.35%
2.5	1.10%	19.80%	43.90%	35.20%
2.6	0.85%	18.05%	42.15%	38.95%
2.7	0.55%	15.90%	41.33%	42.22%
2.8	0.20%	14.00%	39.70%	46.10%
2.9	0.08%	12.19%	37.75%	49.98%
3.0	0.05%	10.08%	36.07%	53.80%
3.1	0.02%	8.20%	34.03%	57.75%
3.2	0.00%	5.53%	33.17%	61.30%
3.3	0.00%	3.10%	31.90%	65.00%
3.4	0.00%	0.95%	30.22%	68.83%
3.5	0.00%	0.18%	26.48%	73.34%
3.6	0.00%	0.00%	21.86%	78.14%
3.7	0.00%	0.00%	16.98%	83.02%
3.8	0.00%	0.00%	12.10%	87.90%
3.9	0.00%	0.00%	7.20%	92.80%
4.0	0.00%	0.00%	0.00%	100.00%

`

Table 2-28 Child Model

Size	Workers	Income	0 C	1 C	2 C	3 C	4 C	5+C	Children/HH
1	0	1	100%	0%	0%	0%	0%	0%	0.00
1	0	2	100%	0%	0%	0%	0%	0%	0.00
1	0	3	100%	0%	0%	0%	0%	0%	0.00
1	0	4	100%	0%	0%	0%	0%	0%	0.00
1	1	1	100%	0%	0%	0%	0%	0%	0.00
1	1	2	100%	0%	0%	0%	0%	0%	0.00
1	1	3	100%	0%	0%	0%	0%	0%	0.00
1	1	4	100%	0%	0%	0%	0%	0%	0.00
2	0	1	83%	17%	0%	0%	0%	0%	0.17
2	0	2	98%	2%	0%	0%	0%	0%	0.02
2	0	3	99%	1%	0%	0%	0%	0%	0.01
2	0	4	100%	0%	0%	0%	0%	0%	0.00
2	1	1	72%	28%	0%	0%	0%	0%	0.28
2	1	2	78%	22%	0%	0%	0%	0%	0.22
2	1	3	92%	8%	0%	0%	0%	0%	0.08
2	1	4	100%	0%	0%	0%	0%	0%	0.00
2	2	1	100%	0%	0%	0%	0%	0%	0.00
2	2	2	100%	0%	0%	0%	0%	0%	0.00
2	2	3	100%	0%	0%	0%	0%	0%	0.00
2	2	4	100%	0%	0%	0%	0%	0%	0.00
3	0	1	30%	21%	49%	0%	0%	0%	1.20
3	0	2	54%	34%	12%	0%	0%	0%	0.59
3	0	3	80%	20%	0%	0%	0%	0%	0.20
3	0	4	80%	20%	0%	0%	0%	0%	0.20
3	1	1	15%	49%	37%	0%	0%	0%	1.22
3	1	2	21%	57%	22%	0%	0%	0%	1.00
3	1	3	30%	63%	7%	0%	0%	0%	0.77
3	1	4	30%	68%	1%	0%	0%	0%	0.71
3	2	1	37%	56%	9%	0%	0%	0%	0.74
3	2	2	28%	72%	0%	0%	0%	0%	0.72
3	2	3	33%	67%	0%	0%	0%	0%	0.67
3	2	4	47%	53%	0%	0%	0%	0%	0.53
3	3	1	100%	0%	0%	0%	0%	0%	0.00
3	3	2	100%	0%	0%	0%	0%	0%	0.00
3	3	3	100%	0%	0%	0%	0%	0%	0.00
3	3	4	100%	0%	0%	0%	0%	0%	0.00
4	0	1	14%	8%	33%	45%	0%	0%	2.08
4	0	2	7%	17%	53%	25%	0%	0%	1.95
4	0	3	0%	0%	100%	0%	0%	0%	2.00
4	0	4	8%	26%	64%	2%	0%	0%	1.60
4	1	1	5%	16%	54%	25%	0%	0%	1.98
4	1	2	2%	10%	80%	8%	0%	0%	1.94
4	1	3	6%	11%	81%	1%	0%	0%	1.78
4	1	4	10%	17%	73%	0%	0%	0%	1.63
4	2	1	10%	29%	61%	1%	0%	0%	1.53
4	2	2	8%	24%	68%	0%	0%	0%	1.59
4	2	3	7%	18%	75%	0%	0%	0%	1.68
4	2	4	9%	22%	69%	0%	0%	0%	1.60
4	3	1	0%	100%	0%	0%	0%	0%	1.00
4	3	2	42%	54%	4%	0%	0%	0%	0.62
4	3	3	55%	45%	0%	0%	0%	0%	0.45
4	3	4	70%	30%	0%	0%	0%	0%	0.30
5	0	1	0%	13%	7%	33%	47%	0%	3.13
5	0	2	3%	8%	19%	58%	12%	0%	2.68
5	0	3	0%	33%	0%	67%	0%	0%	2.33
5	0	4	0%	0%	100%	0%	0%	0%	2.00
5	1	1	3%	10%	20%	60%	7%	0%	2.57
5	1	2	0%	10%	22%	65%	3%	0%	2.61
5	1	3	3%	5%	21%	71%	0%	0%	2.60
5	1	4	4%	8%	12%	77%	0%	0%	2.62
5	2	1	0%	10%	40%	50%	0%	0%	2.40
5	2	2	6%	16%	19%	59%	0%	0%	2.32
5	2	3	3%	14%	32%	51%	0%	0%	2.31
5	2	4	12%	12%	44%	32%	0%	0%	1.96
5	3	1	0%	50%	50%	0%	0%	0%	1.50
5	3	2	18%	45%	37%	0%	0%	0%	1.19
5	3	3	28%	39%	33%	0%	0%	0%	1.05
5	3	4	53%	37%	10%	0%	0%	0%	0.57
6	0	1	0%	0%	0%	7%	29%	64%	4.57
6	0	2	0%	1%	7%	9%	43%	40%	4.14
6	0	3	0%	4%	12%	15%	53%	17%	3.69
6	0	4	2%	6%	14%	32%	40%	8%	3.24
6	1	1	0%	1%	7%	9%	43%	40%	4.14
6	1	2	0%	3%	13%	9%	53%	22%	3.78
6	1	3	0%	14%	14%	17%	48%	7%	3.21
6	1	4	3%	7%	15%	44%	29%	4%	3.01
6	2	1	0%	4%	12%	15%	53%	17%	3.69
6	2	2	3%	5%	10%	33%	33%	15%	3.36
6	2	3	3%	10%	20%	25%	35%	8%	3.03
6	2	4	8%	8%	17%	25%	42%	0%	2.83
6	3	1	2%	6%	14%	32%	40%	8%	3.24
6	3	2	0%	20%	15%	40%	15%	10%	2.80
6	3	3	6%	14%	47%	17%	13%	3%	2.23
6	3	4	26%	19%	26%	19%	3%	6%	1.74

2.4.3. Automobile Ownership Model

2.4.3.1. Introduction

The initial automobile ownership model was developed in 2000 using a structural form developed by James Ryan and Greg Han[3]. The initial model was developed using the 1990 home interview survey for the Atlanta region, the 1990 Census Public Use Microdata Sample (PUMS) and the 1990 Census Journey to Work data. A complete description of the model development is contained in the ARC's Report "Transportation Solutions for a New Century".[4] The automobile ownership model will remain a part of the ARC travel demand estimation process. For the 2003 travel demand model update, the automobile ownership model was updated using the home interview survey to investigate necessary changes in the coefficients of the model. These evaluations led to revisions in the income coefficients. Detailed evaluations of the mode choice model were conducted in 2007 and early 2008 which led to investigating other model components that occur in the model sequence before the mode choice model. An assessment of the auto ownership model found that the auto ownership model's estimation of the geographic distribution of zero auto households was inadequate, which has a very important impact on the mode choice model. Therefore, in 2008 the auto ownership model was updated and validated using census data that was not available in 2003.

2.4.3.2. Model Summary

The automobile ownership model is a logit model which estimates the probability of a household owning 0, 1, 2 or 3 or more automobiles. The logit model is implemented by calculating a disutility expression (equation) for each of the automobile ownership choices (that is no automobiles, 1, 2, or 3 or more automobiles). The automobile ownership equations have three independent variables. These variables are income of the household, stratified by four groups, the natural logarithm of density of the area, and the automobile importance. The density of the area is the population plus the employment divided by the acreage of the zone. The automobile importance is a ratio of the accessibility to employment by highway divided by the sum of the accessibility to employment by highway, transit and the walk mode. The automobile importance measure is modified by an automobile sufficiency value. The automobile sufficiency value depends upon the number of persons and workers in the household and is simply the number of available automobiles per worker or non-worker. For example in a household with 2 workers and one non-worker, the ownership of 1 automobile would provide a worker sufficiency rating of 1 and a non-worker sufficiency rating of 0, while the ownership of 4 automobiles would provide a worker sufficiency of 2 and a non-worker sufficiency of 1. A complete listing of the sufficiency ratings used in the model is shown on Table 2.29.

[3] "Vehicle-Ownership Model Using Family Structure and Accessibility Application to Honolulu, Hawaii", by Ryan, JM and Han, G., Transportation Research Record 1676, 1999.

[4] "Transportation Solutions for a new Century, Appendix 4 Model Documentation", Atlanta Regional Commission, August 28, 2002, pages 5-1 to 5-21. .

Table 2.29
Sufficiency Ratings

Persons per Household	Number of Workers	Number of Cars	Worker Suff.	Other Suff.
1	0	0	NA	0
1	0	1	NA	1
1	0	2	NA	1
1	0	3	NA	1
1	1	0	0	NA
1	1	1	1	NA
1	1	2	1	NA
1	1	3	1	NA
2	0	0	NA	0
2	0	1	NA	1
2	0	2	NA	2
2	0	3	NA	2
2	1	0	0	0
2	1	1	1	0
2	1	2	1	1
2	1	3	1	1
2	2	0	0	NA
2	2	1	1	NA
2	2	2	2	NA
2	2	3	2	NA
3	0	0	NA	0
3	0	1	NA	1
3	0	2	NA	2
3	0	3	NA	3
3	1	0	0	0
3	1	1	1	0
3	1	2	1	1
3	1	3	1	2
3	2	0	0	0
3	2	1	1	0
3	2	2	2	0
3	2	3	2	1
3	3	0	0	NA
3	3	1	1	NA
3	3	2	2	NA
3	3	3	3	NA
4	0	0	NA	0
4	0	1	NA	1
4	0	2	NA	2
4	0	3	NA	3
4	1	0	0	0
4	1	1	1	0
4	1	2	1	1
4	1	3	1	2
4	2	0	0	0
4	2	1	1	0
4	2	2	2	0
4	2	3	2	1
4	3	0	0	0
4	3	1	1	0
4	3	2	2	0
4	3	3	2	1

The auto ownership model uses income groups that are consistent with those that were described previously. New income coefficients were asserted using observed CTPP 2000 auto ownership shares as the basis. CTPP TAZ level data were processed to generate the following cross tabulation:

CTPP 2000

Summary Level: TAZ (13-county model area plus Bartow County)

Number of Autos	Income Group				
	1	2	3	4	Total
0	53,633	30,820	11,518	3,792	99,763
1	99,604	212,226	104,453	24,571	440,854
2	34,199	152,493	251,959	136,316	574,967
3+	9,231	43,845	117,665	87,737	258,478
Total	196,667	439,384	485,595	252,416	1,374,062

To estimate income coefficients, household auto ownership percents within each income group were then calculated as follows:

Percent by Income Group (CTPP)

Number of Autos	Income Group				
	1	2	3	4	Total
0	27.3%	7.0%	2.4%	1.5%	7.3%
1	50.6%	48.3%	21.5%	9.7%	32.1%
2	17.4%	34.7%	51.9%	54.0%	41.8%
3+	4.7%	10.0%	24.2%	34.8%	18.8%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

From these values, shares relative to the zero auto percents were then calculated as:

Shares Relative to Zero Autos

Number of Autos	Income Group			
	1	2	3	4
0	1.0000	1.0000	1.0000	1.0000
1	1.8571	6.8860	9.0687	6.4797
2	0.6376	4.9479	21.8752	35.9483
3+	0.1721	1.4226	10.2157	23.1374

Income coefficients were then estimated by taking the natural logarithm of these relative shares. The following are the resulting income coefficients:

Income Coefficients

Number of Autos	Income Group			
	1	2	3	4
0	0.000	0.000	0.000	0.000
1	0.619	1.929	2.205	1.869
2	-0.450	1.599	3.085	3.582
3+	-1.760	0.352	2.324	3.141

The previous auto ownership model's direct use of zonal densities was a significant reason for the model's poor geographic allocation of zero auto households. However, when the auto ownership model was applied and recalibrated without the density variable it led to the conclusion that some form of density measure was important. Therefore, a different density measure was selected. The primary problem with the previous density measure occurred for very high density zones. For very high density zones, the density variable's contribution to the total zonal disutility was much greater than the other independent variables. The result was that nearly 100% of the households in very dense zones were estimated to own zero autos. As a result, most zero auto households were allocated to high density areas rather than being more widely distributed throughout the region as observed in census data. Using floating zone densities was considered as a potential revised density measure. Floating zone densities would lessen the potential of having very high densities, but cannot eliminate the possibility, so this approach was not selected. The selected approach was to use the natural logarithm of the density, which essentially removes the potential of the density variable contributing an inordinate amount to the overall disutility.

The previous density coefficients were developed using logit estimation and the 1990 household survey. These coefficients were used as the basis for developing density coefficients for the new density measure. New density coefficients were set to produce roughly the same disutility values as the previous density coefficients when using the average and median regional population-employment densities.

Auto Sufficiency coefficients were left unchanged. The final disutility equations are shown in Table 2.30.

Table 2.30
Automobile Ownership Disutility Equations

No Cars = 0 (this is by definition)

One car = -1.992 + 0.619 * Inc1 + 1.929 * Inc2 + 2.205 * Inc3 + 1.869 * Inc4
- 0.115 * ln(Emp-Pop Density) + 3.38 * WorkSuff * auto imp + 1.27 * OthSuff * auto imp

Two Car = -3.314 – 0.450 * Inc1 + 1.559 * Inc2 + 3.085* Inc3 + 3.582 * Inc 4
- 0.295 * ln(Emp-Pop Density) + 3.38 * WorkSuff * auto imp + 1.27 * OthSuff * auto imp

Three or more cars = -3.482 – 1.760 * Inc1 + 0.352 * Inc2 + 2.324 * Inc3 + 3.141 * Inc4
- 0.803 * ln(Emp-Pop Density) + 3.38 * WorkSuff * auto imp + 1.27 * OthSuff * auto imp

Where:

Inc1 is a dummy variable which is 1 for low income households and 0 otherwise
Inc2 is a dummy variable which is 1 for medium low income and 0 otherwise
Inc3 is a dummy variable which is 1 for medium high income and 0 otherwise
Inc4 is a dummy variable which is 1 for High income households and 0 otherwise
Emp–Pop Density is the population plus employment of a zone divided by the acreage
WorkSufff is the sufficiency of automobiles for workers
OthSuff is the sufficiency of the automobiles for non-workers
Auto imp is the automobile importance variable

2.4.3.3. Model Validation

Model results were compared to census data for validation purposes. At the regional level model results were compared to CTPP households cross tabulated by number of autos and income group (same as previously described):

CTPP 2000

Summary Level: TAZ (13-county model area plus Bartow County)

Number of Autos	Income Group				
	1	2	3	4	Total
0	53,633	30,820	11,518	3,792	99,763
1	99,604	212,226	104,453	24,571	440,854
2	34,199	152,493	251,959	136,316	574,967
3+	9,231	43,845	117,665	87,737	258,478
Total	196,667	439,384	485,595	252,416	1,374,062

A similar cross tabulation of the model results produces:

ARC Model 2000 4/1/2008

Summary Level: TAZ (20-county model area)

Number of Autos	Income Group				
	1	2	3	4	Total
0	82,328	25,096	6,085	1,629	115,138
1	117,860	258,424	96,135	20,231	492,650
2	25,246	171,186	292,621	148,402	637,455
3+	6,169	48,205	145,739	97,826	297,939
Total	231,603	502,911	540,580	268,088	1,543,182

Since these cross tabulations use different geographic areas, shares of the total households are used for comparison.

Percent of Total Households (CTPP)

Number of Autos	Income Group				
	1	2	3	4	Total
0	3.9%	2.2%	0.8%	0.3%	7.3%
1	7.2%	15.4%	7.6%	1.8%	32.1%
2	2.5%	11.1%	18.3%	9.9%	41.8%
3+	0.7%	3.2%	8.6%	6.4%	18.8%
Total	14.3%	32.0%	35.3%	18.4%	100.0%

Percent of Total Households (Model)

Number of Autos	Income Group				
	1	2	3	4	Total
0	5.3%	1.6%	0.4%	0.1%	7.5%
1	7.6%	16.7%	6.2%	1.3%	31.9%
2	1.6%	11.1%	19.0%	9.6%	41.3%
3+	0.4%	3.1%	9.4%	6.3%	19.3%
Total	15.0%	32.6%	35.0%	17.4%	100.0%

The absolute differences of these values are shown below:

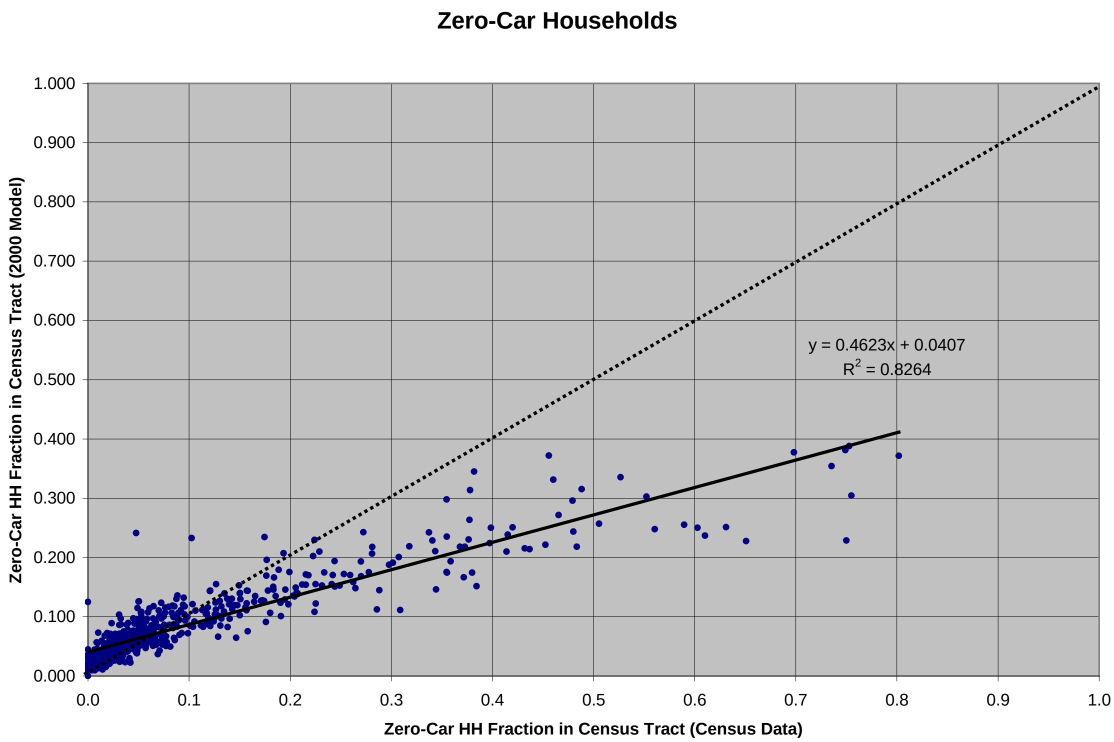
Absolute Difference (Model - CTPP)

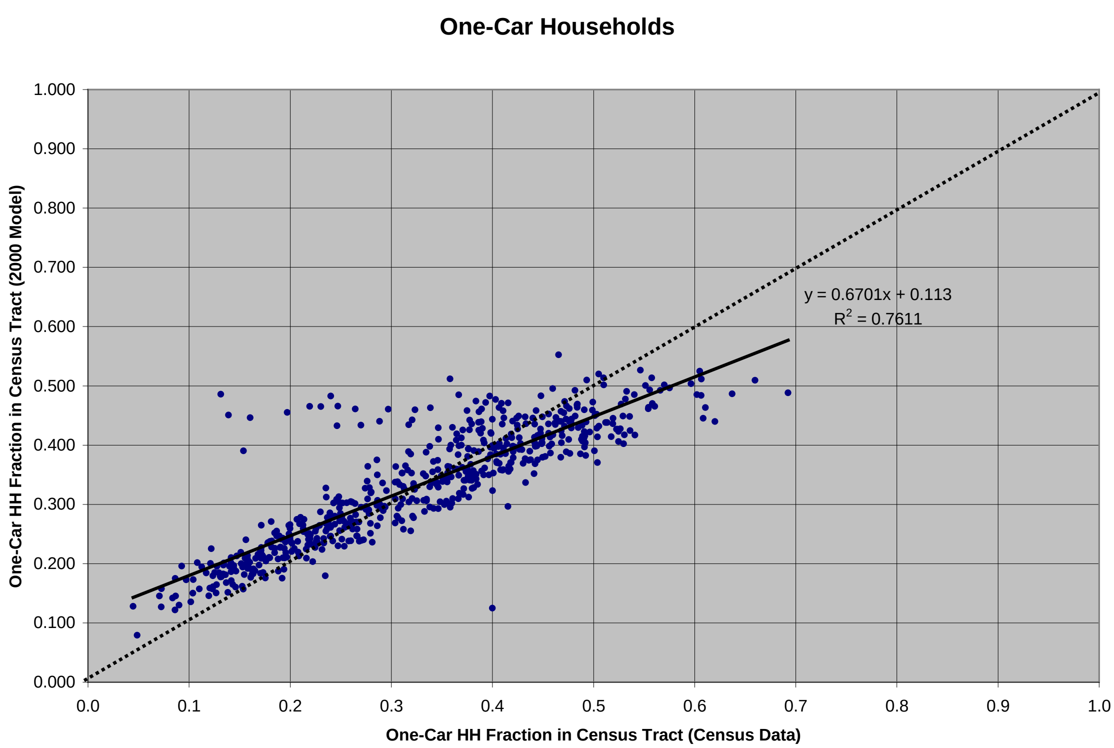
Number of Autos	Income Group				
	1	2	3	4	Total
0	1.4%	-0.6%	-0.4%	-0.2%	0.2%
1	0.4%	1.3%	-1.4%	-0.5%	-0.2%
2	-0.9%	0.0%	0.6%	-0.3%	-0.5%
3+	-0.3%	-0.1%	0.9%	0.0%	0.5%
Total	0.7%	0.6%	-0.3%	-1.0%	0.0%

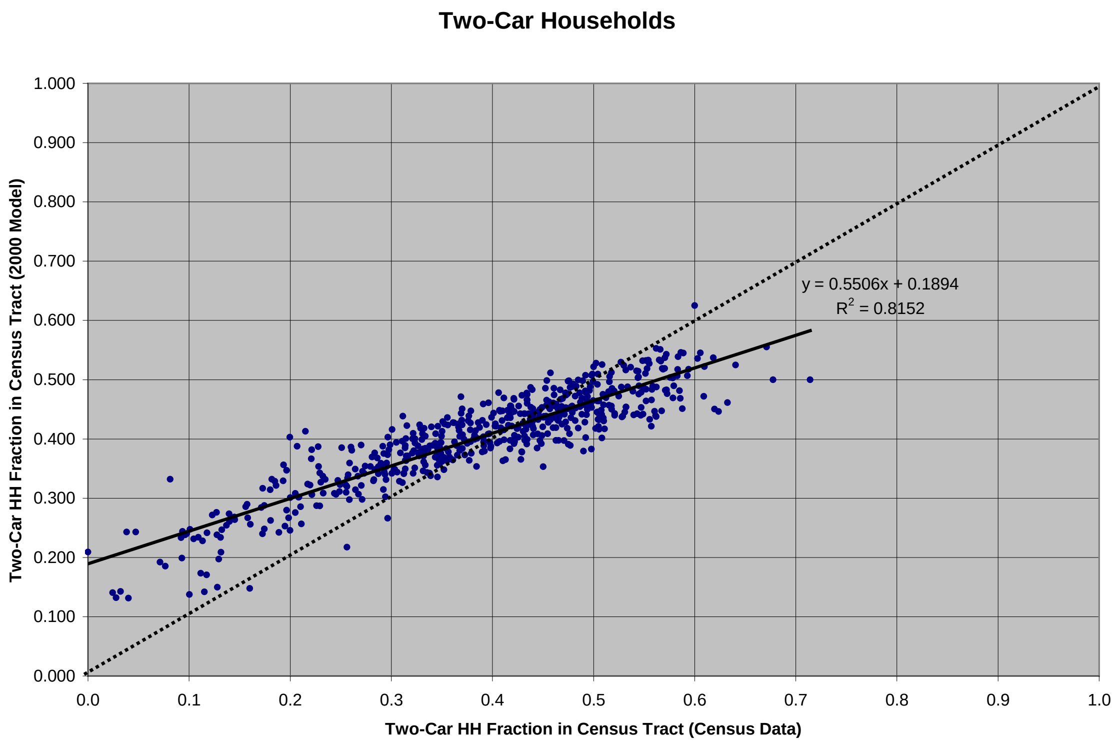
Since CTPP data includes a certain degree of uncertainty due to rounding, data suppression and sampling error, these absolute differences seem well within acceptable ranges.

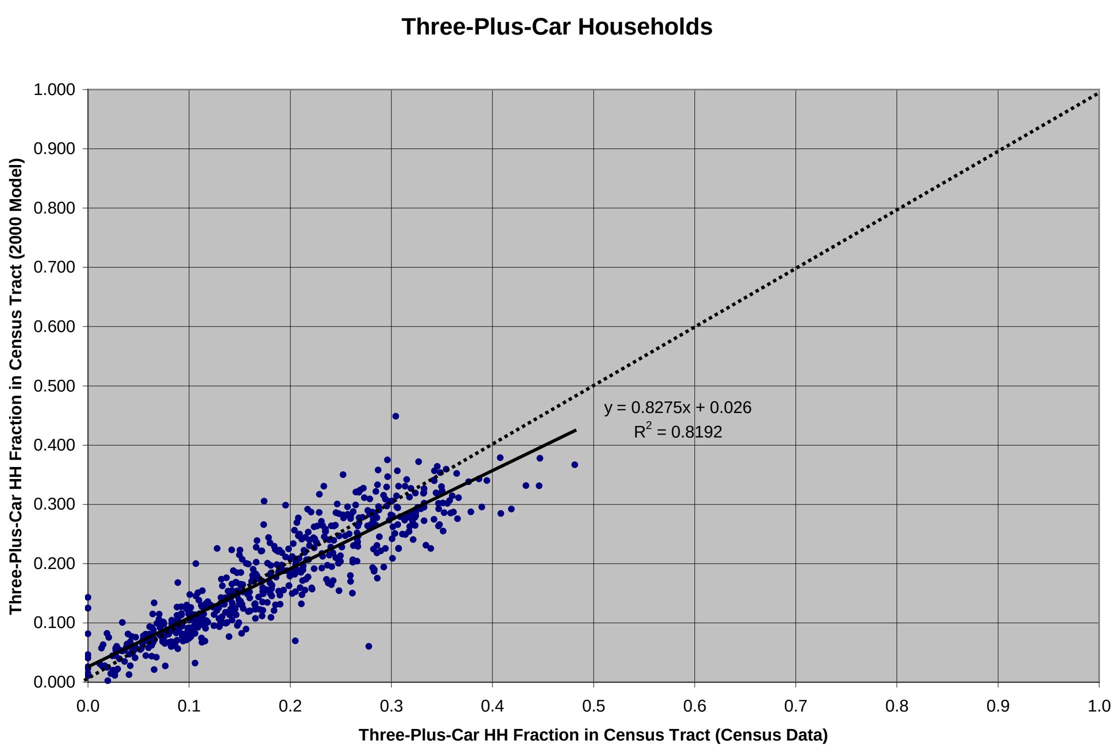
The auto ownership model was further validated by comparing model results to census data at the census tract level. The following charts display the share of households in each auto ownership group within each census tract versus the comparable share from the model. The results are generally good with strong correlations. Although the model results for the zero auto households do not closely match census data, the results are significantly better than the previous auto ownership model.

When compared to census data, the new model estimates fewer tracts with high shares of zero auto households. Census data includes a substantial number of tracts where 40 to 80 percent of households own zero autos. It is not clear whether such high shares of zero auto households are reasonable at the census tract level. Such high shares may be somewhat attributable to rounding, data suppression and sampling errors. The model estimates the highest zero auto shares at the tract level at around 30 to 40 percent, which seems more plausible.


Zero-Car Households
Zero-Car HH Fraction in Census Tract (2000 Model)
Zero-Car HH Fraction in Census Tract (Census Data)
y = 0.4623x + 0.0407
R2 = 0.8264
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0


One-Car Households
One-Car HH Fraction in Census Tract (2000 Model)
One-Car HH Fraction in Census Tract (Census Data)
y = 0.6701x + 0.113
R2 = 0.7611
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0


Two-Car Households
y = 0.5506x + 0.1894
R2 = 0.8152
Two-Car HH Fraction in Census Tract (2000 Model)
Two-Car HH Fraction in Census Tract (Census Data)


Three-Plus-Car Households
y = 0.8275x + 0.026
R2 = 0.8192
Three-Plus-Car HH Fraction in Census Tract (2000 Model)
Three-Plus-Car HH Fraction in Census Tract (Census Data)

2.5. Attraction Model

The trip production model used the home interview survey performed in 2000. ARC staff conducted an Establishment Survey where both employees and visitors were surveyed. This data, since it was directed at specific establishments, provided the travel demand model team the ability to develop cross-classification attractions models instead of the regression models normally developed using home interview data.

This section describes the development of the attraction model trip rates, one for each of the four purposes[5]. All four models have the same basic structure of a 2-way cross-classification matrix of trip rates per employee, or person, or household. There are as many as 70 trip rates for each purpose; one for each type of demographic data (types of employment, households, and persons) and one for each of seven area types. The original Home Based Grade School and Home Based University regression models were not changed in this analysis.

As part of the mode choice model refinement work in 2005, an attraction share model was incorporated into this model component. The purpose of the attraction share model is to determine the zonal attractions by the socio-economic groups based on highway and transit accessibility. Previously the average probability for each income group was used to split the attractions into the four income groups.

2.5.1. Calibration Data and Procedures

The ARC conducted an Establishment Survey of 277 establishments In the fall of 1998 [6]. Both employee and visitors were surveyed. Over 14,000 visitors and over 10,000 employees were surveyed in this Establishment survey.

Trips are "attracted" not only to non-residential establishments but also to residences. Therefore the information from the Establishment survey had to be combined with the information from the home interview survey to obtain a correct "balance" between non-residential establishment "attractiveness" and residential "attractiveness". Because the Establishment survey was taken in a series of different places, one of the variables in the cross-classification model could be the area type. The area type, for a traffic analysis zone, is a measure of the general density in and around the traffic analysis zone. These area types range from the highest density (CBD area types) to the lowest densities (Rural are types)[7]. The trip rates for these area type classifications showed some interesting differences. For the home based work trips, the CBD had the highest rate, with the next categories (Urban Commercial and Urban Residential had the lowest rates. For home based Other trips the reverse was true for the major employment categories (of F.I.R.E., Service, and Government[8]), with the two urban categories having the highest rates, the

[5] This section is essentially a repeat of the attraction model description found in the report ""Transportation Solutions for a new Century, Appendix 4 Model Documentation", Atlanta Regional Commission, August 28, 2002, pages 5-1 to 5-21.

[6] "Atlanta Regional Commission Establishment Survey Final Report", Prepared by Barton-Aschman Associates, Inc., CB&A Market Research, and Nancy McGuckin, March 1999

[7] The area types have been given names, which are indicative of the densities they represent. These names thought are based strictly on the density (population and employment density) of the area and not the type of urban form of the area. The names of the area types (ranging from the highest to the lowest density) are: 1 – CBD; 2- Urban Commercial; 3 – Urban Residential; 4 - Suburban Commercial; 5 – Suburban Residential; 6 – Exurban; 7 – Rural.

[8] The model uses the eight employment categories forecasted by the DRAM/EPAL model. These categories are: 1 – Construction; 2 – Manufacturing; 3 – Retail; 4 – Transportation Communications

CBD the next highest rates, and the suburban, exurban and rural having the lowest rates. The pattern of the Non-home Based rates were similar to the Home Based Other trip rates, except for retail employment – where the rate per retail employee was substantially higher in the suburban areas than in the CBD and urban areas. This was also true of the home-based shopping trip rates, where the suburban rates were almost three times the CBD rates. It should be noted that these trip rates are for “motorized” travel (automobile and transit) and do not include walk trips. Therefore the reduced trip rates for Home Based Other, Home Based Shopping and Non-home Based trips, for the CBD areas, may simply be a reflection that many of the CBD trips are made by workers during the lunch hour and after work by walking and are therefore not identified as motorized trips. The trip rates for the four purposes are shown on Table 2.32.

and Utilities (TCU); 5 – Wholesale; 6 – Financial, Insurance, Real Estate; 7 – Service; 8 – Government.

Table 2.32 Attraction Trip Rates

Attraction Rates for Home Based Work Trips

Variable	Measured as	Trip Rate By Area Type						
		CBD	Urban Commercial	Urban Residential	Suburban Commercial	Suburban Residential	Exurban	Rural
Construction	Employee	1.2953	1.2111	1.2111	1.2532	1.2532	1.2321	1.2321
Manufacturing	Employee	1.2953	1.2111	1.2111	1.2532	1.2532	1.2321	1.2321
Retail	Employee	1.1584	1.1584	1.1584	1.1479	1.1479	1.1058	1.1058
TCU	Employee	1.2953	1.2111	1.2111	1.2532	1.2532	1.2321	1.2321
Wholesale	Employee	1.2953	1.2111	1.2111	1.2532	1.2532	1.2321	1.2321
F.I.R.E.	Employee	1.2953	1.2111	1.2111	1.2532	1.2532	1.2321	1.2321
Service	Employee	1.2953	1.2111	1.2111	1.2532	1.2532	1.2321	1.2321
Government	Employee	1.2953	1.2111	1.2111	1.2532	1.2532	1.2321	1.2321

Attraction Rates for Home Shopping Trips

Variable	Measured as	Trip Rate By Area Type						
		CBD	Urban Commercial	Urban Residential	Suburban Commercial	Suburban Residential	Exurban	Rural
Retail	Employee	5.56	5.92	5.92	14.16	14.16	12.71	12.71

Attraction Rates for Home Based Other Trips

Variable	Measured as	Trip Rate By Area Type						
		CBD	Urban Commercial	Urban Residential	Suburban Commercial	Suburban Residential	Exurban	Rural
Population	Person	0.619	0.619	0.619	0.619	0.619	0.619	0.619
Construction	Employee	0.170	0.170	0.170	0.170	0.170	0.170	0.170
Manufacturing	Employee	0.170	0.170	0.170	0.170	0.170	0.170	0.170
Retail	Employee	2.120	2.620	2.620	2.220	2.220	1.620	1.620
TCU	Employee	0.170	0.170	0.170	0.170	0.170	0.170	0.170
Wholesale	Employee	0.170	0.170	0.170	0.170	0.170	0.170	0.170
F.I.R.E.	Employee	0.470	0.640	0.640	0.350	0.350	0.350	0.350
Service	Employee	0.470	0.640	0.640	0.350	0.350	0.350	0.350
Government	Employee	0.470	0.640	0.640	0.350	0.350	0.350	0.350

Attraction Rates for Non-Home Based Trips

Variable	Measured as	Trip Rate By Area Type						
		CBD	Urban Commercial	Urban Residential	Suburban Commercial	Suburban Residential	Exurban	Rural
Households	Household	0.1711	0.1711	0.1711	0.1711	0.1711	0.1711	0.1711
Population	Person	0.0134	0.0134	0.0134	0.0134	0.0134	0.0134	0.0134
Construction	Employee	0.3640	0.4393	0.4393	0.4351	0.4351	0.4351	0.4351
Manufacturing	Employee	0.3640	0.4393	0.4393	0.4351	0.4351	0.4351	0.4351
Retail	Employee	4.7113	3.2971	3.2971	6.9456	6.9456	5.6967	5.6967
TCU	Employee	0.3640	0.4393	0.4393	0.4351	0.4351	0.4351	0.4351
Wholesale	Employee	0.3640	0.4393	0.4393	0.4351	0.4351	0.4351	0.4351
F.I.R.E.	Employee	0.6339	0.8180	0.8180	0.4519	0.4519	0.4519	0.4519
Service	Employee	0.6339	0.8180	0.8180	0.4519	0.4519	0.4519	0.4519
Government	Employee	0.6339	0.8180	0.8180	0.4519	0.4519	0.4519	0.4519

2.5.2. Attraction Share Model

The trip attraction share model estimation used the SMARTRAQ data. This home interview survey was performed in 2001. The initial step in the development of the attraction share model was to modify the trip generation program, so that a file listing households by strata in each zone was produced. Second, a FORTRAN program was written to calculate highway and transit accessibility measures. Finally, ALOGIT models were estimated to split attraction trips into four socio-economic strata for each trip purpose.

2.5.1.1. Socio-Economic Groups (Strata)

Because of the data requirements of the mode choice model, the zonal attractions are separated into several socio-economic groups. By looking at the SMARTRAQ household data, the modeling team agreed on the following four strata:

- Households without cars. (Strata 1)
- Households with the number of cars < the number of workers (Strata 2)
- Low income households with # cars >= # workers (Strata 3)
- High income households with # cars >= # workers (Strata 4)

2.5.1.2. Attraction Share Model Summary

The attraction share model uses a multinomial logit structure to split total attractions into attractions for each stratum. A separate model is applied for each purpose. Variables used in the utility equations are shown in the table below.

Utility Variable(s)	Influence on attraction share probabilities
Strata Accessibility	If households within a stratum have better access to a zone than other strata households, then the probability for the more accessible strata increases.
Transit Accessibility	As the transit accessibility increases, the attraction shares become more weighted toward strata one (more transit dependent).
Total Employment	As the total employment in a zone becomes larger, the attraction shares become closer to regional shares of trip productions by strata.
Employment Class • Finance, Insurance Real Estate (FIRE) • Retail • Government • Transportation, Communications, Utilities (TCU) • Wholesale • Construction	Employment in a zone is used to influence attraction shares to become closer to observed shares of workers by strata for each employment class. Note: employment class is only used in the Home Based Work purpose because utility coefficients are based on the employment class of workers. Little data is available to determine how the mix of employment in a zone influences attraction shares for non-work purposes.

2.5.1.3. Derivation of Utility Coefficients

Coefficients for the attraction share model logit equations were asserted rather than being calculated through a logit estimation process. Coefficients were derived by taking the natural logarithm of observed relative shares. For example, employment class coefficients were derived from the percent of employees within each stratum that work in a particular employment class. Using Finance, Insurance and Real Estate (FIRE) employment as a specific example should help to further explain this approach.

Census data were summarized to estimate that 4.36% of Strata 1 workers are employed in FIRE employment classes. Similarly 4.92%, 5.75% and 8.33% are employed in FIRE employment classes for Strata 2, 3 and 4 respectively. Relative to the Strata 1 share, workers in Strata 2 are 1.13 times (4.92/4.36) more likely to work in FIRE employment industries. Likewise workers in Strata 3 and 4 are 1.32 and 1.91 times more likely, respectively. Utility coefficients were derived by taking the natural logarithm of these relative shares:
Strata 1: ln(4.36/4.36) = ln(1.00) = 0
Strata 2: ln(4.92/4.36) = ln(1.13) = 0.12
Strata 3: ln(5.75/4.36) = ln(1.32) = 0.28
Strata 4: ln(8.33/4.36) = ln(1.91) = 0.65

Since logit probabilities are calculated using the exponential of the utilities, using coefficients derived in this way ensures that the variable results in the expected probabilities (i.e. FIRE employee is 1.91 times more probable to be Strata 4 than Strata1). For example, if no other variables influenced the attraction share model except 100 FIRE employees, the attraction shares would be calculated as shown below. Note: to avoid using unreasonably large values in the logit calculation process the employment class independent variable is the employment class share of the zone's total employment rather than the absolute number of employees in a class.

Utilities:
Utility Strata 1 = 0
Utility Strata 2 = 0.12 * (100 FIRE employees / 100 total employees) = 0.12 * 1 = 0.12
Utility Strata 3 = 0.28 * (100 FIRE employees / 100 total employees) = 0.28 * 1 = 0.28
Utility Strata 4 = 0.65 * (100 FIRE employees / 100 total employees) = 0.65 * 1 = 0.65

Exponentiated Utilities:
EU(Strata 1) = exp(0) = 1
EU(Strata 2) = exp(0.12) = 1.13
EU(Strata 3) = exp(0.28) = 1.32
EU(Strata 4) = exp(0.65) = 1.91
SumEU = 1 + 1.13 + 1.32 + 1.91 = 5.37

Probabilities:
Probability(Strata1) = 1.00 / 5.37 = 18.6%
Probability(Strata2) = 1.13 / 5.37 = 21.0% (1.13 times more likely than Strata 1 as expected)
Probability(Strata3) = 1.32 / 5.37 = 24.7% (1.32 times more likely than Strata 1 as expected)
Probability(Strata4) = 1.91 / 5.37 = 35.7% (1.91 times more likely than Strata 1 as expected)

2.5.1.4. Accessibility Measures

The accessibility measures that are used in the logit utility equations are calculated by combining the following measures:

$$\text{Strata}_x \text{ Highway Accessibility}_j = \text{Sum}_i (\text{Strata}_x \text{ Household}_i / \text{Highway Time}_{ij}^2) / \text{Sum}_i (\text{Strata}_x \text{ Household}_i)$$

$$\text{Strata}_x \text{ Walk-Transit Accessibility}_j = \text{Sum}_i (\text{Strata}_x \text{ Household}_i / \text{Walk to Transit Time}_{ij}^2) / \text{Sum}_i (\text{Strata}_x \text{ Household}_i)$$

$$\text{Strata}_x \text{ Drive-Transit Accessibility}_j = \text{Sum}_i (\text{Strata}_x \text{ Household}_i / \text{Drive to Transit Time}_{ij}^2) / \text{Sum}_i (\text{Strata}_x \text{ Household}_i)$$

$$\text{Strata}_x \text{ Total Transit Accessibility}_j = \text{Strata}_x \text{ Walk-Transit Accessibility}_j$$

+ Strata_x Drive-Transit Accessibility $_j$

Where x =1,2,3,4

The strata accessibility measure is calculated by dividing the highway accessibility for the subject stratum by the sum of the highway accessibilities for all four strata. This makes the strata accessibility a stratum's share of the total highway accessibility. The transit accessibility measure is calculated by dividing the sum of all four strata total transit accessibilities by the sum of all four strata highway accessibilities. Since the transit accessibility measure uses the sum of all four strata for the transit and highway accessibility measures, it does not vary across the strata.

The coefficient for the strata accessibility is one and the natural logarithm of the strata accessibility measure is used rather than the measure directly. This simply results in the utility for a given stratum to be increased by that stratum's share of the highway accessibilities. So if the highway accessibility for stratum one is five percent of the sum of all four highway accessibilities, then 0.05 will be added to the stratum one utility. Likewise if the stratum one accessibility was 50% of the total, 0.5 will be added to the stratum one utility.

Coefficients for the transit measure are based on observed transit shares relative to the stratum one transit share. Since the transit share is usually highest for stratum one, this measure increases the probability for strata one and decreases the probabilities for the other strata as the overall transit accessibility for a zone increases.

2.5.1.5. Total Employment Variable

As the total employment in a zone becomes larger, the attraction shares become closer to regional shares of trip productions by strata. This is accomplished by using coefficients that are derived from the calculated trip productions (relative to the productions for stratum one). To avoid using unreasonably large values in the logit calculation process, a substitute for total employment is used. The total employment independent variable is calculated as the minimum of 10,000 or the total employment, which is then divided by 10,000. So for a zone with a total employment of less than 10000, the independent variable is the total employment divided by 10000. If the total employment is 10000 or greater, the independent variable becomes equal to one (10000/10000).

2.5.1.6. Employment Class Variables

As noted in the table above, employment class variables are only used for the Home Based Work trip purpose. Employment classes that are used in the ARC modeling process that are not included in the table above were not included in the attraction share model because they showed very little variability across strata. For example, similar shares of workers in each stratum are employed in service industries. Since the shares are similar, service employment is not used to influence the attraction shares.

2.5.1.7. Utility Equations

The tables below summarize the attraction share model utility coefficients:

Home Based Work				
	Strata1	Strata2	Strata3	Strata4
Constant	0.00	2.14	1.30	1.61
ln(Hwy-strata/HwyTot)	1.00	1.00	1.00	1.00
TrnTot/HwyTot	0.00	-1.44	-2.28	-2.39
min(10000,TOTEMP)/10000	0.00	2.16	3.17	3.84
FIRE/TOTEMP	0.00	0.12	0.28	0.65
RETAIL/TOTEMP	0.00	0.04	-0.22	-0.53
GOVT/TOTEMP	0.00	0.44	0.46	0.70
TCU/TOTEMP	0.00	0.23	0.25	0.29
WHOLESALE/TOTEMP	0.00	0.27	0.10	0.63
CONSTRUCTION/TOTEMP	0.00	-0.63	-0.51	-1.08

Shopping				
	Strata1	Strata2	Strata3	Strata4
Constant	0.00	1.14	0.70	1.02
ln(Hwy-strata/HwyTot)	1.00	1.00	1.00	1.00
TrnTot/HwyTot	0.00	-1.53	-3.20	-4.50
min(10000,TOTEMP)/10000	0.00	1.03	2.39	3.03

University				
	Strata1	Strata2	Strata3	Strata4
Constant	0.00	1.01	0.29	0.59
ln(Hwy-strata/HwyTot)	1.00	1.00	1.00	1.00
TrnTot/HwyTot	0.00	-1.53	-3.20	-4.50
min(10000,TOTEMP)/10000	0.00	0.23	1.43	1.75

School				
	Strata1	Strata2	Strata3	Strata4
Constant	0.00	1.17	0.78	1.04
ln(Hwy-strata/HwyTot)	1.00	1.00	1.00	1.00
TrnTot/HwyTot	0.00	-1.53	-3.20	-4.50
min(10000,TOTEMP)/10000	0.00	0.89	2.18	2.64

Home Based Other				
	Strata1	Strata2	Strata3	Strata4
Constant	0.00	1.16	0.78	1.11
ln(Hwy-strata/HwyTot)	1.00	1.00	1.00	1.00
TrnTot/HwyTot	0.00	-1.53	-3.20	-4.50
min(10000,TOTEMP)/10000	0.00	0.89	2.28	2.84

Non-Home Based				
	Strata1	Strata2	Strata3	Strata4
Constant	0.00	1.24	0.75	1.08
ln(Hwy-strata/HwyTot)	1.00	1.00	1.00	1.00
TrnTot/HwyTot	0.00	-1.04	-2.77	-2.95
min(10000,TOTEMP)/10000	0.00	1.11	2.47	3.14

2.5.1.8. Non-Motorized Model

Finally the attractions by socio-economic level are separated into motorized and non-motorized trips. If non-motorized production trips is less than or equal to total attraction trips in the zone, then non-motorized attraction are set to be the same as non-motorized production. If non-motorized production trips are more than total attraction trips, then all attraction trips in this zone are set as non-motorized, and assigned the remaining production trips to adjacent zones.

2.6. Application Program

The complete trip generation procedure, including trip production model, trip attraction model, the non-motorized model, school bus procedure, and the socio-economic model, was implemented using a specially written 32 bit FORTRAN program. This program reads the land use data provided by the ARC land use models, accessibility measures, and school bus percentages and produces a set of productions and attractions which can be used by the distribution model. The program runs in less than a minute and produces a report showing the total number of motorized trips and the non-motorized and school bus productions by traffic analysis zone. The application program is detailed in the report “User’s Guide to the 2003 Trip Generation Model Application Program for the ARC Region”.

2.7. Census Adjustment for Zero Auto Household Work Trips

A comparison of the number of zero auto household work trips between the Census Transportation Planning Package (CTPP) 2000 to the year 2005 estimated results revealed that the model underestimated these trips. Since a significant number of transit work trips are made by zero auto households, it is important that the trip generation model accurately reflect those trips. The CTPP data represents worker flows while the model represents trips. To properly compare, a factor was computed to scale the total worker flows to total work trips. This factor was then applied to the CTPP zero auto worker flows to compute an equivalent number of work trips. The zero auto household work trip adjustment was computed by dividing the adjusted CTPP trips by the model estimated trips. The adjustment factor is applied after the application of the trip generation component. The steps for computing this adjustment factor are shown below:

- 2005 Model Total HBW Trips = 2,984,372
- 2000 CTPP Total Worker Flows = 1,687,422
- CTPP Work Trip Factor (Model Trips / CTPP Flows) = 1.77
- 2000 CTPP Zero Auto Household Worker Flows = 65,737
- 2005 CTPP Adjusted Zero Auto Household Work Trips (65,737 x 1.77) = 116,262
- 2005 Model Zero Auto Household Work Trips = 81,598
- CTPP Zero Auto Household Work Trip Adjustment Factor (116,262 / 81,598) = 1.42

3. Trip Distribution

In the fall of 2006, the market segments used in the mode choice model were revised. As a result the market segments used in the trip distribution model were also revised. The market segments were revised from four income groups to the following stratifications or market groups.

- *Zero Car Households*
- *Cars < workers*
- *Cars >= workers Incomes 1-2*
- *Cars >= workers Incomes 3-4*

The internal-internal trip generation model developed trip end estimates for 18 trip purposes. For each of the three home-based and the non-home based trip purposes (work, other, shop, and NHB) there were four individual income groups resulting in 16 home-based trip purposes. University and home-based school based trips were maintained as single trip purposes. The initial challenge in the development of the trip distribution models was to determine if separate distribution models were required for the individual income groups within each of the home-based trip purposes.

The second challenge was the development of a spatial separation variable that recognized that transit service between traffic analysis zone pairs is perceived by travelers as increasing traffic analysis zone pair accessibility. A methodology that has been used in other areas is to develop a composite time (combination of highway and transit time). The formulation of the composite time includes the combining of the highway and transit travel times between traffic analysis zone pairs to reflect a single (composite) time. It is acknowledged that it is not logical that both the highway and transit times should receive equal weight, i.e., the composite time should be weighted more heavily to the highway travel time. The trip distribution model was calibrated using this new spatial separation variable, composite time.

3.1. Selection of Market Group Stratifications by Trip Purpose

The stratification of market groups within a trip purpose was determined using two criteria. The first criterion was a determination of the number of survey samples available within each trip purpose and market group. If there were not sufficient samples in a market group for statistical reliability, the market groups within a trip purpose were combined to have a minimum of 300 sample records in a particular group. The number of trip records by market segment is listed below.

Zero Cars	*1,117*
Cars < workers	*1,614*
Cars >= workers Inc 1-2	*23,421*
Cars >= workers Inc 3-4	*53,158*
Total	*79,310*

Table 3.1.1 shows the allocation of survey records by purpose and market group. Table 3.1.1 shows that there are only a total of 970 sample records for university trips. Based upon the lack of sufficient survey samples in an individual market group, university trips were combined into a single market group. Table 3.1.1 also shows that the number of sample records for home-based school trips for the market segments for 1 and 2 (zero cars and cars < workers) are too few to be statistically significant. As a result, home-based school trips were combined into a single market group.

The second criterion for stratification by market group was the average trip length of the trips within each trip purpose. If the average trip lengths of individual market groups were not deemed to be significantly different they were combined, i.e., these market groups had the same observed distribution pattern. Table 3.1.2 shows the combination of market groups for the final Gravity Model trip purposes. A total of 15 trip purposes were developed.

Table 3.1.1
Household Travel Survey Trip Records by Trip Purpose and Market Group

Purpose	Segment	Trips
HBW	Zero Cars	229
	Cars < workers	509
	Cars >= workers Inc 1-2	4,806
	Cars >= workers Inc 3-4	11,626
	Total	17,170
HBSCHOOL	Zero Cars	56
	Cars < workers	37
	Cars >= workers Inc 1-2	892
	Cars >= workers Inc 3-4	2,429
	Total	3,414
HBUNIV	Zero Cars	22
	Cars < workers	39
	Cars >= workers Inc 1-2	382
	Cars >= workers Inc 3-4	527
	Total	970
HBSHOP	Zero Cars	140
	Cars < workers	184
	Cars >= workers Inc 1-2	4,097
	Cars >= workers Inc 3-4	8,829
	Total	13,250
HBOTHER	Zero Cars	269
	Cars < workers	382
	Cars >= workers Inc 1-2	6,449
	Cars >= workers Inc 3-4	13,985
	Total	21,085
NHB	Zero Cars	401
	Cars < workers	463
	Cars >= workers Inc 1-2	6,795
	Cars >= workers Inc 3-4	15,762
	Total	23,421

Table 3.1.2
Final Trip Purposes Used In Gravity Model Calibration

Average Trip Lengths - New Market Segmentation

Purpose	Market	Household Survey		
		Average Trip Lengths (minutes)	Average Trip Lengths (miles)	Number of O-D Survey Trip Records
HBW	Zero Cars + Cars < Workers	31.44	11.4	738
	Cars >= Workers Inc1-2	31.61	11.5	4,806
	Cars >= Workers Inc3-4	38.53	14.2	11,626
HBOTHER	Zero Cars + Cars < Workers	17.68	7.6	651
	Cars >= Workers Inc1-2	17.72	7.2	6,449
	Cars >= Workers Inc3-4	18.66	7.8	13,985
HBSHOP	Zero Cars + Cars < Workers	16.82	7.1	324
	Cars >= Workers Inc1-2	16.03	6.0	4,097
	Cars >= Workers Inc3-4	16.70	6.2	8,829
HBSCHOOL	All segments	15.57	5.6	3,414
HBUNIV	All segments	29.66	10.8	970
NHB	Zero Cars	15.64	7.0	401
	Cars < Workers	17.25	7.8	463
	Cars >= Workers Inc1-2	18.09	7.7	6,795
	Cars >= Workers Inc3-4	18.75	8.0	15,762

3.2. Development of Composite Time

There is a substantial number of factors travelers use in making a decision concerning the trip from an origin to a particular destination. The trip distribution model considers two of these factors as the primary determinate of the origin-destination decision: (1) the relative number of destinations at a particular destination traffic analysis zone and (2) the spatial (travel time) separation between the traffic analysis zones. The trip generation model determines the number of destinations in a particular traffic analysis zone. Thus, the measure of spatial separation (travel time) is the only parameter unique to the distribution model.

The development of composite time requires two major decisions to be made: (1) the determination of transit services that are perceived by travelers as increasing the accessibility of zone pairs and (2) the weighting of highway and transit travel times in developing the composite time. In determining the transit services that the majority of travelers perceive as increasing origin-destination zone pair accessibility, it was believed that the availability of transit service was the primary consideration. Therefore, only those trips that had zone pair transit access would be considered as eligible for increased accessibility.

The second decision required in determining the composite time was the weight to be assigned to the highway and transit times. From experience, it seemed logical that these weights should be different by market group of the traveler. For the traveler in the market group without autos (segment #1) , the availability of transit would be more important than for the traveler in the market group with more cars than workers and the higher incomes (segment #4). Thus, for the first two market groups, the availability of transit would increase the traffic analysis zone accessibility more than for the second two market groups.

Based upon these considerations, the composite time was developed using the following relationship:

$$CT = \frac{1}{\frac{1}{HT} + \frac{X}{TT}}$$

Where:

CT = Composite Time (Minutes)
HT = Highway Travel Time (Minutes)
TT = Transit Travel Time (Minutes)
X = Weighting Factor Varying By Income Group

The weighting factors selected for each market group were:

Market Group 1 – 0.50
Market Group 2 – 0.12
Market Group 3 – 0.06
Market Group 4 – 0.03

Table 3.2.1 shows the application of this procedure for a typical traffic analysis zone pair for each of the four market groups. As can be seen from the data in Table 3.2.1, the influence of transit travel time substantially decreases from market group one to market group four.

Table 3.2.1
Example Composite Time

Market Segment	Weighting Factor	Highway Travel Time (minutes)	Transit Travel Time (minutes)	Composite Travel Time (minutes)	Percent Decrease in Travel Time
1	0.50	25.0	30.0	17.6	29%
2	0.12	25.0	30.0	22.7	9%
3	0.06	25.0	30.0	23.8	5%
4	0.03	25.0	30.0	24.4	2%

3.3. Calibration of Home-Based Work Gravity Model

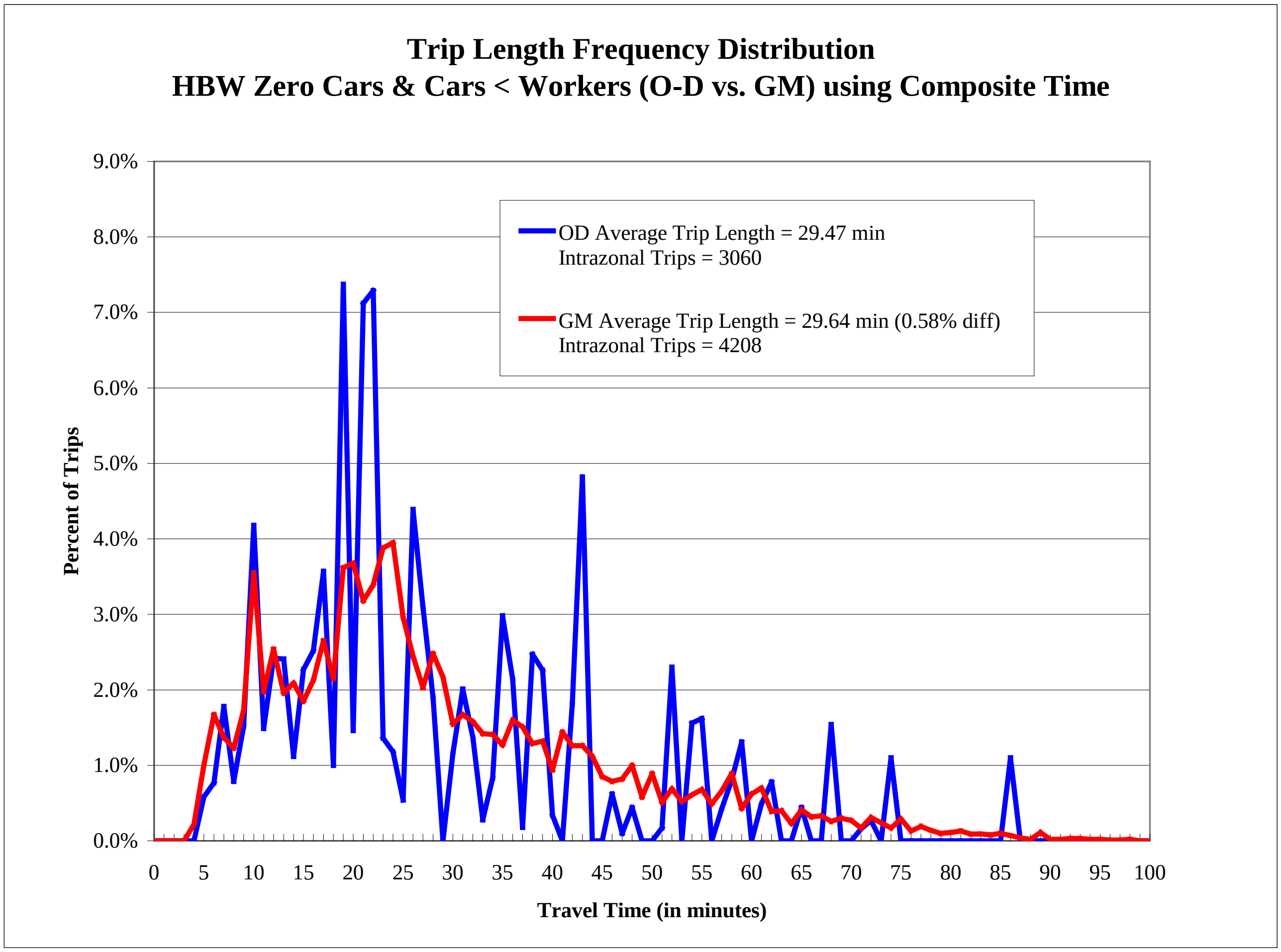
The travel survey data used in the calibration of the four home-based work gravity models was the 2001-2002 Atlanta Regional Commission's (ARC) household travel survey data. The home-based work person trips in this file were stratified by market group and reviewed. Based on the review of the data, the market segments 1 and 2 were combined for this task. Then, origin-destination trip tables (in production and attraction format) by market group were developed. Zone-to-zone highway travel times were skimmed from the A.M. peak period, base year 2000, loaded highway network. Zone-to-zone transit times were skimmed from the base year 2000, A.M. peak period transit network reflecting highway travel times generated by the loaded highway network. Highway and transit travel times were combined using the composite time formula and weighting factors for each market group to develop the zone-to-zone composite time files (one for each market group). Different factors were used to weight the contribution of transit travel time in the calculation of the composite time. The factors for the HBW market groups are listed below. These composite travel times were updated to include highway terminal times and intrazonal highway travel times.

Using the 2001-2002 survey trip tables and the composite travel time files a standard gravity model calibration process was conducted. This process involved adjusting the gravity model travel time factors, or friction factors, until the computed average trip length of the gravity model was within three percent of the average trip length observed in the survey data. In addition, the calibration took into account that the trip length frequency curve of the gravity model should generally replicate the trip length frequency curve from the observed survey data.

Figures 3.3.1 through 3.3.3 illustrate the comparison of the trip length frequency curves for each of the three market groups. As can be seen from the data in these figures, average trip length for each of the three calibrated gravity models are within the three percent criteria and the shape of the gravity model trip length frequency curves generally conform to the shape of the observed origin-destination (O-D) survey data.

The gravity model friction factors developed from this calibration process are shown graphically in Figures 3.3.4 through 3.3.6 for the market groups, respectively. Tables 3.3.1 through 3.3.3 indicate the actual calibrated friction factor values for individual composite time increments between 1 and 120 minutes.

Figure 3.3.1



Trip Length Frequency Distribution
HBW Zero Cars & Cars < Workers (O-D vs. GM) using Composite Time
OD Average Trip Length = 29.47 min
Intrazonal Trips = 3060
GM Average Trip Length = 29.64 min (0.58% diff)
Intrazonal Trips = 4208
Percent of Trips
9.0%
8.0%
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Travel Time (in minutes)

Figure 3.3.2

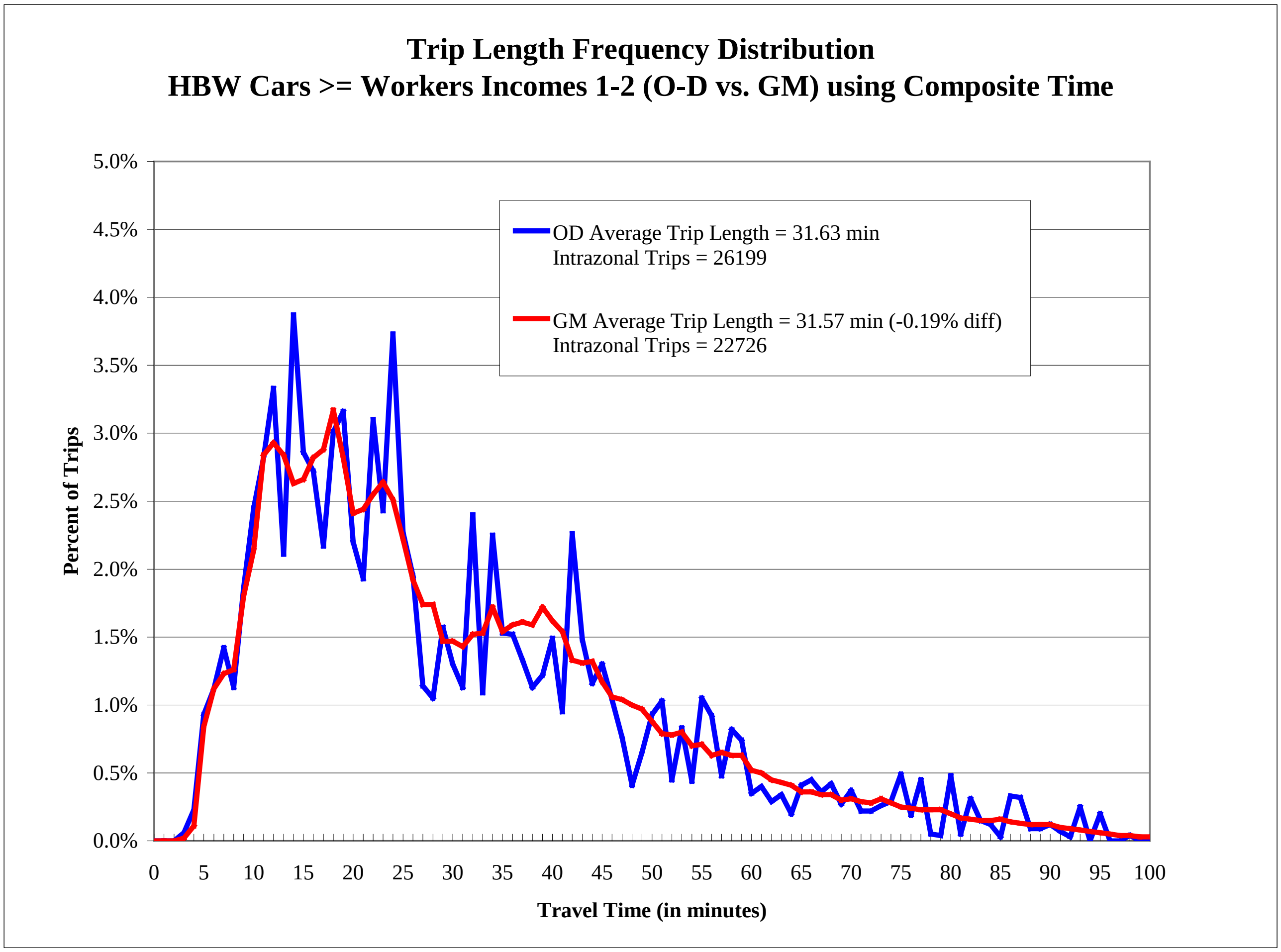

Trip Length Frequency Distribution
HBW Cars >= Workers Incomes 1-2 (O-D vs. GM) using Composite Time
OD Average Trip Length = 31.63 min
Intrazonal Trips = 26199
GM Average Trip Length = 31.57 min (-0.19% diff)
Intrazonal Trips = 22726
Percent of Trips
5.0%
4.5%
4.0%
3.5%
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Travel Time (in minutes)

Figure 3.3.3

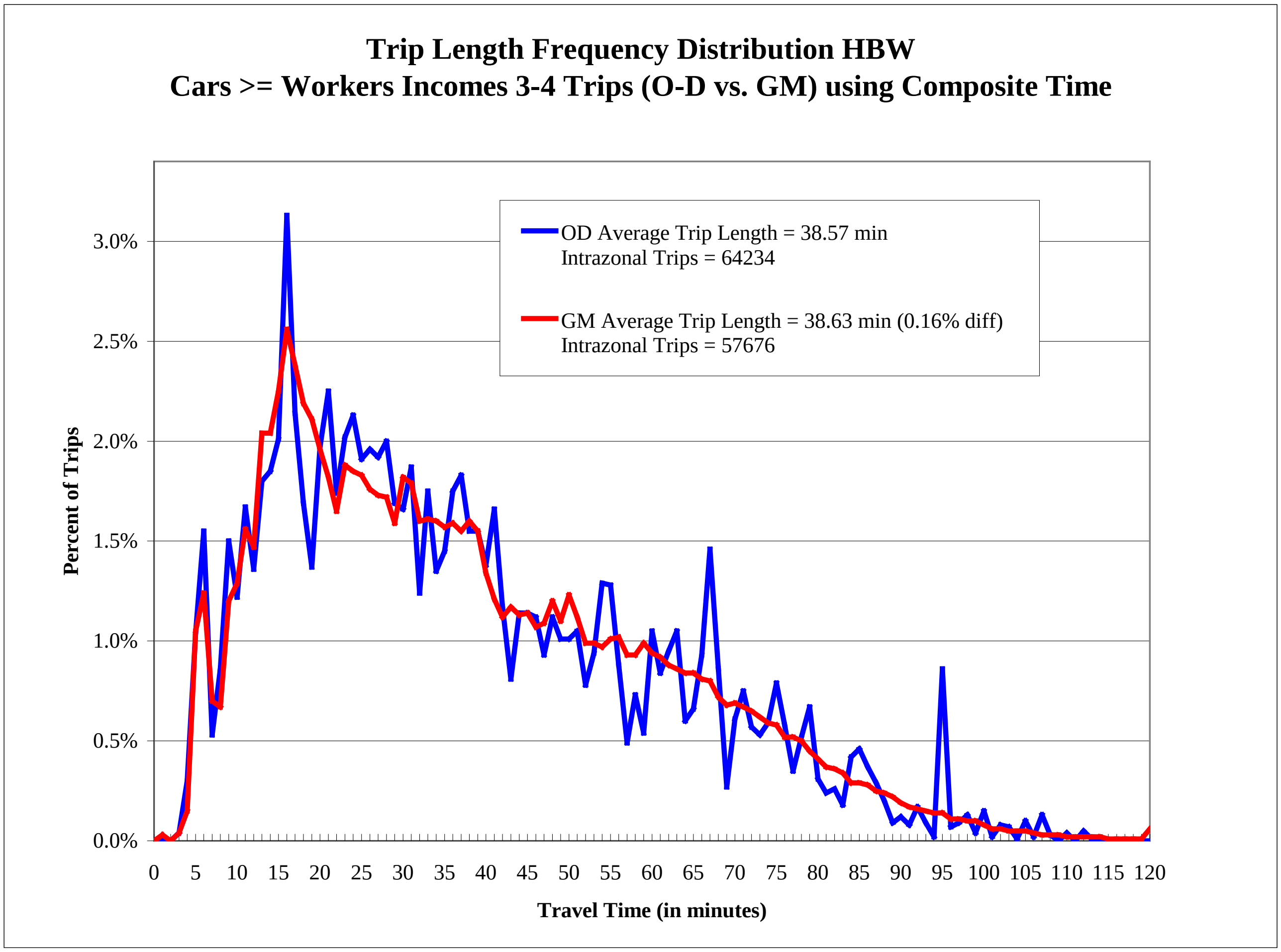

Trip Length Frequency Distribution HBW
Cars >= Workers Incomes 3-4 Trips (O-D vs. GM) using Composite Time
OD Average Trip Length = 38.57 min
Intrazonal Trips = 64234
GM Average Trip Length = 38.63 min (0.16% diff)
Intrazonal Trips = 57676
Percent of Trips
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120
Travel Time (in minutes)

Figure 3.3.4
Home Based Work Calibrated Gravity Model Market Groups 1 & 2 Friction Factor Curve

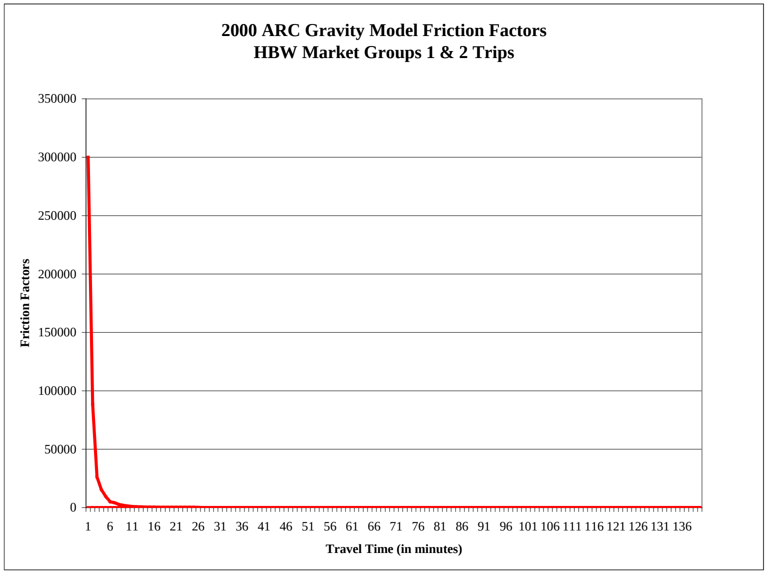


Table 3.3.1
Home Based Work Calibrated Gravity Model Market Groups 1 & 2 Friction Factors

Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor
1	300,000	31	108	61	24	91	7
2	88,493	32	96	62	24	92	6
3	26,219	33	90	63	24	93	6
4	15,507	34	78	64	24	94	6
5	9,420	35	75	65	24	95	6
6	5,087	36	73	66	24	96	6
7	4,120	37	69	67	24	97	4
8	2,761	38	63	68	21	98	3
9	1,941	39	59	69	21	99	2
10	1,413	40	53	70	17	100	2
11	1,060	41	40	71	17	101	2
12	818	42	40	72	17	102	2
13	715	43	40	73	17	103	2
14	572	44	40	74	17	104	2
15	535	45	40	75	13	105	2
16	508	46	36	76	13	106	2
17	426	47	36	77	13	107	2
18	356	48	36	78	13	108	1
19	345	49	36	79	13	109	1
20	335	50	30	80	13	110	1
21	325	51	30	81	10	111	1
22	317	52	30	82	10	112	1
23	310	53	30	83	10	113	1
24	302	54	30	84	10	114	1
25	293	55	30	85	10	115	1
26	208	56	30	86	7	116	1
27	162	57	30	87	7	117	1
28	155	58	30	88	7	118	1
29	142	59	30	89	7	119	0
30	117	60	30	90	7	120	0

Figure 3.3.5
Home Based Work Calibrated Gravity Model Market Group 3 Friction Factor Curve

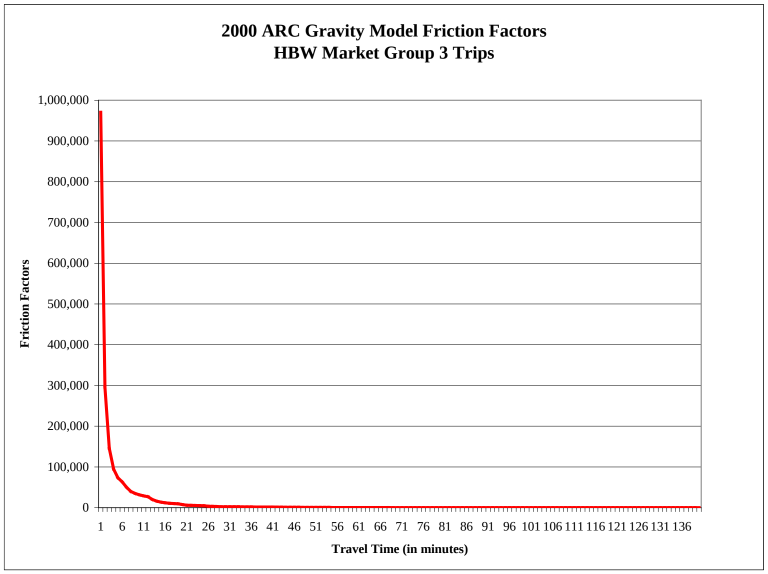


Table 3.3.2
Home Based Work Calibrated Gravity Model Market Group 3 Friction Factors

Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor
1	970,445	31	2,153	61	260	91	192
2	295,338	32	2,100	62	251	92	172
3	145,442	33	2,050	63	240	93	164
4	94,500	34	2,006	64	230	94	156
5	73,500	35	1,872	65	189	95	150
6	63,000	36	1,771	66	180	96	141
7	50,000	37	1,705	67	172	97	138
8	40,000	38	1,632	68	165	98	129
9	35,000	39	1,598	69	154	99	124
10	31,500	40	1,577	70	140	100	117
11	29,000	41	1,423	71	138	101	96
12	26,742	42	1,221	72	133	102	90
13	20,056	43	1,150	73	129	103	87
14	16,046	44	1,078	74	125	104	83
15	13,371	45	1,000	75	110	105	79
16	12,034	46	881	76	105	106	76
17	10,696	47	814	77	101	107	72
18	10,028	48	747	78	98	108	69
19	9,360	49	713	79	95	109	66
20	7,508	50	647	80	89	110	62
21	6,000	51	546	81	78	111	60
22	5,700	52	533	82	73	112	57
23	5,400	53	520	83	71	113	55
24	5,100	54	478	84	68	114	53
25	4,600	55	437	85	65	115	50
26	3,600	56	403	86	63	116	45
27	3,150	57	391	87	59	117	44
28	2,700	58	377	88	57	118	41
29	2,250	59	365	89	52	119	40
30	2,200	60	351	90	50	120	38

Figure 3.3.6
Home Based Work Calibrated Gravity Model
Market Group 4 Friction Factor Curve

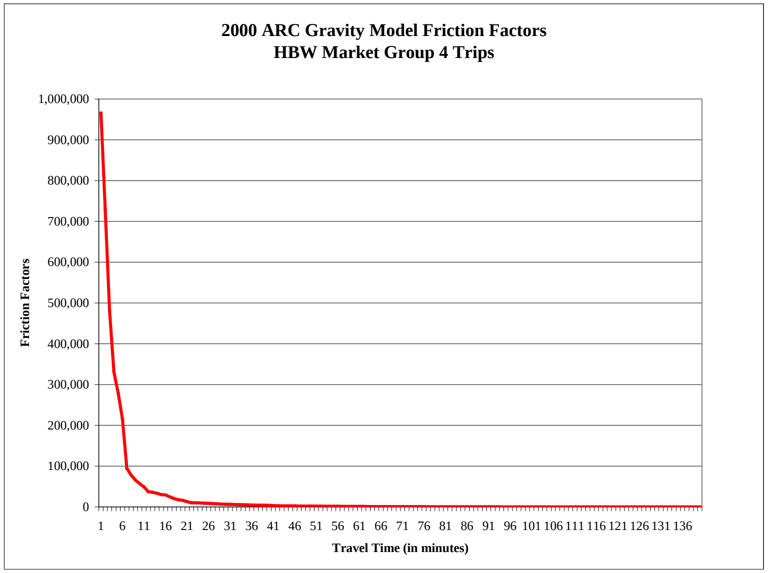


Table 3.3.3
Home Based Work Calibrated Gravity Model
Market Group 4 Friction Factors

Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor
1	965,604	31	6,400	61	1,200	91	192
2	730,540	32	6,073	62	1,128	92	172
3	481,478	33	5,656	63	1,060	93	164
4	331,378	34	5,272	64	996	94	156
5	280,000	35	4,920	65	936	95	150
6	215,000	36	4,597	66	880	96	141
7	95,000	37	4,298	67	827	97	138
8	78,000	38	4,180	68	777	98	129
9	66,000	39	4,070	69	730	99	124
10	57,000	40	3,850	70	686	100	117
11	49,000	41	3,000	71	645	101	96
12	37,750	42	2,878	72	606	102	90
13	35,910	43	2,653	73	570	103	87
14	33,488	44	2,573	74	536	104	83
15	30,568	45	2,493	75	504	105	79
16	29,282	46	2,372	76	474	106	76
17	24,890	47	2,252	77	446	107	72
18	20,497	48	2,171	78	419	108	69
19	17,569	49	2,125	79	394	109	66
20	16,000	50	2,074	80	370	110	62
21	13,000	51	2,023	81	331	111	60
22	10,500	52	1,838	82	310	112	57
23	10,000	53	1,681	83	295	113	55
24	9,600	54	1,586	84	277	114	53
25	9,200	55	1,498	85	266	115	50
26	8,800	56	1,432	86	253	116	45
27	8,033	57	1,363	87	241	117	44
28	7,432	58	1,305	88	229	118	41
29	6,886	59	1,259	89	219	119	40
30	6,600	60	1,236	90	217	120	38

3.4. Validation of Home-Based Work Gravity Model

Although the home-based work gravity models are considered to be calibrated based upon the average trip length and trip length frequency statistics, there remains the potential that the model could have area biases. Natural features, such as the Chattahoochee River, could pose a potential obstacle to the geographic distribution of certain types of trips. When natural features are combined with political or service delivery boundaries, the presence of "area" bias in trip distribution can be even more significant.

"Area" bias formed by the Chattahoochee River did significantly affect the initial distribution of HBW trips. Table 3.4.1 shows the results of the comparison between the gravity model results without the topological (topo) penalty and the O-D survey. According to the origins and destinations of HBW trips observed crossing the Chattahoochee River in the O-D Survey, the gravity model distribution was 20% higher for trips produced in zones located south or east of the Chattahoochee River. For zones north or west of the river, the gravity model calculated approximately 6% higher for trips crossing the Chattahoochee than were observed in the O-D Survey. Trip productions from zones south or east of the river that were observed crossing the Chattahoochee River in the O-D Survey totaled 132,382. In contrast, the gravity model estimated 158,757 HBW production trips from zones south and east of the river crossed the Chattahoochee River.

Table 3.4.1
Comparison of Gravity Model (Without Topo Penalty) and 2001-2002 Origin Destination Survey
Crossings of Chattahoochee River

Home Based Work											
	Destination						Total		Total Crossing		
	North of River			South of River							
Origin	OD	GM	Percent Diff	OD	GM	Percent Diff	OD	GM	OD	GM	Percent Diff
North of River	590,046	569,239	-3.5%	339,657	360,482	6.1%	929,703	929,721	472,039	519,239	10.0%
South of River	132,382	158,757	19.9%	1,779,936	1,753,593	-1.5%	1,912,318	1,912,350			
Total	722,428	727,996	0.8%	2,119,593	2,114,075	-0.3%	2,842,021	2,842,071			

A topographic penalty or "Topo" penalty was incorporated in the gravity model process to compensate for the "area" bias created by the Chattahoochee River. The "Topo" penalty is a lump sum of time (in minutes) that is added to the composite time of interzonal times for all zonal pairs on opposite sides of the Chattahoochee River. The appropriate "Topo" penalties for the HBW trips by market segment are listed below.

Market Groups 1 & 2 – 2.0
Market Group 3 – 3.5
Market Group 4 – 3.0

With the "Topo" penalty added to composite times, gravity model estimates of HBW trips crossing the Chattahoochee River cutline were greatly improved. Gravity model results of trips crossing the Chattahoochee River cutline, using a "Topo" penalty application, are shown in Table 3.4.2 along with the number of trips observed crossing the river in the O-D Survey. The gravity model estimated 145,497 HBW trips crossing the Chattahoochee River from zones south and east of the river. This figure is only 9.9% higher than the observed in the O-D Survey. The addition of the topo penalty reduced the difference between the gravity model and the O-D survey trips crossing the Chattahoochee River from the south and east of the river from 20% to 10%. Total trips crossing improved from 10% to about 4% with the time penalty.

Table 3.4.2
Comparison of Gravity Model (With Topo Penalty) and 2001-2002 Origin Destination Survey
Crossings of Chattahoochee River

Home Based Work											
	Destination										
	North of River			South of River			Total		Total Crossing		
Origin	OD	GM	Percent Diff	OD	GM	Percent Diff	OD	GM	OD	GM	Percent Diff
North of River	590,046	584,623	-0.9%	339,657	345,093	1.6%	929,703	929,716	472,039	490,590	3.9%
South of River	132,382	145,497	9.9%	1,779,936	1,766,851	-0.7%	1,912,318	1,912,348			
Total	722,428	730,120	1.1%	2,119,593	2,111,944	-0.4%	2,842,021	2,842,064			

The gravity model and origin-destination survey trips crossing Interstate 20 (I-20) were compared. I-20, running east-west through the central area, basically divides the Atlanta region into two generally equal north and south geographical areas (see Figure 3.4.1). Table 3.4.3 compares the gravity model estimate of home-based work person trips crossing Interstate 20 with the 2001-2002 ARC household origin-destination survey data. Table 3.4.2 shows that the gravity model estimates the total home-based work person trips crossing I-20 within 2.2%.

Table 3.4.3
Comparison of Gravity Model and 2001-2002 Origin Destination Survey
Crossings of Interstate 20

	Destination										
	North of I-20			South of I-20			Total		Total Crossing		
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
North of I-20	1,982,261	1,977,094	-0.3%	152,816	158,016	3.4%	2,135,077	2,135,110	452,922	463,047	2.2%
South of I-20	300,106	305,031	1.6%	406,844	401,927	-1.2%	706,950	706,958			
Total	2,282,367	2,282,125	0.0%	559,660	559,943	0.1%	2,842,027	2,842,068			

Interstate 285 (I-285) serves as a significant travel facility within the Atlanta region. It is also a boundary between the highly urbanized area within its boundaries and the suburban and exurban development outside its boundaries (see Figure 3.4.1). Thus, I-285 was used as a boundary to check the gravity model's distribution of home based work trips from the suburban areas to the high density urban areas. Table 3.4.4 compares the gravity model estimate of home-based work person trips crossing I-285 with the 2001-2002 ARC household O-D survey data. As can be seen from the data in Table 3.4.4, the gravity model estimates the total home-based work person trips crossing I-285 within one percent.

Table 3.4.4
Comparison of Gravity Model and 2001-2002 Origin Destination Survey Crossings of Interstate 285

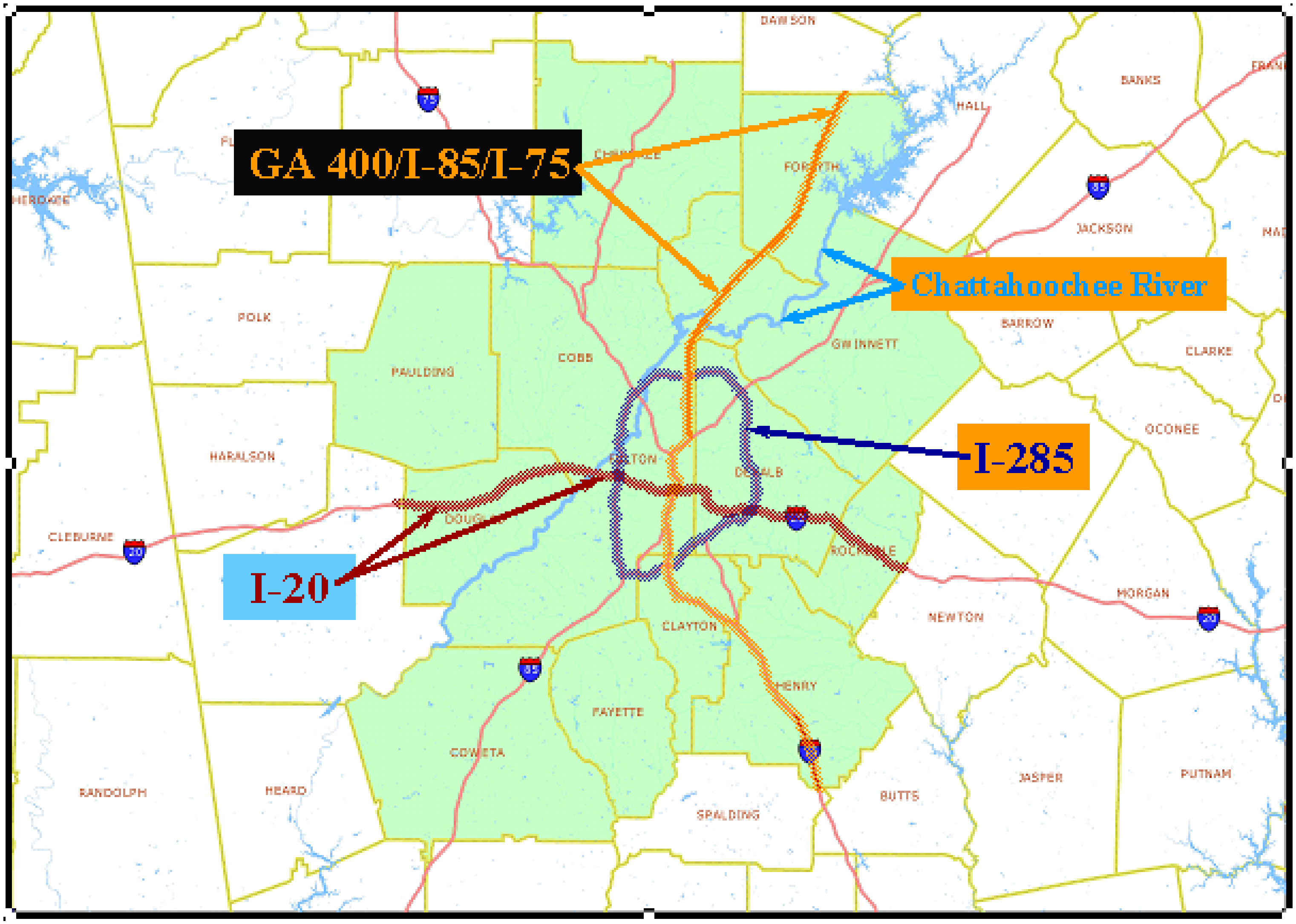
Home Based Work											
	Destination										
	Outside of I-285			Inside of I-285			Total		Total Crossing		
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
Outside of I-285	1,518,896	1,525,378	0.4%	650,781	643,142	-1.2%	2,169,677	2,168,520	830,306	827,612	-0.3%
Inside of I-285	179,525	184,470	2.8%	498,645	494,850	-0.8%	678,170	679,320			
Total	1,698,421	1,709,848	0.7%	1,149,426	1,137,992	-1.0%	2,847,847	2,847,840			

Previous checks of the ability of the calibrated home based work gravity model to reliably reproduce the observed travel patterns from the 2001-2002 O-D Survey have accounted for travel across the Chattahoochee River (the Atlanta region's only topographic barrier), north-south travel (I-20), and urban/suburban travel (I-285). In order to validate the model's ability to replicate major east-west travel patterns the Atlanta region was divided along a line defined by Georgia 400, I-85 and I-75 (see Figure 3.4.1). This line generally divided the Atlanta region into eastern and western geographical areas. Table 3.4.5 compares the gravity model estimate of home-based work person trips crossing this north-south boundary with the 2001-2002 ARC household origin-destination survey data. As can be seen from the data in Table 3.4.5, the gravity model estimates the total home-based work person trips crossing I-285 to less than one percent difference from the survey.

Table 3.4.5
Comparison of Gravity Model and 2001-2002 Origin Destination Survey Crossings of Georgia 400/I-85/I-75

Home Based Work											
	Destination										
	Outside of I-285			Inside of I-285			Total		Total Crossing		
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
Outside of I-285	1,518,896	1,525,378	0.4%	650,781	643,142	-1.2%	2,169,677	2,168,520	830,306	827,612	-0.3%
Inside of I-285	179,525	184,470	2.8%	498,645	494,850	-0.8%	678,170	679,320			
Total	1,698,421	1,709,848	0.7%	1,149,426	1,137,992	-1.0%	2,847,847	2,847,840			

Figure 3.4.1
Validation Cutlines and Topographic Barriers



As a final check of the ability of the calibrated home based work gravity model to replicated observed travel patterns, a comparison of the county-to-county work trips between the gravity model, the 2001-2002 Household Travel Survey (O-D), and the 2000 Census Journey-to-Work data was made. Tables 3.4.6 through 3.4.18 show these county by county comparisons. It is important to note that the reason for the major difference in total trips in the 2000 Census and the Gravity Model and O-D survey is that the Census trips account for only the home-to-work trip while the Gravity Model and O-D survey account for both the home-to-work trip and work-to-home trip. Since the survey was done prior to the expansion to 20 counties, the worker flows do not include any information on the 7 additional counties. The Gravity Model shows the distribution of the survey trip ends.

A review of the data in these tables shows that the calibrated gravity model generally provides reasonable estimates of the home based work trips for individual counties. There are several counties where the gravity model appears to underestimate the intra-county trips: Coweta County, Douglas County, and Rockdale County. It is important to note that all these counties are located on the edge of the regional travel demand model study area with relatively large traffic analysis zones. Thus, the calculation of intrazonal times would yield fairly large travel times for the closest three traffic analysis zones. These large intrazonal travel times would make accessibility to adjacent counties (Fulton and DeKalb) with large employment centers highly attractive.

In the case of Coweta County, the Atlanta Airport area with its large employee base is attracting resident workers from Coweta County. In the case of Douglas County, the large employment base of the Fulton Industrial Park area is located in Fulton County adjacent to the county line (Chattahoochee River) with easy access to residents of Douglas County. The Stonecrest Mall area and the Panola Industrial Park employment centers are located in DeKalb County in close proximity to the Rockdale County line.

These potential home based work gravity model problem areas could be addressed by adjusting the intrazonal times of large traffic analysis zones in those counties. However, the analysis of the major regional travel patterns, crossings of the Chattahoochee River, I-20, I-285, and GA 400/I-85,I-75, has shown that the overall performance of the home base work gravity model is well within the generally accepted criteria for model accuracy. Thus, adjustments to the intrazonal travel times in these outlying counties were not deemed warranted at this time.

Tables 3.4.19 through 3.4.25 show the comparison between the 2000 Census and the model for the 7 additional counties. These tables are different than the tables for the 13 counties because with no survey data available, the trip generation output had to be used for comparison. Again, the major difference in total trips is how the census accounts for trips versus the model. In terms of percentages, the model does reasonably well distributing trips compared to census; however, the model does appear to underestimate the number of intra-county trips for these additional counties. With no new data available in these 7 additional counties and how well the model performs in the original 13 counties, the results were deemed acceptable for regional planning purposes.

Table 3.4.6
Comparison of Census, Gravity Model, and O-D Survey
HBW Trips From Cherokee County

HBW Trips From Cherokee County						
To	2000 Census		GM		OD Survey	
Cherokee	26,239	37.4%	28,767	28.6%	35,015	34.8%
Clayton	257	0.4%	244	0.2%	-	0.0%
Cobb	18,911	26.9%	31,305	31.1%	23,052	22.9%
Coweta	23	0.0%	117	0.1%	-	0.0%
DeKalb	2,898	4.1%	3,911	3.9%	4,900	4.9%
Douglas	174	0.2%	487	0.5%	1,474	1.5%
Fayette	41	0.1%	47	0.0%	-	0.0%
Forsyth	1,961	2.8%	3,673	3.7%	4,158	4.1%
Fulton	17,494	24.9%	28,359	28.2%	26,271	26.1%
Gwinnett	2,037	2.9%	3,038	3.0%	5,722	5.7%
Henry	37	0.1%	43	0.0%	-	0.0%
Paulding	117	0.2%	553	0.5%	-	0.0%
Rockdale	34	0.0%	48	0.0%	-	0.0%
Total	70,223	100.0%	100,590	100.0%	100,593	100.0%

Table 3.4.7
Comparison of Census, Gravity Model, and O-D Survey
HBW Trips From Clayton County

HBW Trips From Clayton County						
To	2000 Census		GM		OD Survey	
Cherokee	148	0.2%	82	0.1%	-	0.0%
Clayton	42,924	61.1%	46,241	46.0%	58,782	58.4%
Cobb	4,053	5.8%	4,971	4.9%	1,760	1.7%
Coweta	582	0.8%	1,597	1.6%	973	1.0%
DeKalb	9,024	12.9%	18,673	18.6%	19,099	19.0%
Douglas	567	0.8%	1,210	1.2%	699	0.7%
Fayette	3,760	5.4%	6,675	6.6%	7,720	7.7%
Forsyth	213	0.3%	43	0.0%	-	0.0%
Fulton	40,271	57.3%	62,304	61.9%	50,810	50.5%
Gwinnett	2,785	4.0%	3,025	3.0%	5,898	5.9%
Henry	4,413	6.3%	8,998	8.9%	10,272	10.2%
Paulding	45	0.1%	117	0.1%	-	0.0%
Rockdale	652	0.9%	2,176	2.2%	95	0.1%
Total	109,437	155.8%	156,110	155.2%	156,108	155.2%

Table 3.4.8
Comparison of Census, Gravity Model, and O-D Survey
HBW Trips From Cobb County

HBW Trips From Cobb County						
To	2000 Census		GM		OD Survey	
Cherokee	5,234	1.7%	14,046	2.7%	10,170	2.0%
Clayton	3,166	1.0%	3,982	0.8%	2,853	0.6%
Cobb	179,750	57.0%	255,972	49.5%	282,677	54.6%
Coweta	228	0.1%	1,060	0.2%	474	0.1%
DeKalb	18,098	5.7%	35,559	6.9%	28,053	5.4%
Douglas	4,011	1.3%	10,543	2.0%	5,444	1.1%
Fayette	483	0.2%	894	0.2%	1,403	0.3%
Forsyth	1,529	0.5%	2,516	0.5%	3,321	0.6%
Fulton	92,014	29.2%	173,288	33.5%	166,604	32.2%
Gwinnett	8,723	2.8%	11,674	2.3%	13,054	2.5%
Henry	324	0.1%	619	0.1%	201	0.0%
Paulding	1,624	0.5%	6,647	1.3%	3,037	0.6%
Rockdale	191	0.1%	663	0.1%	158	0.0%
Total	315,375	100.0%	517,463	100.0%	517,449	100.0%

Table 3.4.9
Comparison of Census, Gravity Model, and O-D Survey
HBW Trips From Coweta County

HBW Trips From Coweta County						
To	2000 Census		GM		OD Survey	
Cherokee	26	0.0%	30	0.0%	-	0.0%
Clayton	3,097	1.0%	3,774	0.7%	2,601	0.5%
Cobb	1,136	0.4%	2,380	0.5%	2,633	0.5%
Coweta	20,735	6.6%	19,245	3.7%	28,459	5.5%
DeKalb	1,014	0.3%	2,725	0.5%	1,897	0.4%
Douglas	220	0.1%	2,011	0.4%	520	0.1%
Fayette	5,517	1.7%	6,225	1.2%	7,228	1.4%
Forsyth	45	0.0%	15	0.0%	-	0.0%
Fulton	8,855	2.8%	21,042	4.1%	15,800	3.1%
Gwinnett	397	0.1%	435	0.1%	-	0.0%
Henry	172	0.1%	863	0.2%	-	0.0%
Paulding	15	0.0%	175	0.0%	-	0.0%
Rockdale	17	0.0%	216	0.0%	-	0.0%
Total	41,246	13.1%	59,136	11.4%	59,138	11.4%

Table 3.4.10
Comparison of Census, Gravity Model, and O-D Survey
HBW Trips From DeKalb County

HBW Trips From DeKalb County						
To	2000 Census		GM		OD Survey	
Cherokee	448	0.1%	400	0.1%	79	0.0%
Clayton	5,644	1.7%	12,068	2.5%	6,051	1.3%
Cobb	13,448	4.0%	19,417	4.0%	15,834	3.3%
Coweta	241	0.1%	705	0.1%	225	0.0%
DeKalb	149,919	45.0%	201,899	41.8%	205,728	42.6%
Douglas	674	0.2%	1,495	0.3%	521	0.1%
Fayette	680	0.2%	1,380	0.3%	1,476	0.3%
Forsyth	1,629	0.5%	757	0.2%	1,356	0.3%
Fulton	121,921	36.6%	189,773	39.3%	198,212	41.0%
Gwinnett	34,747	10.4%	42,253	8.7%	45,938	9.5%
Henry	1,174	0.4%	4,738	1.0%	2,924	0.6%
Paulding	94	0.0%	199	0.0%	1,115	0.2%
Rockdale	2,708	0.8%	8,347	1.7%	3,951	0.8%
Total	333,327	100.0%	483,431	100.0%	483,409	100.0%

Table 3.4.11
Comparison of Census, Gravity Model, and O-D Survey
HBW Trips From Douglas County

HBW Trips From Douglas County						
To	2000 Census		GM		OD Survey	
Cherokee	104	0.0%	150	0.0%	-	0.0%
Clayton	1,196	0.4%	1,910	0.4%	-	0.0%
Cobb	7,450	2.2%	8,970	1.9%	4,887	1.0%
Coweta	156	0.0%	1,292	0.3%	-	0.0%
DeKalb	2,211	0.7%	3,406	0.7%	5,059	1.0%
Douglas	16,924	5.1%	16,197	3.4%	32,953	6.8%
Fayette	204	0.1%	882	0.2%	674	0.1%
Forsyth	104	0.0%	32	0.0%	-	0.0%
Fulton	14,253	4.3%	23,122	4.8%	12,116	2.5%
Gwinnett	747	0.2%	607	0.1%	-	0.0%
Henry	87	0.0%	315	0.1%	-	0.0%
Paulding	596	0.2%	1,231	0.3%	2,591	0.5%
Rockdale	61	0.0%	167	0.0%	-	0.0%
Total	44,093	13.2%	58,281	12.1%	58,280	12.1%

Table 3.4.12
Comparison of Census, Gravity Model, and O-D Survey
HBW Trips From Fayette County

HBW Trips From Fayette County						
To	2000 Census		GM		OD Survey	
Cherokee	8	0.0%	28	0.0%	-	0.0%
Clayton	6,048	13.9%	7,512	11.2%	3,968	5.9%
Cobb	1,124	2.6%	2,476	3.7%	1,622	2.4%
Coweta	1,439	3.3%	4,946	7.4%	1,264	1.9%
DeKalb	1,683	3.9%	3,428	5.1%	8,796	13.2%
Douglas	245	0.6%	1,142	1.7%	-	0.0%
Fayette	16,977	39.1%	20,029	30.0%	21,415	32.0%
Forsyth	70	0.2%	19	0.0%	-	0.0%
Fulton	14,745	33.9%	23,436	35.1%	27,827	41.6%
Gwinnett	362	0.8%	605	0.9%	95	0.1%
Henry	706	1.6%	2,727	4.1%	1,842	2.8%
Paulding	7	0.0%	85	0.1%	-	0.0%
Rockdale	40	0.1%	399	0.6%	-	0.0%
Total	43,454	100.0%	66,831	100.0%	66,830	100.0%

Table 3.4.13
Comparison of Census, Gravity Model, and O-D Survey
HBW Trips From Forsyth County

HBW Trips From Forsyth County						
To	2000 Census		GM		OD Survey	
Cherokee	457	1.1%	1,577	2.4%	889	1.3%
Clayton	73	0.2%	94	0.1%	-	0.0%
Cobb	1,790	4.1%	3,471	5.2%	4,301	6.4%
Coweta	8	0.0%	9	0.0%	736	1.1%
DeKalb	3,067	7.1%	2,875	4.3%	3,052	4.6%
Douglas	57	0.1%	51	0.1%	-	0.0%
Fayette	20	0.0%	12	0.0%	-	0.0%
Forsyth	21,039	48.4%	12,921	19.3%	15,189	22.7%
Fulton	15,251	35.1%	23,900	35.8%	23,228	34.8%
Gwinnett	5,663	13.0%	6,834	10.2%	4,452	6.7%
Henry	16	0.0%	20	0.0%	-	0.0%
Paulding	16	0.0%	28	0.0%	-	0.0%
Rockdale	79	0.2%	54	0.1%	-	0.0%
Total	47,536	109.4%	51,847	77.6%	51,847	77.6%

Table 3.4.14
Comparison of Census, Gravity Model, and O-D Survey
HBW Trips From Fulton County

HBW Trips From Fulton County						
To	2000 Census		GM		OD Survey	
Cherokee	1,129	0.3%	2,806	0.5%	1,305	0.2%
Clayton	9,722	2.6%	14,844	2.6%	11,286	2.0%
Cobb	24,991	6.7%	46,023	8.0%	37,438	6.5%
Coweta	950	0.3%	1,438	0.2%	-	0.0%
DeKalb	41,232	11.0%	81,400	14.2%	85,104	14.8%
Douglas	1,192	0.3%	3,094	0.5%	319	0.1%
Fayette	1,633	0.4%	2,652	0.5%	2,384	0.4%
Forsyth	5,626	1.5%	4,583	0.8%	4,319	0.8%
Fulton	265,870	70.9%	388,299	67.5%	398,280	69.3%
Gwinnett	21,211	5.7%	25,746	4.5%	28,278	4.9%
Henry	954	0.3%	1,922	0.3%	1,056	0.2%
Paulding	128	0.0%	445	0.1%	-	0.0%
Rockdale	571	0.2%	1,818	0.3%	5,289	0.9%
Total	375,209	100.0%	575,069	100.0%	575,058	100.0%

Table 3.4.15
Comparison of Census, Gravity Model, and O-D Survey
HBW Trips From Gwinnett County

HBW Trips From Gwinnett County						
To	2000 Census		GM		OD Survey	
Cherokee	582	0.2%	807	0.1%	534	0.1%
Clayton	1,913	0.5%	3,518	0.6%	3,960	0.7%
Cobb	8,648	2.3%	12,512	2.2%	10,602	1.8%
Coweta	227	0.1%	197	0.0%	846	0.1%
DeKalb	51,481	13.7%	92,378	16.1%	101,118	17.6%
Douglas	259	0.1%	504	0.1%	275	0.0%
Fayette	256	0.1%	391	0.1%	129	0.0%
Forsyth	3,977	1.1%	5,923	1.0%	2,308	0.4%
Fulton	57,737	15.4%	111,011	19.3%	120,113	20.9%
Gwinnett	169,000	45.0%	290,387	50.5%	282,971	49.2%
Henry	491	0.1%	2,022	0.4%	375	0.1%
Paulding	179	0.0%	73	0.0%	-	0.0%
Rockdale	1,611	0.4%	8,442	1.5%	4,929	0.9%
Total	296,361	79.0%	528,164	91.8%	528,163	91.8%

Table 3.4.16
Comparison of Census, Gravity Model, and O-D Survey
HBW Trips From Henry County

HBW Trips From Henry County						
To	2000 Census		GM		OD Survey	
Cherokee	74	0.1%	27	0.0%	-	0.0%
Clayton	13,541	23.6%	13,939	13.4%	21,345	20.5%
Cobb	1,365	2.4%	2,249	2.2%	6,127	5.9%
Coweta	173	0.3%	646	0.6%	-	0.0%
DeKalb	5,597	9.8%	13,249	12.8%	6,562	6.3%
Douglas	200	0.3%	435	0.4%	-	0.0%
Fayette	1,137	2.0%	2,539	2.4%	254	0.2%
Forsyth	39	0.1%	40	0.0%	-	0.0%
Fulton	14,157	24.7%	29,174	28.1%	29,653	28.5%
Gwinnett	1,531	2.7%	3,367	3.2%	651	0.6%
Henry	18,751	32.7%	32,622	31.4%	38,405	37.0%
Paulding	33	0.1%	37	0.0%	-	0.0%
Rockdale	784	1.4%	5,573	5.4%	903	0.9%
Total	57,382	100.0%	103,895	100.0%	103,900	100.0%

Table 3.4.17
Comparison of Census, Gravity Model, and O-D Survey
HBW Trips From Paulding County

HBW Trips From Paulding County						
To	2000 Census		GM		OD Survey	
Cherokee	459	0.8%	1,024	1.0%	-	0.0%
Clayton	440	0.8%	1,375	1.3%	229	0.2%
Cobb	14,850	25.9%	28,244	27.2%	23,155	22.3%
Coweta	69	0.1%	1,981	1.9%	851	0.8%
DeKalb	1,288	2.2%	3,719	3.6%	503	0.5%
Douglas	2,865	5.0%	12,708	12.2%	7,634	7.3%
Fayette	79	0.1%	515	0.5%	-	0.0%
Forsyth	128	0.2%	115	0.1%	-	0.0%
Fulton	7,432	13.0%	25,474	24.5%	41,168	39.6%
Gwinnett	655	1.1%	881	0.8%	-	0.0%
Henry	26	0.0%	216	0.2%	437	0.4%
Paulding	10,094	17.6%	11,151	10.7%	13,579	13.1%
Rockdale	24	0.0%	153	0.1%	-	0.0%
Total	38,409	66.9%	87,555	84.3%	87,556	84.3%

Table 3.4.18
Comparison of Census, Gravity Model and O-D Survey
HBW Trips from Rockdale County

HBW Trips From Rockdale County						
To	2000 Census		GM		OD Survey	
Cherokee	15	0.1%	13	0.0%	-	0.0%
Clayton	804	2.7%	2,820	5.3%	717	1.3%
Cobb	570	1.9%	986	1.8%	727	1.4%
Coweta	23	0.1%	99	0.2%	-	0.0%
DeKalb	6,187	21.0%	9,915	18.5%	7,361	13.7%
Douglas	56	0.2%	148	0.3%	-	0.0%
Fayette	27	0.1%	345	0.6%	256	0.5%
Forsyth	47	0.2%	49	0.1%	-	0.0%
Fulton	4,792	16.2%	12,039	22.4%	8,972	16.7%
Gwinnett	1,985	6.7%	5,319	9.9%	2,828	5.3%
Henry	602	2.0%	4,293	8.0%	3,068	5.7%
Paulding	9	0.0%	14	0.0%	-	0.0%
Rockdale	14,378	48.7%	17,654	32.9%	29,766	55.4%
Total	29,495	100.0%	53,695	100.0%	53,697	100.0%

Table 3.4.19
Comparison of Census and Gravity Model HBW Trips from Barrow

HBW Trips from Barrow				
	CTPP		MODEL	
To	Trips	%	Trips	%
Barrow	7,751	38.8%	6,994	24.1%
Bartow	19	0.1%	11	0.0%
Carroll	0	0.0%	5	0.0%
Cherokee	19	0.1%	45	0.2%
Clayton	41	0.2%	228	0.8%
Cobb	159	0.8%	396	1.4%
Coweta	0	0.0%	10	0.0%
Dekalb	1,177	5.9%	2,892	10.0%
Douglas	38	0.2%	18	0.1%
Fayette	24	0.1%	18	0.1%
Forsyth	270	1.3%	565	1.9%
Fulton	959	4.8%	3,179	11.0%
Gwinnett	8,229	41.1%	10,432	36.0%
Hall	692	3.5%	2,271	7.8%
Henry	14	0.1%	77	0.3%
Newton	60	0.3%	314	1.1%
Paulding	0	0.0%	4	0.0%
Rockdale	107	0.5%	425	1.5%
Spalding	0	0.0%	15	0.1%
Walton	443	2.2%	1,098	3.8%
Total	**20,002**	**100.0%**	**28,997**	**100.0%**

Table 3.4.20
Comparison of Census and Gravity Model HBW Trips from Bartow

HBW Trips from Bartow				
	CTPP		MODEL	
To	Trips	%	Trips	%
Barrow	12	0.0%	3	0.0%
Bartow	20,692	63.3%	21,720	45.2%
Carroll	100	0.3%	301	0.6%
Cherokee	1,154	3.5%	2,492	5.2%
Clayton	174	0.5%	350	0.7%
Cobb	6,936	21.2%	12,665	26.3%
Coweta	33	0.1%	68	0.1%
Dekalb	678	2.1%	1,314	2.7%
Douglas	109	0.3%	600	1.2%
Fayette	5	0.0%	56	0.1%
Forsyth	130	0.4%	438	0.9%
Fulton	1,882	5.8%	6,473	13.5%
Gwinnett	392	1.2%	569	1.2%
Hall	38	0.1%	84	0.2%
Henry	26	0.1%	24	0.0%
Newton	28	0.1%	7	0.0%
Paulding	229	0.7%	891	1.9%
Rockdale	27	0.1%	16	0.0%
Spalding	20	0.1%	5	0.0%
Walton	7	0.0%	7	0.0%
Total	**32,672**	**100.0%**	**48,083**	**100.0%**

Table 3.4.21
Comparison of Census and Gravity Model HBW Trips from Carroll

HBW Trips from Carroll				
	CTPP		MODEL	
To	Trips	%	Trips	%
Barrow	0	0.0%	7	0.0%
Bartow	82	0.2%	249	0.5%
Carroll	24,611	65.7%	26,410	50.8%
Cherokee	52	0.1%	116	0.2%
Clayton	369	1.0%	2,044	3.9%
Cobb	2,044	5.5%	4,136	8.0%
Coweta	1,335	3.6%	2,653	5.1%
Dekalb	700	1.9%	1,495	2.9%
Douglas	3,438	9.2%	3,253	6.3%
Fayette	245	0.7%	878	1.7%
Forsyth	38	0.1%	72	0.1%
Fulton	3,570	9.5%	8,936	17.2%
Gwinnett	359	1.0%	550	1.1%
Hall	0	0.0%	66	0.1%
Henry	39	0.1%	133	0.3%
Newton	5	0.0%	32	0.1%
Paulding	493	1.3%	721	1.4%
Rockdale	36	0.1%	69	0.1%
Spalding	28	0.1%	115	0.2%
Walton	9	0.0%	11	0.0%
Total	**37,453**	**100.0%**	**51,946**	**100.0%**

Table 3.4.22
Comparison of Census and Gravity Model HBW Trips from Hall

HBW Trips from Hall				
	CTPP		MODEL	
To	Trips	%	Trips	%
Barrow	336	1.0%	735	0.9%
Bartow	25	0.1%	67	0.1%
Carroll	15	0.0%	12	0.0%
Cherokee	224	0.7%	373	0.4%
Clayton	66	0.2%	233	0.3%
Cobb	389	1.2%	831	1.0%
Coweta	7	0.0%	16	0.0%
Dekalb	1,716	5.3%	3,513	4.2%
Douglas	14	0.0%	22	0.0%
Fayette	0	0.0%	28	0.0%
Forsyth	1,577	4.8%	2,908	3.5%
Fulton	2,244	6.9%	6,515	7.8%
Gwinnett	7,189	22.0%	13,593	16.3%
Hall	46,680	142.9%	54,193	64.8%
Henry	4	0.0%	42	0.1%
Newton	4	0.0%	98	0.1%
Paulding	21	0.1%	6	0.0%
Rockdale	6	0.0%	164	0.2%
Spalding	0	0.0%	5	0.0%
Walton	0	0.0%	223	0.3%
Total	**60,517**	**100.0%**	**83,577**	**100.0%**

Table 3.4.23
Comparison of Census and Gravity Model
HBW Trips from Newton

HBW Trips from Newton				
	CTPP		MODEL	
To	Trips	%	Trips	%
Barrow	20	0.1%	167	0.4%
Bartow	5	0.0%	12	0.0%
Carroll	0	0.0%	28	0.1%
Cherokee	30	0.1%	24	0.1%
Clayton	480	1.7%	2,263	5.8%
Cobb	411	1.5%	912	2.3%
Coweta	50	0.2%	80	0.2%
Dekalb	3,567	12.9%	5,877	14.9%
Douglas	14	0.1%	109	0.3%
Fayette	28	0.1%	288	0.7%
Forsyth	43	0.2%	54	0.1%
Fulton	2,399	8.7%	7,261	18.5%
Gwinnett	1,320	4.8%	3,353	8.5%
Hall	38	0.1%	121	0.3%
Henry	387	1.4%	1,777	4.5%
Newton	11,545	41.8%	9,161	23.3%
Paulding	7	0.0%	12	0.0%
Rockdale	6,513	23.6%	6,173	15.7%
Spalding	40	0.1%	332	0.8%
Walton	755	2.7%	1,339	3.4%
Total	**27,652**	**100.0%**	**39,343**	**100.0%**

Table 3.4.24
Comparison of Census and Gravity Model
HBW Trips from Spalding

HBW Trips from Spalding				
	CTPP		MODEL	
To	Trips	%	Trips	%
Barrow	36	0.2%	9	0.0%
Bartow	22	0.1%	17	0.0%
Carroll	3	0.0%	96	0.3%
Cherokee	9	0.0%	15	0.0%
Clayton	2,113	9.1%	3,476	10.0%
Cobb	273	1.2%	672	1.9%
Coweta	342	1.5%	820	2.4%
Dekalb	583	2.5%	1,532	4.4%
Douglas	30	0.1%	167	0.5%
Fayette	1,468	6.3%	2,204	6.3%
Forsyth	28	0.1%	31	0.1%
Fulton	1,917	8.2%	5,602	16.1%
Gwinnett	185	0.8%	419	1.2%
Hall	0	0.0%	30	0.1%
Henry	2,426	10.4%	2,660	7.6%
Newton	22	0.1%	175	0.5%
Paulding	9	0.0%	15	0.0%
Rockdale	88	0.4%	342	1.0%
Spalding	13,715	58.9%	16,515	47.4%
Walton	0	0.0%	40	0.1%
Total	**23,269**	**100.0%**	**34,837**	**100.0%**

Table 3.4.25
Comparison of Census and Gravity Model
HBW Trips from Walton

HBW Trips from Walton				
	CTPP		MODEL	
To	Trips	%	Trips	%
Barrow	554	2.0%	1,368	3.5%
Bartow	20	0.1%	14	0.0%
Carroll	7	0.0%	11	0.0%
Cherokee	24	0.1%	25	0.1%
Clayton	254	0.9%	1,086	2.8%
Cobb	283	1.0%	597	1.5%
Coweta	0	0.0%	46	0.1%
Dekalb	2,978	11.0%	5,342	13.8%
Douglas	0	0.0%	70	0.2%
Fayette	6	0.0%	89	0.2%
Forsyth	121	0.4%	294	0.8%
Fulton	1,666	6.2%	5,411	14.0%
Gwinnett	7,037	26.0%	10,092	26.2%
Hall	124	0.5%	730	1.9%
Henry	42	0.2%	538	1.4%
Newton	1,089	4.0%	2,434	6.3%
Paulding	2	0.0%	11	0.0%
Rockdale	1,645	6.1%	2,495	6.5%
Spalding	12	0.0%	98	0.3%
Walton	11,204	41.4%	7,820	20.3%
Total	**27,068**	**100.0%**	**38,571**	**100.0%**

3.5. Calibration of Home-Based Other Gravity Model

Trip distribution of HBO trips was done similarly to HBW trips, which was explained in the preceding two sections. The number of HBO trip purposes were identical to HBW trip purposes. HBO trips were distributed over three the same (3) separate market groups. There was, however, one significant difference. The composite measures of time were based on off-peak period time skims in comparison with A.M. peak period time skims for the HBW trip purposes.

In calculating composite time, three different factors were used to weight the contribution of transit travel time. There was one factor for each HBO trip grouping, as follows:

HBO Market Groups 1-2: 0.19;
HBO Market Group 3: 0.06;
HBO Market Group 4: 0.03.

Final highway skims used in computing the composite time included terminal time on top of interzonal and intrazonal travel times.

The overall process of calibrating and validating the HBO trip purposes was exactly the same as for HBW trips. Production and attraction trip ends came directly from the Atlanta Regional Commission's 2001-2002 Household Travel Survey. Composite times were calculated using terminal times and interzonal travel times from the Atlanta Regional Commission's base year 2000 highway and transit model networks. The gravity model calibration consisted of making adjustments to friction factors for each HBO trip purpose. Friction factor adjustments were made to achieve two desired outcomes. The first desired outcome was to get the average trip length of the gravity model within three percent (3%) of the average trip length observed in the Household Travel Survey data. The second desirable objective was getting the trip length frequency curve from the gravity model to generally replicate the trip length frequency curve of the observed origin-destination trip file that was extracted from the Household Travel Survey.

Results of the calibration process for the three HBO trip purposes are presented in Figures 3.5.1 through 3.5.3. They illustrate the comparison of the trip length frequency curves for each HBO income group or purpose. The line graphs show that trip length frequency distributions from the gravity model generally match their corresponding trip length frequency curve that was observed in the O-D Survey. In addition to the trip length frequency curves, computed average trip lengths for each of the three HBO trip purposes are within the three percent (3%) criteria. The average trip lengths for the gravity models for the three trip purposes are all essentially the same as the average trips lengths from the O-D Survey. For Market Group 1-2 trips, the average trip length from the gravity model was 16.87 minutes while the O-D Survey average of 16.93 minutes. The gravity model average trip length of 17.81 minutes for Market Group 3 was essentially the same as the 17.73 minute average for the O-D Survey. The average trip length for Group 4 calculated by the gravity model was 18.95 minutes while the O-D Survey average was 18.81 minutes.

The gravity model friction factors developed from this calibration process are shown graphically in Figures 3.5.4 through 3.5.6 for market groups 1-2, 3 and 4, respectively. Tables 3.5.1 through 3.5.3 indicate the actual calibrated friction factor values for individual composite time increments between 1 and 100 minutes.

Figure 3.5.1

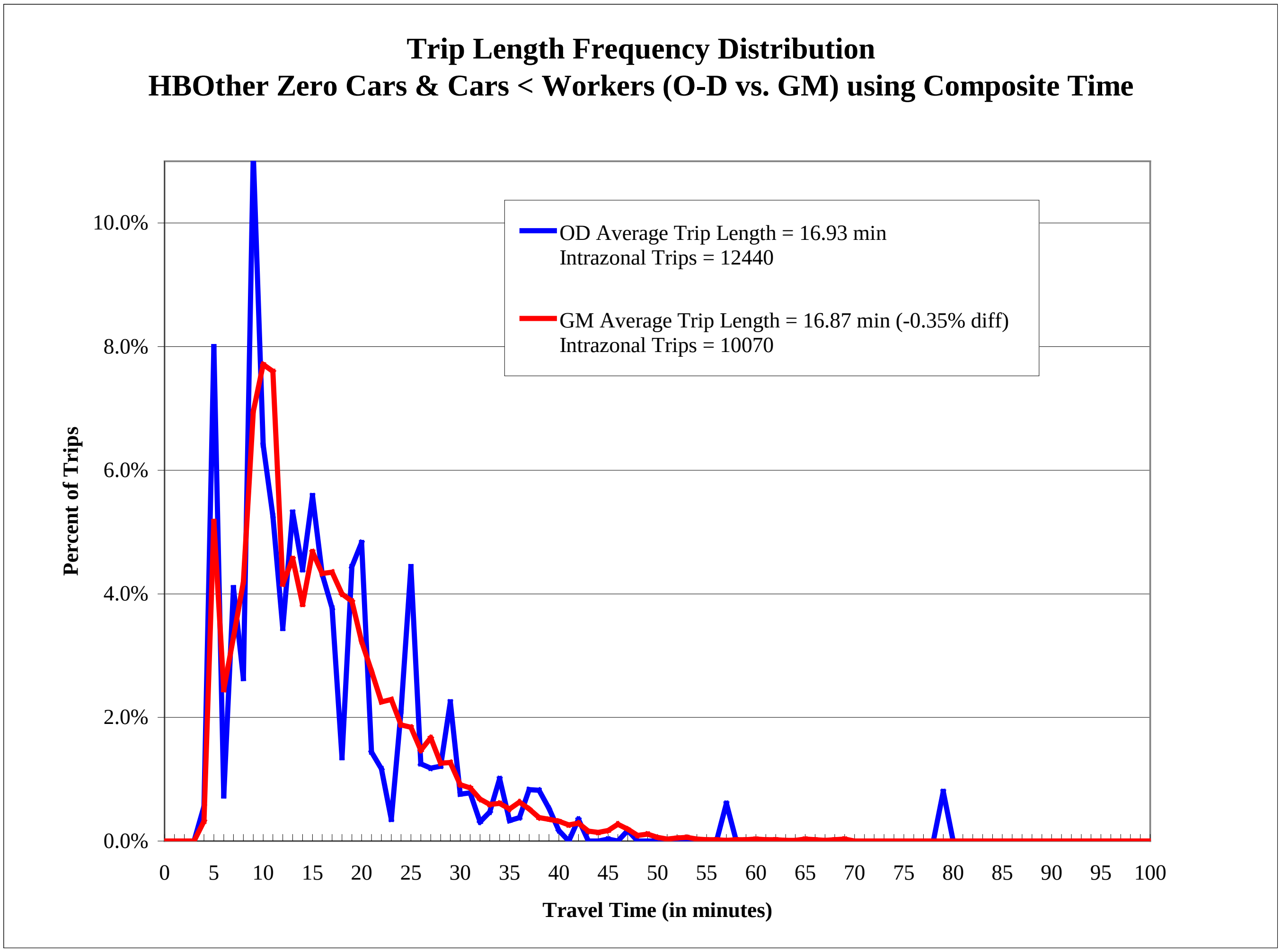
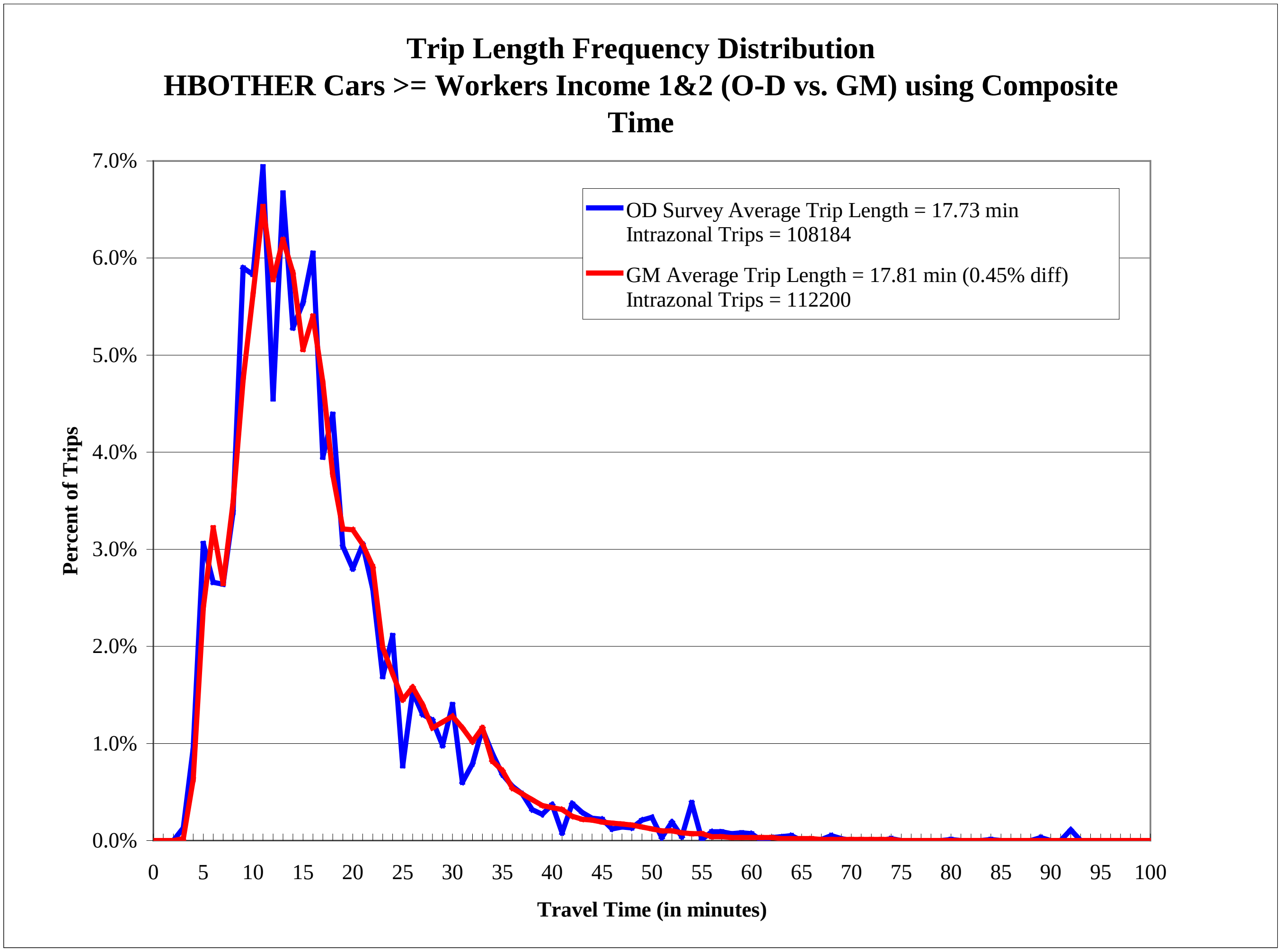
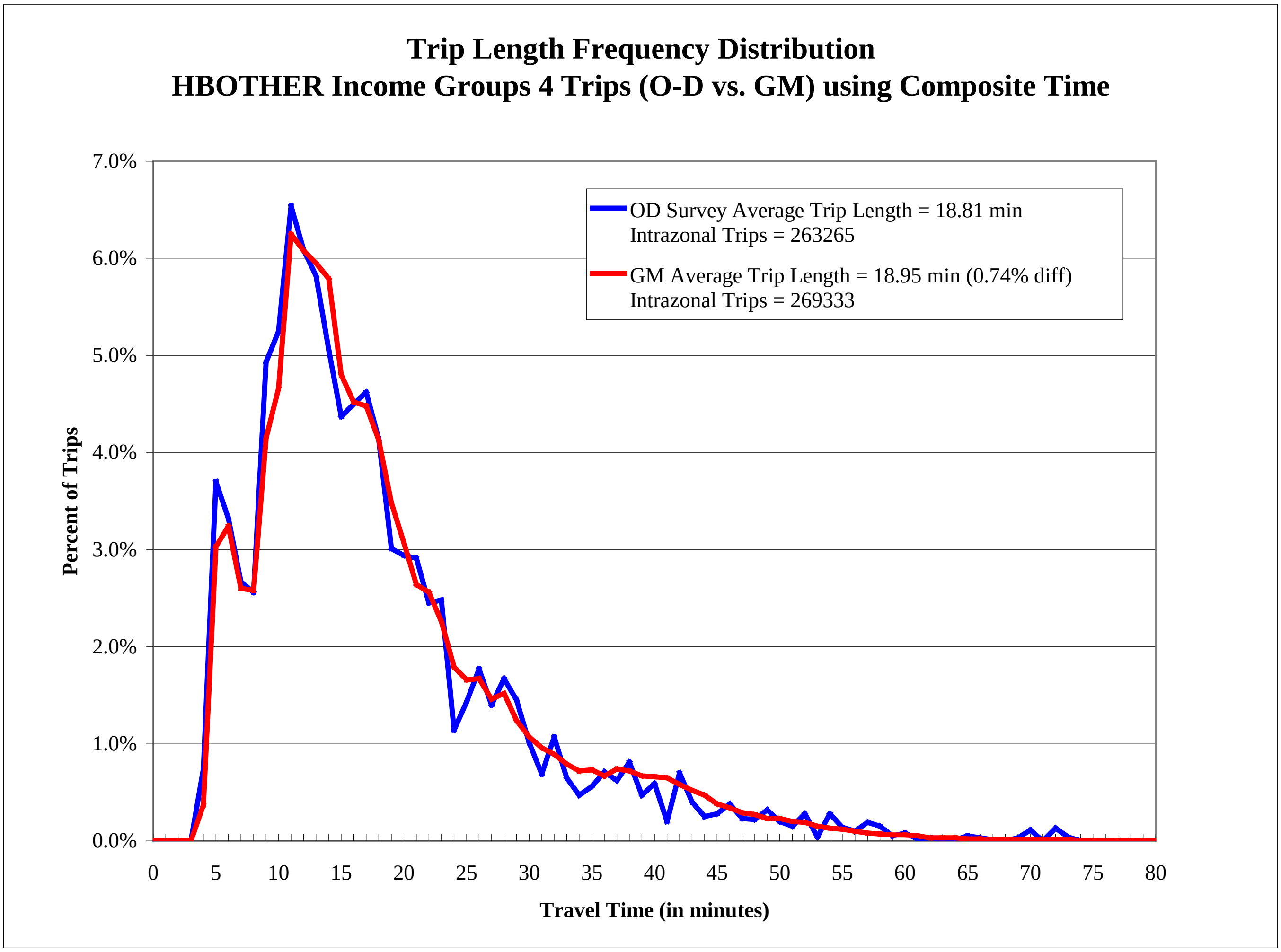

Trip Length Frequency Distribution
HBOther Zero Cars & Cars < Workers (O-D vs. GM) using Composite Time
OD Average Trip Length = 16.93 min
Intrazonal Trips = 12440
GM Average Trip Length = 16.87 min (-0.35% diff)
Intrazonal Trips = 10070
Percent of Trips
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Travel Time (in minutes)

Figure 3.5.2



Trip Length Frequency Distribution
HBOTHER Cars >= Workers Income 1&2 (O-D vs. GM) using Composite Time
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
Percent of Trips
OD Survey Average Trip Length = 17.73 min
Intrazonal Trips = 108184
GM Average Trip Length = 17.81 min (0.45% diff)
Intrazonal Trips = 112200
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Travel Time (in minutes)

Figure 3.5.3



Trip Length Frequency Distribution
HBOTHER Income Groups 4 Trips (O-D vs. GM) using Composite Time
OD Survey Average Trip Length = 18.81 min
Intrazonal Trips = 263265
GM Average Trip Length = 18.95 min (0.74% diff)
Intrazonal Trips = 269333
Percent of Trips
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
Travel Time (in minutes)

Figure 3.5.4
Home Based Other Calibrated Gravity Model
Market Groups 1-2 Friction Factor Curve

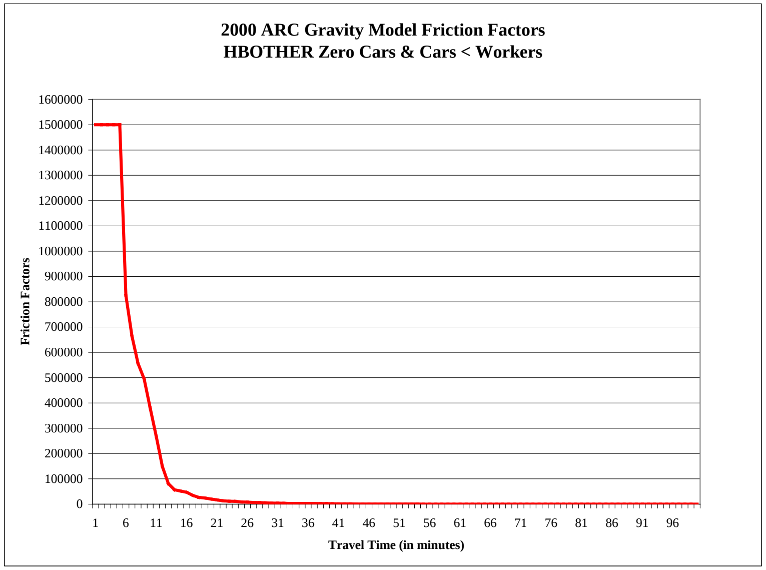


Table 3.5.1
Home Based Other Calibrated Gravity Model
Market Groups 1-2 Friction Factors

Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor
1	1500000	26	7812	51	365	76	9
2	1500000	27	6355	52	337	77	8
3	1500000	28	5936	53	295	78	7
4	1500000	29	5092	54	257	79	6
5	1500000	30	4227	55	223	80	5
6	825000	31	3989	56	194	81	5
7	662731	32	3320	57	170	82	4
8	556085	33	2758	58	149	83	4
9	495144	34	2600	59	130	84	3
10	380880	35	2500	60	114	85	3
11	267363	36	2425	61	91	86	3
12	148353	37	2328	62	79	87	2
13	81051	38	1954	63	70	88	2
14	57000	39	1793	64	60	89	2
15	52000	40	1511	65	53	90	2
16	47000	41	1138	66	46	91	1
17	34630	42	1009	67	41	92	1
18	26560	43	871	68	36	93	1
19	23925	44	706	69	31	94	1
20	20350	45	685	70	28	95	1
21	16500	46	643	71	17	96	1
22	13268	47	575	72	15	97	1
23	11762	48	485	73	13	98	1
24	10862	49	430	74	11	99	1
25	8634	50	391	75	10	100	1

Figure 3.5.5
Home Based Other Calibrated Gravity Model
Market Group 3 Friction Factor Curve

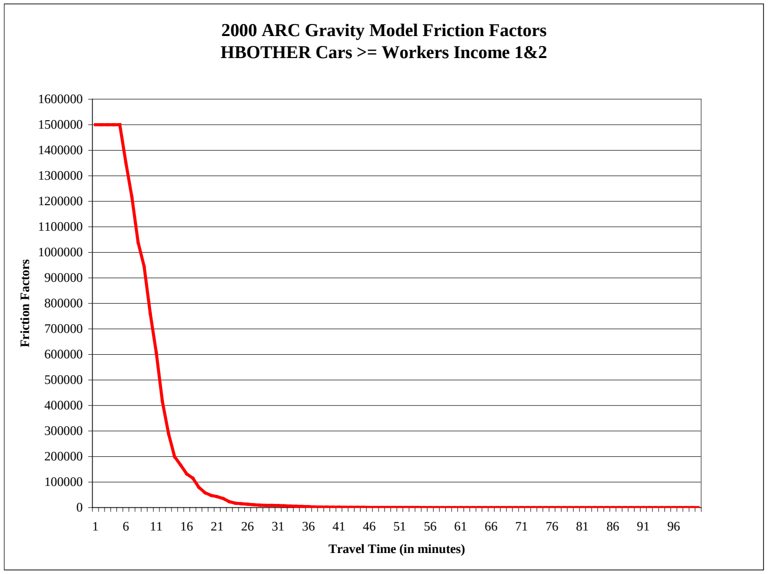


Table 3.5.2
Home Based Other Calibrated Gravity Model
Market Group 3 Friction Factors

Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor
1	1500000	26	13283	51	345	76	16
2	1500000	27	11149	52	328	77	14
3	1500000	28	9384	53	294	78	13
4	1500000	29	8750	54	255	79	11
5	1500000	30	8300	55	222	80	9
6	1350000	31	7877	56	149	81	9
7	1215000	32	6805	57	138	82	8
8	1039500	33	5788	58	124	83	8
9	945000	34	4936	59	109	84	5
10	760810	35	4395	60	100	85	5
11	607463	36	3398	61	94	86	5
12	415000	37	2620	62	86	87	3
13	289800	38	2247	63	79	88	3
14	199625	39	1928	64	68	89	3
15	166023	40	1656	65	60	90	3
16	132178	41	1357	66	52	91	1
17	114937	42	1172	67	49	92	1
18	79200	43	1008	68	45	93	1
19	58447	44	873	69	40	94	1
20	47700	45	794	70	35	95	1
21	42570	46	718	71	31	96	1
22	35000	47	652	72	27	97	1
23	23000	48	597	73	24	98	1
24	17205	49	534	74	20	99	1
25	15074	50	444	75	18	100	1

Figure 3.5.6
Home Based Other Calibrated Gravity Model
Market Group 4 Friction Factor Curve

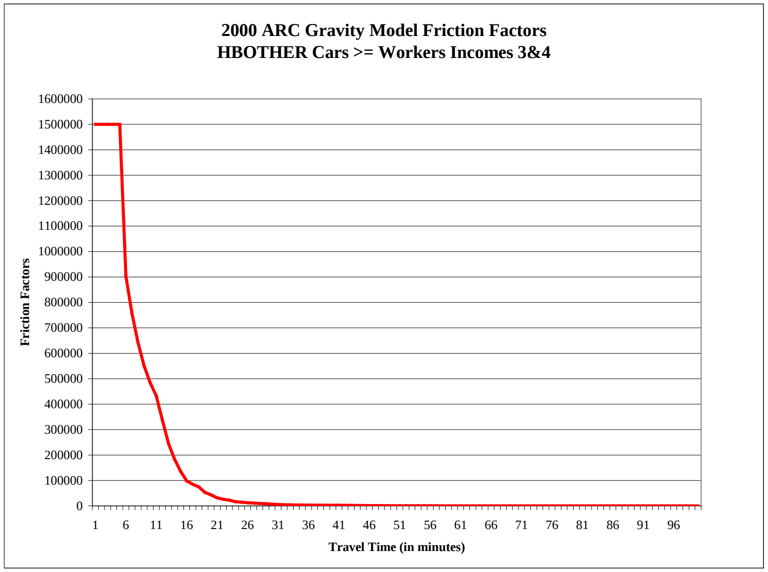


Table 3.5.3
Home Based Other Calibrated Gravity Model
Market Group 4 Friction Factors

Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor
1	1500000	26	12614	51	650	76	14
2	1500000	27	10815	52	564	77	13
3	1500000	28	9628	53	493	78	11
4	1500000	29	8306	54	430	79	10
5	1500000	30	6846	55	373	80	8
6	902500	31	5352	56	302	81	8
7	757656	32	4662	57	263	82	6
8	640723	33	4050	58	231	83	6
9	550505	34	3510	59	202	84	5
10	484000	35	3303	60	177	85	5
11	432725	36	2906	61	140	86	5
12	337250	37	2800	62	105	87	3
13	245224	38	2700	63	90	88	3
14	183472	39	2600	64	80	89	3
15	135401	40	2500	65	70	90	3
16	98524	41	2375	66	57	91	1
17	85000	42	2197	67	45	92	1
18	74320	43	1894	68	40	93	1
19	53439	44	1640	69	35	94	1
20	42970	45	1373	70	31	95	1
21	31451	46	1189	71	27	96	1
22	26167	47	1028	72	24	97	1
23	22353	48	891	73	21	98	1
24	16425	49	775	74	18	99	1
25	14743	50	689	75	16	100	1

3.6. Validation of Home-Based Other Gravity Model

The distribution of HBO trips was already validated in terms of trip length distribution and average trip lengths. There are "area" biases to consider as well. Natural features, such as the Chattahoochee River, pose a potential obstacle to the geographic distribution of certain types of trips. When natural features are combined with political or service delivery boundaries, the presence of "area" bias in trip distribution can be even more significant.

"Area" bias formed by the Chattahoochee River did significantly affect the initial distribution of HBO trips. According to the origins and destinations of HBO trips observed crossing the Chattahoochee River in the O-D Survey, the gravity model distribution was 53% higher for trips produced in zones located south or east of the Chattahoochee River. For zones north or west of the river, the gravity model calculated 42% more trips crossing the Chattahoochee than were observed in the O-D Survey. The impact of "area" bias on the distribution of HBO trips crossing the Chattahoochee River is depicted in Table 3.6.1 using a compressed matrix of trips from the O-D Survey and another from the gravity model. Trip productions from zones south or east of the river and that were observed crossing the Chattahoochee River in the O-D Survey totaled 87,465. In contrast, the gravity model estimated 134,448 HBO production trips from the same zones crossing the Chattahoochee River.

Table 3.6.1
Comparison of Gravity Model (Without Topo Penalty) and O-D Survey HBO Trips Crossing the Chattahoochee River Cutline Boundary

	Destination										
	North of River			South of River			Total		Total Crossing		
Origin	OD	GM	Percent Diff	OD	GM	Percent Diff	OD	GM	OD	GM	Percent Diff
North of River	1,145,111	1,085,191	-5.2%	141,838	201,707	42.2%	1,286,949	1,286,898	229,303	336,155	46.6%
South of River	87,465	134,448	53.7%	2,595,666	2,548,577	-1.8%	2,683,131	2,683,025			
Total	1,232,576	1,219,639	-1.0%	2,737,504	2,750,284	0.5%	3,970,080	3,969,923			

A topographic penalty or "Topo" penalty was incorporated in the gravity model process to compensate for the "area" bias created by the Chattahoochee River. The "Topo" penalty is a lump sum of time (in minutes) that is added to the composite time of interzonal times for all zonal pairs on opposite sides of the Chattahoochee River. The appropriate "Topo" penalties in minutes for the HBO market groups are listed below.

Market Groups 1 & 2 – 2.0
Market Group 3 – 3.5
Market Group 4 – 3.0

With the "Topo" penalties added to composite times, gravity model estimates of HBO trips crossing the Chattahoochee River cutline were greatly improved. Gravity model results of trips crossing the Chattahoochee River cutline, using a "Topo" penalty application, are shown in Table 3.6.2 along with the number of trips observed crossing the river in the O-D Survey. The gravity model estimated a much improved 86,480 HBO trips crossing the Chattahoochee River from zones south and east of the river. This figure is only 1.1% lower than the 87,465 trips observed in the O-D Survey.

Table 3.6.2
Comparison of Gravity Model (With Topo Penalty) and O-D Survey HBO Trips Crossing the Chattahoochee River Cutline Boundary

	Destination										
	North of River			South of River			Total		Total Crossing		
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
North of River	1,145,111	1,139,803	-0.5%	141,838	147,084	3.7%	1,286,949	1,286,887	229,303	233,564	1.9%
South of River	87,465	86,480	-1.1%	2,595,666	2,596,514	0.0%	2,683,131	2,682,994			
Total	1,232,576	1,226,283	-0.5%	2,737,504	2,743,598	0.2%	3,970,080	3,969,881			

Three other lengthy cutline boundaries were used to validate the trip distribution model: I-20; I-285; and, Ga.400/I-85/I-75. The likelihood of "area" biases may be most obvious along the Chattahoochee River, but others may exist in the region. These other cutline boundaries were used to identify whether other notable "area" biases could be identified. They also tested whether the introduction of "Topo" penalties for trips crossing the Chattahoochee River had an adverse impact in travel movements away from the Chattahoochee River.

The number of trips crossing I-20 from the gravity model was 4% lower, overall, in comparison with those observed in the O-D Survey. It indicated that there was no obvious "area" bias in trip distribution along that cutline boundary. I-20 cutline boundary findings, comparing gravity model crossings with O-D Study crossings, are displayed in Table 3.6.3. Gravity model trips crossing the cutline boundary that were produced in zones north of I-20 were 10.9% below their O-D Survey counterparts. For trips originating in zones south of I-20, gravity model estimates were essentially the same as those observed in the O-D Survey.

Table 3.6.3
Comparison of Gravity Model (With Topo Penalty) and O-D Survey HBO Trips Crossing the I-20 Cutline Boundary

	Destination										
	North of I-20			South of I-20			Total		Total Crossing		
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
North of I-20	2,773,783	2,789,971	0.6%	149,573	133,252	-10.9%	2,923,356	2,923,223	377,048	362,041	-4.0%
South of I-20	227,475	228,789	0.6%	819,254	817,867	-0.2%	1,046,729	1,046,656			
Total	3,001,258	3,018,760	0.6%	968,827	951,119	-1.8%	3,970,085	3,969,879			

The number of HBO trips crossing I-285 in the gravity model was 9.8% higher, overall, in comparison with those observed in the O-D Survey. That level of deviation does not indicate that there was an obvious "area" bias in trip distribution along that boundary. I-285 cutline boundary findings, comparing gravity model crossings with O-D Study crossings, are displayed in Table 3.6.4. Gravity model trips crossing the cutline boundary that were produced from zones inside I-285 were 13.5% higher than their O-D Survey counterparts. For trips originating in zones outside of the I-285 boundary, gravity model estimates were 8.3% above those observed in the O-D Survey.

Table 3.6.4
Comparison of Gravity Model (With Topo Penalty) and O-D Survey HBO Trips Crossing the I-285 Cutline Boundary

	Destination										
	Outside of I-285			Inside of I-285			Total		Total Crossing		
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
Outside of I-285	2,665,431	2,632,415	-1.2%	363,863	393,960	8.3%	3,029,294	3,026,375	514,814	565,292	9.8%
Inside of I-285	150,951	171,332	13.5%	796,498	778,956	-2.2%	947,449	950,288			
Total	2,816,382	2,803,747	-0.4%	1,160,361	1,172,916	1.1%	3,976,743	3,976,663			

The total number of trips crossing the Ga. 400/I-85/I-75 cutline in the gravity model was 2.1% higher in comparison with HBO trips observed in the O-D Survey. That level of deviation indicates that there was not an obvious "area" bias in trip distribution along that boundary. Ga. 400/I-85/I-75 cutline boundary findings, comparing gravity model crossings with O-D Study crossings, are displayed in Table 3.6.5. Gravity model trips crossing the cutline boundary that were produced from zones west of the boundary, were 5.8% higher than their O-D Survey counterparts. For trips originating in zones east of the Ga. 400/I-85/I-75 boundary, gravity model estimates were essentially the same as those observed in the O-D Survey.

Table 3.6.5
Comparison of Gravity Model (With Topo Penalty) and O-D Survey HBO Trips Crossing the Ga. 400/I-85/I-75 Cutline Boundary

	Destination										
	East of GA400/I-85/I-75			West of GA400/I-85/I-75			Total		Total Crossing		
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
East of GA400/□I-8	1,611,652	1,608,734	-0.2%	298,802	296,440	-0.8%	1,910,454	1,905,174	524,125	534,878	2.1%
West of GA400/□I-	225,323	238,438	5.8%	1,683,964	1,672,428	-0.7%	1,909,287	1,910,866			
Total	1,836,975	1,847,172	0.6%	1,982,766	1,968,868	-0.7%	3,819,741	3,816,040			

3.7. Calibration of Home-Based Shop Gravity Model

The distribution of HBShop trips was done similarly to HBW trips, which was explained earlier. There is only one difference, the composite measures of time were based on off-peak period time skims in comparison with A.M. peak period travel time skims for the HBW trip purposes.

In calculating composite time, three different factors were used to weight the contribution of transit travel time. There was one factor for each HBShop trip market grouping, as follows:

HBShop Market Groups 1 & 2: 0.19;
HBShop Market Group 3: 0.06;
HBShop Market Group 4: 0.03.

Final highway skims used in computing the composite time included terminal time on top of interzonal and intrazonal travel times.

The overall process of calibrating and validating the HBShop trip purposes was exactly the same as for HBW trips. Production and attraction trip ends came directly from the Atlanta Regional Commission's 2001-2002 Household Travel Survey. Travel times were calculated using terminal times and interzonal travel times from the Atlanta Regional Commission's base year 2000 highway and transit model networks. The gravity model calibration consisted of making adjustments to friction factors for each HBShop trip purpose. Friction factor adjustments were made to achieve two desired outcomes. The first desired outcome was to get the average trip length of the gravity model within three percent (3%) of the average trip length observed in the Household Travel Survey data. The second desirable objective was getting the trip length frequency curve from the gravity model to generally replicate the trip length frequency curve of the observed origin-destination trip file that was extracted from the Household Travel Survey.

Results of the calibration process for the three HBShop trip purposes are presented in Figures 3.7.1 through 3.7.3. The figures illustrate the comparison of the trip length frequency curves for each HBShop market group or purpose. The line graphs show that trip length frequency distributions from the gravity model generally match their corresponding trip length frequency curve that was observed in the O-D Survey. In addition to the trip length frequency curves, computed average trip lengths for each of the three HBShop trip purposes are within the three percent (3%) criteria. For all of the market groups, the computed average trip lengths were practically identical to the average trip length from the O-D survey.

The gravity model friction factors developed from this calibration process are shown graphically in Figures 3.7.4 through 3.7.6 for market groups 1, 2 and 3-4, respectively. Tables 3.7.1 through 3.7.3 indicate the actual calibrated friction factor values for individual composite time increments between 1 and 100 minutes.

Figure 3.7.1

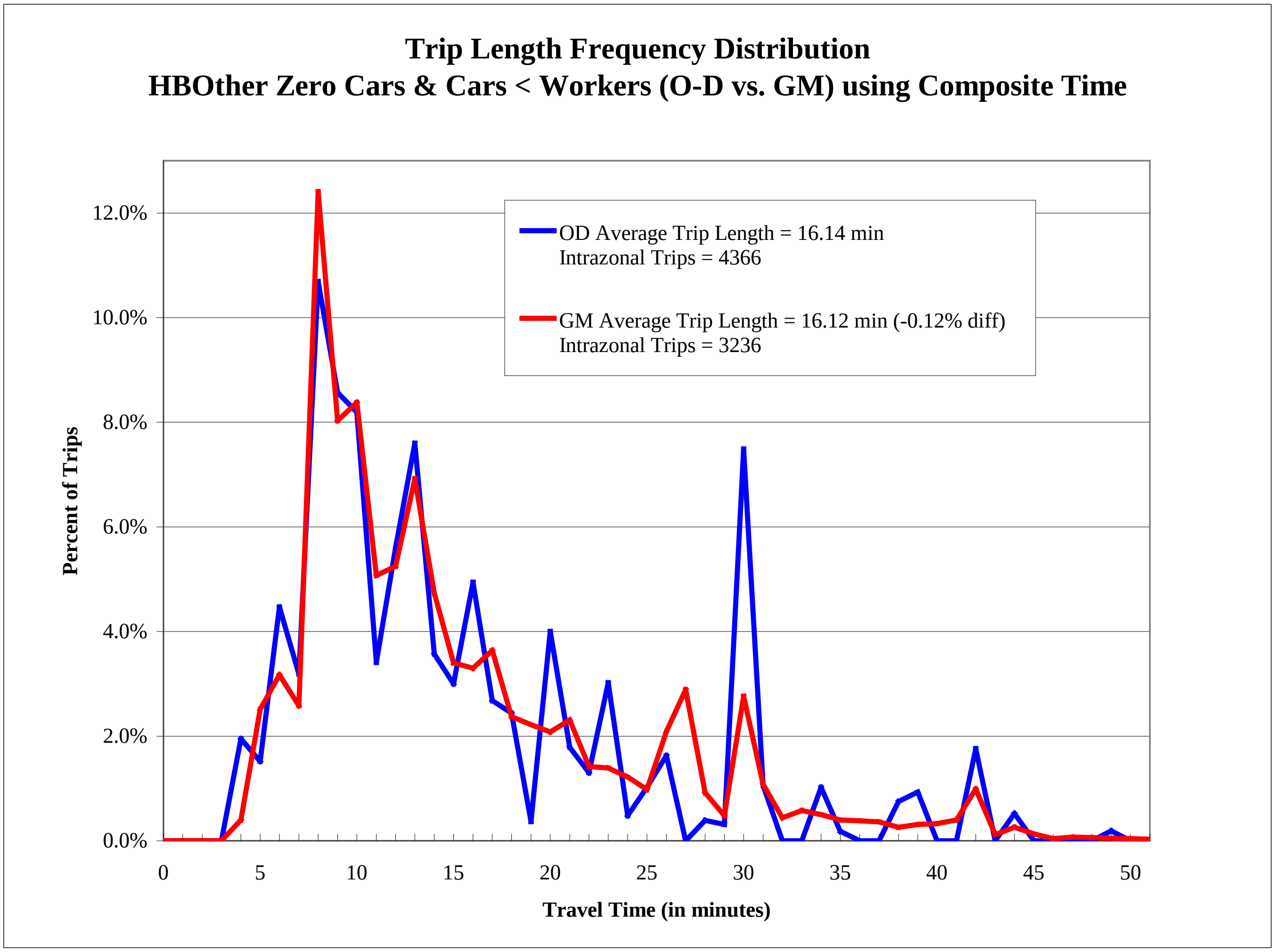
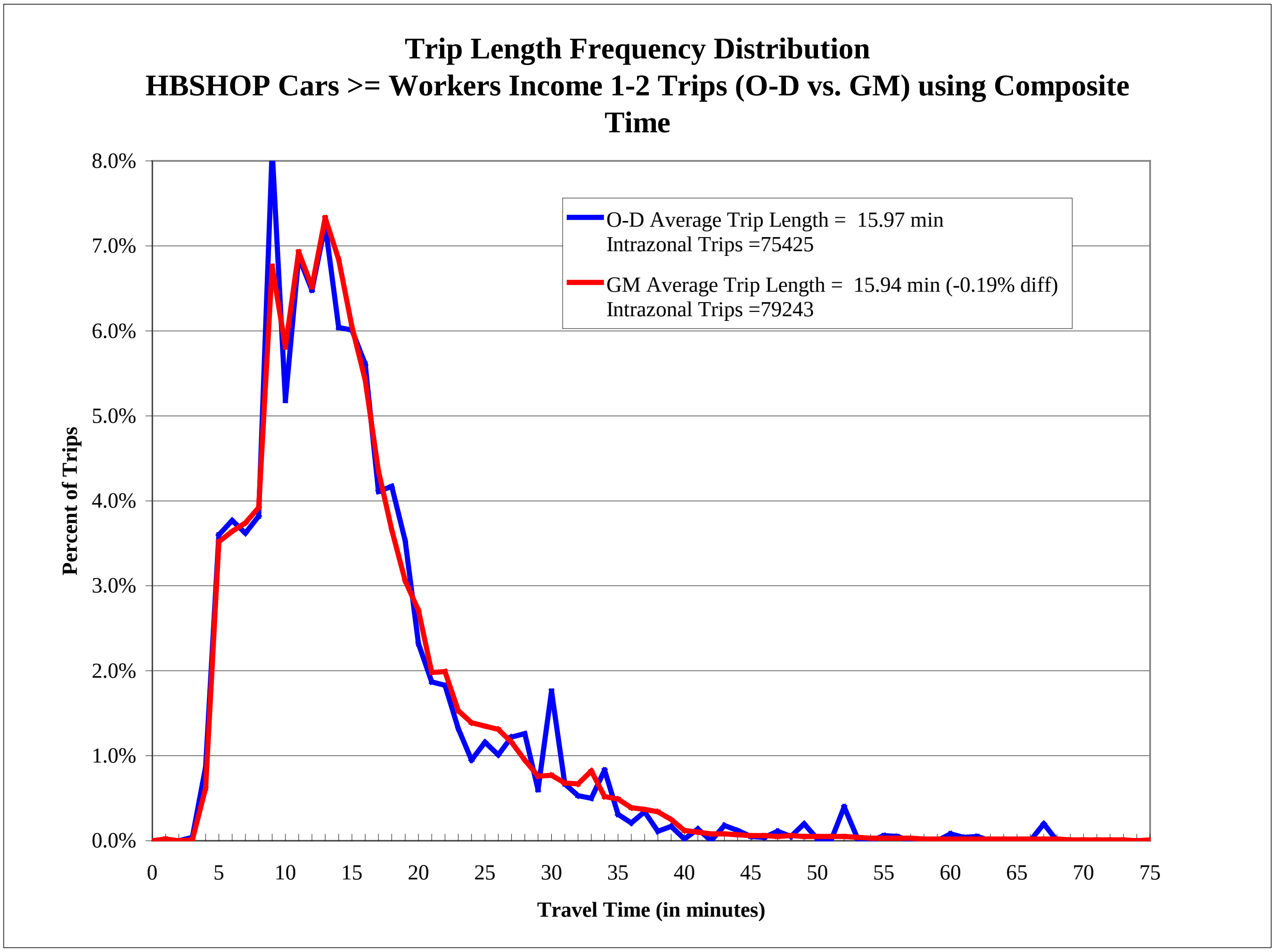
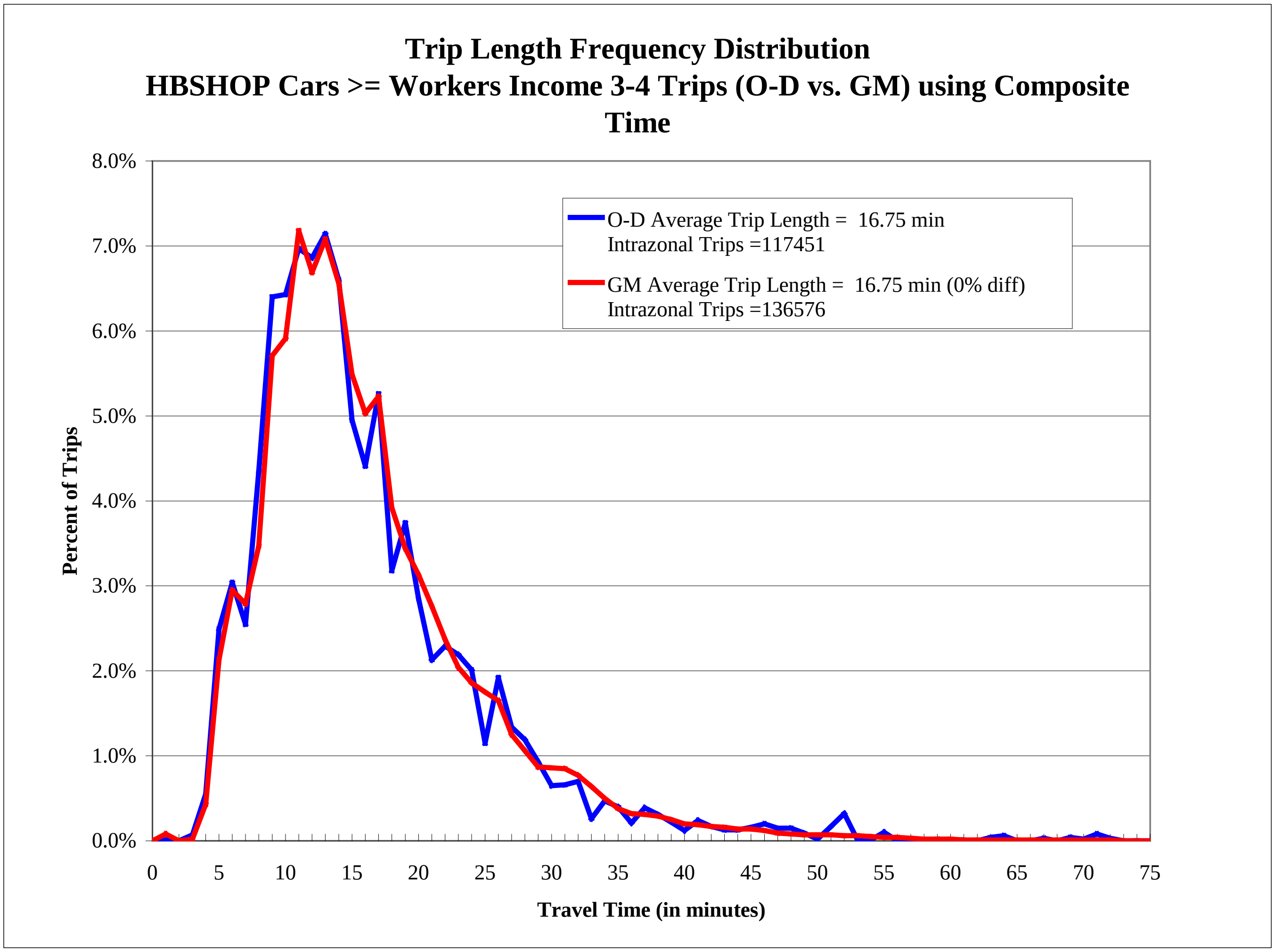


Figure 3.7.2



Trip Length Frequency Distribution
HBSHOP Cars >= Workers Income 1-2 Trips (O-D vs. GM) using Composite Time
O-D Average Trip Length = 15.97 min
Intrazonal Trips =75425
GM Average Trip Length = 15.94 min (-0.19% diff)
Intrazonal Trips =79243
Percent of Trips
8.0%
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Travel Time (in minutes)

Figure 3.7.3



Trip Length Frequency Distribution
HBSHOP Cars >= Workers Income 3-4 Trips (O-D vs. GM) using Composite Time
O-D Average Trip Length = 16.75 min
Intrazonal Trips =117451
GM Average Trip Length = 16.75 min (0% diff)
Intrazonal Trips =136576
Percent of Trips
8.0%
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Travel Time (in minutes)

Figure 3.7.4
Home Based Shop Calibrated Gravity Model
Market Groups 1 & 2 Friction Factors Curve

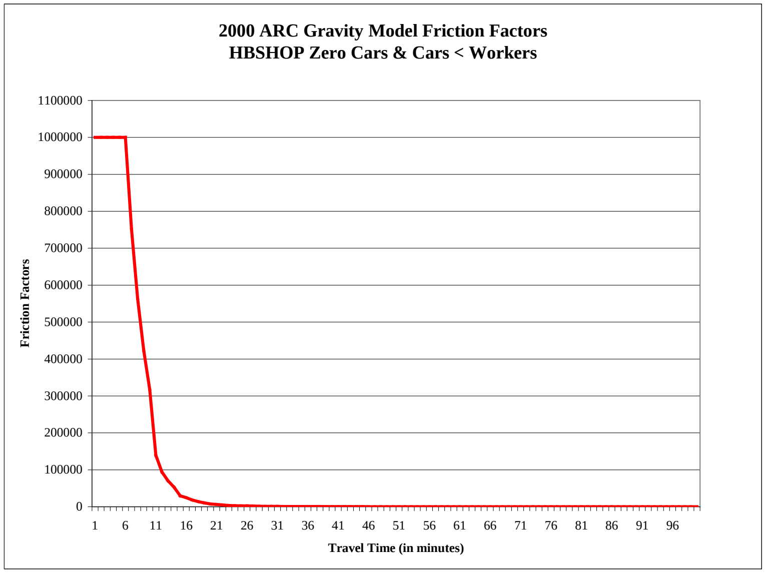


Table 3.7.1
Home Based Shop Calibrated Gravity Model
Market Groups 1 & 2 Friction Factors

Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor
1	1000000	26	2255	51	77	76	6
2	1000000	27	2070	52	69	77	4
3	1000000	28	1553	53	62	78	4
4	1000000	29	1165	54	56	79	4
5	1000000	30	982	55	50	80	4
6	1000000	31	910	56	45	81	4
7	751734	32	819	57	41	82	2
8	563800	33	737	58	37	83	2
9	422851	34	690	59	33	84	2
10	317139	35	667	60	30	85	2
11	139119	36	650	61	27	86	2
12	94167	37	584	62	24	87	2
13	70625	38	527	63	22	88	1
14	52969	39	473	64	20	89	1
15	29607	40	427	65	18	90	1
16	24556	41	384	66	16	91	1
17	18418	42	345	67	14	92	1
18	13814	43	311	68	12	93	1
19	10361	44	278	69	10	94	1
20	7771	45	250	70	8	95	1
21	6232	46	128	71	8	96	1
22	4673	47	115	72	8	97	1
23	3505	48	104	73	6	98	1
24	2900	49	94	74	6	99	1
25	2500	50	85	75	6	100	1

Figure 3.7.5
Home Based Shop Calibrated Gravity Model Market Group 3 Friction Factors Curve

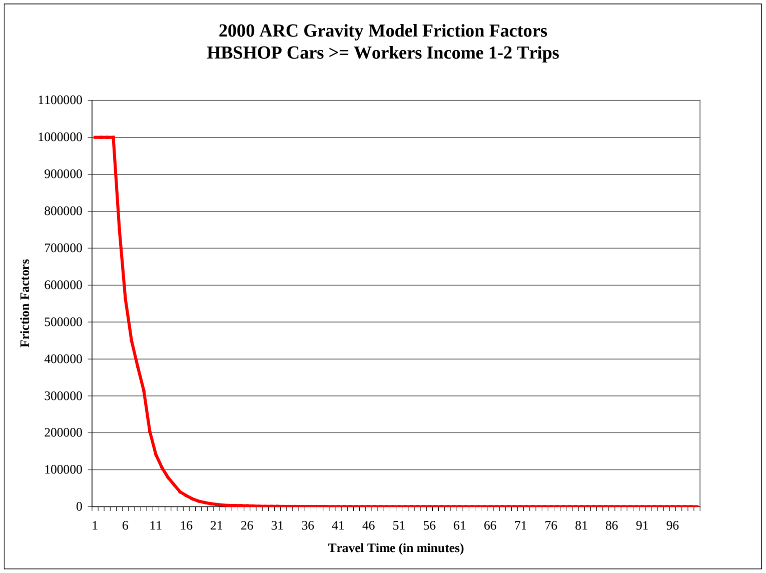


Table 3.7.2
Home Based Shop Calibrated Gravity Model Market Group 3 Friction Factors

Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor
1	1000000	26	2569	51	29	76	3
2	1000000	27	1927	52	26	77	3
3	1000000	28	1518	53	23	78	3
4	1000000	29	1139	54	22	79	3
5	750000	30	1021	55	19	80	3
6	562500	31	944	56	17	81	3
7	450000	32	851	57	16	82	2
8	380000	33	766	58	14	83	2
9	315000	34	541	59	12	84	2
10	204676	35	486	60	12	85	2
11	141226	36	437	61	12	86	2
12	105920	37	393	62	11	87	2
13	79440	38	354	63	10	88	1
14	59580	39	320	64	10	89	1
15	40124	40	151	65	9	90	1
16	30093	41	82	66	9	91	1
17	21442	42	75	67	8	92	1
18	15278	43	67	68	8	93	1
19	11458	44	60	69	7	94	1
20	8164	45	54	70	5	95	1
21	6123	46	48	71	5	96	1
22	4592	47	43	72	5	97	1
23	3445	48	39	73	3	98	1
24	3100	49	36	74	3	99	1
25	2855	50	31	75	3	100	1

Figure 3.7.6
Home Based Shop Calibrated Gravity Model Market Group 4 Friction Factors Curve

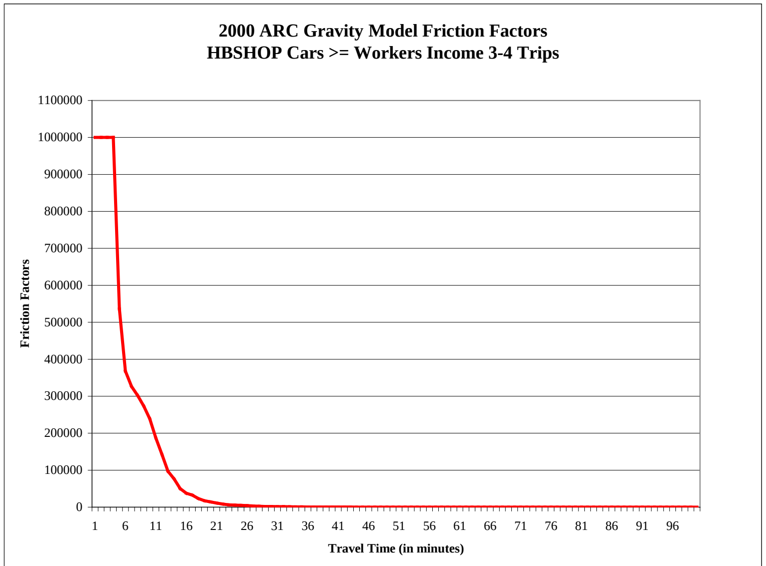


Table 3.7.3
Home Based Shop Calibrated Gravity Model Market Group 4 Friction Factors

Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor
1	1000000	26	4112	51	63	76	3
2	1000000	27	3082	52	58	77	3
3	1000000	28	2317	53	51	78	3
4	1000000	29	1738	54	49	79	3
5	535870	30	1625	55	44	80	3
6	368000	31	1447	56	33	81	3
7	326600	32	1301	57	31	82	2
8	301990	33	1174	58	24	83	2
9	273212	34	765	59	18	84	2
10	239020	35	643	60	18	85	2
11	186930	36	458	61	14	86	2
12	142400	37	412	62	13	87	2
13	97091	38	373	63	12	88	1
14	76465	39	335	64	12	89	1
15	50129	40	248	65	11	90	1
16	37595	41	220	66	11	91	1
17	32353	42	200	67	10	92	1
18	23053	43	181	68	10	93	1
19	17290	44	163	69	9	94	1
20	14168	45	145	70	7	95	1
21	11156	46	131	71	7	96	1
22	8367	47	95	72	7	97	1
23	6277	48	86	73	3	98	1
24	5370	49	76	74	3	99	1
25	4769	50	66	75	3	100	1

3.8. Validation of Home-Based Shop Gravity Model

Although the HBShop gravity models were already validated in terms of trip length distribution and average trip lengths, there are potential “area” biases to consider as well. “Area” bias from the Chattahoochee River did affect the initial distribution of HBShop trips, although not as much as HBO trips. According to the origins and destinations of HBShop trips observed crossing the Chattahoochee River in the O-D Survey, the overall gravity model distribution was 33.2% higher than the O-D Survey. For zones north or west of the river, the gravity model calculated 42.3% more trips crossing the Chattahoochee than were observed in the O-D Survey. The impacts of “area” bias on the distribution of HBShop trips crossing the Chattahoochee River is depicted in Table 3.8.1 using a compressed matrix of trips from the O-D Survey and another from the gravity model. Trip productions from zones south or east of the river that were observed crossing the Chattahoochee River in the O-D Survey totaled 49,918. In contrast, the gravity model estimated 62,246 HBShop production trips from zones south and east of the river crossed the Chattahoochee River.

Table 3.8.1
Comparison of Gravity Model (Without Topo Penalty) and O-D Survey HBShop Trips Crossing the Chattahoochee River Cutline Boundary

	Destination										
	North of River			South of River			Total		Total Crossing		
Origin	OD	GM	Percent Diff	OD	GM	Percent Diff	OD	GM	OD	GM	Percent Diff
North of River	698,146	678,525	-2.8%	46,119	65,646	42.3%	744,265	744,171	96,037	127,892	33.2%
South of River	49,918	62,246	24.7%	1,405,402	1,392,882	-0.9%	1,455,320	1,455,128			
Total	748,064	740,771	-1.0%	1,451,521	1,458,528	0.5%	2,199,585	2,199,299			

A topographic penalty or “Topo” penalty was incorporated in the gravity model process to compensate for the “area” bias created by the Chattahoochee River. The “Topo” penalty is a lump sum of time (in minutes) that is added to the composite time of interzonal times for all zonal pairs on opposite sides of the Chattahoochee River. The appropriate “Topo” penalties for the HBShop market groups are listed below in minutes.

Market Groups 1 & 2 – 2.5
Market Group 3 – 1.5
Market Group 4 – 2.0

With the addition of the “Topo” penalties to the composite times, gravity model estimates of HBShop trips crossing the Chattahoochee River cutline were greatly improved. Gravity model results of trips crossing the Chattahoochee River cutline, using a “Topo” penalty application, are shown in Table 3.8.2 along with the number of trips observed crossing the river in the O-D Survey. The gravity model estimated a much improved 45,111 HBShop trips crossing the Chattahoochee River from zones south and east of the river. This figure is 9.6% fewer than the 49,919 trips observed in the O-D Survey.

Table 3.8.2
Comparison of Gravity Model (With Topo Penalty) and O-D Survey HBShop Trips Crossing the Chattahoochee River Cutline Boundary

	Destination										
	North of River			South of River			Total		Total Crossing		
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
North of River	698,146	695,440	-0.4%	46,119	48,720	5.6%	744,265	744,160	96,037	93,831	-2.3%
South of River	49,918	45,111	-9.6%	1,405,402	1,410,008	0.3%	1,455,320	1,455,119			
Total	748,064	740,551	-1.0%	1,451,521	1,458,728	0.5%	2,199,585	2,199,279			

"Area" bias findings from the other three cutline boundaries are reported below for the I-20, I-285, and Ga.400/I-85/I-75. The total number of trips crossing I-20 from the gravity model was 12% higher in comparison with those observed in the O-D Survey. It indicated that there was no obvious "area" bias in trip distribution along that cutline boundary. I-20 cutline boundary findings, comparing gravity model crossings with O-D Study crossings, are displayed in Table 3.8.3. Gravity model trips crossing the cutline boundary that were produced in zones north I-20 were 9.5% above their O-D Survey counterparts. For trips originating in zones south of I-20, gravity model estimates were 13.2% higher than those observed in the O-D Survey.

Table 3.8.3
Comparison of Gravity Model (With Topo Penalty) and O-D Survey HBShop Trips Crossing the I-20 Cutline Boundary

	Destination						Total		Total Crossing		
	North of I-20			South of I-20							
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
North of I-20	1,623,941	1,619,562	-0.3%	43,607	47,756	9.5%	1,667,548	1,667,318	131,412	147,190	12.0%
South of I-20	87,805	99,434	13.2%	444,234	432,528	-2.6%	532,039	531,962			
Total	1,711,746	1,718,996	0.4%	487,841	480,284	-1.5%	2,199,587	2,199,280			

The total number of HBShop trips crossing I-285 in the gravity model was 11.9% higher in comparison with those observed in the O-D Survey. That level of deviation does not indicate that there was an obvious "area" bias in trip distribution along that boundary. I-285 cutline boundary findings, comparing gravity model crossings with O-D Study crossings, are displayed in Table 3.8.4. Gravity model trips crossing the cutline boundary that were produced from zones inside I-285 were virtually the same as their O-D Survey counterparts. For trips originating in zones outside of the I-285 boundary, gravity model estimates were 24.6% above those observed in the O-D Survey.

Table 3.8.4
Comparison of Gravity Model (With Topo Penalty) and O-D Survey HBShop Trips Crossing the I-285 Cutline Boundary

	Destination						Total		Total Crossing		
	Outside of I-285			Inside of I-285							
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
Outside of I-285	1,558,985	1,534,736	-1.6%	96,441	120,191	24.6%	1,655,426	1,654,927	195,455	218,784	11.9%
Inside of I-285	99,014	98,593	-0.4%	446,049	446,705	0.1%	545,063	545,298			
Total	1,657,999	1,633,329	-1.5%	542,490	566,896	4.5%	2,200,489	2,200,225			

The number of trips crossing the Ga. 400/I-85/I-75 cutline in the gravity model was 10.2% higher, overall, in comparison with HBShop trips observed in the O-D Survey. That level of deviation indicates there was not an obvious "area" bias in trip distribution along that boundary. Ga. 400/I-85/I-75 cutline boundary findings, comparing gravity model crossings with O-D Study crossings, are displayed in Table 3.8.5. Gravity model trips crossing the cutline boundary that were produced from zones west of the boundary were 13.2% higher than their O-D Survey counterparts. For trips originating in zones east of the Ga. 400/I-85/I-75 boundary, gravity model estimates were 8.2% above those observed in the O-D Survey.

Table 3.8.5
Comparison of Gravity Model (Without Topo Penalty) and O-D Survey HBShop Trips Crossing the Ga. 400/I-85/I-75 Cutline Boundary

	Destination											
	East of GA400/I-85/I-75			West of GA400/I-85/I-75			Total		Total Crossing			
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
East of GA400/□I-	944,986	933,852	-1.2%	121,040	131,002	8.2%	1,066,026	1,064,854	203,682	224,548	10.2%
West of GA400/□I-	82,642	93,546	13.2%	979,954	965,462	-1.5%	1,062,596	1,059,008			
Total	1,027,628	1,027,398	0.0%	1,100,994	1,096,464	-0.4%	2,128,622	2,123,862			

3.9. Calibration of Home-Based School Gravity Model

HBSch trips were distributed similarly to HBW trips, which was explained in a previous section. There were two significant differences. The first is the number of HBSch trip purposes. HBSch trips were distributed over just one separate market range, as opposed to three for HBW trips. Secondly, composite measures of travel time were based on off-peak period time skims in comparison with A.M. peak period time skims for the HBW trip purposes.

In calculating composite time, two different factors were used to weight the contribution of transit travel time. There was one factor for all of the HBSch trip market grouping, as follows:

HBSch Income Groups 1-4: 0.12.

Final highway skims used in computing the composite time included terminal time in addition to interzonal and intrazonal travel times.

The overall process of calibrating and validating the HBSch trip purposes was exactly the same as for HBW trips. Production and attraction trip ends came directly from the Atlanta Regional Commission's 2001-2002 Household Travel Survey. Travel times were calculated using terminal times and interzonal travel times from the Atlanta Regional Commission's base year 2000 highway and transit model networks. The gravity model calibration consisted of making adjustments to friction factors for each HBSch trip purpose. Friction factor adjustments were made to achieve two desired outcomes. The first desired outcome was to get the average trip length of the gravity model within three percent (3%) of the average trip length observed in the Household Travel Survey data. The second desirable objective was getting the trip length frequency curve from the gravity model to generally replicate the trip length frequency curve of the observed origin-destination trip file that was extracted from the Household Travel Survey.

Results of the calibration process for the two HBSch trip purposes are presented in Figure 3.9.1. Figure 3.9.1 illustrates the comparison of the trip length frequency curves for combined HBSch income groups or purposes. The line graphs show that trip length frequency distribution from the gravity model generally matches the corresponding trip length frequency curve that was observed in the O-D Survey. In addition to the trip length frequency curve, computed average trip length for the combined HBSch trip purpose is within the three percent (3%) criteria. The average trip length from the gravity model was 15.59 minutes which was practically the same as the O-D Survey average of 15.48 minutes. There is less than 1% difference between the two.

The gravity model friction factors developed from this calibration process are shown graphically in Figure 3.9.2 while Table 3.9.1 lists the actual calibrated friction factor values for individual composite time increments between 1 and 100 minutes.

Figure 3.9.1

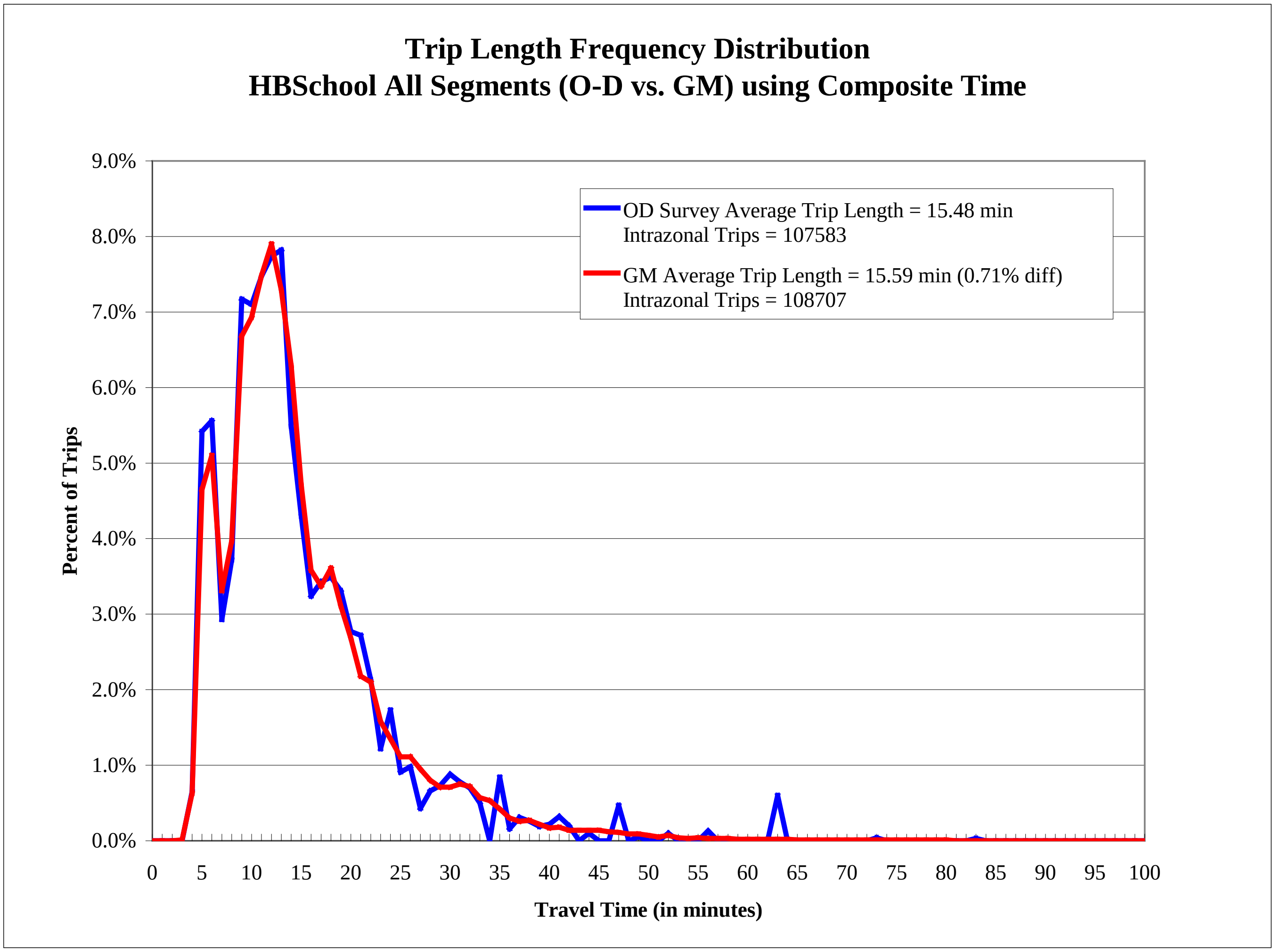

Trip Length Frequency Distribution
HBSchool All Segments (O-D vs. GM) using Composite Time
OD Survey Average Trip Length = 15.48 min
Intrazonal Trips = 107583
GM Average Trip Length = 15.59 min (0.71% diff)
Intrazonal Trips = 108707
Percent of Trips
9.0%
8.0%
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Travel Time (in minutes)

Figure 3.9.2
Home Based School Calibrated Gravity Model
All Market Groups Friction Factors Curve

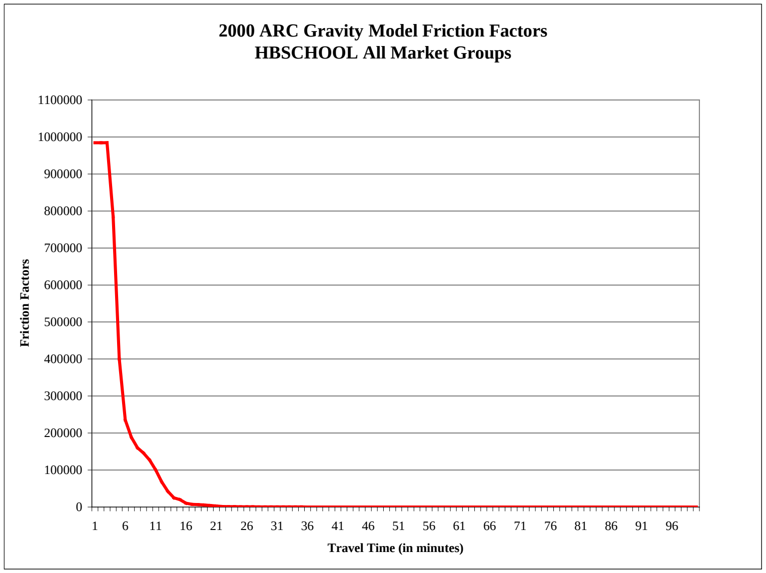


Table 3.9.1
Home Based School Calibrated Gravity Model
All Market Groups Friction Factors

Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor
1	984609	26	693	51	20	76	4
2	984609	27	530	52	20	77	3
3	984609	28	418	53	20	78	3
4	784609	29	390	54	10	79	3
5	400000	30	366	55	10	80	3
6	235225	31	316	56	10	81	3
7	188180	32	274	57	10	82	1
8	159953	33	237	58	10	83	1
9	145800	34	208	59	10	84	1
10	127000	35	180	60	5	85	1
11	100000	36	121	61	5	86	1
12	67900	37	88	62	5	87	1
13	42500	38	80	63	5	88	1
14	25000	39	72	64	5	89	1
15	20000	40	48	65	5	90	1
16	10289	41	46	66	5	91	1
17	7331	42	43	67	5	92	1
18	6413	43	36	68	5	93	1
19	5498	44	36	69	4	94	1
20	4073	45	36	70	4	95	1
21	2874	46	30	71	4	96	1
22	1331	47	28	72	4	97	1
23	1132	48	25	73	4	98	1
24	932	49	24	74	4	99	1
25	733	50	20	75	4	100	1

3.10. Validation of Home-Based School Gravity Model

Although the HBSch gravity models were already validated in terms of trip length distribution and average trip lengths, potential "area" biases were investigated as well. "Area" bias formed by the Chattahoochee River dramatically affected the initial distribution of HBSch trips. According to the origins and destinations of HBSch trips observed crossing the Chattahoochee River in the O-D Survey, the gravity model distribution was 111.8% higher for trips produced in zones located north or west of the Chattahoochee River. For zones south or east of the river, the gravity model calculated 77.7% more trips crossing the Chattahoochee than were observed in the O-D Survey. The impacts of "area" bias on the distribution of HBSch trips crossing the Chattahoochee River is depicted in Table 3.10.1 using a compressed matrix of trips from the O-D Survey and another from the gravity model. Trip productions from zones north or west of the river and that were observed crossing the Chattahoochee River in the O-D Survey totaled 11,500. In contrast, the gravity model estimated 24,356 HBSch production trips from zones north and west of the river that crossed the Chattahoochee River.

Table 3.10.1
Comparison of Gravity Model (Without Topo Penalty) and O-D Survey
HBSch Trips Crossing the Chattahoochee River Cutline Boundary

	Destination										
	North of River			South of River			Total		Total Crossing		
Origin	OD	GM	Percent Diff	OD	GM	Percent Diff	OD	GM	OD	GM	Percent Diff
North of River	234,311	221,445	-5.5%	11,500	24,356	111.8%	245,811	245,801	19,822	39,145	97.5%
South of River	8,322	14,789	77.7%	540,469	533,982	-1.2%	548,791	548,771			
Total	242,633	236,234	-2.6%	551,969	558,338	1.2%	794,602	794,572			

A topographic penalty or "Topo" penalty was incorporated in the gravity model process to compensate for the "area" bias created by the Chattahoochee River. The "Topo" penalty is a lump sum of time (in minutes) that is added to the composite time of interzonal times for all zonal pairs on opposite sides of the Chattahoochee River. The appropriate "Topo" penalty for the HBSch market groups was calculated to be 4.0 minutes.

With the 4.0 minute "Topo" penalty added to composite times, gravity model estimates of HBSch trips crossing the Chattahoochee River cutline were greatly improved. Gravity Model results of trips crossing the Chattahoochee River cutline, using a "Topo" penalty application, are shown in Table 3.10.2 along with the number of trips observed crossing the river in the O-D Survey. Overall, total crossings from the gravity model improved from being 97.5% higher without "Topo" penalties to only 8.9% higher in comparison with the observed O-D trips. The gravity model estimated a much improved 14,261 HBSch trips crossing the Chattahoochee River from zones north and west of the river. This volume was 24% higher than the 11,500 trips observed in the O-D Survey but far better than if no "Topo" penalty was used.

Table 3.10.2
Comparison of Gravity Model (With Topo Penalty) and O-D Survey HBSch Trips Crossing the Chattahoochee River Cutline Boundary

	Destination										
	North of River			South of River			Total		Total Crossing		
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
North of River	234,311	231,536	-1.2%	11,500	14,261	24.0%	245,811	245,797	19,822	21,589	8.9%
South of River	8,322	7,328	-11.9%	540,469	541,437	0.2%	548,791	548,765			
Total	242,633	238,864	-1.6%	551,969	555,698	0.7%	794,602	794,562			

"Area" bias findings from the other three cutline boundaries are reported below for the I-20, I-285, and Ga.400/I-85/I-75. The number of HBSch trips crossing I-20 from the gravity model was 21.7% higher, overall, in comparison with those observed in the O-D Survey. It indicated that there was no obvious "area" bias in trip distribution along that cutline boundary. I-20 cutline boundary findings, comparing gravity model crossings with O-D Study crossings, are displayed in Table 3.10.3. Gravity model trips crossing the cutline boundary that were produced in zones north I-20, were 7.6% lower their O-D Survey counterparts. For trips originating in zones south of I-20, gravity model estimates were 52.7% higher than those observed in the O-D Survey.

Table 3.10.3
Comparison of Gravity Model (With Topo Penalty) and O-D Survey HBSch Trips Crossing the I-20 Cutline Boundary

	Destination										
	North of I-20			South of I-20			Total		Total Crossing		
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
North of I-20	563,082	564,419	0.2%	20,212	18,843	-6.8%	583,294	583,262	38,683	47,086	21.7%
South of I-20	18,471	28,243	52.9%	192,838	183,057	-5.1%	211,309	211,300			
Total	581,553	592,662	1.9%	213,050	201,900	-5.2%	794,603	794,562			

The number of HBSch trips crossing I-285 in the gravity model was 8.9% higher, overall, in comparison with those observed in the O-D Survey. That level of deviation does not indicate that there was an obvious "area" bias in trip distribution along that boundary. I-285 cutline boundary findings, comparing gravity model crossings with O-D Study crossings, are displayed in Table 3.10.4. Gravity model trips crossing the cutline boundary, which were produced from zones inside I-285, were 9.2% higher than their O-D Survey counterparts. For trips originating in zones outside of the I-285 boundary, gravity model estimates were 8.7% above those observed in the O-D Survey.

Table 3.10.4
Comparison of Gravity Model (With Topo Penalty) and O-D Survey HBSch Trips Crossing the I-285 Cutline Boundary

	Destination										
	Outside of I-285			Inside of I-285			Total		Total Crossing		
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
Outside of I-285	582,265	578,247	-0.7%	45,498	49,479	8.7%	627,763	627,726	64,779	70,526	8.9%
Inside of I-285	19,281	21,047	9.2%	147,558	145,789	-1.2%	166,839	166,836			
Total	601,546	599,294	-0.4%	193,056	195,268	1.1%	794,602	794,562			

The number of HBSch trips crossing the Ga. 400/I-85/I-75 cutline in the gravity model was 4.1% lower, overall, in comparison with HBSch trips observed in the O-D Survey. That level of deviation indicates that Ga. 400, I-85 and I-75, in combination, do not form a physical barrier that deters school trips. For the most part, Ga. 400, I-85 and I-75 split political jurisdictions, instead of dividing them. As such, it is not surprising that a relatively high number of school trips were observed crossing this particular cutline boundary. While this amount of deviation between the observed and gravity model trip distributions is relatively high in comparison with the other trip purposes and cutlines, no adjustments was made to modify HBSch trips beyond the 4.0 minute Chattahoochee River “Topo” penalty. Ga.400/I-85/I-75 cutline boundary findings, comparing gravity model crossings with O-D Study crossings, are displayed in Table 3.10.5. Gravity model trips crossing the cutline boundary that were produced from zones west of the boundary were 14.7% higher than their O-D Survey counterparts. For trips originating in zones east of the Ga. 400/I-85/I-75 boundary, gravity model estimates were 11% below those observed in the O-D Survey.

Table 3.10.5
Comparison of Gravity Model (With Topo Penalty) and O-D Survey
HBSch Trips Crossing the Ga. 400/I-85/I-75 Cutline Boundary

	Destination										
	East of GA400/I-85/I-75			West of GA400/I-85/I-75			Total		Total Crossing		
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
East of GA400/□I-8	355,245	365,297	2.8%	48,456	43,141	-11.0%	403,701	408,438	66,258	63,568	-4.1%
West of GA400/□I-	17,802	20,427	14.7%	346,714	338,205	-2.5%	364,516	358,632			
Total	373,047	385,724	3.4%	395,170	381,346	-3.5%	768,217	767,070			

3.11. Calibration of Home-Based University Gravity Model

Trip distribution of HBU trips was done similarly to HBW trips, which was explained earlier. There were two significant differences. The first is the number of HBU trip purposes. HBU trips were distributed over one household market group (1-4), as opposed to three (3) for HBW trips. Secondly, composite measures of travel time were based on off-peak period time skims in comparison with A.M. peak period time skims for the HBW trip purposes.

In calculating composite time, the factor used to weight the contribution of transit travel time was 0.12. Final highway skims used in computing the composite times included terminal time on top of interzonal and intrazonal travel times.

The overall process of calibrating and validating the HBU trip purpose was exactly the same as for HBW trips. Production and attraction trip ends came directly from the Atlanta Regional Commission’s 2001-2002 Household Travel Survey. Travel times were calculated using terminal times and interzonal travel times from the Atlanta Regional Commission’s base year 2000 highway and transit model networks. The gravity model calibration consisted of making adjustments to friction factors. Friction factor adjustments were made to achieve two desired outcomes. The first desired outcome was to get the average trip length of the gravity model within three percent (3%) of the average trip length observed in the Household Travel Survey data. The second desirable objective was getting the trip length frequency curve from the gravity model to generally replicate the trip length frequency curve of the observed origin-destination trip file that was extracted from the Household Travel Survey.

Results of the calibration process for the HBU trip purpose is presented in Figure 3.11.1. It illustrates the difference between the O-D Survey and gravity model trip length frequency curves. The line graphs show that the trip length frequency distribution from the gravity model generally matches its corresponding trip length frequency curve observed in the O-D Survey. In addition to the trip length frequency curves, computed average trip lengths for the HBU trip purpose are within the three percent (3%) criteria. The average trip length from the gravity model was 28.81 minutes which was slightly lower than the O-D Survey average of 28.95 minutes but well within the 3% criteria.

The gravity model friction factors developed in the calibration process are shown graphically in Figure 3.11.2. Table 3.11.1 lists the actual calibrated friction factor values for individual composite time increments between 1 and 100 minutes.

Figure 3.11.1

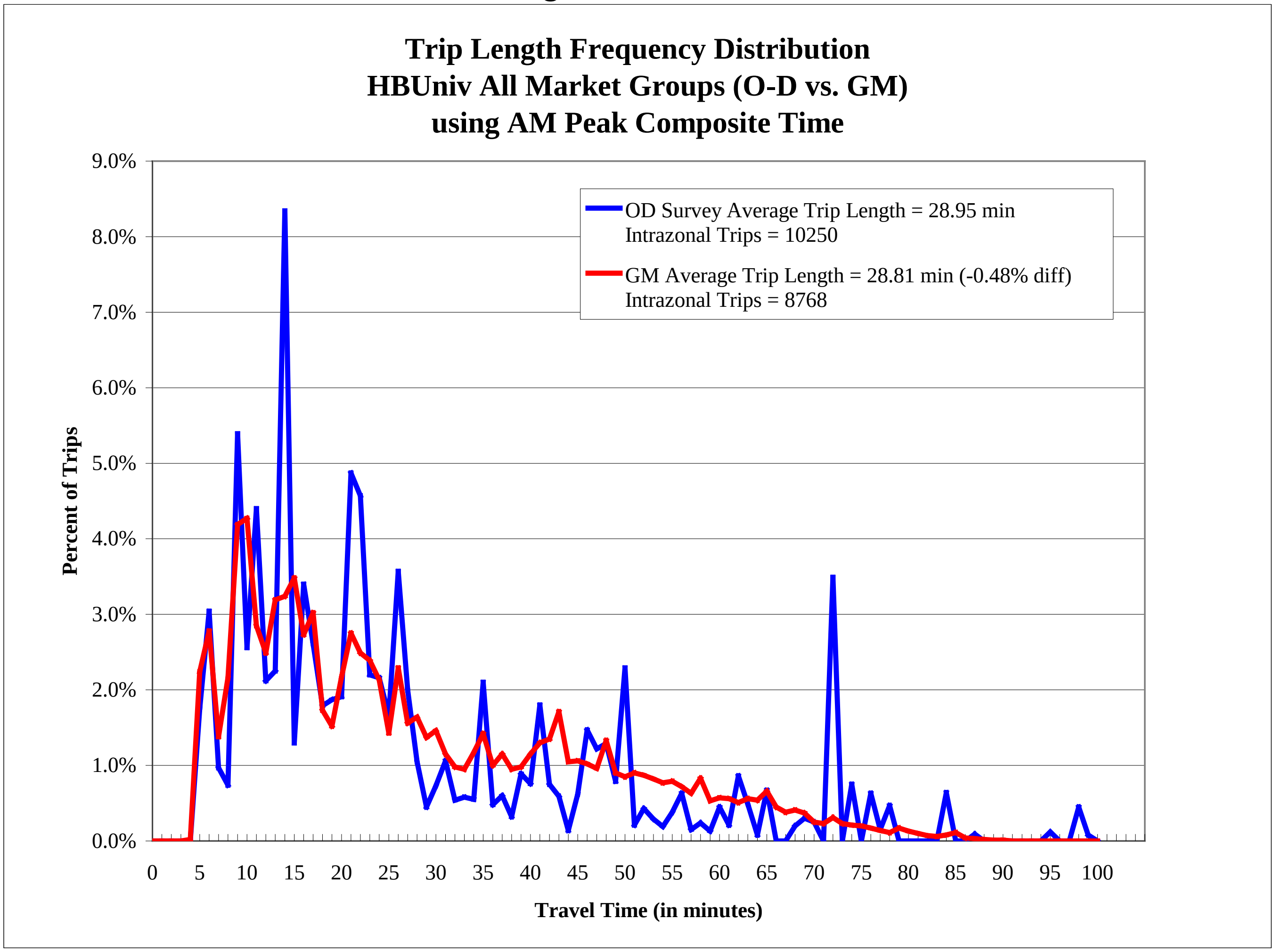


Figure 3.11.2
Home Based University Calibrated Gravity Model
All Market Groups Friction Factors Curve

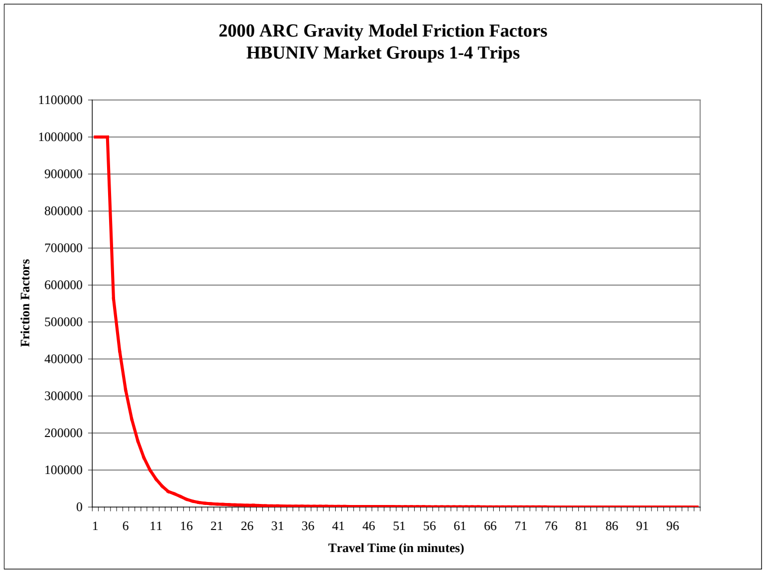


Table 3.11.1
Home Based University Calibrated Gravity Model
All Market Groups Friction Factors

Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor
1	1,000,000	26	4,989	51	1,197	76	156
2	1,000,000	27	4,816	52	1,162	77	143
3	1,000,000	28	4,293	53	1,132	78	106
4	562,500	29	3,484	54	1,032	79	106
5	421,875	30	3,265	55	921	80	92
6	316,406	31	2,939	56	851	81	91
7	237,305	32	2,641	57	790	82	76
8	177,979	33	2,492	58	770	83	68
9	133,484	34	2,350	59	750	84	67
10	100,113	35	2,253	60	726	85	63
11	75,085	36	2,157	61	696	86	57
12	56,314	37	2,100	62	667	87	37
13	42,235	38	2,004	63	624	88	34
14	36,000	39	1,898	64	542	89	15
15	28,600	40	1,805	65	494	90	15
16	20,957	41	1,726	66	428	91	4
17	15,717	42	1,605	67	397	92	4
18	12,298	43	1,543	68	375	93	4
19	10,222	44	1,483	69	325	94	2
20	8,914	45	1,434	70	295	95	2
21	7,865	46	1,392	71	262	96	2
22	7,260	47	1,350	72	237	97	2
23	6,622	48	1,313	73	229	98	1
24	5,980	49	1,277	74	196	99	1
25	5,454	50	1,234	75	182	100	1

3.12. Validation of Home-Based University Gravity Model

Although the HBU gravity model was already validated in terms of trip length distribution and average trip lengths, there are potential "area" biases to consider as well. "Area" bias formed by the Chattahoochee River dramatically affect some trip purposes. The distribution of HBU trips, however, appears not to have been significantly affected by the Chattahoochee River. According to the origins and destinations of HBU trips observed crossing the Chattahoochee River in the O-D Survey, the gravity model distribution was just 2.8% lower for trips produced in zones located north or west of the Chattahoochee River. For zones south or east of the river, the gravity model calculated 7% more trips crossing the Chattahoochee than were observed in the O-D Survey. The impacts of "area" bias on the distribution of HBU trips crossing the Chattahoochee River is depicted in Table 3.12.1 using a compressed matrix of trips from the O-D Survey and another from the gravity model. Trip productions from zones north or west of the river and that were observed crossing the Chattahoochee River in the O-D Survey totaled 10,847. In contrast, the gravity model estimated 10,548 HBU production trips from zones north and west of the river that crossed the Chattahoochee River.

Table 3.12.1
Comparison of Gravity Model (Without Topo Penalty) and O-D Survey HBU Trips Crossing the Chattahoochee River Cutline Boundary

	Destination										
	North of River			South of River			Total		Total Crossing		
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
North of River	45,505	45,802	0.7%	10,847	10,548	-2.8%	56,352	56,350	19,108	19,386	1.5%
South of River	8,261	8,838	7.0%	107,988	107,415	-0.5%	116,249	116,253			
Total	53,766	54,640	1.6%	118,835	117,963	-0.7%	172,601	172,603			

It appears that HBU gravity model trips are distributed reasonably well over the Chattahoochee River cutline boundary without a "Topo" penalty. Therefore, no "Topo" penalty was incorporated into the HBU gravity model process.

"Area" bias findings from the other three cutline boundaries are reported below for the I-20, I-285, and Ga.400/I-85/I-75. The number of HBU trips crossing I-20 from the gravity model was 61.5% higher, overall, in comparison with those observed in the O-D Survey. It indicated that there is possibly an "area" bias in trip distribution along that cutline boundary. I-20 cutline boundary findings, comparing gravity model crossings with O-D Study crossings, are displayed in Table 3.12.2. Gravity model trips crossing the cutline boundary that were produced in zones north of I-20 were 53.8% above their O-D Survey counterparts. For trips originating in zones south of I-20, gravity model estimates were 65.1% higher than those observed in the O-D Survey.

While these differences between gravity model calculations and the O-D Survey are relatively large at the I-20 cutline boundary, in terms of the percentage deviation, no remediation procedures were incorporated in the HBU trip distribution process. There are two reasons for not implementing corrective measures. First, the sample size of HBU trips in the O-D Survey is very small in comparison with other trip purposes. In light of its sample size, the 60.4% deviation falls within an acceptable range of deviation. Second, the HBU trip purpose accounts for a small share of the total population of household-based trips. Any changes in the distribution of HBU trips would have a very small impact on the rest of the travel demand model.

Table 3.12.2
Comparison of Gravity Model (No Topo Penalty) and O-D Survey
HBU Trips Crossing the I-20 Cutline Boundary

	Destination										
	North of I-20			South of I-20			Total		Total Crossing		
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
North of I-20	130,462	126,791	-2.8%	6,826	10,499	53.8%	137,288	137,290	16,222	26,013	60.4%
South of I-20	9,396	15,514	65.1%	25,917	19,801	-23.6%	35,313	35,315			
Total	139,858	142,305	1.7%	32,743	30,300	-7.5%	172,601	172,605			

The total number of HBU trips crossing I-285 in the gravity model was essentially the same as those observed in the O-D Survey. That level of deviation indicates there was not an “area” bias in trip distribution along that boundary. I-285 cutline boundary findings, comparing gravity model crossings with O-D Study crossings, are displayed in Table 3.12.3. Gravity model trips crossing the cutline boundary that were produced from zones inside I-285 were 8.4% higher than their O-D Survey counterparts. For trips originating in zones outside of the I-285 boundary, gravity model estimates were 2.4% lower those observed in the O-D Survey.

Table 3.12.3
Comparison of Gravity Model (No Topo Penalty) and O-D Survey
HBU Trips Crossing the I-285 Cutline Boundary

	Destination										
	Outside of I-285			Inside of I-285			Total		Total Crossing		
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
Outside of I-285	94,184	94,878	0.7%	28,659	27,969	-2.4%	122,843	122,847	38,446	38,575	0.3%
Inside of I-285	9,787	10,606	8.4%	39,973	39,151	-2.1%	49,760	49,757			
Total	103,971	105,484	1.5%	68,632	67,120	-2.2%	172,603	172,604			

The number of HBU trips crossing the Ga. 400/I-85/I-75 cutline in the gravity model was 6.2% lower, overall, in comparison with HBU trips observed in the O-D Survey. That level of deviation indicates that there is not an “area” bias along this cutline boundary. Ga.400/I-85/I-75 cutline boundary findings, comparing gravity model crossings with O-D Study crossings, are displayed in Table 3.12.4. Gravity model trips crossing the cutline boundary that were produced from zones west of the boundary were 6.2% lower than their O-D Survey counterparts. For trips originating in zones east of the Ga. 400/I-85/I-75 boundary, gravity model estimates were 12% below those observed in the O-D Survey.

Table 3.12.4
Comparison of Gravity Model (No Topo Penalty) and O-D Survey
HBU Trips Crossing the Ga. 400/I-85/I-75 Cutline Boundary

Origin	Destination						Total		Total Crossing		
	East of GA400/I-85/I-75			West of GA400/I-85/I-75							
	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
East of GA400/□I-!	49,285	53,769	9.1%	35,302	31,082	-12.0%	84,587	84,851	44,836	40,027	-10.7%
West of GA400/□I-	9,534	8,945	-6.2%	70,498	71,001	0.7%	80,032	79,946			
Total	58,819	62,714	6.6%	105,800	102,083	-3.5%	164,619	164,797			

3.13. Calibration of Non-Home Based Gravity Model

NHB trips were distributed similarly to HBW trips, which were explained earlier. There were two important differences. The first is the number of NHB trip purposes. NHB trips were distributed over four household market segments as opposed to the three (3) for HBW trips. Secondly, composite measures of travel time were based on off-peak period time skims in comparison with A.M. peak period time skims for the HBW trip purposes.

In calculating composite time, the factor used to weight the contribution of transit travel time was 0.115. Final highway skims used in computing the composite times included terminal time and intrazonal travel times.

The overall process of calibrating and validating the NHB trip purpose was exactly the same as for HBW trips. Production and attraction trip ends came directly from the Atlanta Regional Commission's 2001-2002 Household Travel Survey. Travel times were calculated using terminal times and interzonal travel times from the Atlanta Regional Commission's base year 2000 highway and transit model networks. The gravity model calibration consisted of making adjustments to friction factors. Friction factor adjustments were made to achieve two desired outcomes. The first desired outcome was to get the average trip length of the gravity model within three percent (3%) of the average trip length observed in the Household Travel Survey data. The second desirable objective was getting the trip length frequency curve from the gravity model to generally replicate the trip length frequency curve of the observed origin-destination trip file that was extracted from the Household Travel Survey.

The results from the calibration of the NHB trips by each market segment are presented in Figures 3.13.1 – 3.13.4. These figures also illustrate the difference between the O-D Survey and gravity model trip length frequency curves. The line graphs show that the trip length frequency distributions from the gravity models generally match their corresponding trip length frequency curve observed in the O-D Survey. In addition to the trip length frequency curves, computed average trip lengths for the NHB trip purposes are within the three percent (3%) criteria. The average trip length from the gravity models are all within 1% of the average trip length from the O-D Survey for all of the market groups.

The gravity model friction factors developed in the calibration process are shown graphically in Figures 3.13.5 – 3.13.8. Tables 3.13.1 - 3.13.4 list the actual calibrated friction factor values for individual composite time increments between 1 and 100 minutes.

Figure 3.13.1
NHB Market Group 1 Trips (O-D vs. GM)

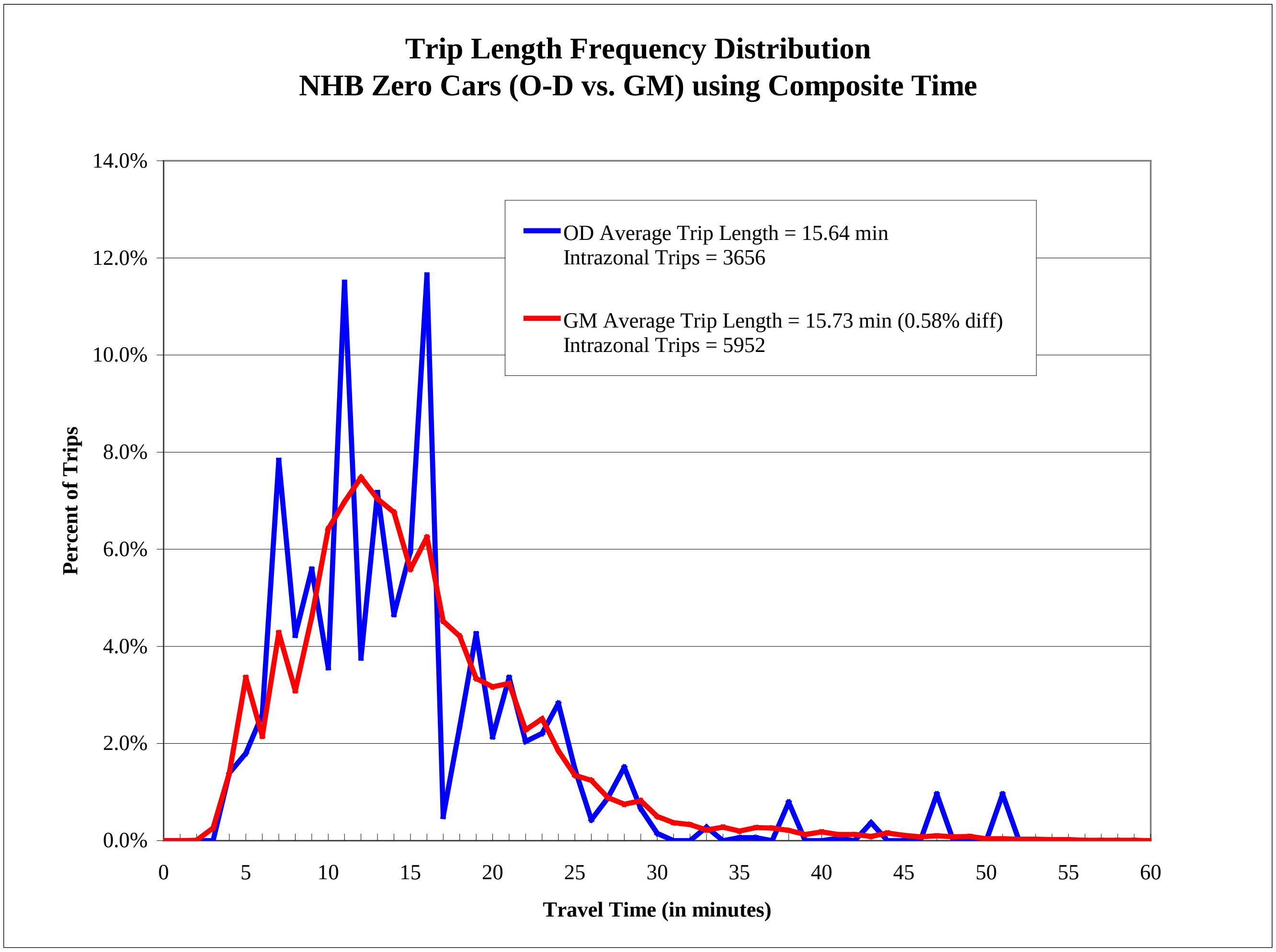


Figure 3.13.2
NHB Market Group 2 Trips (O-D vs. GM)

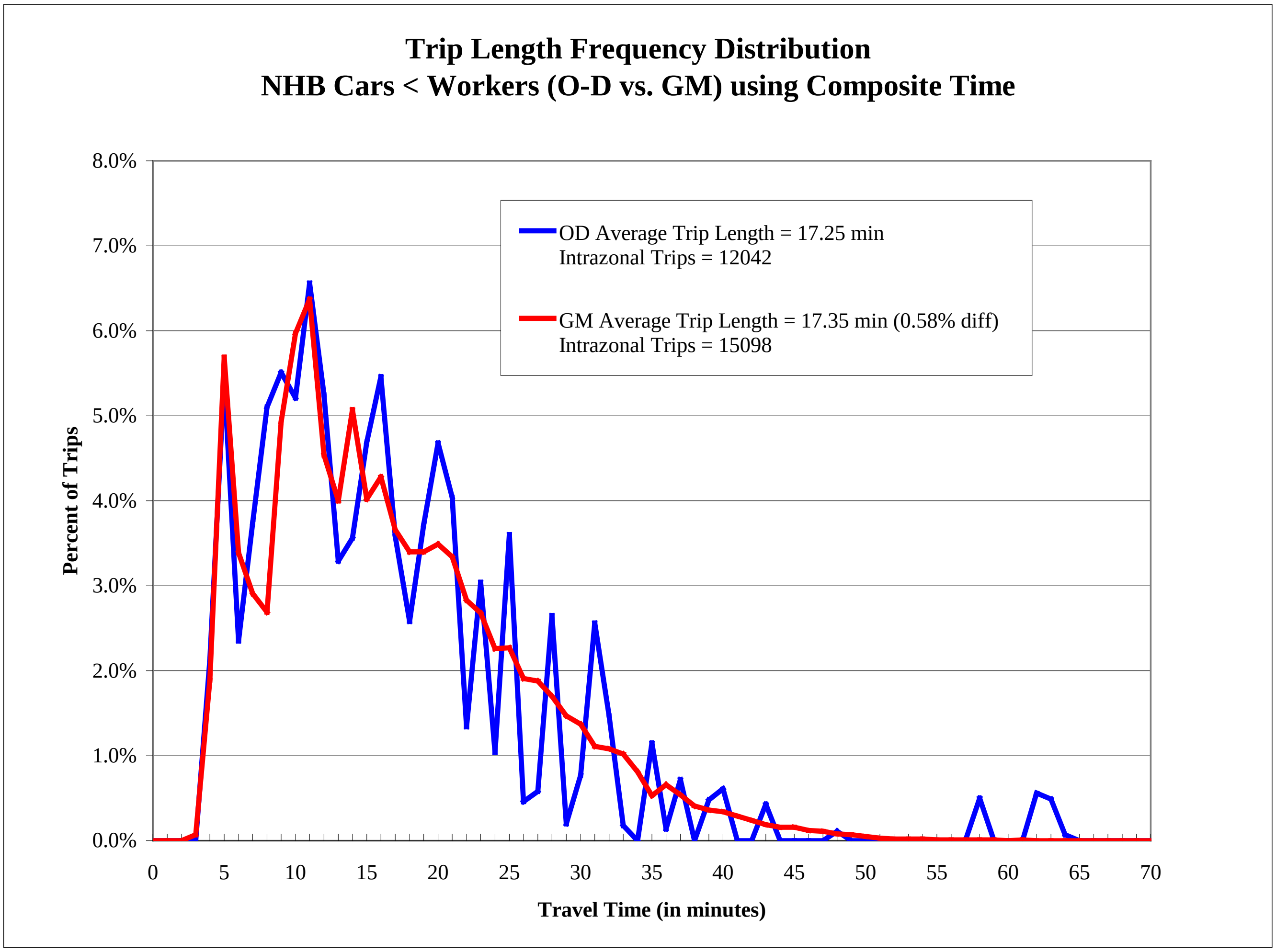

Trip Length Frequency Distribution
NHB Cars < Workers (O-D vs. GM) using Composite Time
OD Average Trip Length = 17.25 min
Intrazonal Trips = 12042
GM Average Trip Length = 17.35 min (0.58% diff)
Intrazonal Trips = 15098
Percent of Trips
8.0%
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
Travel Time (in minutes)

Figure 3.13.3
NHB Market Group 3 Trips (O-D vs. GM)

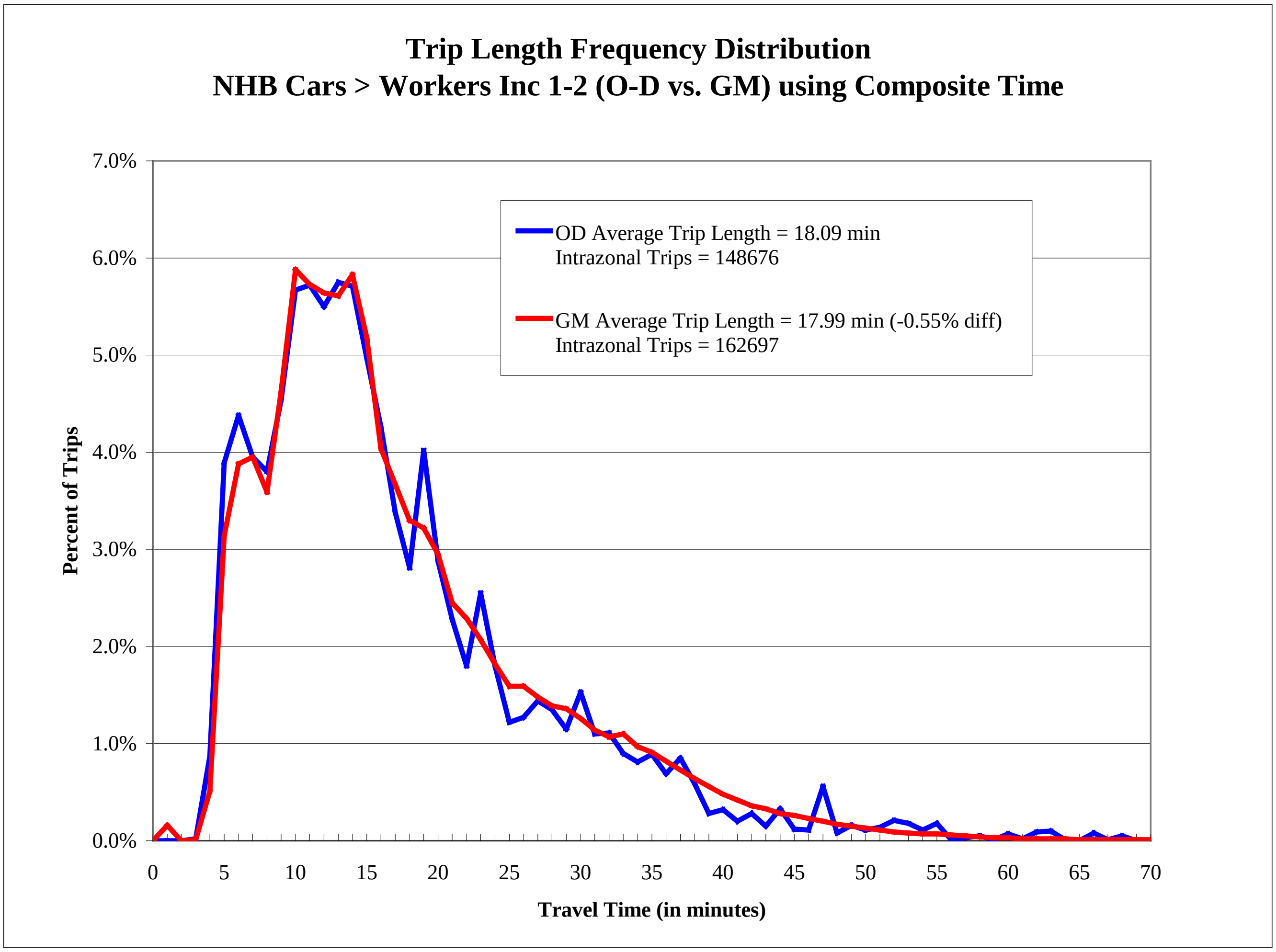
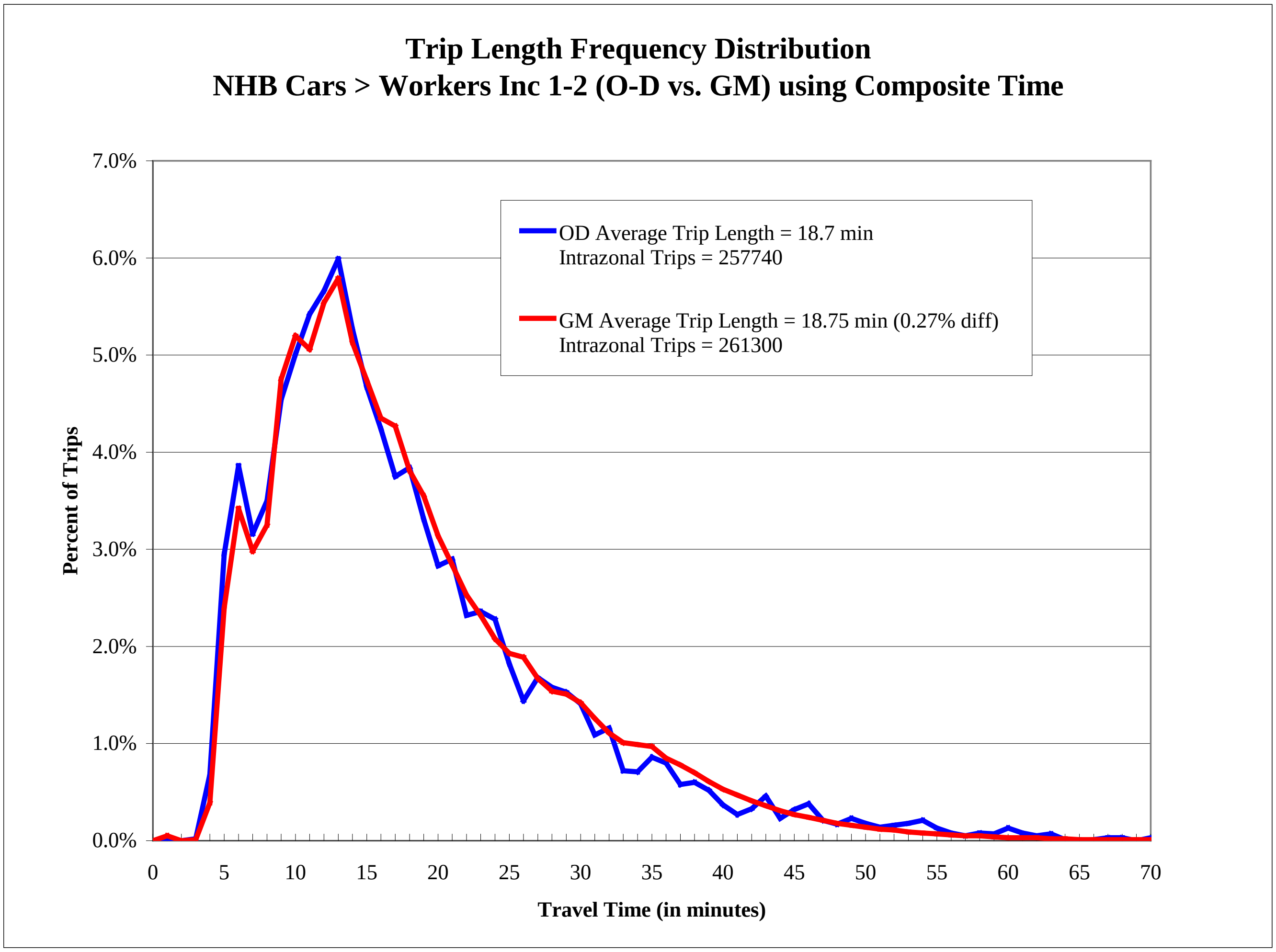


Figure 3.13.4
NHB Market Group 4 Trips (O-D vs. GM)



Trip Length Frequency Distribution
NHB Cars > Workers Inc 1-2 (O-D vs. GM) using Composite Time
OD Average Trip Length = 18.7 min
Intrazonal Trips = 257740
GM Average Trip Length = 18.75 min (0.27% diff)
Intrazonal Trips = 261300
Percent of Trips
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
Travel Time (in minutes)

Figure 3.13.5
Non Home Based Calibrated Gravity Model
Market Group 1 Friction Factors Curve

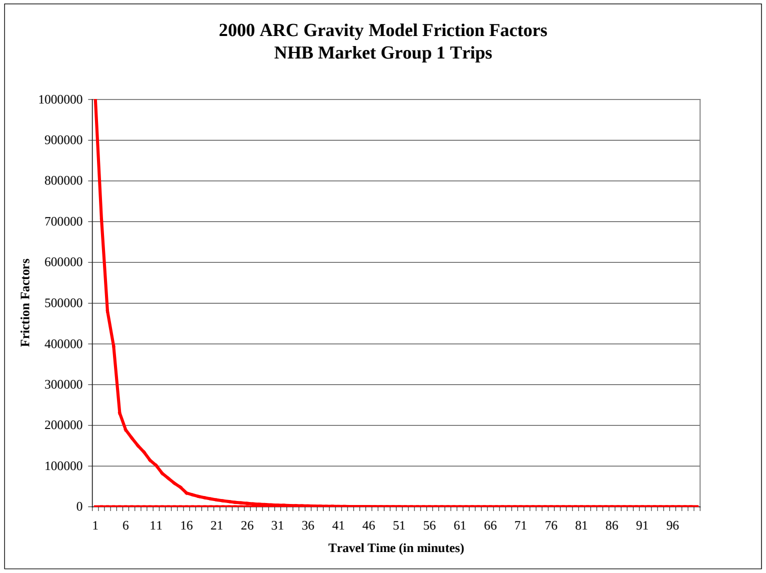


Table 3.13.1
Non Home Based Calibrated Gravity Model
Market Group 1 Friction Factors

Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor
1	999999	26	8372	51	215	76	5
2	705000	27	7285	52	139	77	4
3	480000	28	6337	53	121	78	3
4	395000	29	5514	54	105	79	3
5	230000	30	4799	55	91	80	3
6	189000	31	4175	56	79	81	3
7	169000	32	3632	57	69	82	3
8	150000	33	3161	58	60	83	3
9	134000	34	2749	59	52	84	3
10	114276	35	2393	60	45	85	1
11	101462	36	2080	61	39	86	1
12	82135	37	1811	62	34	87	1
13	70000	38	1574	63	30	88	1
14	58000	39	1370	64	26	89	1
15	48000	40	1192	65	23	90	1
16	33703	41	987	66	20	91	1
17	29323	42	860	67	17	92	1
18	25510	43	747	68	15	93	1
19	22193	44	660	69	13	94	1
20	19309	45	624	70	11	95	1
21	16797	46	542	71	10	96	1
22	14615	47	470	72	9	97	1
23	12716	48	409	73	8	98	1
24	11063	49	358	74	7	99	1
25	9623	50	310	75	6	100	1

Figure 3.13.6
Non Home Based Calibrated Gravity Model Market Group 2 Friction Factors Curve

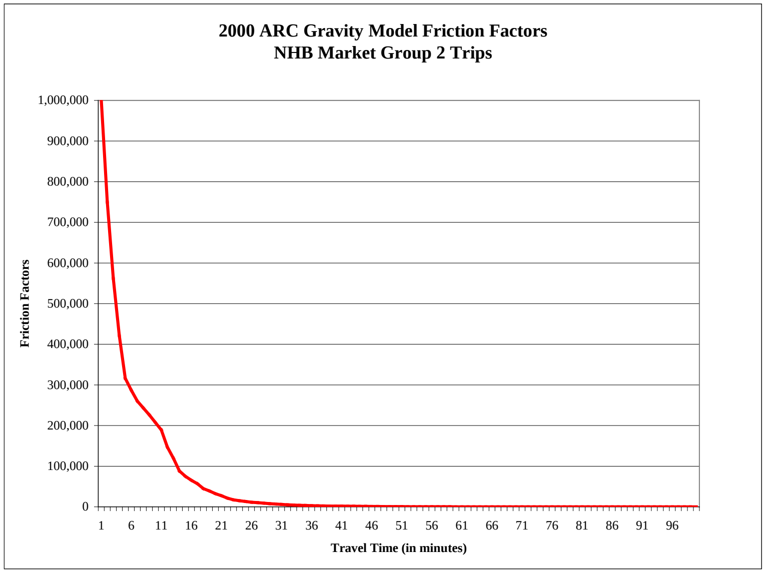


Table 3.13.2
Non Home Based Calibrated Gravity Model Market Group 2 Friction Factors

Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor
1	999999	26	11341	51	491	76	14
2	749999	27	10385	52	427	77	12
3	562499	28	9036	53	372	78	10
4	421874	29	7861	54	323	79	9
5	316406	30	6838	55	282	80	8
6	287140	31	5950	56	245	81	7
7	260150	32	5175	57	213	82	6
8	243000	33	4504	58	186	83	5
9	225980	34	3918	59	162	84	4
10	207557	35	3408	60	141	85	3
11	189135	36	2965	61	122	86	3
12	147378	37	2580	62	107	87	3
13	119466	38	2244	63	92	88	3
14	88204	39	1953	64	80	89	3
15	75003	40	1759	65	70	90	3
16	65252	41	1825	66	56	91	3
17	56770	42	1719	67	49	92	1
18	44900	43	1496	68	43	93	1
19	39062	44	1301	69	37	94	1
20	32480	45	1132	70	32	95	1
21	27405	46	985	71	28	96	1
22	21315	47	857	72	24	97	1
23	17220	48	746	73	21	98	1
24	14982	49	649	74	18	99	1
25	13035	50	564	75	16	100	1

Figure 3.13.7
Non Home Based Calibrated Gravity Model Market Group 3 Friction Factors Curve

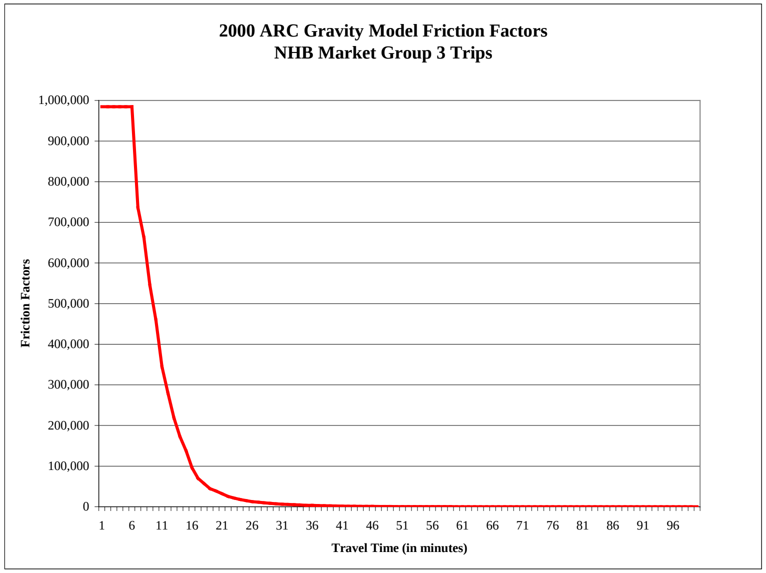


Table 3.13.3
Non Home Based Calibrated Gravity Model Market Group 3 Friction Factors

Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor
1	984609	26	12668	51	455	76	20
2	984609	27	11297	52	400	77	18
3	984609	28	9596	53	351	78	16
4	984609	29	8600	54	307	79	15
5	984609	30	7266	55	271	80	13
6	984609	31	6214	56	239	81	12
7	736250	32	5528	57	209	82	10
8	663049	33	5079	58	184	83	9
9	545000	34	4368	59	163	84	7
10	460000	35	3387	60	143	85	7
11	344592	36	3417	61	126	86	6
12	279722	37	2953	62	111	87	6
13	218598	38	2556	63	98	88	4
14	172776	39	2214	64	88	89	4
15	137899	40	1920	65	78	90	4
16	95865	41	1589	66	69	91	3
17	69971	42	1381	67	60	92	3
18	57121	43	1202	68	53	93	3
19	44562	44	1048	69	47	94	3
20	38627	45	914	70	42	95	3
21	32041	46	797	71	37	96	1
22	25359	47	698	72	32	97	1
23	21211	48	610	73	29	98	1
24	17804	49	534	74	26	99	1
25	14996	50	468	75	23	100	1

Figure 3.13.8
Non Home Based Calibrated Gravity Model Market Group 4 Friction Factors Curve

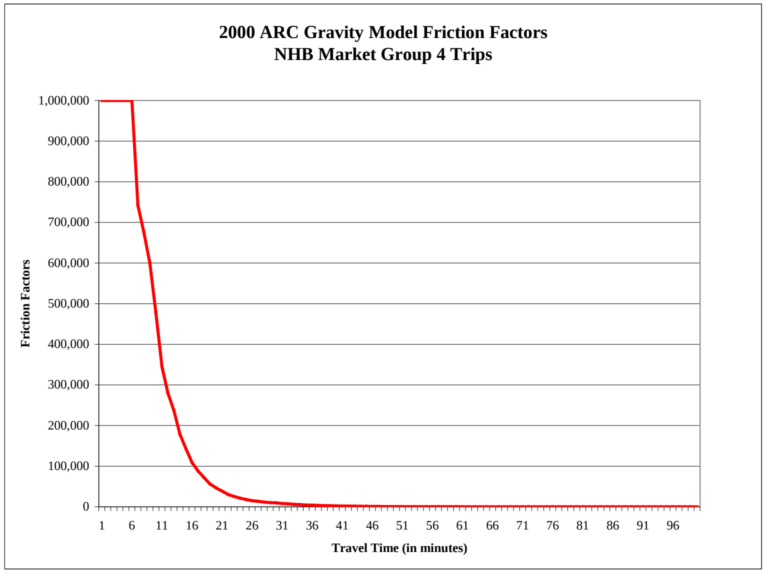


Table 3.13.4
Non Home Based Calibrated Gravity Model Market Group 4 Friction Factors

Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor	Time[1] (minutes)	Friction Factor
1	1000000	26	15222	51	517	76	23
2	1000000	27	13575	52	454	77	21
3	1000000	28	11531	53	399	78	16
4	1000000	29	10334	54	348	79	15
5	1000000	30	9702	55	308	80	13
6	1000000	31	8297	56	272	81	12
7	742000	32	7110	57	237	82	10
8	675000	33	6103	58	209	83	9
9	599500	34	5249	59	185	84	7
10	477873	35	4522	60	163	85	7
11	344592	36	4107	61	143	86	6
12	279722	37	3547	62	127	87	6
13	236414	38	3070	63	111	88	4
14	178363	39	2660	64	100	89	4
15	142359	40	2308	65	89	90	4
16	108862	41	2005	66	78	91	3
17	88285	42	1743	67	68	92	3
18	72072	43	1516	68	61	93	3
19	56226	44	1321	69	53	94	3
20	46417	45	1153	70	47	95	3
21	38502	46	1006	71	42	96	1
22	30473	47	881	72	37	97	1
23	25487	48	770	73	33	98	1
24	21394	49	674	74	29	99	1
25	18020	50	590	75	26	100	1

3.14. Validation of Non-Home Based Gravity Model

Although the NHB gravity model was already validated in terms of trip length distribution and average trip lengths, there are potential "area" biases to consider as well. "Area" bias formed by the Chattahoochee River significantly affected NHB trips. According to the origins and destinations of NHB trips observed crossing the Chattahoochee River in the O-D Survey, the gravity model distribution was 45.2% greater for trips produced in zones located north or west of the Chattahoochee River. For zones south or east of the river, the gravity model calculated 23.1% more trips crossing the Chattahoochee than were observed in the O-D Survey. The impacts of "area" bias on the distribution of NHB trips crossing the Chattahoochee River is depicted in Table 3.14.1 using a compressed matrix of trips from the O-D Survey and another from the gravity model. Trip productions from zones north or west of the river and that were observed crossing the Chattahoochee River in the O-D Survey totaled 153,818. In contrast, the gravity model estimated 223,375 NHB production trips from zones north and west of the river that crossed the Chattahoochee River.

Table 3.14.1
Comparison of Gravity Model (Without Topo Penalty) and O-D Survey NHB Trips Crossing the Chattahoochee River Cutline Boundary

	Destination										
	North of River			South of River			Total		Total Crossing		
Origin	OD	GM	Percent Diff	OD	GM	Percent Diff	OD	GM	OD	GM	Percent Diff
North of River	1,061,485	991,838	-6.6%	153,818	223,375	45.2%	1,215,303	1,215,213	323,799	432,560	33.6%
South of River	169,981	209,185	23.1%	2,658,495	2,619,136	-1.5%	2,828,476	2,828,321			
Total	1,231,466	1,201,023	-2.5%	2,812,313	2,842,511	1.1%	4,043,779	4,043,534			

A topographic penalty or "Topo" penalty was incorporated in the gravity model process to compensate for the "area" bias created by the Chattahoochee River. The "Topo" penalty is a lump sum of time (in minutes) that is added to the composite time of interzonal times for all zonal pairs on opposite sides of the Chattahoochee River. The appropriate "Topo" penalties in minutes for the NHB market groups are listed below.

Market Group 1 – 3.0
Market Group 2 – 1.0
Market Group 3 – 3.0
Market Group 4 – 2.0

With the "Topo" penalties added to composite times, gravity model estimates of NHB trips crossing the Chattahoochee River cutline were greatly improved. Gravity model results of trips crossing the Chattahoochee River cutline, using a "Topo" penalty application, are shown in Table 3.14.2 along with the number of trips observed crossing the river in the O-D Survey. The gravity model estimated 177,959 NHB trips crossing the Chattahoochee River from zones north and west of the river which was much better than the 223,375 computed when "Topo" penalties were not applied. This volume is still 15.7% higher than the 153,818 trips observed in the O-D Survey but far better than without a "Topo" penalty.

Table 3.14.2
Comparison of Gravity Model (With Topo Penalty) and O-D Survey
NHB Trips Crossing the Chattahoochee River Cutline Boundary

	Destination										
	North of River			South of River			Total		Total Crossing		
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
North of River	1,061,485	1,037,231	-2.3%	153,818	177,959	15.7%	1,215,303	1,215,190	323,799	336,939	4.1%
South of River	169,981	158,980	-6.5%	2,658,495	2,669,310	0.4%	2,828,476	2,828,290			
Total	1,231,466	1,196,211	-2.9%	2,812,313	2,847,269	1.2%	4,043,779	4,043,480			

"Area" bias findings from the other three cutline boundaries are reported below for the I-20, I-285, and Ga.400/I-85/I-75. The number of NHB trips crossing I-20 from the gravity model was 10.3% higher, overall, in comparison with those observed in the O-D Survey. This comparison indicated that the level of deviation fell within a reasonable range. I-20 cutline boundary findings, comparing gravity model crossings with O-D Study crossings, are displayed in Table 3.14.3. Gravity model trips crossing the cutline boundary that were produced in zones north I-20 were 2.6% above their O-D Survey counterparts. For trips originating in zones south of I-20, gravity model estimates were 18.4% higher than those observed in the O-D Survey.

Table 3.14.3
Comparison of Gravity Model (With Topo Penalty) and O-D Survey

	Destination										
	North of I-20			South of I-20			Total		Total Crossing		
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
North of I-20	2,991,293	2,986,381	-0.2%	178,796	183,512	2.6%	3,170,089	3,169,893	346,940	382,654	10.3%
South of I-20	168,144	199,142	18.4%	765,545	674,446	-11.9%	933,689	873,588			
Total	3,159,437	3,185,523	0.8%	944,341	857,958	-9.1%	4,103,778	4,043,481			

The number of NHB trips crossing I-285 in the gravity model was 8.8% higher, overall, in comparison with those observed in the O-D Survey. That level of deviation indicates there was not an "area" bias in trip distribution along that boundary. I-285 cutline boundary findings, comparing gravity model crossings with O-D Study crossings, are displayed in Table 3.14.4. Gravity model trips crossing the cutline boundary that were produced from zones inside I-285 were 2.6% lower than their O-D Survey counterparts. For trips originating in zones outside of the I-285 boundary, gravity model estimates were 22.1% above those observed in the O-D Survey.

Table 3.14.4
Comparison of Gravity Model (With Topo Penalty) and O-D Survey
NHB Trips Crossing the I-285 Cutline Boundary

	Destination										
	Outside of I-285			Inside of I-285			Total		Total Crossing		
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
Outside of I-285	2,353,216	2,286,879	-2.8%	296,902	362,520	22.1%	2,650,118	2,649,399	642,414	699,053	8.8%
Inside of I-285	345,512	336,533	-2.6%	1,053,882	1,063,434	0.9%	1,399,394	1,399,967			
Total	2,698,728	2,623,412	-2.8%	1,350,784	1,425,954	5.6%	4,049,512	4,049,366			

The number of NHB trips crossing the Ga. 400/I-85/I-75 cutline in the gravity model was 7.8% greater, overall, in comparison with NHB trips observed in the O-D Survey. That level of deviation indicates that there is not an “area” bias along this cutline boundary. Ga.400/I-85/I-75 cutline boundary findings, comparing gravity model crossings with O-D Study crossings, are displayed in Table 3.14.5. Gravity model trips crossing the cutline boundary that were produced from zones west of the boundary were 10% higher than their O-D Survey counterparts. For trips originating in zones east of the Ga. 400/I-85/I-75 boundary, gravity model estimates were 5.5% over those observed in the O-D Survey.

Table 3.14.5
Comparison of Gravity Model (With Topo Penalty) and O-D Survey NHB Trips Crossing the Ga. 400/I-85/I-75 Cutline Boundary

	Destination										
	East of GA400/I-85/I-75			West of GA400/I-85/I-75			Total		Total Crossing		
Origin	OD	GM	Percent Diff.	OD	GM	Percent Diff.	OD	GM	OD	GM	Percent Diff.
East of GA400/□I-8	1,419,688	1,388,677	-2.2%	295,561	311,731	5.5%	1,715,249	1,700,408	601,431	648,139	7.8%
West of GA400/□I-	305,870	336,408	10.0%	1,628,622	1,585,241	-2.7%	1,934,492	1,921,649			
Total	1,725,558	1,725,085	0.0%	1,924,183	1,896,972	-1.4%	3,649,741	3,622,057			

3.15. All Trip Purposes

Following is a summary of the calibrated gravity model for all trip purposes combined using county-level tabulations. Table 3.15.1 shows the total number of household-based trips used to calibrate and validate the new gravity model. The county totals represent weighted survey trips from the Atlanta Regional Commission’s 2001-2002 Household Travel Survey of the 13-county study area. There were a total of 15, 133, 500 trips (expanded) in the survey trip file. The highest number of trips (3,631,800) was produced in Fulton County. Fulton County was followed by Cobb County, DeKalb County and Gwinnett County.

Table 3.15.1
Total Trips By County (Weighted Survey Trips) Used in Gravity Model Calibration

County	Total Productions	% of Total
Cherokee	519,000	3%
Clayton	883,000	6%
Cobb	2,664,000	18%
Coweta	308,100	2%
DeKalb	2,649,100	18%
Douglas	330,500	2%
Fayette	364,900	2%
Forsyth	312,500	2%
Fulton	3,631,800	24%
Gwinnett	2,453,400	16%
Henry	464,500	3%
Paulding	254,900	2%
Rockdale	297,800	2%
Total	**15,133,500**	**100%**

A summary of travel patterns computed by the calibrated gravity model for all trip purposes combined are shown in Tables 3.15.2 through 3.15.14. For all thirteen counties, the highest movement is the intra-county volume of travel. For each county, except Paulding, the distribution of intra-county trips exceeds 50%. In Paulding County, 41% of the trips produced there also have their destinations inside the county. The county with the highest share of internal trips is Gwinnett where 76% of its productions were also attracted to a place inside the county.

Table 3.15.2
County-to-County Trip Table
O-D Survey and Gravity Model
All Trip Purposes Combined

Destination County	O-D Survey	% of Total	Gravity Model	% of Total
Cherokee	324,932	65.0%	280,474	56.0%
Clayton	0	0.0%	436	0.0%
Cobb	86,179	17.0%	123,229	25.0%
Coweta	0	0.0%	215	0.0%
DeKalb	10,521	2.0%	7,336	1.0%
Douglas	1,474	0.0%	745	0.0%
Fayette	0	0.0%	93	0.0%
Forsyth	10,714	2.0%	11,805	2.0%
Fulton	59,419	12.0%	69,092	14.0%
Gwinnett	6,801	1.0%	5,454	1.0%
Henry	111	0.0%	84	0.0%
Paulding	117	0.0%	1,182	0.0%
Rockdale	0	0.0%	74	0.0%
Total	**500,268**	100.0%	**500,217**	100.0%

Table 3.15.3
County-to-County Trip Table
O-D Survey and Gravity Model
All Trip Purposes Combined
Clayton County

Destination County	O-D Survey	% of Total	Gravity Model	% of Total
Cherokee	244	0.0%	191	0.0%
Clayton	498,929	63.0%	452,611	57.0%
Cobb	5,771	1.0%	9,764	1.0%
Coweta	5,164	1.0%	3,029	0.0%
DeKalb	39,909	5.0%	51,584	6.0%
Douglas	3,615	0.0%	2,646	0.0%
Fayette	40,247	5.0%	45,807	6.0%
Forsyth	0	0.0%	79	0.0%
Fulton	129,048	16.0%	166,280	21.0%
Gwinnett	8,141	1.0%	5,964	1.0%
Henry	65,372	8.0%	53,943	7.0%
Paulding	0	0.0%	179	0.0%
Rockdale	354	0.0%	4,676	1.0%
Total	**796,793**	100.0%	**796,753**	100.0%

Table 3.15.4
County-to-County Trip Table
O-D Survey and Gravity Model
All Trip Purposes Combined
Cobb County

Destination County	O-D Survey	% of Total	Gravity Model	% of Total
Cherokee	57,711	2.0%	75,080	3.0%
Clayton	6,145	0.0%	8,372	0.0%
Cobb	1,911,603	77.0%	1,815,154	73.0%
Coweta	591	0.0%	1,866	0.0%
DeKalb	62,579	3.0%	82,365	3.0%
Douglas	24,882	1.0%	32,751	1.0%
Fayette	3,809	0.0%	1,757	0.0%
Forsyth	7,401	0.0%	4,831	0.0%
Fulton	354,509	14.0%	406,096	16.0%
Gwinnett	31,914	1.0%	25,050	1.0%
Henry	2,155	0.0%	1,205	0.0%
Paulding	16,996	1.0%	25,301	1.0%
Rockdale	778	0.0%	1,095	0.0%
Total	**2,481,074**	100.0%	**2,480,922**	100.0%

Table 3.15.5
County-to-County Trip Table
O-D Survey and Gravity Model
All Trip Purposes Combined
Coweta County

Destination County	O-D Survey	% of Total	Gravity Model	% of Total
Cherokee	290	0.0%	109	0.0%
Clayton	8,402	3.0%	10,122	4.0%
Cobb	4,772	2.0%	3,980	1.0%
Coweta	191,200	66.0%	172,575	60.0%
DeKalb	3,512	1.0%	5,403	2.0%
Douglas	520	0.0%	4,669	2.0%
Fayette	37,072	13.0%	43,940	15.0%
Forsyth	0	0.0%	32	0.0%
Fulton	35,143	12.0%	43,582	15.0%
Gwinnett	6,163	2.0%	754	0.0%
Henry	625	0.0%	1,677	1.0%
Paulding	0	0.0%	478	0.0%
Rockdale	0	0.0%	338	0.0%
Total	**287,699**	100.0%	**287,658**	100.0%

Table 3.15.6
County-to-County Trip Table
O-D Survey and Gravity Model
All Trip Purposes Combined
DeKalb County

Destination County	O-D Survey	% of Total	Gravity Model	% of Total
Cherokee	789	0.0%	1,583	0.0%
Clayton	31,102	1.0%	41,311	2.0%
Cobb	54,820	2.0%	57,076	2.0%
Coweta	1,161	0.0%	1,048	0.0%
DeKalb	1,569,749	64.0%	1,473,958	60.0%
Douglas	13,830	1.0%	4,071	0.0%
Fayette	4,194	0.0%	3,875	0.0%
Forsyth	4,302	0.0%	2,038	0.0%
Fulton	609,488	25.0%	650,352	26.0%
Gwinnett	140,480	6.0%	173,944	7.0%
Henry	15,513	1.0%	21,644	1.0%
Paulding	1,115	0.0%	411	0.0%
Rockdale	11,473	0.0%	26,666	1.0%
Total	**2,458,014**	100.0%	**2,457,977**	100.0%

Table 3.15.7
County-to-County Trip Table
O-D Survey and Gravity Model
All Trip Purposes Combined
Douglas County

Destination County	O-D Survey	% of Total	Gravity Model	% of Total
Cherokee	0	0.0%	378	0.0%
Clayton	979	0.0%	4,104	1.0%
Cobb	23,070	8.0%	37,071	13.0%
Coweta	0	0.0%	2,397	1.0%
DeKalb	11,208	4.0%	7,936	3.0%
Douglas	202,547	73.0%	168,956	61.0%
Fayette	746	0.0%	2,255	1.0%
Forsyth	0	0.0%	69	0.0%
Fulton	27,355	10.0%	48,111	17.0%
Gwinnett	0	0.0%	1,133	0.0%
Henry	3,335	1.0%	626	0.0%
Paulding	9,328	3.0%	5,840	2.0%
Rockdale	601	0.0%	291	0.0%
Total	**279,168**	100.0%	**279,167**	100.0%

Table 3.15.8
County-to-County Trip Table
O-D Survey and Gravity Model
All Trip Purposes Combined
Fayette County

Destination County	O-D Survey	% of Total	Gravity Model	% of Total
Cherokee	0	0.0%	54	0.0%
Clayton	13,669	4.0%	36,635	11.0%
Cobb	2,630	1.0%	3,690	1.0%
Coweta	9,173	3.0%	15,759	5.0%
DeKalb	12,978	4.0%	6,975	2.0%
Douglas	0	0.0%	1,869	1.0%
Fayette	255,372	73.0%	227,606	65.0%
Forsyth	0	0.0%	25	0.0%
Fulton	48,721	14.0%	47,257	14.0%
Gwinnett	1,660	0.0%	942	0.0%
Henry	3,993	1.0%	6,621	2.0%
Paulding	0	0.0%	108	0.0%
Rockdale	0	0.0%	611	0.0%
Total	**348,196**	100.0%	**348,151**	100.0%

Table 3.15.9
County-to-County Trip Table
O-D Survey and Gravity Model
All Trip Purposes Combined
Forsyth County

Destination County	O-D Survey	% of Total	Gravity Model	% of Total
Cherokee	2,597	1.0%	7,033	2.0%
Clayton	0	0.0%	193	0.0%
Cobb	5,594	2.0%	9,692	3.0%
Coweta	736	0.0%	20	0.0%
DeKalb	6,866	2.0%	6,851	2.0%
Douglas	0	0.0%	121	0.0%
Fayette	0	0.0%	32	0.0%
Forsyth	193,371	67.0%	172,503	60.0%
Fulton	61,046	21.0%	69,769	24.0%
Gwinnett	13,851	5.0%	20,803	7.0%
Henry	3,138	1.0%	46	0.0%
Paulding	0	0.0%	43	0.0%
Rockdale	0	0.0%	81	0.0%
Total	**287,199**	100.0%	**287,186**	100.0%

Table 3.15.10
County-to-County Trip Table
O-D Survey and Gravity Model
All Trip Purposes Combined
Fulton County

Destination County	O-D Survey	% of Total	Gravity Model	% of Total
Cherokee	10,993	0.0%	17,997	1.0%
Clayton	77,832	2.0%	85,202	2.0%
Cobb	173,768	5.0%	219,479	6.0%
Coweta	6,614	0.0%	4,142	0.0%
DeKalb	368,979	11.0%	444,030	13.0%
Douglas	14,157	0.0%	14,439	0.0%
Fayette	22,389	1.0%	16,132	0.0%
Forsyth	20,816	1.0%	23,128	1.0%
Fulton	2,592,832	76.0%	2,461,362	72.0%
Gwinnett	94,519	3.0%	108,894	3.0%
Henry	17,585	1.0%	9,314	0.0%
Paulding	1,992	0.0%	1,385	0.0%
Rockdale	8,704	0.0%	5,603	0.0%
Total	**3,411,179**	100.0%	**3,411,106**	100.0%

Table 3.15.11
County-to-County Trip Table
O-D Survey and Gravity Model
All Trip Purposes Combined
Gwinnett County

Destination County	O-D Survey	% of Total	Gravity Model	% of Total
Cherokee	962	0.0%	1,783	0.0%
Clayton	6,493	0.0%	6,337	0.0%
Cobb	28,479	1.0%	28,044	1.0%
Coweta	1,541	0.0%	227	0.0%
DeKalb	263,383	12.0%	283,763	13.0%
Douglas	1,725	0.0%	836	0.0%
Fayette	328	0.0%	637	0.0%
Forsyth	11,463	1.0%	14,922	1.0%
Fulton	213,357	10.0%	237,816	11.0%
Gwinnett	1,698,710	76.0%	1,642,904	73.0%
Henry	2,858	0.0%	3,707	0.0%
Paulding	0	0.0%	119	0.0%
Rockdale	9,235	0.0%	17,231	1.0%
Total	**2,238,534**	100.0%	**2,238,325**	100.0%

Table 3.15.14
County-to-County Trip Table
O-D Survey and Gravity Model
All Trip Purposes Combined
Rockdale County

Table 3.15.12
County-to-County Trip Table
O-D Survey and Gravity Model
All Trip Purposes Combined
Henry County

Destination County	O-D Survey	% of Total	Gravity Model	% of Total
Cherokee	160	0.0%	59	0.0%
Clayton	75,179	17.0%	56,227	13.0%
Cobb	7,422	2.0%	3,337	1.0%
Coweta	234	0.0%	812	0.0%
DeKalb	17,613	4.0%	33,273	8.0%
Douglas	0	0.0%	655	0.0%
Fayette	4,111	1.0%	6,698	2.0%
Forsyth	0	0.0%	55	0.0%
Fulton	49,730	12.0%	47,581	11.0%
Gwinnett	1,534	0.0%	5,852	1.0%
Henry	268,908	62.0%	261,438	61.0%
Paulding	193	0.0%	49	0.0%
Rockdale	6,492	2.0%	15,454	4.0%
Total	**431,578**	100.0%	**431,491**	100.0%

Table 3.15.13
County-to-County Trip Table
O-D Survey and Gravity Model
All Trip Purposes Combined
Paulding County

Destination County	O-D Survey	% of Total	Gravity Model	% of Total
Cherokee	1,101	1.0%	1,985	1.0%
Clayton	229	0.0%	1,557	1.0%
Cobb	60,550	28.0%	74,399	34.0%
Coweta	1,702	1.0%	4,903	2.0%
DeKalb	2,638	1.0%	4,569	2.0%
Douglas	17,302	8.0%	23,847	11.0%
Fayette	0	0.0%	588	0.0%
Forsyth	0	0.0%	134	0.0%
Fulton	43,817	20.0%	29,445	13.0%
Gwinnett	1,324	1.0%	1,067	0.0%
Henry	437	0.0%	254	0.0%
Paulding	90,276	41.0%	76,429	35.0%
Rockdale	0	0.0%	175	0.0%
Total	**219,375**	100.0%	**219,352**	100.0%

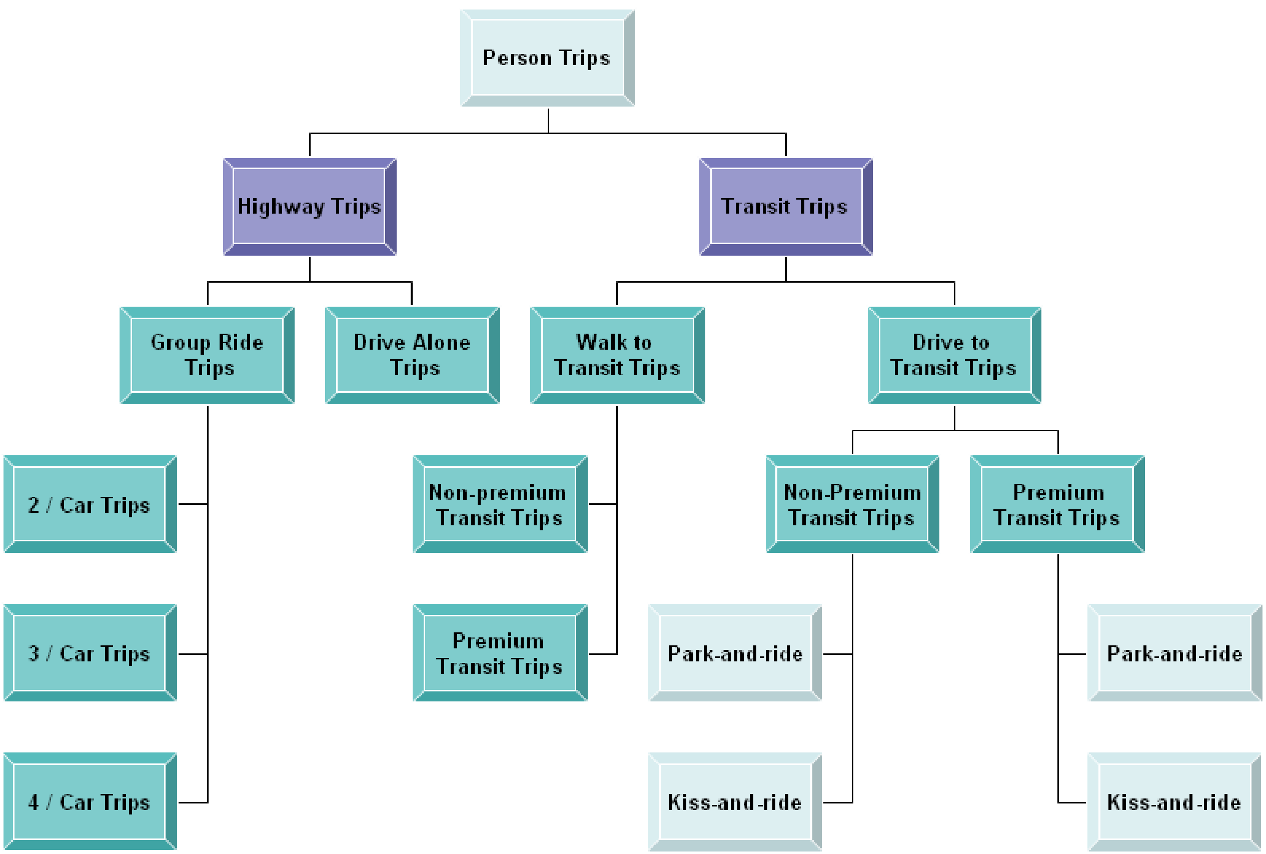
Destination County	O-D Survey	% of Total	Gravity Model	% of Total
Cherokee	160	0.0%	34	0.0%
Clayton	3,154	1.0%	6,499	2.0%
Cobb	853	0.0%	1,676	1.0%
Coweta	0	0.0%	120	0.0%
DeKalb	22,876	8.0%	38,360	14.0%
Douglas	61	0.0%	254	0.0%
Fayette	511	0.0%	593	0.0%
Forsyth	0	0.0%	68	0.0%
Fulton	14,503	5.0%	20,788	7.0%
Gwinnett	5,366	2.0%	15,791	6.0%
Henry	9,481	3.0%	16,881	6.0%
Paulding	0	0.0%	21	0.0%
Rockdale	226,638	80.0%	182,483	64.0%
Total	**283,603**	100.0%	**283,569**	100.0%

4. Mode Choice

4.1 Introduction

The ARC mode choice models use an underlying nested logit structure (Figure 4.1) to predict the probability individuals in the Atlanta metropolitan area will select one of several different modes of transportation. Initial system variables and coefficients were estimated with the ALOGIT statistical estimation package using input data from the household travel survey. ARC conducted a regional transit on-board survey in 2009-2010 to get a better understanding of transit travel behavior. While the full expansion of the survey was not available in time for this model version, the survey was used to make important updates to the mode choice model.

Figure 4.1
Nesting Structure



4.2 Survey Expansion

A preliminary expansion of the survey data was performed to tabulate new transit targets by trip purpose, mode of access, and socioeconomic class. The preliminary expansion factors were determined as follows:

- Unlinked trip weights were computed on a non-directional route basis by comparing daily ridership to survey observations.
- Unlinked to linked trip weights were computed as the reciprocal of the number of transit vehicles boarded during the origin to destination trip.

The preliminary expansion of trips by mode of access and socioeconomic class is provided in Table 4.1. With a base year model of 2005, a downward adjustment was necessary to create 2005 calibration targets. This adjustment is provided in Table 4.2.

Table 4.1 Year 2009-2010 Survey Linked Trips

Mode of Access	Zero Auto	Autos < Workers	Autos >= Workers Inc 1-2	Autos >= Workers Inc 3-4	Total
Walk	91,926	31,746	33,125	10,937	167,734
Kiss and ride	19,242	15,602	15,585	6,264	56,693
Park and ride	1,681	9,960	23,023	24,820	59,484
Total	112,849	57,308	71,733	42,021	283,911

Table 4.2 Adjustments for Year 2005

Control Totals	Year 2009	Year 2005	% Change
Unlinked Trips	454,239	409,862	-10.8%
Linked Trips	283,911	254,171	-11.7%

Unlinked control totals provided by regional transit operators (MARTA, CCT, GRTA, GCT)

4.2 Transit Path Parameters

With the preliminary expanded survey database, an initial assignment of the survey trip tables was performed to obtain a general assessment of the transit path builder. This initial assignment led to several modifications to the treatment of access connectors and path building parameters.

In the previous model version, the walk access connectors were limited to 0.4 miles. A cumulative distribution (Figure 4.2) plot of the survey revealed that this restriction potentially eliminated approximately 30% of the transit market. As a result, the maximum walk distance was extended to 1 mile. As part of this, the manner in which the walk times are computed was also updated. Previously, an average zonal walk time was computed and applied to all connectors to/from a zone. However, with the connectors extended to 1 mile, it was necessary to differentiate between nearby transit stops and ones that could be up to a 20 minute walk. Therefore, the distance used for the walk time computation was modified to be the straight line distance from the zone centroid to the transit stop.

Similarly, the drive access connectors to minor park-n-ride lots were extended from 10 minutes to 20 minutes based on analysis of the survey records to appropriately capture the markets.

As part of the survey assignment, modifications were made to the path building parameters to obtain better assignment accuracy. Adjustments were made to the weight times for walk access/egress, all walk time, and drive access time. The revised parameters are provided in Table 4.3.

Figure 4.2 Cumulative Walk Access Distance

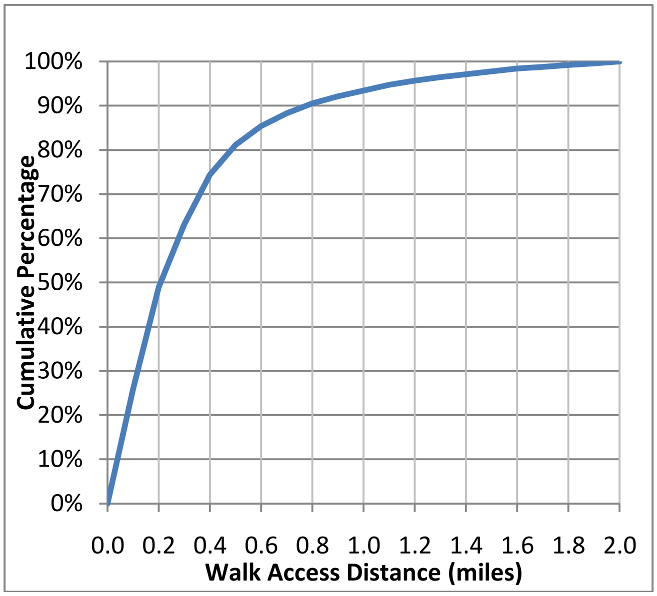


Table 4.3 Transit Path Parameters

Path Parameter	Original Settings	Revised Settings
Initial wait time (non-premium)	2.50	2.50
Initial wait time (premium)	1.75	1.75
Walk time	2.50	2.00
All walk time (sidewalk proxy)	2.50	5.00
Drive time	2.50	2.00
In-vehicle time (non-premium)	1.00	1.00
In-vehicle time (premium)	0.70	0.70
Transfer time (non-premium)	2.50	2.50
Transfer time (premium)	1.75	1.75

4.3 Calibration/Validation

Calibration of the mode choice models entails adjusting the bias coefficients until the estimated modal shares match the target shares by purpose, strata, and sub-mode. This was done using the self-calibration subroutine within the mode choice model. The subroutine is an iterative process which compares the model shares to the observed shares and adjusts the bias coefficients accordingly. Each trip purpose was calibrated using this methodology.

4.3.1 Transfer Penalty

In the previous model version, transfer penalties were implied in how the alternative specific constants were applied. The issue with the application of the previous model is that the transfer penalty varied by transit sub-mode as shown in Table 4.4. The structure of this format would likely not be acceptable by FTA for a New Starts type of analysis. A better approach for reflecting the undesirability of transferring is to recognize that customers are less to make a transfer for specific types of trips (e.g. a trip involving park-and-ride) than for reasons related to a particular transit technology. In the revised model, the implied transfer penalty by transit mode was removed and replaced with a transfer penalty for walk access trips (5 minutes) and a transfer penalty for drive access trips (10 minutes). These transfer penalties are applied to all transit modes equally both in the transit path builder and mode choice.

Table 4.4 Previous Model Transfer Penalties

Sub-Mode	HBW Implied Transfer Penalty	HBO Implied Transfer Penalty	NHB Implied Transfer Penalty
Local Bus	0	0	0
Express Bus	37	42	43
BRT	21	25	27
Heavy/Light Rail	6	11	5
Commuter Rail	6	11	5

4.3.2 Pedestrian Environment Factor

The existing model had sub-mode constants that added more benefit (i.e., 30 minutes or more) to certain modes than what is considered acceptable by FTA (i.e., 12 to 15 minutes). The intent of the large mode specific constants was to match observed MARTA rail trips and boardings which occur in the more urban areas of the Atlanta region but resulted in factors that complicate the analysis of user benefits.

To improve the model's representation of the geographic nature of transit travel and better represent the split between rail and bus travel, a pedestrian environment factor was introduced to differentiate between suburban and urban locations that for the most part mimicked the implied rail preferences without explicitly favoring any one mode over another.

This approach also helps to reflect the fact that transit ridership is higher in urban settings than it is in less dense environments. This reflects not just density but also the fact that suburban land uses and street topologies often require circuitous walk paths with little or no provision of sidewalks to provide access to transit stops. These characteristics make walking to and from transit in the suburbs less appealing. By contrast, urban settings in Atlanta typically include more direct walk access opportunities with sidewalks and pedestrian crossings.

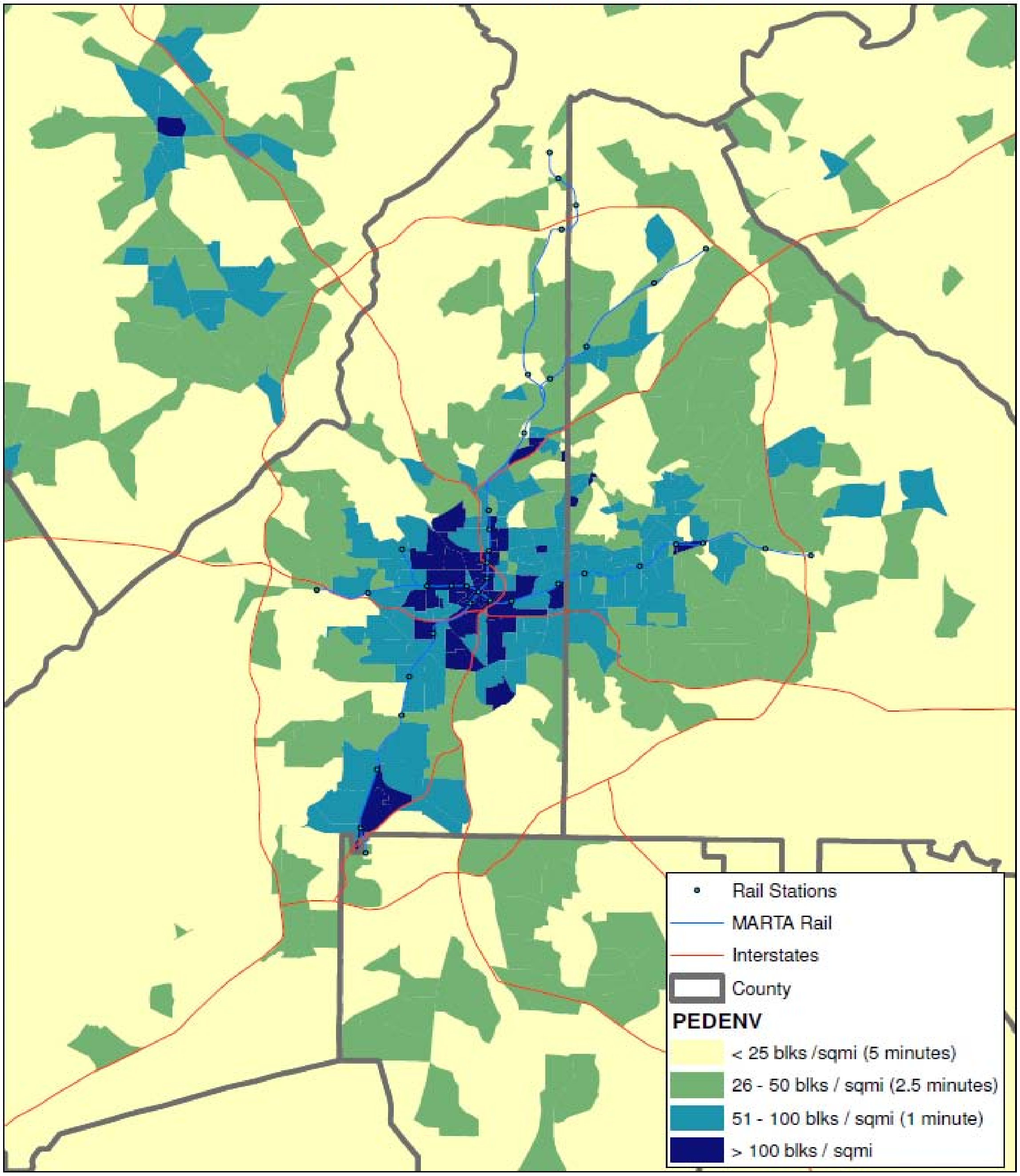
To differentiate between the varying walk access opportunities across the region, a proxy of the walkability of each zone was generated based on the census blocks per square mile. The idea for this proxy is that areas with a higher number of census blocks per square mile are more likely to have a complete street grid (usually with sidewalks) that allow easy access to transit stations and stops.

This variable is applied by adding time to the modeled walk access and egress times as follows:

- Blocks per square mile < 25: 5 minutes additional time
- Blocks per square mile between 25 and 50: 2.5 minutes additional time
- Blocks per square mile between 50 and 100: 1.0 minutes additional time
- Blocks per square mile > 100: no additional time

The time is added to both the production end and attraction end of a zone interchange. Consequently, if the production zone and attraction zone are both located in the lowest (least walkable) grouping, a maximum of 10 minutes is added to the walk time. For drive access trips, only the attraction zone was considered for application of the additional time. An illustration of how it is applied is provided in Figure 4.3.

Figure 4.3 Pedestrian Environment Application Plot



4.3.3 CBD Constant for Walk Access and Drive Access Modes

After accounting for the effects of walk distance and convenience by area, the CBD generates a larger transit market share than can be explained by the level-of-service variables included in the model. There are a number of reasons why taking transit to the CBD may be perceived as more attractive than a non-CBD location. These include having related places of business in close proximity to the ultimate destination (e.g., being able to walk to a restaurant for lunch) and better surrounding transit accessibility that reduce the importance of having a car available for other trips made during the day.

The existing model included a CBD transit bias which attempted to account for this effect. This constant was modified to incorporate a drive-to-transit CBD add-on benefit. This was done because drive access trips are much more oriented to the CBD. This constant improved model accuracy for drive trips to terminal MARTA rail stations that serve as major park-n-ride lots. The CBD transit constants are applied to all transit sub-modes. The equivalent benefit of IVTT is provided in Table 4.5.

Table 4.5 CBD Equivalent IVTT Benefit

CBD Bias	HBW	HBO	NHB
Any Transit	10	28	25
Drive to Transit Add-On	30	10	10

4.3.4 Alternative Specific Constants

An alternative specific constant is used to help model the unmeasured attributes of various transit modes such as reliability, comfort, passenger amenities, etc. Upon incorporation of the changes described above, the alternative specific constants were recalibrated to match the revised regional control totals stratified by purpose and socioeconomic class. As already discussed, transit transfer penalties by sub-mode were removed. The recalibrated model revealed a sizable reduction of the large mode specific constants that existed in the previous model. The final calibrated constants are now much closer to desirable values. The heavy rail constants now have an impact of between 14 and 19 minutes of equivalent IVTT as shown in Table 4.6.

Table 4.6 Alternative Specific Constants Equivalent IVTT Minutes

Alternative	HBW	HBO	NHB
Express Bus	5	9	9
BRT	11	16	16
Heavy/Light Rail	14	19	19
Commuter Rail	14	19	19

4.3.5 Mode Choice Results

After utilizing the calibration subroutine, the results were summarized by purpose, socioeconomic class, mode of access, presence of transfer, and transit sub-mode and compared to the revised calibration targets values from the preliminary expansion of the on board survey data. The comparisons for HBW, HBO, NHB, and total are provided below in tables 4.7 through 4.10.

The focus of this model calibration has been to ensure the model accurately reflects subtotals by socioeconomic stratification, mode of access, and transit sub-mode while approximately matching the detailed breakdowns of the individual cells grayed out in each table. At the same time, the calibration sought to maintain a model structure that does not include unreasonable sub-mode bias constants.

This model version has a much better understanding of transit customers across socioeconomic class, particularly for households with zero autos. The model predicts 98,000 zero auto transit trips while the observed total was 101,000. The other socioeconomic classes were similarly well represented in the model both in total and by trip purpose. The updates resulted in a more accurate estimation of transit usage by trip purpose. The model now estimates 142,000 transit HBW trips compared to 140,000 observed (< 2% difference). The model also predicted each of the non-work purposes to less than 2,000 difference in transit trips from the observed.

Comparisons by mode of access indicate that the model reliably demonstrates how patrons access the transit system. The total observed walk access trips was 150,000 and the model predicted 148,000. Both the observed and modeled total drive access trips were approximately 104,000. When reviewed in more detail, the model also closely predicted the mode of access by socioeconomic class and by transit sub-mode.

The full set of mode choice coefficients and constants is provided in Table 4.11 expressed as equivalent IVTT.

Table 4.7 HBW Observed Versus Estimated Mode Choice Results

OBSERVED					
HBW	**Zero Auto**	**Auto < Worker**	**Autos >= Workers Inc 1-2**	**Autos >= Workers Inc 3-4**	**Total**
Walk local no transfer	*9,942*	*3,685*	*3,074*	*465*	*17,166*
Walk local transfer	*4,661*	*1,624*	*1,009*	*139*	*7,433*
Walk MARTA no transfer	*4,090*	*2,920*	*2,694*	*1,905*	*11,609*
Walk MARTA transfer	*18,013*	*7,623*	*6,328*	*1,188*	*33,152*
Walk express no transfer	*85*	*43*	*45*	*49*	*222*
Walk express transfer	*218*	*88*	*71*	*50*	*427*
Subtotal walk local	14,603	5,309	4,083	604	24,599
Subtotal walk MARTA	22,103	10,543	9,022	3,093	44,761
Subtotal walk express	303	131	116	99	649
Subtotal Walk	**37,009**	**15,983**	**13,221**	**3,796**	**70,009**
Drive local no transfer	*2,600*	*1,871*	*1,536*	*424*	*6,431*
Drive local transfer	*624*	*333*	*291*	*44*	*1,292*
Drive MARTA no transfer	*2,258*	*8,796*	*15,430*	*15,537*	*42,021*
Drive MARTA transfer	*3,196*	*3,271*	*3,645*	*1,539*	*11,651*
Drive express no transfer	*47*	*1,067*	*2,100*	*4,788*	*8,002*
Drive express transfer	*83*	*186*	*343*	*489*	*1,101*
Subtotal drive local	3,224	2,204	1,827	468	7,723
Subtotal drive MARTA	5,454	12,067	19,075	17,076	53,672
Subtotal drive express	130	1,253	2,443	5,277	9,103
Subtotal Drive	**8,808**	**15,524**	**23,345**	**22,821**	**70,498**
Total local	**17,827**	**7,513**	**5,910**	**1,072**	**32,322**
Total MARTA	**27,557**	**22,610**	**28,097**	**20,169**	**98,433**
Total express	**433**	**1,384**	**2,559**	**5,376**	**9,752**
Total	**45,817**	**31,507**	**36,566**	**26,617**	**140,507**

ESTIMATED					
HBW	**Zero Auto**	**Auto < Worker**	**Autos >= Workers Inc 1-2**	**Autos >= Workers Inc 3-4**	**Total**
Walk local no transfer	*6,669*	*3,724*	*2,860*	*1,042*	*14,295*
Walk local transfer	*4,888*	*1,889*	*1,185*	*347*	*8,309*
Walk MARTA no transfer	*3,455*	*1,897*	*2,153*	*642*	*8,147*
Walk MARTA transfer	*19,212*	*7,848*	*6,784*	*1,446*	*35,290*
Walk express no transfer	*185*	*148*	*113*	*42*	*488*
Walk express transfer	*1,735*	*562*	*268*	*61*	*2,626*
Subtotal walk local	11,557	5,613	4,045	1,389	22,604
Subtotal walk MARTA	22,667	9,745	8,937	2,088	43,437
Subtotal walk express	1,920	710	381	103	3,114
Subtotal Walk	**36,144**	**16,068**	**13,363**	**3,580**	**69,155**
Drive local no transfer	*1,000*	*1,596*	*1,275*	*1,407*	*5,278*
Drive local transfer	*291*	*414*	*273*	*386*	*1,364*
Drive MARTA no transfer	*4,485*	*8,818*	*16,617*	*14,855*	*44,775*
Drive MARTA transfer	*1,297*	*2,318*	*2,783*	*3,095*	*9,493*
Drive express no transfer	*1,024*	*1,865*	*3,396*	*3,557*	*9,842*
Drive express transfer	*560*	*635*	*547*	*766*	*2,508*
Subtotal drive local	1,291	2,010	1,548	1,793	6,642
Subtotal drive MARTA	5,782	11,136	19,400	17,950	54,268
Subtotal drive express	1,584	2,500	3,943	4,323	12,350
Subtotal Drive	**8,657**	**15,646**	**24,891**	**24,066**	**73,260**
Total local	**12,848**	**7,623**	**5,593**	**3,182**	**29,246**
Total MARTA	**28,449**	**20,881**	**28,337**	**20,038**	**97,705**
Total express	**3,504**	**3,210**	**4,324**	**4,426**	**15,464**
Total	**44,801**	**31,714**	**38,254**	**27,646**	**142,415**

ESTIMATED - OBSERVED					
HBW	**Zero Auto**	**Auto < Worker**	**Autos >= Workers Inc 1-2**	**Autos >= Workers Inc 3-4**	**Total**
Walk local no transfer	*-3,273*	*39*	*-214*	*577*	*-2,871*
Walk local transfer	*227*	*265*	*176*	*208*	*876*
Walk MARTA no transfer	*-635*	*-1,023*	*-541*	*-1,263*	*-3,462*
Walk MARTA transfer	*1,199*	*225*	*456*	*258*	*2,138*
Walk express no transfer	*100*	*105*	*68*	*-7*	*266*
Walk express transfer	*1,517*	*474*	*197*	*11*	*2,199*
Subtotal walk local	-3,046	304	-38	785	-1,995
Subtotal walk MARTA	564	-798	-85	-1,005	-1,324
Subtotal walk express	1,617	579	265	4	2,465
Subtotal Walk	**-865**	**85**	**142**	**-216**	**-854**
Drive local no transfer	*-1,600*	*-275*	*-261*	*983*	*-1,153*
Drive local transfer	*-333*	*81*	*-18*	*342*	*72*
Drive MARTA no transfer	*2,227*	*22*	*1,187*	*-682*	*2,754*
Drive MARTA transfer	*-1,899*	*-953*	*-862*	*1,556*	*-2,158*
Drive express no transfer	*977*	*798*	*1,296*	*-1,231*	*1,840*
Drive express transfer	*477*	*449*	*204*	*277*	*1,407*
Subtotal drive local	-1,933	-194	-279	1,325	-1,081
Subtotal drive MARTA	328	-931	325	874	596
Subtotal drive express	1,454	1,247	1,500	-954	3,247
Subtotal Drive	**-530**	**-530**	**-530**	**-530**	**-530**
Total local	**-4,979**	**110**	**-317**	**2,110**	**-3,076**
Total MARTA	**892**	**-1,729**	**240**	**-131**	**-728**
Total express	**3,071**	**1,826**	**1,765**	**-950**	**5,712**
Total	**-1,016**	**207**	**1,688**	**1,029**	**1,908**

Table 4.8 HBO Observed Versus Estimated Mode Choice Results

OBSERVED					
HBO	**Zero Auto**	**Auto < Worker**	**Autos >= Workers Inc 1-2**	**Autos >= Workers Inc 3-4**	**Total**
Walk local no transfer	*13,868*	*2,759*	*3,380*	*290*	*20,297*
Walk local transfer	*4,361*	*959*	*1,392*	*108*	*6,820*
Walk MARTA no transfer	*2,961*	*926*	*1,446*	*791*	*6,124*
Walk MARTA transfer	*14,609*	*3,853*	*5,563*	*726*	*24,751*
Walk express no transfer	*0*	*13*	*0*	*0*	*13*
Walk express transfer	*45*	*24*	*26*	*0*	*95*
Subtotal walk local	18,229	3,718	4,772	398	27,117
Subtotal walk MARTA	17,570	4,779	7,009	1,517	30,875
Subtotal walk express	45	37	26	0	108
Subtotal Walk	**35,844**	**8,534**	**11,807**	**1,915**	**58,100**
Drive local no transfer	*3,190*	*1,038*	*1,672*	*121*	*6,021*
Drive local transfer	*785*	*309*	*507*	*59*	*1,660*
Drive MARTA no transfer	*1,517*	*2,999*	*5,261*	*3,377*	*13,154*
Drive MARTA transfer	*2,480*	*1,577*	*2,091*	*381*	*6,529*
Drive express no transfer	*30*	*54*	*54*	*101*	*239*
Drive express transfer	*24*	*30*	*20*	*10*	*84*
Subtotal drive local	3,975	1,347	2,179	180	7,681
Subtotal drive MARTA	3,997	4,576	7,352	3,758	19,683
Subtotal drive express	54	84	74	111	323
Subtotal Drive	**8,026**	**6,007**	**9,605**	**4,049**	**27,687**
Total local	**22,204**	**5,065**	**6,951**	**578**	**34,798**
Total MARTA	**21,567**	**9,355**	**14,361**	**5,275**	**50,558**
Total express	**99**	**121**	**100**	**111**	**431**
Total	**43,870**	**14,541**	**21,412**	**5,964**	**85,787**

ESTIMATED					
HBO	**Zero Auto**	**Auto < Worker**	**Autos >= Workers Inc 1-2**	**Autos >= Workers Inc 3-4**	**Total**
Walk local no transfer	*12,445*	*4,316*	*4,990*	*995*	*22,746*
Walk local transfer	*4,826*	*905*	*1,263*	*202*	*7,196*
Walk MARTA no transfer	*3,156*	*1,164*	*1,907*	*296*	*6,523*
Walk MARTA transfer	*13,994*	*2,396*	*4,411*	*454*	*21,255*
Walk express no transfer	*96*	*59*	*49*	*21*	*225*
Walk express transfer	*204*	*26*	*38*	*7*	*275*
Subtotal walk local	17,271	5,221	6,253	1,197	29,942
Subtotal walk MARTA	17,150	3,560	6,318	750	27,778
Subtotal walk express	300	85	87	28	500
Subtotal Walk	**34,721**	**8,866**	**12,658**	**1,975**	**58,220**
Drive local no transfer	*2,072*	*1,308*	*1,822*	*737*	*5,939*
Drive local transfer	*837*	*243*	*359*	*166*	*1,605*
Drive MARTA no transfer	*3,181*	*2,724*	*5,491*	*1,897*	*13,293*
Drive MARTA transfer	*1,781*	*928*	*1,560*	*491*	*4,760*
Drive express no transfer	*124*	*113*	*149*	*115*	*501*
Drive express transfer	*23*	*4*	*14*	*3*	*44*
Subtotal drive local	2,909	1,551	2,181	903	7,544
Subtotal drive MARTA	4,962	3,652	7,051	2,388	18,053
Subtotal drive express	147	117	163	118	545
Subtotal Drive	**8,018**	**5,320**	**9,395**	**3,409**	**26,142**
Total local	**20,180**	**6,772**	**8,434**	**2,100**	**37,486**
Total MARTA	**22,112**	**7,212**	**13,369**	**3,138**	**45,831**
Total express	**447**	**202**	**250**	**146**	**1,045**
Total	**42,739**	**14,186**	**22,053**	**5,384**	**84,362**

ESTIMATED - OBSERVED					
HBO	**Zero Auto**	**Auto < Worker**	**Autos >= Workers Inc 1-2**	**Autos >= Workers Inc 3-4**	**Total**
Walk local no transfer	*-1,423*	*1,557*	*1,610*	*705*	*2,449*
Walk local transfer	*465*	*-54*	*-129*	*94*	*376*
Walk MARTA no transfer	*195*	*238*	*461*	*-495*	*399*
Walk MARTA transfer	*-615*	*-1,457*	*-1,152*	*-272*	*-3,496*
Walk express no transfer	*96*	*46*	*49*	*21*	*212*
Walk express transfer	*159*	*2*	*12*	*7*	*180*
Subtotal walk local	-958	1,503	1,481	799	2,825
Subtotal walk MARTA	-420	-1,219	-691	-767	-3,097
Subtotal walk express	255	48	61	28	392
Subtotal Walk	**-1,123**	**332**	**851**	**60**	**120**
Drive local no transfer	*-1,118*	*270*	*150*	*616*	*-82*
Drive local transfer	*52*	*-66*	*-148*	*107*	*-55*
Drive MARTA no transfer	*1,664*	*-275*	*230*	*-1,480*	*139*
Drive MARTA transfer	*-699*	*-649*	*-531*	*110*	*-1,769*
Drive express no transfer	*94*	*59*	*95*	*14*	*262*
Drive express transfer	*-1*	*-26*	*-6*	*-7*	*-40*
Subtotal drive local	-1,066	204	2	723	-137
Subtotal drive MARTA	965	-924	-301	-1,370	-1,630
Subtotal drive express	93	33	89	7	222
Subtotal Drive	**-530**	**-530**	**-530**	**-530**	**-530**
Total local	**-2,024**	**1,707**	**1,483**	**1,522**	**2,688**
Total MARTA	**545**	**-2,143**	**-992**	**-2,137**	**-4,727**
Total express	**348**	**81**	**150**	**35**	**614**
Total	**-1,131**	**-355**	**641**	**-580**	**-1,425**

Table 4.9 NHB Observed Versus Estimated Mode Choice Results

OBSERVED					
NHB	Zero Auto	Auto < Worker	Autos >= Workers Inc 1-2	Autos >= Workers Inc 3-4	Total
Walk local no transfer	*2,658*	*900*	*825*	*124*	*4,507*
Walk local transfer	*699*	*278*	*276*	*27*	*1,280*
Walk MARTA no transfer	*2,581*	*1,500*	*2,137*	*3,599*	*9,817*
Walk MARTA transfer	*3,486*	*1,192*	*1,379*	*317*	*6,374*
Walk express no transfer	*0*	*17*	*0*	*10*	*27*
Walk express transfer	*19*	*16*	*11*	*4*	*50*
Subtotal walk local	3,357	1,178	1,101	151	5,787
Subtotal walk MARTA	6,067	2,692	3,516	3,916	16,191
Subtotal walk express	19	33	11	14	77
Subtotal Walk	**9,443**	**3,903**	**4,628**	**4,081**	**22,055**
Drive local no transfer	*538*	*376*	*338*	*39*	*1,291*
Drive local transfer	*138*	*57*	*93*	*24*	*312*
Drive MARTA no transfer	*623*	*647*	*818*	*790*	*2,878*
Drive MARTA transfer	*588*	*260*	*343*	*90*	*1,281*
Drive express no transfer	*10*	*9*	*21*	*12*	*52*
Drive express transfer	*0*	*4*	*0*	*4*	*8*
Subtotal drive local	676	433	431	63	1,603
Subtotal drive MARTA	1,211	907	1,161	880	4,159
Subtotal drive express	10	13	21	16	60
Subtotal Drive	**1,897**	**1,353**	**1,613**	**959**	**5,822**
Total local	**4,033**	**1,611**	**1,532**	**214**	**7,390**
Total MARTA	**7,278**	**3,599**	**4,677**	**4,796**	**20,350**
Total express	**29**	**46**	**32**	**30**	**137**
Total	**11,340**	**5,256**	**6,241**	**5,040**	**27,877**

ESTIMATED					
NHB	Zero Auto	Auto < Worker	Autos >= Workers Inc 1-2	Autos >= Workers Inc 3-4	Total
Walk local no transfer	*1,669*	*968*	*1,271*	*1,192*	*5,100*
Walk local transfer	*836*	*274*	*281*	*231*	*1,622*
Walk MARTA no transfer	*2,049*	*967*	*1,598*	*1,423*	*6,037*
Walk MARTA transfer	*4,427*	*1,390*	*1,344*	*1,052*	*8,213*
Walk express no transfer	*30*	*36*	*38*	*59*	*163*
Walk express transfer	*55*	*29*	*23*	*31*	*138*
Subtotal walk local	2,505	1,242	1,552	1,423	6,722
Subtotal walk MARTA	6,476	2,357	2,942	2,475	14,250
Subtotal walk express	85	65	61	90	301
Subtotal Walk	**9,066**	**3,664**	**4,555**	**3,988**	**21,273**
Drive local no transfer	*379*	*228*	*254*	*152*	*1,013*
Drive local transfer	*111*	*25*	*35*	*26*	*197*
Drive MARTA no transfer	*926*	*603*	*942*	*500*	*2,971*
Drive MARTA transfer	*97*	*56*	*62*	*29*	*244*
Drive express no transfer	*13*	*24*	*21*	*25*	*83*
Drive express transfer	*0*	*0*	*0*	*0*	*0*
Subtotal drive local	490	253	289	178	1,210
Subtotal drive MARTA	1,023	659	1,004	529	3,215
Subtotal drive express	13	24	21	25	83
Subtotal Drive	**1,526**	**936**	**1,314**	**732**	**4,508**
Total local	**2,995**	**1,495**	**1,841**	**1,601**	**7,932**
Total MARTA	**7,499**	**3,016**	**3,946**	**3,004**	**17,465**
Total express	**98**	**89**	**82**	**115**	**384**
Total	**10,592**	**4,600**	**5,869**	**4,720**	**25,781**

ESTIMATED - OBSERVED					
NHB	Zero Auto	Auto < Worker	Autos >= Workers Inc 1-2	Autos >= Workers Inc 3-4	Total
Walk local no transfer	*-989*	*68*	*446*	*1,068*	*593*
Walk local transfer	*137*	*-4*	*5*	*204*	*342*
Walk MARTA no transfer	*-532*	*-533*	*-539*	*-2,176*	*-3,780*
Walk MARTA transfer	*941*	*198*	*-35*	*735*	*1,839*
Walk express no transfer	*30*	*19*	*38*	*49*	*136*
Walk express transfer	*36*	*13*	*12*	*27*	*88*
Subtotal walk local	-852	64	451	1,272	935
Subtotal walk MARTA	409	-335	-574	-1,441	-1,941
Subtotal walk express	66	32	50	76	224
Subtotal Walk	**-377**	**-239**	**-73**	**-93**	**-782**
Drive local no transfer	*-159*	*-148*	*-84*	*113*	*-278*
Drive local transfer	*-27*	*-32*	*-58*	*2*	*-115*
Drive MARTA no transfer	*303*	*-44*	*124*	*-290*	*93*
Drive MARTA transfer	*-491*	*-204*	*-281*	*-61*	*-1,037*
Drive express no transfer	*3*	*15*	*0*	*13*	*31*
Drive express transfer	*0*	*-4*	*0*	*-4*	*-8*
Subtotal drive local	-186	-180	-142	115	-393
Subtotal drive MARTA	-188	-248	-157	-351	-944
Subtotal drive express	3	11	0	9	23
Subtotal Drive	**-530**	**-530**	**-530**	**-530**	**-530**
Total local	**-1,038**	**-116**	**309**	**1,387**	**542**
Total MARTA	**221**	**-583**	**-731**	**-1,792**	**-2,885**
Total express	**69**	**43**	**50**	**85**	**247**
Total	**-748**	**-656**	**-372**	**-320**	**-2,096**

Table 4.10 Total Observed Versus Estimated Mode Choice Results

OBSERVED					
TOTAL	**Zero Auto**	**Auto < Worker**	**Autos >= Workers Inc 1-2**	**Autos >= Workers Inc 3-4**	**Total**
Walk local no transfer	*26,468*	*7,344*	*7,279*	*879*	*41,970*
Walk local transfer	*9,721*	*2,861*	*2,677*	*274*	*15,533*
Walk MARTA no transfer	*9,632*	*5,346*	*6,277*	*6,295*	*27,550*
Walk MARTA transfer	*36,108*	*12,668*	*13,270*	*2,231*	*64,277*
Walk express no transfer	*85*	*73*	*45*	*59*	*262*
Walk express transfer	*282*	*128*	*108*	*54*	*572*
Subtotal walk local	36,189	10,205	9,956	1,153	57,503
Subtotal walk MARTA	45,740	18,014	19,547	8,526	91,827
Subtotal walk express	367	201	153	113	834
Subtotal Walk	**82,296**	**28,420**	**29,656**	**9,792**	**150,164**
Drive local no transfer	*6,328*	*3,285*	*3,546*	*584*	*13,743*
Drive local transfer	*1,547*	*699*	*891*	*127*	*3,264*
Drive MARTA no transfer	*4,398*	*12,442*	*21,509*	*19,704*	*58,053*
Drive MARTA transfer	*6,264*	*5,108*	*6,079*	*2,010*	*19,461*
Drive express no transfer	*87*	*1,130*	*2,175*	*4,901*	*8,293*
Drive express transfer	*107*	*220*	*363*	*503*	*1,193*
Subtotal drive local	7,875	3,984	4,437	711	17,007
Subtotal drive MARTA	10,662	17,550	27,588	21,714	77,514
Subtotal drive express	194	1,350	2,538	5,404	9,486
Subtotal Drive	**18,731**	**22,884**	**34,563**	**27,829**	**104,007**
Total local	**44,064**	**14,189**	**14,393**	**1,864**	**74,510**
Total MARTA	**56,402**	**35,564**	**47,135**	**30,240**	**169,341**
Total express	**561**	**1,551**	**2,691**	**5,517**	**10,320**
Total	**101,027**	**51,304**	**64,219**	**37,621**	**254,171**

ESTIMATED					
TOTAL	**Zero Auto**	**Auto < Worker**	**Autos >= Workers Inc 1-2**	**Autos >= Workers Inc 3-4**	**Total**
Walk local no transfer	*20,783*	*9,008*	*9,121*	*3,229*	*42,141*
Walk local transfer	*10,550*	*3,068*	*2,729*	*780*	*17,127*
Walk MARTA no transfer	*8,660*	*4,028*	*5,658*	*2,361*	*20,707*
Walk MARTA transfer	*37,633*	*11,634*	*12,539*	*2,952*	*64,758*
Walk express no transfer	*311*	*243*	*200*	*122*	*876*
Walk express transfer	*1,994*	*617*	*329*	*99*	*3,039*
Subtotal walk local	31,333	12,076	11,850	4,009	59,268
Subtotal walk MARTA	46,293	15,662	18,197	5,313	85,465
Subtotal walk express	2,305	860	529	221	3,915
Subtotal Walk	**79,931**	**28,598**	**30,576**	**9,543**	**148,648**
Drive local no transfer	*3,451*	*3,132*	*3,351*	*2,296*	*12,230*
Drive local transfer	*1,239*	*682*	*667*	*578*	*3,166*
Drive MARTA no transfer	*8,592*	*12,145*	*23,050*	*17,252*	*61,039*
Drive MARTA transfer	*3,175*	*3,302*	*4,405*	*3,615*	*14,497*
Drive express no transfer	*1,161*	*2,002*	*3,566*	*3,697*	*10,426*
Drive express transfer	*583*	*639*	*561*	*769*	*2,552*
Subtotal drive local	4,690	3,814	4,018	2,874	15,396
Subtotal drive MARTA	11,767	15,447	27,455	20,867	75,536
Subtotal drive express	1,744	2,641	4,127	4,466	12,978
Subtotal Drive	**18,201**	**21,902**	**35,600**	**28,207**	**103,910**
Total local	**36,023**	**15,890**	**15,868**	**6,883**	**74,664**
Total MARTA	**58,060**	**31,109**	**45,652**	**26,180**	**161,001**
Total express	**4,049**	**3,501**	**4,656**	**4,687**	**16,893**
Total	**98,132**	**50,500**	**66,176**	**37,750**	**252,558**

ESTIMATED - OBSERVED					
TOTAL	**Zero Auto**	**Auto < Worker**	**Autos >= Workers Inc 1-2**	**Autos >= Workers Inc 3-4**	**Total**
Walk local no transfer	*-5,685*	*1,664*	*1,842*	*2,350*	*171*
Walk local transfer	*829*	*207*	*52*	*506*	*1,594*
Walk MARTA no transfer	*-972*	*-1,318*	*-619*	*-3,934*	*-6,843*
Walk MARTA transfer	*1,525*	*-1,034*	*-731*	*721*	*481*
Walk express no transfer	*226*	*170*	*155*	*63*	*614*
Walk express transfer	*1,712*	*489*	*221*	*45*	*2,467*
Subtotal walk local	-4,856	1,871	1,894	2,856	1,765
Subtotal walk MARTA	553	-2,352	-1,350	-3,213	-6,362
Subtotal walk express	1,938	659	376	108	3,081
Subtotal Walk	**-2,365**	**178**	**920**	**-249**	**-1,516**
Drive local no transfer	*-2,877*	*-153*	*-195*	*1,712*	*-1,513*
Drive local transfer	*-308*	*-17*	*-224*	*451*	*-98*
Drive MARTA no transfer	*4,194*	*-297*	*1,541*	*-2,452*	*2,986*
Drive MARTA transfer	*-3,089*	*-1,806*	*-1,674*	*1,605*	*-4,964*
Drive express no transfer	*1,074*	*872*	*1,391*	*-1,204*	*2,133*
Drive express transfer	*476*	*419*	*198*	*266*	*1,359*
Subtotal drive local	-3,185	-170	-419	2,163	-1,611
Subtotal drive MARTA	1,105	-2,103	-133	-847	-1,978
Subtotal drive express	1,550	1,291	1,589	-938	3,492
Subtotal Drive	**-530**	**-982**	**1,037**	**378**	**-97**
Total local	**-8,041**	**1,701**	**1,475**	**5,019**	**154**
Total MARTA	**1,658**	**-4,455**	**-1,483**	**-4,060**	**-8,340**
Total express	**3,488**	**1,950**	**1,965**	**-830**	**6,573**
Total	**-2,895**	**-804**	**1,957**	**129**	**-1,613**

Table 4.11: Mode Choice Model Parameters (Equivalent IVTT)

General Coefficients	**HBW**					**HBO**					**NHB**				
IVTT Coefficient	-0.0250					-0.0177					-0.0200				
Walk access time (vs. IVTT)	2					2					2				
Drive access time (vs. IVTT)	2					2					2				
First Wait <7 (vs. IVTT)	2.5					2.5					2.5				
First Wait >7 (vs. IVTT)	1					2.5					1				
Transfer Time (vs. IVTT)	2					2					2				
Transfer for Walk Access (min IVTT)	5					5					5				
Transfer for Drive Access (min IVTT)	10					10					10				
CBD Constant (min IVTT)	-10					-28.3					-25				
Drive Access CBD Add-On Constant (min IVTT)	-30					-10.0					-10				
SE-Based Coefficients	**Zero Car**	**Cars <Workers**	**Cars >=workers, low income**	**Cars >=workers, high income**		**Zero Car**	**Cars <Workers**	**Cars >=workers, low income**	**Cars >=workers, high income**		**Zero Car**	**Cars <Workers**	**Cars >=workers, low income**	**Cars >=workers, high income**	
Cost ($/hr)	1.60	7.39	5.14	16.13		0.53	2.43	1.69	5.30		0.80	3.69	2.56	8.05	
Transit constant (min IVTT)	-209	-56	17	74		-429	0	55	181		-222	32	103	158	
Drive to transit constant (min IVTT)	88	52	47	25		85	42	48	27		90	72	73	87	
Park and ride constant (min IVTT)	-11	-14	-14	-5		-16	-19	-19	-9		-16	-19	-19	-9	
Shared ride constant (min IVTT)	-24	-9	79	79		-136	-19	12	5		-85	-21	23	24	
Shared ride 3 constant (min IVTT)	1	7	11	9		21	21	16	12		18	17	12	9	
Shared ride 4 constant (min IVTT)	9	14	32	29		35	24	19	13		27	20	16	11	
Sub-Mode Constants	**Local**	**Express**	**BRT**	**MARTA**	**Commuter Rail**	**Local**	**Express**	**BRT**	**MARTA**	**Commuter Rail**	**Local**	**Express**	**BRT**	**MARTA**	**Commuter Rail**
Walk access trips w/o transfer	0	-5	-10.5	-14	-14	0	-9	-16	-19	-19	0	-9	-16	-19	-19
Walk access trips w transfer (min IVTT)	0	-5	-10.5	-14	-14	0	-9	-16	-19	-19	0	-9	-16	-19	-19
Drive access trips w/o transfer	0	-5	-10.5	-14	-14	0	-9	-16	-19	-19	0	-9	-16	-19	-19
Drive access trips w transfer (min IVTT)	0	-5	-10.5	-14	-14	0	-9	-16	-19	-19	0	-9	-16	-19	-19

4.3.4 Application Results

This section discusses the results of applying the three modal choice models and comparing these results with the observed data. The estimated transit trips, including the estimated air passenger trips, were assigned to the transit network and the daily boardings on the MARTA rail system were determined. The estimated and observed MARTA rail daily boardings are shown in Table 4.12. The total estimated boardings are within one percent of the actual boardings.

A couple of measures used to determine the quality of a highway assignment are maximum desirable deviation curves and link scatter plots. A similar approach was used for the MARTA rail station boardings to get an idea of how these measures compare on the transit side. Figure 4.4 shows a scatter plot of observed rail station boardings versus modeled. With the exception of a few outliers, the modeled boardings generally fall in line with the observed boardings. Figure 4.5 shows a scatter plot of the regional bus boardings. Again, the modeled boardings generally follow the observed boardings.

Table 4.12
Observed and Estimated Daily Weekday Boardings on MARTA Stations

MARTA Station	Model	Observed	% Diff
Five Points	16,600	20,900	-20.6%
TOTAL	**16,600**	**20,900**	**-20.6%**
EAST LINE			
Georgia State	3,300	2,700	22.2%
MLK Jr. Memorial	3,200	1,700	88.2%
InmanPark	5,000	2,300	117.4%
CandlerPark	3,400	1,000	240.0%
EastLake	1,700	1,000	70.0%
Decatur	2,700	2,500	8.0%
Avondale	3,600	4,900	-26.5%
Kensington	6,200	7,600	-18.4%
IndianCreek	4,700	5,700	-17.5%
TOTAL	**33,800**	**29,400**	**15.0%**
WEST LINE			
Omni	1,800	2,800	-35.7%
VineCity	1,200	1,000	20.0%
Ashby	4,900	1,600	206.3%
Westlake	1,300	2,200	-40.9%
Holmes	6,800	7,100	-4.2%
Bankhead	1,800	2,000	-10.0%
TOTAL	**17,800**	**16,700**	**6.6%**
NORTHEAST LINE			
Lenox	2,600	5,000	-48.0%
Brookhaven	2,100	3,300	-36.4%
Chamblee	2,900	3,500	-17.1%
Doraville	5,600	5,300	5.7%
TOTAL	**13,200**	**17,100**	**-22.8%**

MARTA Station	Model	Actual	% Diff
NORTH LINE			
Buckhead	3,400	1,900	78.9%
MedicalCtr	2,500	2,100	19.0%
Dunwoody	2,600	4,200	-38.1%
SandySprings	2,000	1,900	5.3%
NorthSprings	4,300	4,300	0.0%
TOTAL	**14,800**	**14,400**	**2.8%**
NORTH TRUNK LINE			
PeachtreeCtr	6,500	6,800	-4.4%
CivicCtr	3,500	1,700	105.9%
NorthAve	4,400	4,500	-2.2%
Midtown	7,200	3,400	111.8%
ArtsCtr	7,600	8,300	-8.4%
Lindbergh	9,400	8,000	17.5%
TOTAL	**38,600**	**32,700**	**18.0%**
SOUTH LINE			
Garnett	2,700	1,800	50.0%
WestEnd	5,200	6,300	-17.5%
OaklandCity	7,300	3,200	128.1%
FtMcPherson	6,400	4,900	30.6%
EastPoint	3,100	4,000	-22.5%
CollegePark	9,000	8,300	8.4%
Airport	10,300	10,700	-3.7%
TOTAL	**44,000**	**39,200**	**12.2%**
GRAND TOTAL	**178,800**	**170,400**	**4.9%**

Figure 4.4
MARTA Rail Station Entries Observed vs. Estimated Trend Line

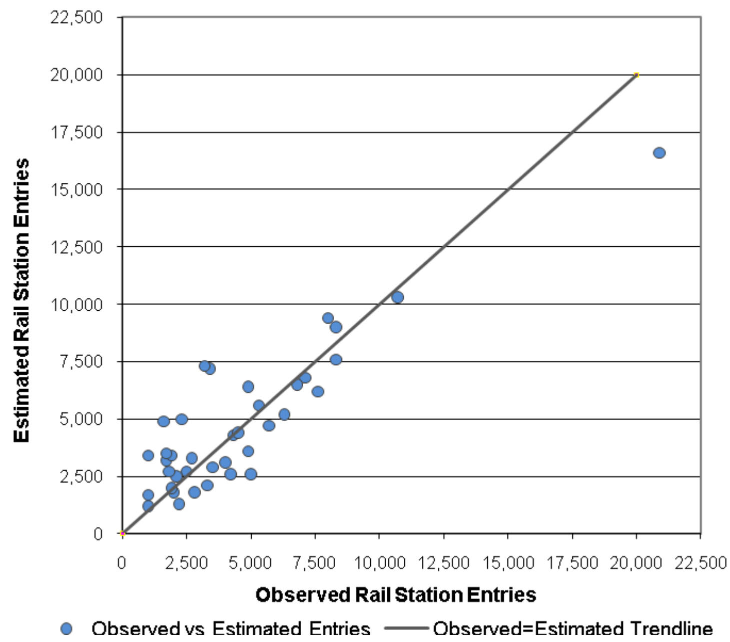
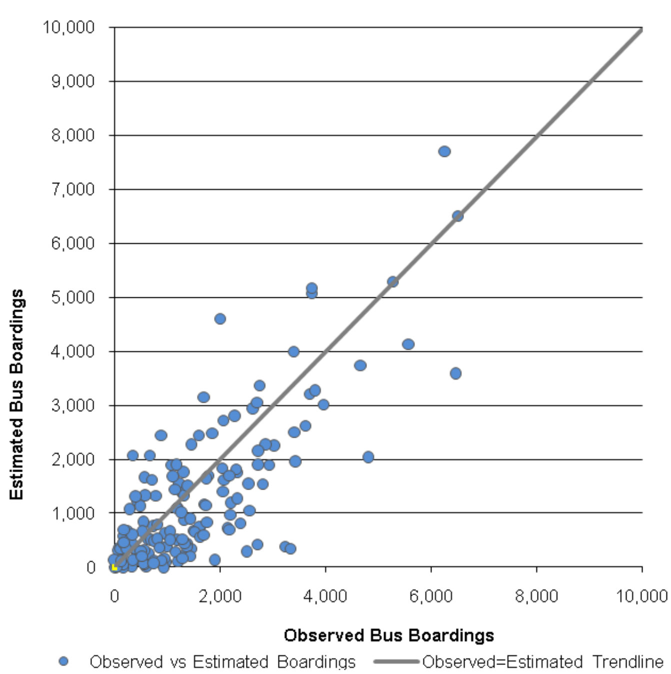


Figure 4.5
Regional Bus Boardings Observed vs. Estimated Trend Line



4.2 Estimating the Percent Walk

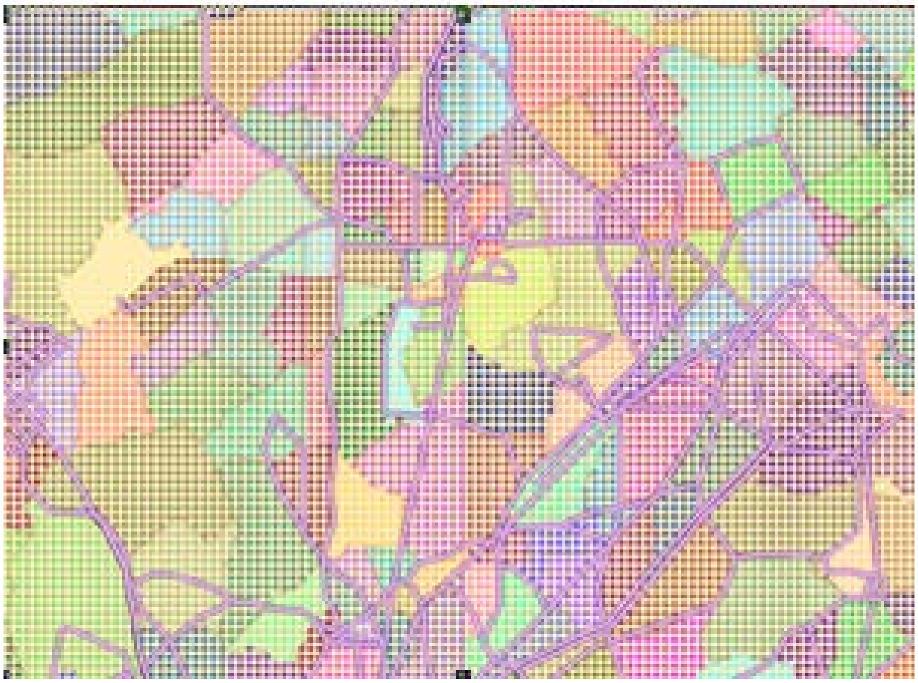
The ARC travel demand model applies TP+ procedures to estimate the percentage of each Traffic Analysis Zone (TAZ) that is walk accessible to transit. The following is a summary of the steps in this estimation process:

- ARC TAZ ID numbers are attached to a grid cell database covering the modeled area. Grid cells are 1/8-mile apart and each is assigned to one TAZ.
- Determine which grid cells are within 1.0-miles (airline distance) of a transit stop.
- For each TAZ, calculate walk accessibility percent by dividing the number of transit accessible grid cells by the total grid cells.
- Calculate average zonal walk time for each TAZ using the grid cells that are within walking distance of transit.

4.2.1 Step One: Grid Cell Database

The geographic area that is included in the ARC model was divided into 1/8-mile X 1/8-mile grid cells, which are represented by the centroid points of each cell. Each grid cell centroid was assigned the ARC TAZ ID that it is within. Figure 4.6 displays a sample of the grid cell centroids, color coded by the TAZ ID.

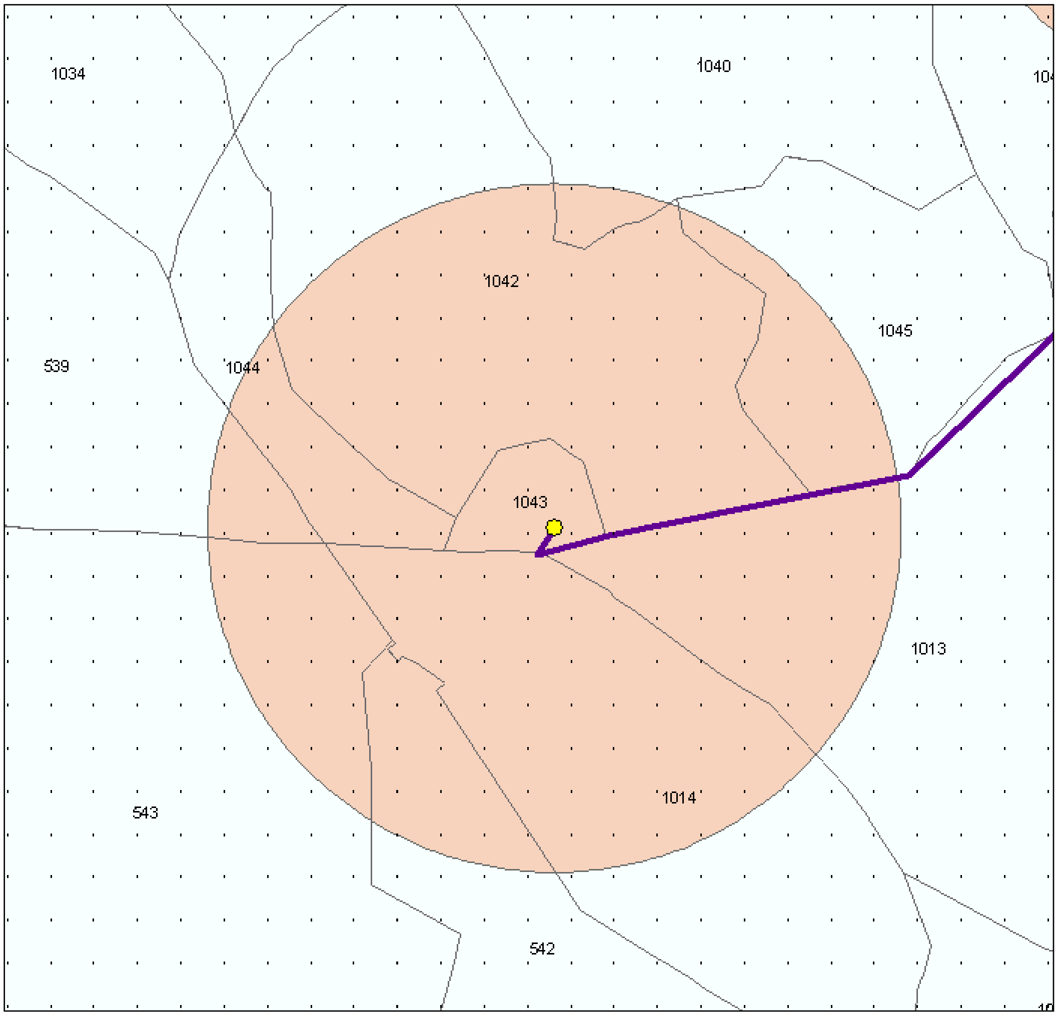
Figure 4.6
ARC 1/8-mile Grid Cell Centroids



4.2.2 Step Two: Determine Grid Cells Within 1.0-miles of Transit

To determine the percentage of each TAZ that has walk access to transit, each grid cell is evaluated to determine if it is within 1.0-miles of a transit stop. Stops that are coded in the transit route files are used for this process, except local bus routes where all nodes along routes are assumed to be stops. Figure 4.7 displays 1.0-mile transit stop buffers relative to an ARC TAZ boundary layer and its associated grid centroids. The grid points that are within the stop buffers are flagged as being walk accessible to transit.

Figure 4.7
Grid Cell Centroids and 1.0-Mile Stop Buffers



4.2.3 Step Three: Calculate Percent Walk Access

The percentage of a TAZ that has walk access to transit is calculated by dividing the number of transit accessible grid cells within a TAZ by the total number of grid cells within that TAZ. This is done for each TAZ.

% Walk Access to Transit = # Grids within 1.0-mile transit stop buffer / # Grids within the TAZ

Using TAZ 1042 from Figure 4.7, the % Walk Access would be calculated as follows:

 # Grids within TAZ 1042 within1.0-miles of Transit = 63

 # Grids within TAZ 1042 = 91

% Walk Access = 63 / 91 = 69.2%

5. External/Internal Model

The External Travel Model forecasts trips for passenger cars and commercial vehicles. The model produces trips for internal-external and external-external movements. ARC has spent considerable time and effort maintaining and updating the External Travel Models. The initial External and Truck Models were developed based on a survey conducted by ARC in 1994-1995 at 30 sites on the periphery of the 13-county travel model study area. The roads were selected so that the survey sites captured nearly all of the high volume facilities where traffic enters and exits the region. Based on the data the following External Travel submodels were developed for 57 locations.

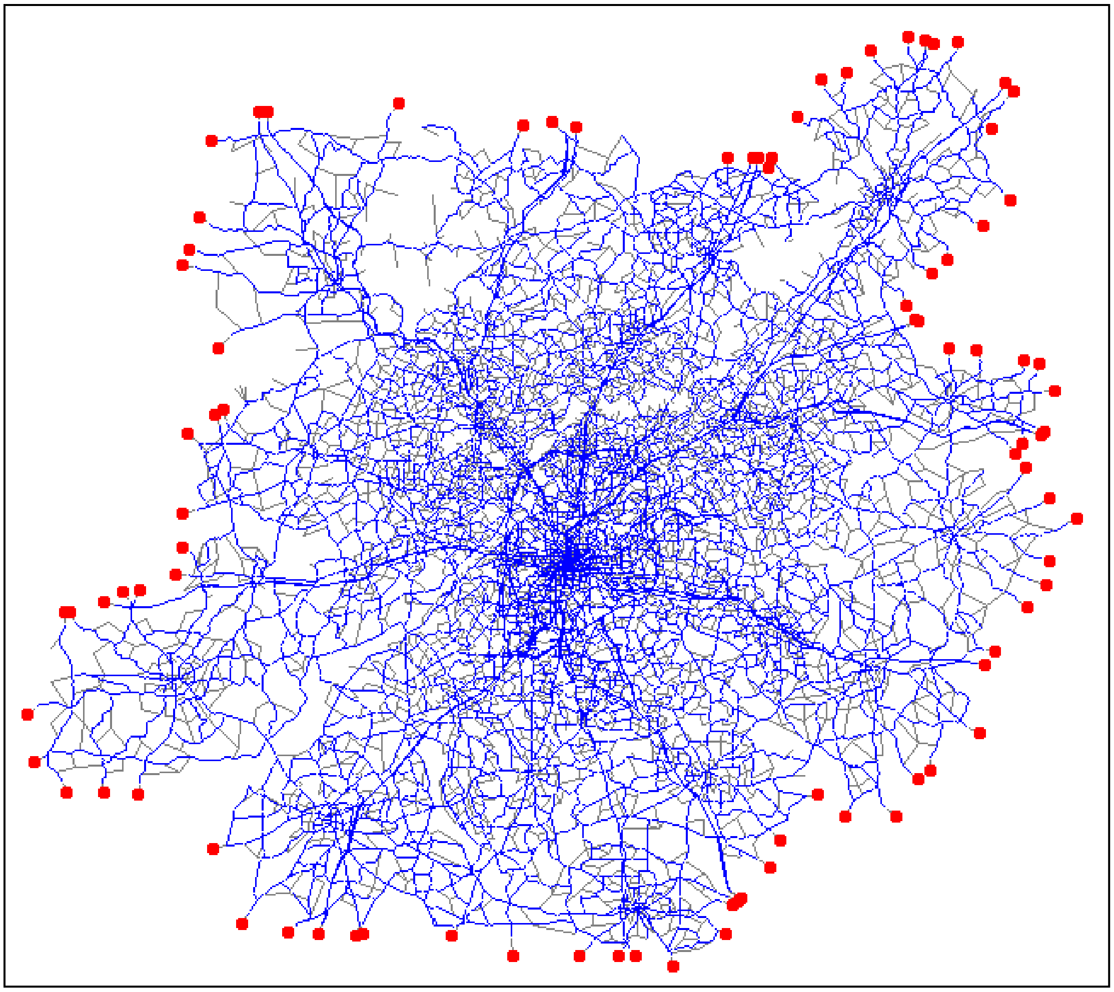
- External-External Passenger Car
- Internal-External
- Work Trips by Interstate Facilities
- Non-Work Trips by Interstate Facilities
- Work Trips by Non-Interstate Facilities
- Non-Work Trips by Non-Interstate Facilities

A new survey has not yet been conducted with the expansion of the modeling area to 20 counties due to time and budget constraints. With no survey available at the new model boundaries, the models developed from the previous survey were used. There were several modifications made to the external models. The most significant involves the new commercial vehicle/truck model. This model replaces the old truck model. Also, the previous external model used a 1995 trip table generated from the survey for creation of the external to external (E-E) trips. It was required to create a new E-E base trip table. This was done using the 1995 trip table to establish patterns between facility types and movements through the region. Finally, a slightly different methodology was used for future year external station forecast volumes.

Figure 5.0 identifies the locations of the external stations. A detailed description of the survey results and initial model design is contained in the Transportation Solutions for A New Century – Appendix IV-V Model Documentation for the 2025 RTP, March 2000.

There have been several refinements to the External Models in the past two years. The Models were converted from TRANPLAN to the TP+ platform. The models were also updated based on 2000 traffic counts and 2000 census population estimates for the internal traffic analysis zones and for surrounding counties. The number of externals is now 91, numbered 2028-2118.

Figure 5.0
External Stations



5.1. Update of the External Travel Model

With the expansion to 20 counties, the methodology for external station forecasting was slightly modified. Previously, a trip table was used to determine each external station's travel shed. The travel shed was defined by the zones which had a significant number of trips to and from that external station. Since no trip table was available at the new external stations, the method for creating the travel sheds had to be updated. Now, the travel shed for an external station consists of all zones within 45 minutes of the station. These sheds are built within the model script.

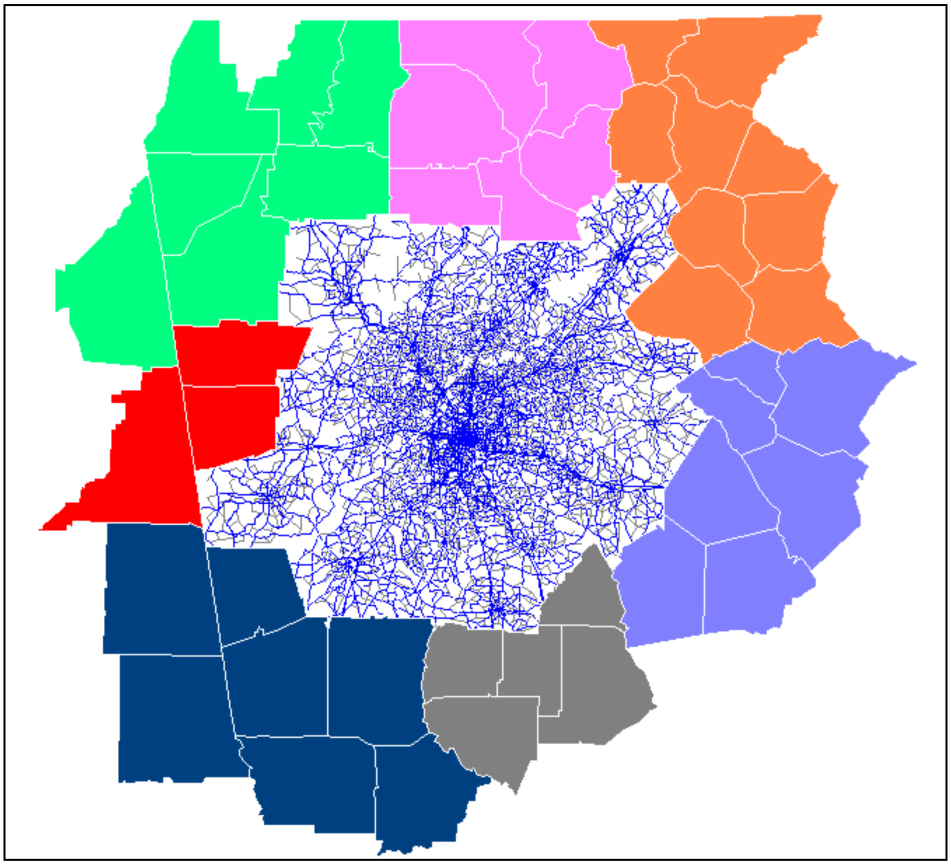
The procedure to forecast future year traffic at the external stations was also slightly modified. Counties outside the model area are still used to help determine the amount of traffic growth at the stations. However, these external counties were grouped together to form large areas that influence a number of external stations. Figure 5.1 shows these external groupings.

Previously, the formula for the external station forecast only included population as a variable in calculating future traffic. The employment of the internal zones has now been added to that formula since it is also a contributing factor to external traffic. The formula used for the forecast is below:

- Fut_int = future year internal zone travel shed population & employment
- Fut_ext = future year external county travel shed population
- Bas_int = year 2000 internal zone travel shed population & employment
- Bas_ext = year 2000 external county travel shed population

Forecast volume = 2000 AADT * (1.2)*(fut_int + fut_ext) / (bas_int + bas_ext)

Figure 5.1
External County Groupings



The external model also requires the percentage splits by vehicle type and purpose (work, non-work, etc.). In the previous model, these values were obtained from the survey data. With no new survey, these values were extracted from a few different sources. As part of the new truck and commercial vehicle model, manual vehicle classification counts were taken at 13 external stations. Since most of the external volume travels on interstates or arterials, these were the types of roads chosen for the manual counts at the external stations. In some cases, GDOT ATR counts were available and were used to split external traffic. For the remaining stations, averages were calculated based on facility types. Figure 5.2 shows a list of the external stations with the vehicle type percentage splits.

Figure 5.2
External Stations

Station #	Name	2000 AADT	% PSGR CAR	% COMVEH	% MEDTRK	% HVYTRK
2028	SR 113	9,229	81.6%	9.6%	6.1%	2.7%
2029	Chulio Rd/Euharlee	1,122	79.7%	10.8%	8.8%	0.7%
2030	SR 20/US 411	18,660	74.5%	10.3%	7.2%	8.0%
2031	SR 293	1,400	74.9%	12.6%	11.1%	1.4%
2032	SR 140	9,420	81.6%	9.6%	6.1%	2.7%
2033	US 41	8,160	84.6%	11.4%	2.9%	1.1%
2034	I-75	53,129	64.5%	4.1%	4.2%	27.2%
2035	US 411	5,343	81.6%	9.6%	6.1%	2.7%
2036	SR 108	2,844	77.0%	10.4%	9.0%	3.6%
2037	I-575 (SR 5)	19,529	84.7%	6.4%	5.0%	3.9%
2038	SR 372	4,438	81.2%	10.2%	7.9%	0.7%
2039	SR 9	8,543	81.7%	11.0%	6.6%	0.7%
2040	Hopewell Rd	1,643	74.9%	12.6%	11.2%	1.3%
2041	SR 400/US 19	24,000	88.4%	5.6%	3.6%	2.3%
2042	Blue Ridge Overlook	1,660	74.9%	12.6%	11.1%	1.3%
2043	SR 53	7,752	92.9%	3.7%	2.6%	0.9%
2044	SR 136	2,914	79.3%	10.5%	7.7%	2.5%
2045	SR 60	10,160	79.3%	8.8%	7.0%	4.9%
2046	SR 115	1,800	74.9%	12.6%	11.2%	1.3%
2047	SR 52	2,158	74.9%	12.6%	11.1%	1.4%
2048	SR 284	1,340	74.9%	12.6%	11.2%	1.3%
2049	US 129	8,740	81.6%	9.6%	6.1%	2.7%
2050	SR 254	864	74.9%	12.6%	11.1%	1.4%
2051	Skitt Mtn Rd	1,714	74.9%	12.6%	11.1%	1.3%
2052	US 23/SR 365	11,120	82.0%	6.3%	5.1%	6.6%
2053	SR 51/Cornelia Hwy	2,176	74.9%	12.6%	11.1%	1.4%
2054	SR 51	6,600	81.6%	9.6%	6.1%	2.7%
2055	SR 52	925	74.9%	12.6%	11.1%	1.3%
2056	SR 82	1,120	74.9%	12.6%	11.2%	1.3%
2057	SR 11/US 129	9,440	81.6%	9.6%	6.1%	2.7%
2058	SR 60/SR 332	2,200	74.1%	10.0%	10.1%	5.8%
2059	SR 53	6,940	74.2%	10.0%	10.1%	5.8%
2060	I-85	39,468	69.7%	4.1%	4.8%	21.3%
2061	SR 124	2,429	74.9%	12.6%	11.1%	1.4%
2062	SR 53	6,280	80.9%	10.9%	6.3%	1.9%
2063	Jefferson Hwy	4,200	79.2%	10.5%	7.7%	2.6%
2064	Double Bridges Rd	1,020	74.9%	12.6%	11.3%	1.2%
2065	SR 82	1,371	78.0%	10.5%	8.5%	2.9%
2066	SR 330 (Tallassee	1,800	74.9%	12.6%	11.2%	1.3%
2067	Atlanta Hwy	7,488	81.1%	10.9%	6.8%	1.2%
2068	SR 316/US 29	17,356	85.9%	5.4%	3.6%	5.1%

Figure 5.2
External Stations (cont'd)

Station #	Name	2000 AADT	% PSGR CAR	% COMVEH	% MEDTRK	% HVYTRK
2069	Barber Creek Rd	757	75.0%	12.6%	11.1%	1.3%
2070	SR 53	3,700	79.2%	10.5%	7.7%	2.6%
2071	US 78	11,380	76.2%	9.3%	8.0%	6.5%
2072	Snows Mill Rd	940	82.9%	11.2%	5.4%	0.5%
2073	SR 186	957	74.8%	12.6%	11.2%	1.4%
2074	SR 83	2,420	74.9%	12.6%	11.1%	1.4%
2075	Monroe Hwy	500	74.9%	12.6%	11.2%	1.4%
2076	Pannell/Prospect R	638	74.9%	12.5%	11.1%	1.4%
2077	US 278	2,371	74.9%	12.6%	11.0%	1.5%
2078	I-20	23,429	73.0%	4.1%	4.9%	18.0%
2079	SR 142	3,840	79.3%	10.5%	7.7%	2.6%
2080	SR 11	2,671	79.2%	10.5%	7.7%	2.6%
2081	Henderson Mill Rd	2,218	74.9%	12.6%	11.1%	1.4%
2082	SR 212	4,300	79.3%	10.5%	7.7%	2.6%
2083	SR 36	2,667	79.3%	10.5%	7.7%	2.6%
2084	Keys Ferry Rd	1,820	92.9%	3.6%	2.6%	0.9%
2085	Old Jackson Rd	760	74.9%	12.6%	11.2%	1.3%
2086	SR 42/US 23	9,353	81.7%	9.3%	5.4%	3.6%
2087	I-75	88,300	74.4%	2.3%	4.6%	18.7%
2088	Jackson Rd	1,740	74.9%	12.6%	11.1%	1.4%
2089	SR 16	8,772	74.4%	10.6%	8.6%	6.4%
2090	SR 36	860	74.9%	12.5%	11.1%	1.4%
2091	Macon Rd	3,600	79.2%	10.5%	7.7%	2.6%
2092	US 41	14,414	83.4%	8.8%	4.1%	3.7%
2093	SR 155	13,743	83.4%	8.8%	5.2%	2.6%
2094	SR 362	7,100	81.6%	9.6%	6.1%	2.7%
2095	SR 18	1,880	92.8%	3.7%	2.6%	0.9%
2096	SR 85	5,280	91.3%	4.5%	3.2%	1.1%
2097	SR 54	1,762	92.8%	3.7%	2.6%	0.9%
2098	US 41	5,914	81.6%	9.6%	5.9%	2.9%
2099	I-85	37,604	71.4%	7.7%	4.8%	16.1%
2100	US 29	2,838	92.8%	3.7%	2.6%	0.9%
2101	Corinth Rd	1,200	74.9%	12.6%	11.1%	1.4%
2102	SR 34	5,085	75.1%	10.1%	10.6%	4.2%
2103	SR 1	4,400	79.2%	10.5%	7.5%	2.8%
2104	Stoney Pt	780	74.9%	12.6%	11.3%	1.3%
2105	SR 100	880	74.9%	12.6%	11.1%	1.4%
2106	SR 100/SR 5	3,857	79.3%	10.5%	7.7%	2.6%
2107	SR 166	5,243	81.6%	9.6%	6.1%	2.7%
2108	SR 100	2,400	74.9%	12.6%	11.2%	1.3%
2109	SR 166	1,200	74.9%	12.6%	11.1%	1.4%
2110	I-20	39,577	65.2%	2.3%	6.0%	26.5%
2111	US 27	10,100	83.4%	8.8%	5.2%	2.6%
2112	SR 1 BUS	9,083	81.6%	9.6%	5.9%	3.0%
2113	SR 78	5,871	80.3%	10.8%	7.8%	1.1%
2114	SR 113	3,015	79.3%	10.5%	7.7%	2.6%
2115	SR 120	3,386	72.3%	15.0%	8.2%	4.5%
2116	Vinson Mtn Rd	1,560	74.9%	12.6%	11.3%	1.2%
2117	SR 101	2,275	74.9%	12.6%	11.1%	1.4%
2118	US 278	10,060	87.2%	6.2%	2.8%	3.7%

Forecasts of population for the external counties were based on the 2010 projections of population by Georgia's Office of Planning Budget (OPB). Population was interpolated and extrapolated for other planning years based on current 2000 population data and the 2010 population forecasts. With the model boundary expansion, there were four external counties in Alabama. The 2000 population data came from the 2000 Census while the 2010 projections came from the US Census Bureau and Center for Business and Economic Research at the University of Alabama.

Table 5.3
Forecasted Population for the External Counties

Zone	COUNTY	Census 2000 Population	2005	2010	2015	2020	2025	2030
2119	BANKS	14,422	15,926	17,429	18,933	20,436	21,940	23,443
2120	BUTTS	19,522	23,447	27,371	31,296	35,220	39,145	43,069
2121	CHAMBERS, AL	35,567	35,961	36,355	36,749	37,143	37,537	37,931
2122	CHATTOOGA	25,470	26,977	28,483	29,990	31,496	33,003	34,509
2123	CHEROKEE, AL	24,525	26,423	28,320	30,218	32,115	34,013	35,910
2124	CLARKE	101,489	102,662	103,834	105,007	106,179	107,352	108,524
2125	CLEBURNE, AL	14,123	14,766	15,409	16,052	16,695	17,338	17,981
2126	DAWSON	15,999	20,121	24,242	28,364	32,485	36,607	40,728
2127	FANNIN	19,798	22,817	25,835	28,854	31,872	34,891	37,909
2128	FLOYD	90,565	92,727	94,889	97,051	99,213	101,375	103,537
2129	FRANKLIN	20,285	22,034	23,783	25,532	27,281	29,030	30,779
2130	GILMER	23,456	26,610	29,764	32,918	36,072	39,226	42,380
2131	GORDON	44,104	49,182	54,259	59,337	64,414	69,492	74,569
2132	GREENE	14,406	16,200	17,994	19,788	21,582	23,376	25,170
2133	HABERSHAM	35,902	40,296	44,690	49,084	53,478	57,872	62,266
2134	HARALSON	25,690	27,848	30,005	32,163	34,320	36,478	38,635
2135	HARRIS	23,695	26,671	29,647	32,623	35,599	38,575	41,551
2136	HEARD	11,012	11,770	12,527	13,285	14,042	14,800	15,557
2137	JACKSON	41,589	50,065	58,540	67,016	75,491	83,967	92,442
2138	JASPER	11,426	13,097	14,768	16,439	18,110	19,781	21,452
2139	LAMAR	15,912	17,298	18,684	20,070	21,456	22,842	24,228
2140	LUMPKIN	21,016	24,005	26,993	29,982	32,970	35,959	38,947
2141	MADISON	25,730	27,437	29,143	30,850	32,556	34,263	35,969
2142	MERIWETHER	22,534	22,867	23,199	23,532	23,864	24,197	24,529
2143	MONROE	21,757	23,200	24,642	26,085	27,527	28,970	30,412
2144	MORGAN	15,457	17,889	20,320	22,752	25,183	27,615	30,046
2145	MURRAY	36,506	40,865	45,223	49,582	53,940	58,299	62,657
2146	OCONEE	26,225	29,148	32,070	34,993	37,915	40,838	43,760
2147	OGLETHORPE	12,635	13,802	14,968	16,135	17,301	18,468	19,634
2148	PICKENS	22,983	29,263	35,542	41,822	48,101	54,381	60,660
2149	PIKE	13,688	15,663	17,637	19,612	21,586	23,561	25,535
2150	POLK	38,127	40,634	43,140	45,647	48,153	50,660	53,166
2151	PUTNAM	18,812	19,810	20,807	21,805	22,802	23,800	24,797
2152	RABUN	15,050	15,990	16,930	17,870	18,810	19,750	20,690
2153	RANDOLPH, AL	22,380	23,600	24,819	26,039	27,258	28,478	29,697
2154	STEPHENS	25,435	26,192	26,949	27,706	28,463	29,220	29,977
2155	TALBOT	6,498	7,227	7,955	8,684	9,412	10,141	10,869
2156	TOWNS	9,319	10,493	11,666	12,840	14,013	15,187	16,360
2157	TROUP	58,779	61,342	63,904	66,467	69,029	71,592	74,154
2158	UNION	17,289	19,439	21,588	23,738	25,887	28,037	30,186
2159	UPSON	27,597	28,030	28,462	28,895	29,327	29,760	30,192
2160	WALKER	61,053	64,010	66,966	69,923	72,879	75,836	78,792
2161	WHITE	19,944	24,282	28,619	32,957	37,294	41,632	45,969
2162	WHITFIELD	83,525	89,564	95,602	101,641	107,679	113,718	119,756

6. Commercial Vehicle and Truck Models

6.1. Introduction

This report documents the development of a new set of regional truck and commercial trip forecasting models for the Atlanta Regional Commission (ARC). In recent years, ARC has been updating various parts of its regional travel forecasting model. The existing truck model was developed in the mid-1990's from survey data. Light-duty commercial trips were not explicitly modelled as a separate category, but were partially covered under what the existing model calls "Light Trucks". In this report, the "existing" truck model refers to the most recent ARC model version, completed in April 2005.

As used in this report, the term "truck model" actually refers to two separate models: one for heavy trucks and one for medium trucks. As defined here, these categories represent a change from the existing model. Segmentation of these two categories is based on the Federal Highway Administration's (FHWA) "F-13" classification scheme. "Heavy" trucks are defined as vehicles with either a single or multiple trailer combination (F8 – F13 in the FHWA scheme). "Medium" trucks include buses (FHWA's F4), vehicles with two axles and six tires (F5), and single-unit vehicle with three or four axles (F6, F7). The existing model uses a category called "light trucks". That terminology is no longer used, to avoid confusion with the more commonly used definition of "light trucks": pickups, vans, minivans, and sport-utility vehicles (SUVs). This change in truck categories from the existing model's weight-based definition was necessitated by the fact that the new model is more closely tied to count data, and truck counts are maintained by classification, using the FHWA scheme. Most truck counts use automatic counting equipment, which counts axles. The FHWA classification system is illustrated in Figure 6.1.

The light truck category is now replaced, more or less, by a new category of trips: "Commercial". This refers to those trips that are mainly business-oriented and are not personal transportation, but do not involve a medium or heavy truck, as described above. Light trucks, vans, and SUVs used for personal transportation are not included here. But the Commercial category does include passenger cars, light trucks, vans, and SUVs that are used for business purposes.

This is a new category of trip that has not been commonly recognized in regional travel demand models but which is currently 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, police, fire, and rescue vehicles, 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. In fact, the extreme difficulty in identifying such trips and surveying their travel patterns has doubtless kept many planners from including these trips in the modelling process.

Simple observation of the traffic stream on any roadway will reveal the basic fact that Commercial trips represent a category of travel that is too large to ignore. Exclusion of these trips results in either underestimating traffic volumes, or (perhaps worse) implicitly incorporating their volume within some other category, most likely non-home-based personal 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.

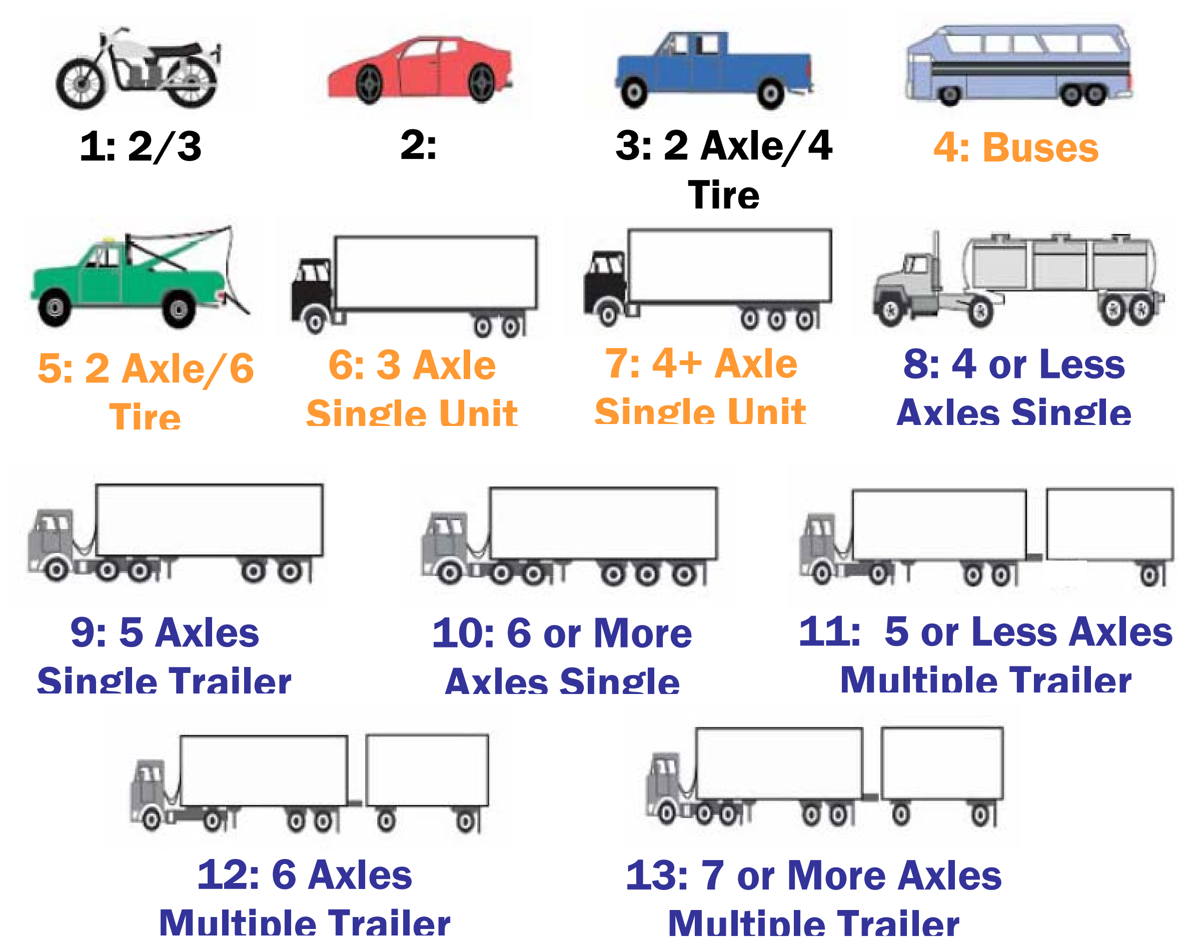
Truck and commercial vehicle modelling has taken on more importance in recent years, for a couple of reasons. Perhaps the primary reason is that trucks contribute disproportionately to the region's mobile source emission inventory, especially for NOx and particulates. The need to meet increasingly stringent regional emission budgets has caused most planning agencies to examine every possible emission source in greater detail. Another reason is an increasing emphasis on goods movement and the role of the region's transportation system in facilitating goods movement, and by implication, the economy.

Atlanta's role as a hub for goods movement throughout the southeastern U.S. makes this even more critical than in other cities.

A survey of truck travel was undertaken in the Atlanta area in 1996 and that was used to develop the existing truck model. However, that survey's coding of vehicle types was not sufficiently detailed to be used in this project. Instead, an innovative approach that addresses this problem in an indirect fashion was used. This new approach relies almost entirely on counts conducted throughout the region. The availability and relative accuracy of classification counts makes them a reliable and usable source of data for truck modelling. The new approach involves using these counts as a basis for synthesizing a truck trip table. That table is then used to "inform" the model, providing a more credible basis for adjusting the model's parameters. In addition, the method provides a systematic calibration adjustment that helps the model to achieve relatively high accuracy of assigned truck volumes on a link-by-link basis.

For Commercial travel, the same approach is used, except that classification count data is unavailable for this category of trips. Given the variety of vehicles in this group, automated count procedures have not yet been developed. Thus, these vehicles must be counted manually. The cost to perform enough counts for model development is prohibitive, so an alternate technique is used. A limited number of counts are collected and this data is used to synthesize other counts, enabling model development.

Figure 6.1
FHWA 13-Bin
Vehicle Classification



6.2. Review of the State of the Art in Truck Modelling Issues

A brief review of the state of the art in truck trip modeling was conducted. Two recent reports greatly facilitated this effort: Travel Model Improvement Program's Quick Response Freight Manual and NCHRP Synthesis 298, Truck Trip Generation Data. These reports provide an excellent overview of current practice and key issues concerning truck trip modelling.

The first issue is: what is the context of the model? There are three levels of analysis detail: 1) national or statewide analyses of tax payments, pavement condition, or general rail vs. truck movement; 2) regional analyses concerned with link volumes, emissions, and corridor studies; and 3) local studies in which traffic engineers are looking at noise, geometrics, pavement, or loading facilities. These are very different kinds of analyses, calling for different kinds of models. Most of the focus of the literature is on regional truck models, and that is the level that this report is concerned with.

One of the most important issues is the definition of just what is a ”truck”. Models based on registration data use gross vehicle weight (GVW) definitions. Models based on classification counts use the number of axles as their criterion. These two definitions are not consistent with each other and create difficulties in comparing models and results. The selection of an appropriate definition also hinges on the purpose of the truck analysis: is it mainly for motor carrier/tax policy, pavement analysis, or emissions calculation?

Another key issue is the structure of the model. So-called ”commodity-based” models attempt to analyze the flow of all goods from their source, through various transformations, and then on to the final consumer. This kind of analysis permits the explicit consideration of trade-offs among different freight modes (e.g., highway, air, rail, water). Many planners consider this the ”ultimate” in freight modelling, but it is generally considered a goal that might be attained in the future, not something that is truly practical today. The alternative is a ”vehicle-based” model, which simply estimates truck trips. This is the form taken by almost all operational truck trip models. The literature considers this to be a reasonable interim approach until such time as commodity-based models become more widely used and accepted.

The difficulty in conducting truck trip surveys is well known. One problem is that almost all regional travel models consider the basic unit of travel to be the ”trip”: a movement between an origin and a destination. For many trucks, however, the unit of travel is instead a ”tour”: a series of connected trips throughout the day. This not only complicates the survey itself, but it makes it extremely difficult to translate tour movements into the origin/destination trip approach taken by most models. An even more significant problem is simply one of participation. Trucking firms treat travel data as proprietary information and are not willing to have this information made available to the public (or their competitors). These firms are not accustomed to working with public planning agencies and often distrust or misunderstand the purpose of the surveys. Even when the trucking company is cooperative, truck drivers themselves usually view surveys as nothing more than an unwarranted and unnecessary intrusion on their workday. Thus, it should come as no surprise that reliable, usable data is rarely achieved in trucking surveys. A possible exception is that roadside intercept surveys, if conducted in a safe and efficient manner, can be very useful in obtaining data on truck trip movements that are external or completely through the region.

Those analysts lucky enough to obtain usable data on truck trips are being confronted with another obstacle: the measures of land use that are causally related to truck activity are generally not among the data items that are available at the traffic zone level, or are forecasted. As a result, in almost all cases, planners try to relate truck travel to the variables that are available. The outcome is usually a relatively crude model that relates truck trips to employment and population. The results are usually less than satisfactory, but are justified by noting that ”trucks are only 5% of all trips”. While this may be true in total, trucks do account for a higher share of traffic on the major roadways and heavy trucks also utilize a greater share of roadway capacity than their volumes indicate.

In summary, the state of the art in truck trip models is still in its infancy, but starting to improve. Substantial enhancements in these models will need to await the widespread acceptance and use of automated, non-intrusive data collection technology (perhaps GPS-based) and the development of traffic-zone-level data that is more closely related to goods movement. In recent years, more planning agencies are paying greater attention to these needs.

6.3. Factors Affecting Truck Forecasting

The above issues relate mainly to the development of a model which can adequately describe today's truck travel. Forecasting truck trips proves to be even more difficult than forecasting personal travel, for a number of reasons. Creating a model that accounts for all the factors that are likely to affect future truck travel would effectively require a crystal ball. One needs only to look at the last 10 years to understand some of these factors.

One of the most important phenomena to affect truck travel over the past two decades is the change in goods movement technology. Containerization has affected practically all aspects of goods movement, including ship, rail, and truck. Containerized freight movement now represents the majority of goods moved at all U.S. ports, for example. In a related development, trailer on flat car (TOFC) and container on flat car (COFC) have created tremendous opportunities for intermodal coordination and efficiency that did not exist until fairly recently.

Another similar development (also related to the above) is the sharp rise in freight labor productivity. Over the past 20 years, the number of truck trips per trucking industry employee has risen sharply. The nature of American industry has changed in recent years and improvements necessitated by international competition have practically revolutionized the freight industry. One example of this is just-in-time (JIT) delivery, in which industries reduce their warehousing space because they no longer stockpile materials used in production. These materials are delivered by suppliers on the day (sometimes at the hour) they are needed and they move directly from the loading dock onto the production line. JIT requires a veritable ballet of truck movements, organized and scheduled with great precision and timing. Obviously, it also increases the number of truck trips serving a manufacturing plant. This kind of operation barely existed ten years ago and now it is commonly used throughout the manufacturing sector, particularly for motor vehicle assembly.

As if recent changes in technology and productivity weren't drastic enough, the past decade has also seen major political changes that affect goods movement. The increase in the global nature of the U.S. economy, aided by actions such as the North American Free Trade Agreement (NAFTA), has had a profound effect on all forms of freight movement. One of the earliest impacts of NAFTA was a sharp increase in truck traffic across the borders with Canada and Mexico, as U.S. companies sought to improve their operations by using facilities in those countries.

Finally, the past few years have seen sharp up and down swings in the price of motor fuel. This has obviously had a major effect on the trucking industry and has provided other types of transport companies, especially railroads, with an opportunity to take market share away from trucks.

Many other external factors have been seen to strongly influence truck travel in recent years, including: deregulation, the shift in retail to "big box" stores, changes in truck weight and size limits, increased emphasis on truck safety, and more centralized warehousing and distribution.

The above commentary serves to highlight how difficult truck forecasting can be, especially in light of the limited resources typically devoted to it. Forecasting freight is certainly no less challenging (and probably more so) than forecasting personal travel. While there will doubtless continue to be changes in technology and productivity in the future, it is not feasible to incorporate them into the model or to estimate their impact at this time. This suggests a need to continually revisit and update any truck model at regular intervals.

6.4. Review of Other Truck Models

Other truck trip models from other urban areas were examined as part of this task. These include Washington, DC, Baltimore, New Orleans, Raleigh, NC, several Ohio cities, and Lehigh Valley, PA. Although these models represent a variety of different environments, a few typical practices can be identified:

- Trucks are often segmented into two groups: heavy and medium. "Medium" sometimes includes light-duty commercial vehicles, but an emerging practice is to use a separate model for commercial light trucks, vans, and automobiles.
- External trip ends have often been defined using an "off-model" procedure. An emerging practice is to estimate an external share based on the zone's distance to the cordon.
- Truck models are frequently based on very old survey data (e.g., 1960's).
- Truck generation models are relatively simple regression equations using population (or households) and employment by different types, with no constant term. The coefficient on population is smaller than that on employment.
- Zonal productions and attractions are set equal to each other.
- Special time of day or assignment procedures for trucks (e.g., to prevent trucks from using certain roadways) are rarely used.

6.5. Commercial Count Model

6.5.1 Collection of Count Data

The basic methodology of this study relies on developing a trip table from counts. The main problem is that counts of Commercial traffic are not commonly available. Worse, it is difficult to obtain such counts due to the difficulty in defining just what a Commercial vehicle is and what is a suitable manner for counting these type of vehicles.

The consultant developed a procedure that leverages the database of daily counts conducted by the Georgia Department of Transportation (GDOT). These counts were available at approximately 2,800 locations throughout the ARC 20-county modelled area for 2000.

For this project, consulting staff conducted new counts of Commercial traffic at 165 of those locations. The best way to define "Commercial" for the purposes of these counts was that a Commercial vehicle is any vehicle that displays any text, logo, or trademark, or that is transporting equipment of an obviously commercial nature. Some of those vehicles are doubtless being used for personal use at times. It is assumed that this overestimation error is equal to the underestimation error of some unmarked vehicles being used for non-personal use. This definition was coordinated with the FHWA commercial vehicle category descriptions so as to avoid duplication with the Medium and Heavy Truck categories.

The size of the sample was calculated as shown in Chapter 5 of the Travel Survey Manual, prepared by Cambridge Systematics, June 1996, for the TMIP project. The equation is:

$$N = CV^2 * z^2 / d^2$$

Where:

N = sample size
CV = coefficient of variation for the statistic of interest (mean/standard deviation)
z = z-statistic for the desired confidence level; for 95% confidence, z = 1.96
d = relative precision (error)

The statistic of interest in this survey is the percent of vehicles that are Commercial ("%COM"). From data in other areas, the CV for %COM is 0.33. In order to have a relative precision of, ±5% of the mean %COM with a confidence level of 95%, then the required sample size is 168. The final sample of 165 should be sufficient.

The counts were conducted during summer and fall of 2005, at a variety of locations throughout the ARC 20-county modelled area. Staff attempted to achieve a representative sample of links stratified by functional class group (freeway, arterial, collector) and area type (urban, suburban, rural). Table 6.1 shows the development of the stratification table for the counts. Counts were conducted for 4 hours, in the middle of the day. Prior research by others had indicated that 4-6 hours' worth of this kind of data is, in general, sufficiently representative of a typical weekday's activity, for the purpose of defining the percentage of traffic that is Commercial. A detailed description of the methodology to determine and select the number of data sites is documented in "Summary of Data Collection Methodology for Commercial Vehicle Data for the Atlanta Region, August 2005."

The ARC network for the 13 counties for year 2000 was stratified by area type and facility type. Area type was aggregated into three categories, urban, suburban and rural while the facility types were aggregated into the three categories freeways/expressways, arterials and collectors. Ramps were excluded. The number of miles by facility and area type by the number of lanes was summarized by the number of lanes. This is because the cost estimates to collect the information was determined by the number of lanes. Then the percentage of miles by each category was calculated. Then through a set of iterations, an initial sample size was determined by facility type and area type. The original goal was to collect information on 168 sites. Data was collected for 166 sites.

Table 6.1
Summarize 2000 Network by Number of Lanes by Facility & Area Type

Link Miles by Number of Lanes
Fwy/Expwy

	1	2	3	4	5	6+7	Total
Urban	143	88	91	106	147	41	616
Suburban	87	123	75	100	33	7	425
Rural	53	197	116	17	16	0	399
Total	283	408	282	223	196	48	1,440

Link Miles by Number of Lanes
Arterial

	1	2	3	4	5	6+7	Total
Urban	484	693	160	22	3	0	1,362
Suburban	1,423	826	61	1	0	0	2,311
Rural	3,915	300	7	1	0	0	4,223
Total	5,822	1,819	228	24	3	0	7,896

Link Miles by Number of Lanes
Collector

	1	2	3	4	5	6+7	Total
Urban	712	236	4	3	0	0	955
Suburban	1,203	119	2	0	0	0	1,324
Rural	1,028	37	7	0	0	0	1,072
Total	2,943	392	13	3	0	0	3,351

Link Miles by Number of Lanes
Total

	1	2	3	4	5	6+7	Total
Urban	1,339	1,017	255	131	150	41	2,933
Suburban	2,713	1,068	138	101	33	7	4,060
Rural	4,996	534	130	18	16	0	5,694
Total	9,048	2,619	523	250	199	48	12,687

Estimate Percent of Miles by Facility and Area Type

Percent of Miles
Fwy/Expwy

	1	2	3	4	5	6+7	Total
Urban	1.1%	0.7%	0.7%	0.8%	1.2%	0.3%	4.9%
Suburban	0.7%	1.0%	0.6%	0.8%	0.3%	0.1%	3.3%
Rural	0.4%	1.6%	0.9%	0.1%	0.1%	0.0%	3.1%
Total	2.2%	3.2%	2.2%	1.8%	1.5%	0.4%	11.4%

Percent of Miles

Arterial

	1	2	3	4	5	6+7	Total
Urban	3.8%	5.5%	1.3%	0.2%	0.0%	0.0%	10.7%
Suburban	11.2%	6.5%	0.5%	0.0%	0.0%	0.0%	18.2%
Rural	30.9%	2.4%	0.1%	0.0%	0.0%	0.0%	33.3%
Total	45.9%	14.3%	1.8%	0.2%	0.0%	0.0%	62.2%

Percent of Miles
Collector

	1	2	3	4	5	6+7	Total
Urban	5.6%	1.9%	0.0%	0.0%	0.0%	0.0%	7.5%
Suburban	9.5%	0.9%	0.0%	0.0%	0.0%	0.0%	10.4%
Rural	8.1%	0.3%	0.1%	0.0%	0.0%	0.0%	8.4%
Total	23.2%	3.1%	0.1%	0.0%	0.0%	0.0%	26.4%

Link Miles by Number of Lanes
Total

	1	2	3	4	5	6+7	Total
Urban	10.6%	8.0%	2.0%	1.0%	1.2%	0.3%	23.1%
Suburban	21.4%	8.4%	1.1%	0.8%	0.3%	0.1%	32.0%
Rural	39.4%	4.2%	1.0%	0.1%	0.1%	0.0%	44.9%
Total	71.3%	20.6%	4.1%	2.0%	1.6%	0.4%	100.0%

Initial Count Samples = 168

Fwy/Expwy

	1	2	3	4	5	6+7	Total
Urban	2	1	1	1	2	1	8
Suburban	1	2	1	1	0	0	6
Rural	1	3	2	0	0	0	5
Total	4	5	4	3	3	1	19

Arterial

	1	2	3	4	5	6+7	Total
Urban	6	9	2	0	0	0	18
Suburban	19	11	1	0	0	0	31
Rural	52	4	0	0	0	0	56
Total	77	24	3	0	0	0	105

Collector

	1	2	3	4	5	6+7	Total
Urban	9	3	0	0	0	0	13
Suburban	16	2	0	0	0	0	18
Rural	14	0	0	0	0	0	14

Total	39	5	0	0	0	0	44

When this process was initiated, ARC was in the process of expanding the modeling domain to 20 counties to meet federal air quality conformity standards. Since the revised model will be developed and applied at the 20 county level, a review of the 20 county GDOT network for new additional ARC counties by facility type and area type was performed. Based on this review, revisions were made to the samples. The following table shows the initial number of potential samples based on area and facility type.

Table 6.2
Summary of Initial Number of Data Samples by Area and Facility type

Initial

	Fwy/Expwy					Arterial			Collector			Total					Total
	10	8	1	4	2	6	4	2	6	4	2	10	8	6	4	2	
Urban	1	2	1	1	2	2	9	6	0	3	10	1	2	3	13	18	37
Suburban	0	1	1	2	1	1	11	19	0	2	16	0	1	2	15	36	54
Rural	0	0	2	2	1	0	4	52	0	0	14	0	0	2	6	67	75
Total	1	3	4	5	4	3	24	77	0	5	40	1	3	7	34	121	166
					17			104			45						

In order to ensure that there was a geographical representation for the 20 county area, the daily 2000 vmt by county was summarized and reviewed.

Table 6.3
Daily VMT by County for Year 2000

County	Rural	Small Urban / Urbanized	Grand Total
Barrow	1,091,492	272,557	1,364,049
Bartow	2,331,528	2,101,296	4,432,824
Carroll	2,014,480	1,159,977	3,174,457
Cherokee	2,238,929	1,834,784	4,073,713
Clayton	254,361	6,842,825	7,097,186
Cobb	1,836	17,392,199	17,394,035
Coweta	2,521,985	940,419	3,462,404
DeKalb	0	20,124,110	20,124,110
Douglas	618,516	3,353,665	3,972,181
Fayette	870,639	1,357,128	2,227,767
Forsyth	3,000,131	0	3,000,131
Fulton	633,745	30,872,667	31,506,412
Gwinnett	2,880,554	13,614,937	16,495,491
Hall	2,085,557	2,212,696	4,298,253
Henry	2,932,162	1,740,398	4,672,560
Newton	1,692,974	570,780	2,263,754
Paulding	1,690,371	0	1,690,371
Rockdale	216,196	2,116,132	2,332,328
Spalding	897,889	763,207	1,661,096

County	Rural	Small Urban / Urbanized	Grand Total
Walton	703,958	1,715,954	2,419,912
Total	28,677,303	108,985,731	137,663,034

Source: Georgia Department of Transportation

The percent of vmt by county was used as an initial guide to determine a potential number of samples for each county. The sites were then selected based on area type, facility type and number of lanes.

Table 6.4
Number of Samples by County

County	Rural	Small Urban / Urbanized	Initial	Final
Barrow	1.2	0.3	1.6	2
Bartow	2.6	2.6	5.2	6
Carroll	2.3	1.4	3.7	4
Cherokee	2.6	2.2	4.8	7
Clayton	0.3	8.4	8.6	12
Cobb	0.0	21.2	21.2	17
Coweta	2.8	1.1	4.0	5
DeKalb	0.0	24.6	24.6	20
Douglas	0.7	4.1	4.8	7
Fayette	1.0	1.7	2.7	4
Forsyth	3.4	0.0	3.4	5
Fulton	0.7	37.7	38.4	35
Gwinnett	3.2	16.6	19.9	17
Hall	2.4	2.7	5.1	5
Henry	3.3	2.1	5.4	7
Newton	1.9	0.7	2.6	3
Paulding	1.9	0.0	1.9	2
Rockdale	0.2	2.6	2.8	4
Spalding	1.0	0.9	2.0	2
Walton	0.8	2.1	1.8	2
Total	32.5	133.0	164.3	166

Although there are more arterial and collector lane miles, the freeways and expressways carry more traffic, so the number of samples were revised to account for this. The final number of samples by area and facility type are listed in Table 6.5.

Table 6.5
Summary of Final Number of Data Samples by Area and Facility type

Final

	Fwy/Expwy	Arterial	Collector	Total	Total

	10+	8	6	4	2	6	4	2	6	4	2	10	8	6	4	2	
Urban	5	2	7	0	0	3	12	4	0	5	12	5	2	10	17	16	50
Suburban	4	4	1	5	0	2	12	9	0	2	14	4	4	3	19	23	53
Rural	0	0	6	8	0	0	9	31	0	0	9	0	0	6	17	40	63
Total	9	6	14	13	0	5	33	44	0	7	35	9	6	19	53	79	166
					42			82			42						

Table 6.6 lists the data sites surveyed by county. As previously mentioned, all of the selected sites were locations where GDOT has a count station so that daily traffic numbers would be available. In addition, some sites were selected that were at the external stations for new ARC 20 county model area.

The final database resulted in 165 observations of the total Commercial (COM) traffic volume. In addition, a total vehicle count was made at the same time. This permits the calculation of a "percent Commercial" value on each link. Additional data for each link was assembled from the year 2000 coded network. This included the county, facility type, area type, number of lanes, year 2000 weekday count, and whether the road is one- or two-way. Table 6.6 shows a tab of %COM by county.

Table 6.6
Percent COM by County

County	% COM
Barrow	5.7%
Bartow	6.1%
Carroll	6.3%
Cherokee	8.8%
Clayton	6.2%
Cobb	7.0%
Coweta	7.2%
Dekalb	7.2%
Douglas	6.5%
Fayette	9.1%
Forsyth	8.3%
Fulton	7.3%
Gwinnett	7.3%
Hall	8.7%
Henry	6.7%
Newton	6.8%
Paulding	12.1%
Rockdale	10.2%
Spalding	3.0%
Walton	9.0%
Total	7.2%

The overall share of 7.2% is very similar to the overall %COM from the Baltimore (7.7%) and Washington (7.9%) surveys and slightly higher than that from the ODOT surveys (5.8%). In the outer counties, the slightly higher share may be related to a higher level of construction currently going on in those areas, and/or the lower total volume of traffic on those roads.

6.5.2 Development of Count Model

The premise of this analysis was that it should be possible to use this data 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. If a model could be developed to estimate the percent Commercial, it could then be applied to the approximately 2,800 daily count links (5,600 one-way observations). This would produce a count database that could be used in the adaptable assignment process.

Two different types of models were developed: a cross-classification model and a logit model. The cross-classification model is simply a table of the survey data, stratified by facility type group and area type group, as shown in Table 6.6.

Table 6.6
Cross-Classification Model

	Freeway	Arterial	Collector	Total
CBD	6.4%	6.9%	4.0%	6.3%
Urban	6.9%	7.3%	7.0%	7.0%
Suburban	7.8%	7.3%	9.0%	7.7%
Rural	4.8%	10.0%		6.9%
Total	6.9%	7.9%	7.8%	7.2%

The look-up table has the advantage of simplicity, but is not terribly rigorous. Based on experience in other areas, the consultant decided to test a logit model. Since the dependent variable is a fraction (0.0 to 1.0), the logit structure is well-suited for this purpose. The logit function is $p = 1/(1+e^U)$, where p is the probability to be estimated (in this case, the percent Commercial) and U is the "utility" of Commercial traffic, expressed as a linear function of the available independent variables, plus a constant term ("bias coefficient"). The model uses separate bias coefficients for each county type and for each facility type/area type combination. 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 results for the best logit model is shown in Table 6.7, with the results of the cross-classification model.

Table 6.7
Count Model Evaluation

	Model Type	
Statistic	**Cross-Classification**	**Logit**
Percent RMSE	33.4%	29.9%
R^2	0.33	0.45
Rho^2 w/r/t zero	N/A	0.5943
Rho^2 w/r/t constant	N/A	0.5775
Percent overestimated	48%	55%
Total error	0%	0%

Percent RMSE = square root of the mean squared error/sum of the observed COM volume (lower is better)

R^2 = square of the correlation coefficient, estimated vs. observed (closer to 1.0 is better)
Rho^2 w/r/t zero = fraction of base likelihood explained by model, compared to a model with zero coefficients (for logit models only) (closer to 1.0 is better)
Rho^2 w/r/t constant = fraction of base likelihood explained by model, compared to a model with only constant terms (for logit models only) (closer to 1.0 is better)
Percent overestimated = percent of cases where error > 0 (closer to 0 is better)
Total error = (estimated total COM volume/observed total COM volume) – 1 (closer to 0 is better)

As this table shows, the cross-classification model didn't do a poor job of explaining the variation in the data. But the logit model performed better, at the cost of somewhat greater complexity. The consultant believes that this is an acceptable trade-off in this particular case. The model was estimated using the Excel Solver function, so more detailed statistics are not available. Table 6.8 shows the logit model.

Table 6.8
Logit Commercial Count Model

Percent Commercial = $1/(1 + e^U)$

Where:

U = 0.1290 * ln(count) – 0.0655 * lanes + FT/AT bias + county bias

FT/AT bias = bias constant related to link facility type group and area type
county bias = bias constant related to county group

The bias coefficients are as follows:

	Area Type Group			
	CBD	Urban	Suburban	Rural
Facility Type	1	2	3	4
1	0.1770	0.0810	-0.0052	0.5626
2	*0.20*	0.3593	0.1048	-0.4918
11	*0.20*	*0.10*	0.0204	0.4811
12	*0.20*	0.1125	0.1384	0.1092
13	0.1967	0.1195	0.1606	-0.1238
14	*0.20*	-0.0595	0.0052	*-0.13*
15	*0.20*	0.2776	0.0415	-0.1460
17	0.7717	0.2890	-0.0409	*-0.15*
18	*0.75*	0.2412	0.2828	*-0.15*

Note: values shown in italics were estimated by interpolation/extrapolation, since no observed data existed for these cells.

County Group	Group Code	Coefficient
high density (DeKalb, Fulton)	1	1.2279
medium density (Clayton, Cobb, Gwinnett)	2	1.2383
low density (all others)	3	1.1674

The negative coefficient on lanes means that the wider roads have higher %COM values, a result which is consistent with the Baltimore, Washington, and Ohio models. This is somewhat counteracted by the effect of the ln(count) variable, whose positive coefficient says that higher-volume roads have lower

%COM values. Maybe in Atlanta the *volume* of COM trips is not much different between major and minor roads, thus making the %COM higher on the minor roads. The natural log of COUNT00 worked better than the count itself.

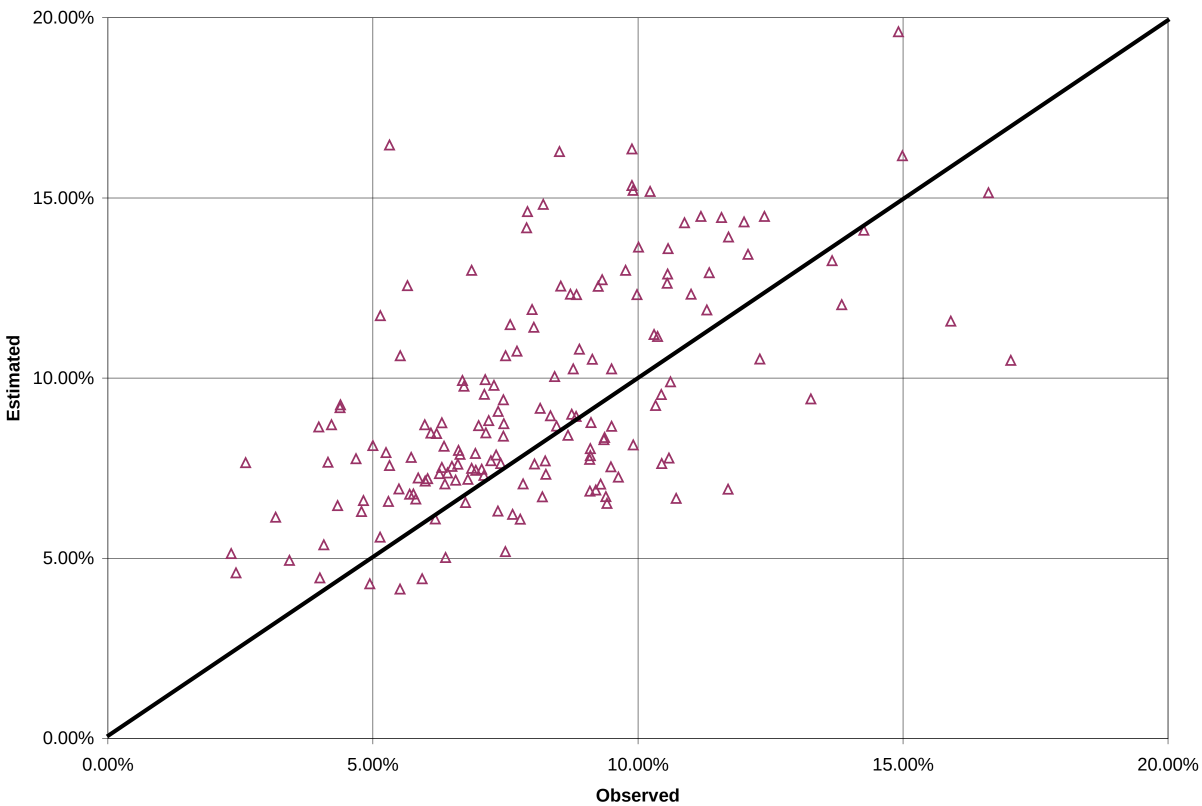
When reading these tables, keep in mind that algebraically higher values of the bias coefficient mean a lower %COM share.

A scatterplot of the estimated and observed results indicated a bias in the model. The initial logit model overestimated %COM at the low end and underestimated it at the high end. Further analysis of the data suggested that the daily count plays a stronger role than was initially assumed. So a count-based adjustment to be applied to the results of the logit model was developed. The resulting model becomes:

%COM revised = %COM (logit model) * 11.0686 / ln(count)

The resulting scatterplot, shown in Figure 6.2, looks reasonable. Although the points are not as tightly packed around the diagonal line as one might like, the points do generally have the same slope as the diagonal line. This reflects a lower bias that makes the revised model more suitable.

Figure 6.2
Scatterplot for Adjusted Logit Model



6.5.3 Application

A TP+ setup file (see Appendix A) was prepared to apply this model to the 2000 highway network. The model produced a count in the COMCNT00 field for 5,696 directional links, with a total count of 5,959,663. The range of estimates for percent Commercial by link was 4.2% - 54.7%. Once the percent Commercial is calculated, it is multiplied by the total weekday counted volume to obtain the (weekday) Commercial count.

The resulting estimated counts were reviewed and it was discovered that in a few cases, the values on adjacent links were inconsistent. In these cases, the estimated count was removed. This is necessary because inconsistent counts have the potential to disrupt the model development process.

6.6. Development of Truck Model

6.6.1 Approach

This study takes an innovative approach to the problem of estimating truck trips. The premise of this approach is that it is usually very difficult to obtain statistically valid survey data on truck movements, due to the diversity of truck travel, the difficulty of conducting the surveys, and the low survey response rates. Even when surveys have been properly conducted, as ARC did in 1996, they often have problems with the definition of vehicle types, geocoding, etc. that make them difficult to use for model calibration.

Thus, the traditional method of calibrating truck trip rates is often not workable. However, it should be possible to obtain relatively accurate counts of truck volumes by type on a number of roadway segments throughout the region. A number of researchers have addressed the problem of using count data to ”work backwards” to obtain a zone-to-zone matrix of trips. The consultant has developed a way to do this, called *adaptable assignment*, that is quick, simple, and easily understood. If the current ARC model can be revised (or replaced with a model from the literature) such that the total estimated truck trips more closely match the truck counts, then the adaptable assignment process can be applied. This will produce a new truck trip table, whose differences from the initial table can be analyzed to identify where changes to the initial model are needed. This can be done separately for medium and heavy trucks.

This same approach has recently been used to develop truck trip models in Washington, Baltimore, and several cities in Ohio. A variation of this approach was also used to forecast truck trip volumes for the new travel model for the New York metropolitan area.

6.6.2 Starting Model

An important element of this approach is to start with an estimated trip table that is ”in the ballpark”. The decision was made to start with the existing model and modify it as needed for this project. The existing ARC model’s definition of Heavy Trucks (HTK) is roughly equivalent to the new model’s definition of Heavy Trucks and Medium Trucks (MTK). So the existing ARC HTK model was used, with the coefficients split 45% to MTK and 55% to HTK, which represents the ratio of the count totals for those vehicle types.

External trips were estimated as a share of the total trip ends in each zone, with that share declining as the zone’s distance to the cordon increased. The external trip ends at the cordon stations by vehicle type were used as a control total.

Trips were distributed using off-peak highway skims with intrazonal and terminal times. F factors were borrowed from the QRFM report for I/I trips and from the MWCOG MTK External model for external trips.

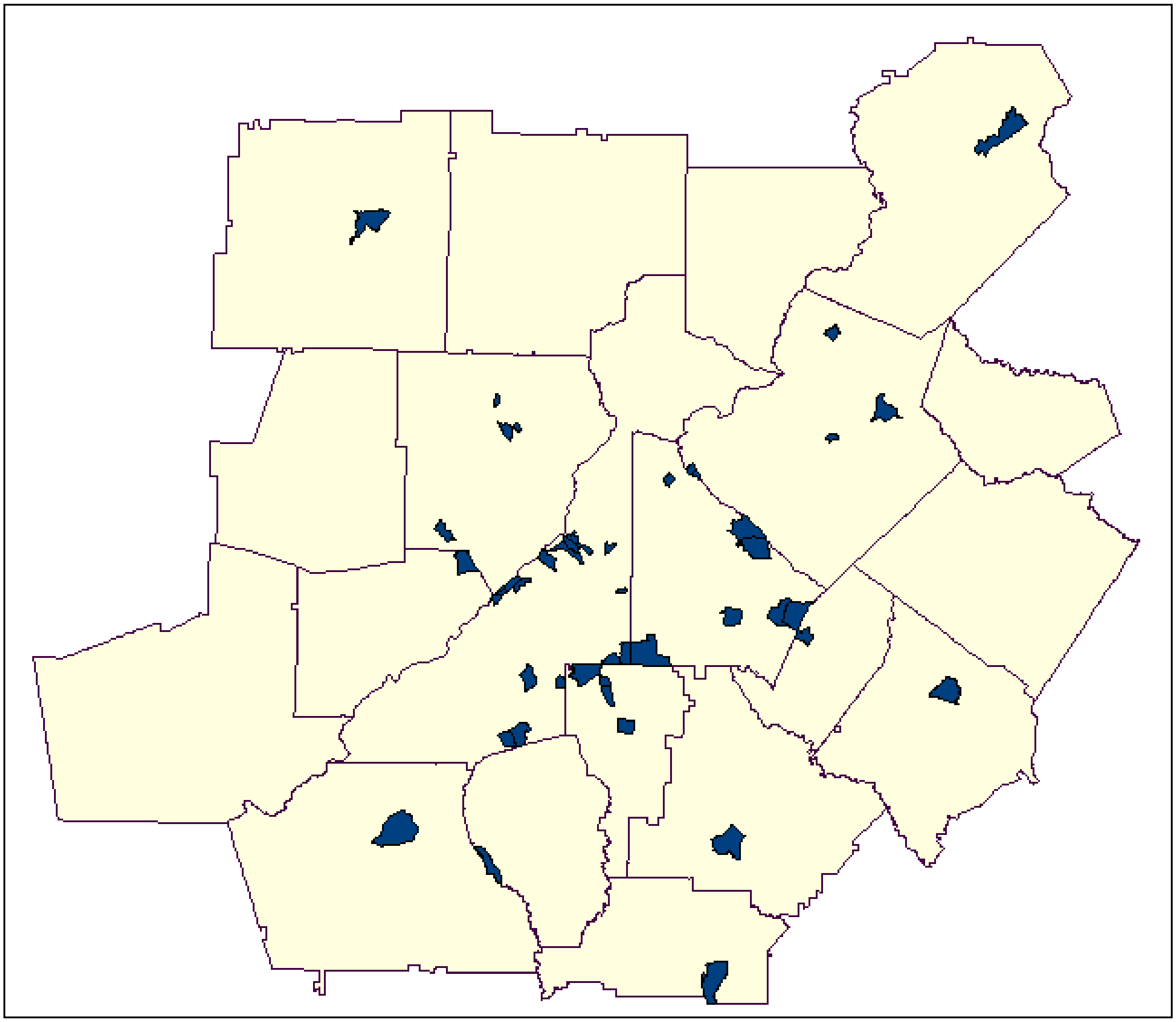
The MTK and HTK trip tables were assigned to the highway network using largely the same protocol as in the existing ARC model. The major difference was that passenger car equivalents (PCEs) were used in the volume/capacity calculation to reflect the greater influence of trucks on V/C. A PCE of 1.5 was used for MTK and 2.0 for HTK.

The resulting MTK and HTK link volumes were compared to the count data and adjustments were made to the starting model so as to better match these counts. Trip generation adjustment factors were incorporated by area type and the model was modified to reflect "truck zones".

Truck zones are areas in which there is strong reason to believe that the truck trip activity is higher than the standard trip rates would indicate. It was determined by the project team that the most important zones are few enough in number that they can be identified individually and classified in a way that allows the interim model to account for them. Although no data are available to specifically determine the increase in truck trips for such areas, a reasonable estimate can be made by those who know the region and confirmed or revised in the adaptable assignment process.

The main purpose of identifying truck zones is to highlight zones whose average truck trips per employee is likely to be higher than that of non-truck zones. This includes truck stops, warehouses, transfer terminals, and the like. ARC staff identified 46 such zones across the 20-county modelled area, as shown below.

Figure 6.3
Truck Zones



6.6.3 Trip Generation

The starting truck trip generation model is shown in Table 6.9.

As applied to ARC's new 2000 zonal data, this model estimates 280,000 daily medium truck trips and 213,000 daily heavy truck trips. Of the medium truck trips, 243,000 are I/I and 37,000 are external. Of the heavy truck trips, 167,000 are I/I and 46,000 are external. As shown in Table 6.9, the trip rates, the area type adjustments, and the truck zone factors constitute the starting model. As the area type adjustments suggest, the truck trip rate per employee is higher in the less developed areas.

Table 6.9
Starting Truck Generation Model

MTK = (0.104 * INDEMP + 0.178 * RETEMP + 0.030 * OFFEMP + 0.058 * HH) * AT factor

HTK = (0.095 * INDEMP + 0.081 * RETEMP + 0.028 * OFFEMP + 0.053 * HH) * AT factor

INDEMP is Industrial Employment (Construction, Manufacturing, TCU, Wholesale)
RETEMP is Retail Employment
OFFEMP is Office Employment (FIRE, Government, Service)
HH is Households

Factor for area type:

Area Type	MTK	HTK
1	0.50	0.50
2	0.75	0.70
3	1.00	0.75
4	1.05	0.80
5	1.10	0.90
6	1.20	1.10
7	1.30	1.30

If a zone is a truck zone, multiply HTK trips by 3.

6.6.4 External Model

The method for estimating external truck trips assumes that the generation model estimates total trip ends, both I/I and external (which includes I/X and X/I). The external share of the total trip ends is then modelled as a function of the zone's distance to the model's cordon, along the highway network. Zones that are closer to the edge of the modelled region will generally have a higher share of external trips than other zones.

In addition, the external trip ends at the internal zones that are calculated in this manner are balanced to match the total external trip ends at the external stations. In this way, the external truck trip volumes at the cordon are conserved and are assumed to be the "correct" volumes.

The proposed external share model is shown in Figure 6.4 and Table 6.10. This calculation is performed for each internal zone. This model was adapted from a similar model calibrated from survey data for Berks County, PA and Baltimore, MD and has been adapted to other areas as well.

Figure 6.4
External Model

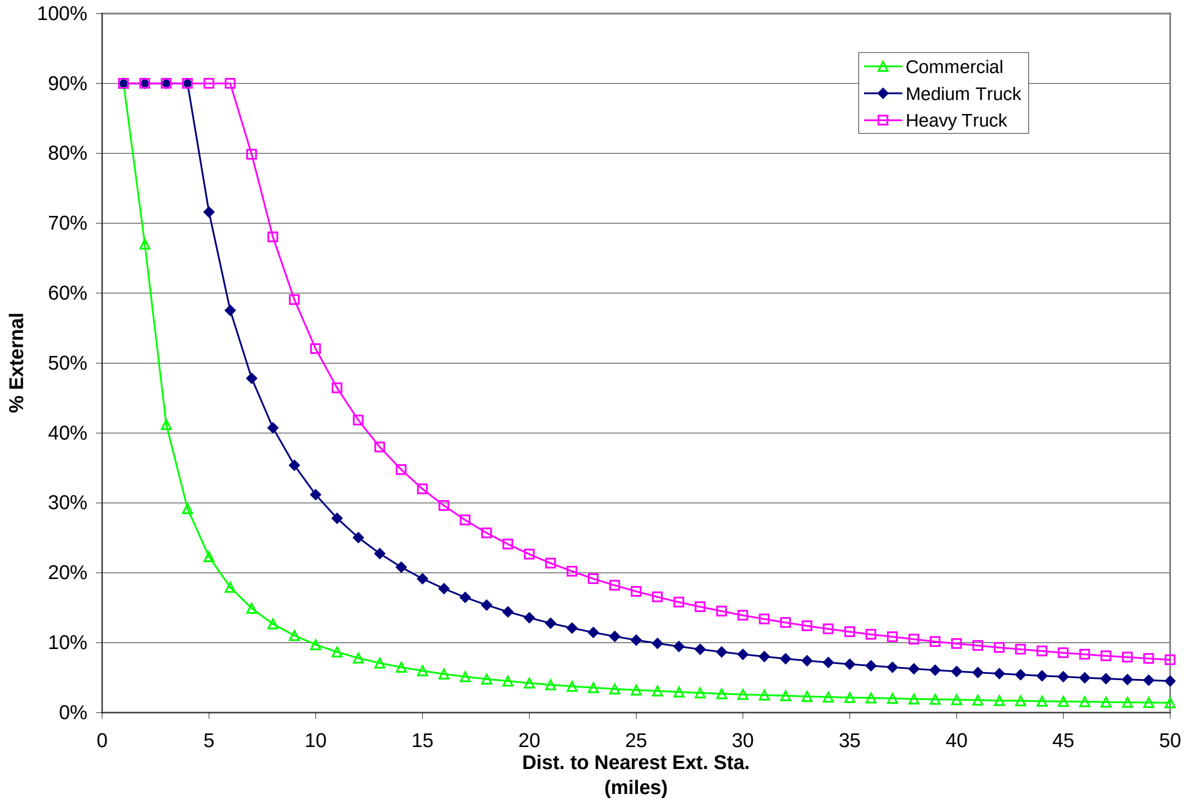


Table 6.10
External Truck Model

Percent External (MTK) = max(0.90, 4.94 * $D^{-1.2}$) Percent External (HTK) = max(0.90, 8.25 * $D^{-1.2}$) Where: D = distance to nearest external station (via highway net), miles

6.6.5 Through Trips

At the external stations, the split of truck trips by type into external vs. through was estimated. This analysis was based on 2000 total weekday volumes posted on the network and a preliminary 2000 total through trip table provided by ARC. The percentage of total through trips by station were first calculated. It is estimated that medium trucks are less likely to make through trips than the general stream of traffic, since medium trucks are typically short-haul delivery vehicles. In contrast, heavy trucks should be *more* likely to make through trips, since they are frequently long-haul carriers.

In addition, the through trip percentage (through trips/total trips at cordon) logically varies by facility type. Freeways have by far the largest through trip percentage, because they are the major routes through the region. However, local roads typically have few, if any, through trips. Based on the relationships and assumptions described above, a look-up table was developed to estimate the external trip share (= 100%

- through trip share) for each station, as shown in Table 6.11. Due to the importance of I-75 and I-85 to truck traffic, separate percentages were used for those roadways.

Table 6.11
External Shares by Road Type

Facility Type	MTK External %	HTK External %	COM External %	Description
1	80%	70%	93%	Interstate/freeway
11	90%	75%	95%	Expressway
12	90%	75%	95%	Principal arterial I
13	95%	80%	98%	Principal arterial II
15	100%	100%	100%	Minor arterial I
17	100%	100%	100%	Major Collector
18	100%	100%	100%	Minor Collector
I-75	80%	50%	93%	
I-85	85%	60%	93%	

Applying this table to the truck trip volumes at the external stations produces the estimated 2000 truck external trip ends at the external stations, as shown in Table 6.12.

Table 6.12
2000 External Truck/Commercial Trip Ends

Station	Name	FTYPE	2000 AADT	Pass Car	Com Veh	Med Trk	Hvy Trk	Com Ext	Med Ext	Hvy Ext	Com EE	Med EE	Hvy EE
2028	SR 113	15	9,229	7,529	885	565	248	885	565	248	0	0	0
2029	Chulio Rd/Euharlee Rd	15	1,122	895	121	99	8	121	99	8	0	0	0
2030	SR 20/US 411	12	18,660	13,902	1,922	1,347	1,489	1,827	1,213	1,117	95	134	372
2031	SR 293	15	1,400	1,049	176	156	19	176	156	19	0	0	0
2032	SR 140	15	9,420	7,685	903	576	253	903	576	253	0	0	0
2033	US 41	15	8,160	6,907	930	234	90	930	234	90	0	0	0
2034	I-75	1	53,129	34,428	2,178	2,224	14,517	2,030	1,778	7,264	148	446	7253
2035	US 411	15	5,343	4,359	512	327	144	512	327	144	0	0	0
2036	SR 108	15	2,844	2,191	295	256	102	295	256	102	0	0	0
2037	I-575 (SR 5)	1	19,529	16,541	1,250	974	764	1,164	779	535	86	195	229
2038	SR 372	15	4,438	3,604	453	350	31	453	350	31	0	0	0
2039	SR 9	15	8,543	6,984	941	560	60	941	560	60	0	0	0
2040	Hopewell Rd	15	1,643	1,231	207	184	22	207	184	22	0	0	0
2041	SR 400/US 19	13	24,000	21,228	1,344	866	564	1,317	823	451	27	43	113
2042	Blue Ridge Overlook	15	1,660	1,244	209	185	22	209	185	22	0	0	0
2043	SR 53	15	7,752	7,200	283	201	68	283	201	68	0	0	0
2044	SR 136	15	2,914	2,309	305	225	74	305	225	74	0	0	0
2045	SR 60	13	10,160	8,047	894	708	501	876	673	401	18	35	100
2046	SR 115	15	1,800	1,349	227	201	24	227	201	24	0	0	0
2047	SR 52	15	2,158	1,617	272	240	30	272	240	30	0	0	0
2048	SR 284	15	1,340	1,004	169	150	18	169	150	18	0	0	0
2049	US 129	15	8,740	7,130	838	534	235	838	534	235	0	0	0
2050	SR 254	15	864	648	109	96	12	109	96	12	0	0	0
2051	Skitt Mtn Rd	15	1,714	1,285	216	191	23	216	191	23	0	0	0
2052	US 23/SR 365	11	11,120	9,130	701	566	736	666	509	552	35	57	184
2053	SR 51/Cornelia Hwy	15	2,176	1,631	274	242	30	274	242	30	0	0	0
2054	SR 51	15	6,600	5,385	633	404	177	633	404	177	0	0	0
2055	SR 52	15	925	693	117	103	12	117	103	12	0	0	0
2056	SR 82	15	1,120	839	141	125	15	141	125	15	0	0	0
2057	SR 11/US 129	15	9,440	7,702	905	578	253	905	578	253	0	0	0
2058	SR 60/SR 332	15	2,200	1,632	220	222	127	220	222	127	0	0	0
2059	SR 53	15	6,940	5,149	694	698	400	694	698	400	0	0	0

Station	Name	FTYPE	2000 AADT	Pass Car	Com Veh	Med Trk	Hvy Trk	Com Ext	Med Ext	Hvy Ext	Com EE	Med EE	Hvy EE
2060	I-85	1	39,468	27,549	1,618	1,914	8,426	1,505	1,627	5,057	113	287	3369
2061	SR 124	15	2,429	1,821	306	271	33	306	271	33	0	0	0
2062	SR 53	15	6,280	5,078	684	398	119	684	398	119	0	0	0
2063	Jefferson Hwy	15	4,200	3,327	440	324	108	440	324	108	0	0	0
2064	Double Bridges Rd	18	1,020	764	129	115	12	129	115	12	0	0	0
2065	SR 82	15	1,371	1,070	144	117	40	144	117	40	0	0	0
2066	SR 330 (Tallassee Rd)	15	1,800	1,349	227	201	24	227	201	24	0	0	0
2067	Atlanta Hwy	15	7,488	6,072	818	511	87	818	511	87	0	0	0
2068	SR 316/US 29	11	17,356	14,926	937	620	890	889	558	668	48	62	222
2069	Barber Creek Rd	15	757	567	95	84	10	95	84	10	0	0	0
2070	SR 53	15	3,700	2,931	388	285	95	388	285	95	0	0	0
2071	US 78	13	11,380	8,672	1,058	912	738	1,037	866	590	21	46	148
2072	Snows Mill Rd	15	940	780	105	51	5	105	51	5	0	0	0
2073	SR 186	15	957	717	121	107	13	121	107	13	0	0	0
2074	SR 83	15	2,420	1,814	305	270	33	305	270	33	0	0	0
2075	Monroe Hwy	15	500	375	63	56	7	63	56	7	0	0	0
2076	Pannell/Prospect Rd	15	638	478	80	71	9	80	71	9	0	0	0
2077	US 278	13	2,371	1,777	299	261	36	293	248	29	6	13	7
2078	I-20	1	23,429	17,103	961	1,149	4,216	893	917	2,951	68	232	1265
2079	SR 142	15	3,840	3,042	402	296	98	402	296	98	0	0	0
2080	SR 11	15	2,671	2,116	280	206	69	280	206	69	0	0	0
2081	Henderson Mill Rd	15	2,218	1,662	279	247	30	279	247	30	0	0	0
2082	SR 212	15	4,300	3,407	450	332	110	450	332	110	0	0	0
2083	SR 36	15	2,667	2,113	279	206	68	279	206	68	0	0	0
2084	Keys Ferry Rd	15	1,820	1,692	66	47	16	66	47	16	0	0	0
2085	Old Jackson Rd	15	760	570	96	85	10	96	85	10	0	0	0
2086	SR 42/US 23	13	9,353	7,641	870	502	340	853	477	272	17	25	68
2087	I-75	1	88,300	65,695	2,031	4,028	16,546	1,888	3,218	8,267	143	810	8279
2088	Jackson Rd	15	1,740	1,304	219	193	24	219	193	24	0	0	0
2089	SR 16	15	8,772	6,526	930	756	559	930	756	559	0	0	0
2090	SR 36	15	860	645	108	96	12	108	96	12	0	0	0
2091	Macon Rd	15	3,600	2,852	377	278	92	377	278	92	0	0	0
2092	US 41	11	14,414	12,021	1,274	591	530	1,208	532	398	66	59	132
2093	SR 155	13	13,743	11,462	1,215	717	351	1,190	681	281	25	36	70
2094	SR 362	15	7,100	5,793	681	435	191	681	435	191	0	0	0

Station	Name	FTYPE	2000 AADT	Pass Car	Com Veh	Med Trk	Hvy Trk	Com Ext	Med Ext	Hvy Ext	Com EE	Med EE	Hvy EE
2095	SR 18	15	1,880	1,745	69	49	17	69	49	17	0	0	0
2096	SR 85	15	5,280	4,821	235	167	56	235	167	56	0	0	0
2097	SR 54	15	1,762	1,636	65	46	15	65	46	15	0	0	0
2098	US 41	13	5,914	4,825	567	347	174	556	330	139	11	17	35
2099	I-85	1	37,604	26,849	2,896	1,795	6,064	2,693	1,528	3,637	203	267	2427
2100	US 29	15	2,838	2,636	104	74	25	104	74	25	0	0	0
2101	Corinth Rd	15	1,200	899	151	133	17	151	133	17	0	0	0
2102	SR 34	15	5,085	3,819	514	540	211	514	540	211	0	0	0
2103	SR 1	13	4,400	3,486	461	329	123	452	313	98	9	16	25
2104	Stoney Pt	17	780	585	98	88	10	98	88	10	0	0	0
2105	SR 100	15	880	660	111	98	12	111	98	12	0	0	0
2106	SR 100/SR 5	15	3,857	3,056	404	297	99	404	297	99	0	0	0
2107	SR 166	15	5,243	4,277	503	320	141	503	320	141	0	0	0
2108	SR 100	15	2,400	1,799	302	268	32	302	268	32	0	0	0
2109	SR 166	15	1,200	899	151	133	17	151	133	17	0	0	0
2110	I-20	1	39,577	25,804	910	2,384	10,479	846	1,911	7,336	64	473	3143
2111	US 27	12	10,100	8,423	893	528	258	848	475	194	45	53	64
2112	SR 1 BUS	12	9,083	7,410	871	532	268	827	479	201	44	53	67
2113	SR 78	15	5,871	4,714	635	456	67	635	456	67	0	0	0
2114	SR 113	15	3,015	2,389	316	232	77	316	232	77	0	0	0
2115	SR 120	15	3,386	2,448	508	278	152	508	278	152	0	0	0
2116	Vinson Mtn Rd	17	1,560	1,169	197	176	19	197	176	19	0	0	0
2117	SR 101	15	2,275	1,705	287	253	31	287	253	31	0	0	0
2118	US 278	11	10,060	8,778	622	286	375	591	257	281	31	29	94
Trip Ends			706,995	543,070	49,529	40,928	73,754	48,206	37,540	46,088	1,323	3,388	27,666
Trips								48,206	37,540	46,088	662	1,694	13,833

6.6.6 Trip Distribution

The ARC truck survey suggested that the average trip length for MTK trips should be about 19.9 miles and for HTK trips 22.8 miles. This HTK figure seems very low, compared to the MTK figure and to other models, for which the HTK trip length is considerably higher than the MTK trip length. Thus, it was assumed that the HTK trip length should be in the range of 25-26 miles (especially given the expansion of the modelled area to 20 counties).

These were used as target values for the calibration of a new set of F (friction) factors for internal trips. For internal trips, the negative exponential function was used to define F factors. Its equation is as follows:

$F = \alpha * e^{(\gamma t)}$
where:
t = travel time, minutes
α, γ = calibrated coefficients

Various coefficient values were tested, using the newly estimated trip ends, until coefficients were found that produced a trip table that had the target average trip lengths, for 2000.

For external trips, the negative exponential function did not produce reasonable looking average trip lengths. Thus, a power function was used:

$F = \alpha * t^{\beta}$
where:
t = travel time, minutes
α, β = calibrated coefficients

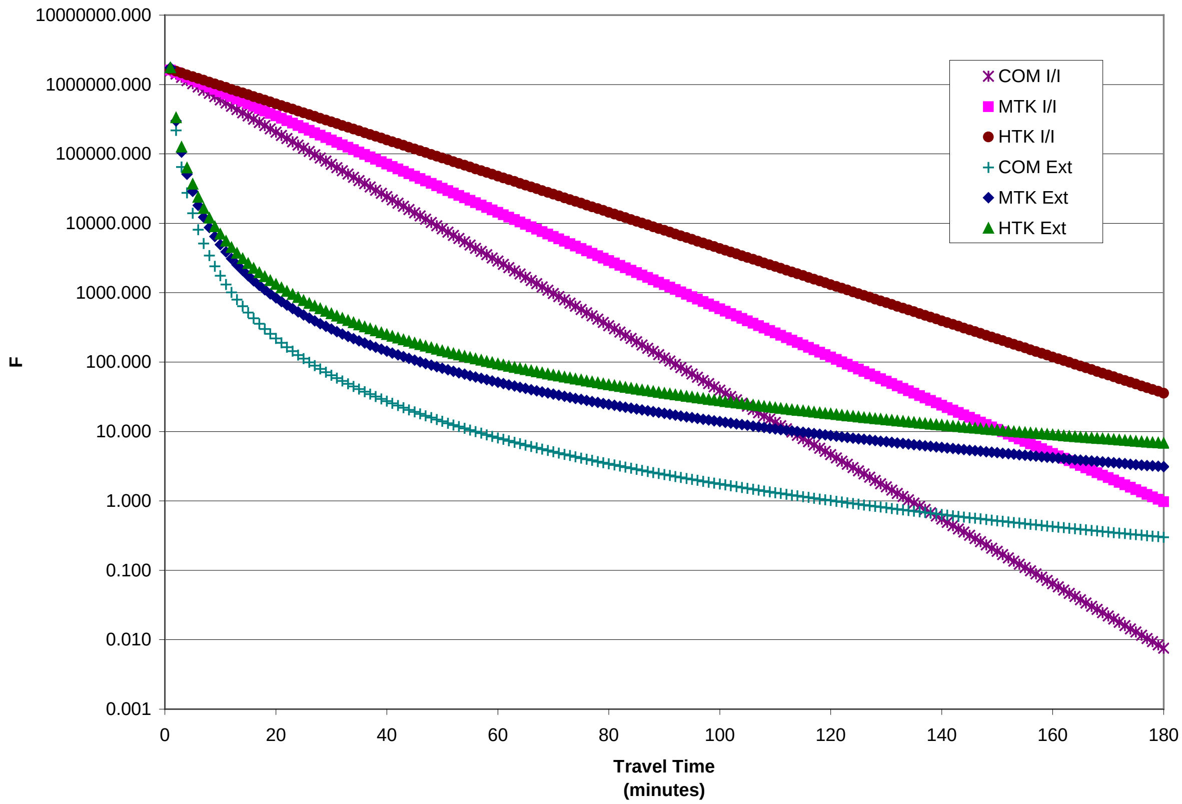
It should be noted that both the negative exponential and power functions are simply special cases of the gamma function, which is commonly used to define F factors: $F = \alpha * t^{\beta} * e^{(\gamma t)}$.

F factors were computed for travel times from 1 to 180 minutes. Table 6.13 shows the final F factor coefficients and Figure 6.5 shows the resulting F factor curves. The estimated trip lengths are 15.0 miles for MTK and 25.4 miles for HTK.

Table 6.13
F Factor Equation Coefficients

	α	β	γ
Commercial I/I	1,750,000		-0.107
Medium Truck I/I	1,750,000		-0.08
Heavy Truck I/I	1,750,000		-0.06
Commercial External	1,750,000	-3.00	
Medium Truck External	1,750,000	-2.55	
Heavy Truck External	1,750,000	-2.40	

Figure 6.5
Truck/Commercial F Factors



6.6.7 Through Trip Synthesis

For through (X/X) trips, the first step was to examine the 2000 total X/X daily vehicle trip table provided by ARC. This was found to be inadequate for describing truck X/X movements. Instead, the external station locations where X/X truck trips should be expected were examined. Then, by inspecting the external station geography and making assumptions about likely X/X patterns (as well as *unlikely* patterns), an "X/X pattern file" was developed. This was used to create a seed matrix, which was then Fratared to match the estimated number of daily X/X truck trip ends at each station, by truck type. The resulting tables were assigned to the network and the loading patterns examined to confirm that they represent a reasonable set of X/X truck volume patterns on the roadways. The final X/X 2000 daily truck totals are 1,694 MTK and 13,833 HTK. These volumes are not significant in the context of the entire model, but they become somewhat more important for analyses that focus on the major through roadways in the region. They also contribute disproportionately to truck VMT.

6.6.8 Time of Day

Since truck and commercial counts are not available by time of day, it is not possible to estimate a specific time of day model, or to validate it. Instead, the existing ARC truck time of day fractions and those of other similar truck models were reviewed. Although many other models use the same four time periods as the ARC model (AM peak, midday, PM peak, night), allowances must be made for the fact that some of these other models use slightly different definitions for the hours that make up those periods. From an examination of the various TOD fractions available, a set of fractions were devised that should be representative. In general, the proposed TOD fractions are lower in the midday and much higher in the nighttime hours than the existing ARC model. If a sufficient number of classification counts were available by time of day, it would be helpful to re-visit these fractions and derive values that more closely match the actual data.

Table 6.14
Time of Day Fractions

	AM	MD	PM	NT
	ARC Model Time Periods			
	6-10	10a-3p	3-7	7p-6a
Commercial				
Existing BMC	25.1%	28.9%	29.4%	16.6%
ODOT	17.0%	39.2%	36.4%	7.4%
Existing ARC (I/I, Ext LTK)	30.7%	45.7%	17.4%	6.2%
Proposed	*23%*	*39%*	*27%*	*11%*
Medium Truck				
Existing BMC	27.3%	36.0%	22.9%	13.8%
Existing ARC (I/I, Ext HTK)	29.9%	49.1%	16.0%	5.1%
Proposed	*23%*	*39%*	*27%*	*11%*
Heavy Truck				
ODOT (MTK+HTK)	16.3%	35.8%	24.2%	23.7%
Existing BMC	22.5%	32.6%	18.3%	26.6%
Existing ARC (I/I, Ext HTK)	29.9%	49.1%	16.0%	5.1%
Proposed	*22%*	*34%*	*20%*	*24%*
Existing ARC EE Truck	21.9%	26.9%	28.5%	22.7%

Note:
BMC period definitions are: 6-10, 10a-3p, 3-7, 7p-6a
ODOT period definitions are: 6-9, 9a-2p, 2-6, 6p-6a

6.6.9 Assignment

The existing ARC model already incorporated several advanced features relating to the assignment of truck trips, including:

- separate assignments by time period
- coding of truck-prohibited links
- separate impedance calculation for trucks, incorporating tolls at a higher value of time than for passenger cars
- assigning trucks to their own path and maintaining the volumes separately on the output network
- separate loading of through trips

In addition, the assignment method included two untypical features: a special truck penalty on one particular link and a technique to assign some heavy trucks to a path that does not go inside the I-285 perimeter.

The only new feature that was added by this study was to incorporate “passenger car equivalents” (PCEs). This adjusts the volume/capacity calculation so as to represent the true impact of trucks on capacity. According to the Highway Capacity Manual and other sources, large trucks ”use up” more roadway capacity than other vehicles, due to their large size and slow acceleration. Thus, the accuracy of ARC's capacity-restrained assignment should be improved if truck volumes could be temporarily factored upwards by a factor to represent their disproportional impact on the V/C calculation.

The question remains as to what PCE values to use. A review of the literature and discussions with other planners suggests that the PCE for heavy trucks is in the range of 2.0 – 4.0. Medium trucks perform more like passenger cars and should thus have a smaller PCE. The model project team recommends that values given in the 2000 Highway Capacity Manual of 1.5 and 2.0 should be used for medium and heavy trucks, respectively.

6.6.10 Validation

The interim model described above was applied to year 2000 conditions, using the input data for the new 20-county modelled area. The resulting daily assigned truck volumes were compared to the counts posted in the network, in total (sum of MTK+HTK).

The total error was +19% and the %RMSE was 89%. These do not indicate a high degree of accuracy, although they are clearly better than the existing model for 2000, which has a total error of -27% and a %RMSE of 117%. In any case, it is apparent that the starting model's results can be improved upon.

The starting model provides a reasonable basis for the subsequent analysis. This model is then applied for 2000 to develop the truck trip tables to be used as the starting point for the adaptable assignment process. This is described in the next section.

6.7. Adaptable Assignment

6.7.1 Approach

The premise of adaptable assignment is that it is possible to systematically compare the traffic counts to the assigned volumes and then use that comparison to adjust the starting trip table for each O/D pair. The resulting O/D volumes will produce assignments that more closely match the counts. However, it is entirely possible that the adjustment for some O/D pairs will counteract the adjustment for other O/D pairs. Thus, the process must be iterated several times until a balance has been achieved and little additional assignment accuracy can be expected.

Having applied the adaptable assignment procedure to several different models, the consultant has discovered that its use is not a deterministic process. In particular, the "strength" of the adjustment and the appropriate number of iterations must be ascertained by trial and error. Typically, the iterations are increased until the improvement in accuracy between iterations is very small and the trip table changes stabilize.

In addition, the output trip table must be examined carefully to determine how it differs from the input trip table. Understanding these differences makes it possible to use them to develop adjustments to the starting model, so that its estimates will better reflect the count data.

Various tests of the adaptable assignment process were run to determine suitable values for its various parameters and options. The best results were achieved by using 10 iterations, with the adapted trip table being Fratared after the last iteration, so that the external station totals will match the counts. This analysis was initially conducted using daily volumes, in the interest of saving processing time. However, it was subsequently discovered that the analysis had to be conducted by time period, in order to achieve sufficiently accurate results.

6.7.2 Uses of the Calibration Adjustment

As noted above, the adaptable assignment process produces a new vehicle trip table. The difference between this table and the starting trip table is called the *delta table*. In effect, the delta table is an O/D matrix of calibration adjustments that, when added to the starting trip table, produce a table that matches the counts fairly closely. Analysis of this delta table can provide clues as to how to modify the starting model, so as to make it more accurate.

Specifically, the trip end summary of this delta table (separately for medium and heavy trucks) was examined. This was then compared to the land use data to see if there was a systematic employment- or household-based adjustment that would improve the model. The finding was that the adjustments were positive in the suburban and rural areas and negative in the downtown areas. This suggested that the trip rate factor on HHs should be increased and the factor on office employment should be decreased.

Next, the delta trip ends were cross-tabulated and compared to the starting model trip ends by truck zone and area type. This analysis indicated that the HTK trips should be increased in the "truck zones" and that area type-based factors were necessary.

After several iterations of this analysis, some adjustments to the initial trip generation model to make it more suitable were developed. The revised model is the one shown in Table 6.9. In general, these adjustments reduce the number of trips in the more developed areas and increase the trips in the less developed areas. This is logical -- since the developed areas have more employees, it would make sense that the truck trip rate per employee might be less in those areas.

Although adaptable assignment helped identify a number of changes that make the initial model more accurate, the resulting accuracy is still not as good as one would like to see. One must recognize the limitations of all relatively simplistic regional travel models, which use fairly basic, available zone-level variables. It is the project team's experience that *no* travel forecasting model can replicate the millions of individual decisions that take place each day, so as to estimate link-level volumes that match the counts with a very high degree of accuracy. Traffic counts may be somewhat consistent from day to day, but they do include a certain degree of randomness that cannot be reproduced perfectly by a travel model that is limited to relatively simple inputs and relatively simple relationships. However, that observation does not invalidate the use of this model, or any regional travel model, for planning purposes.

As described above, adaptable assignment can be used to "inform" a model, to make it more accurate with respect to the counts. However, no matter how accurate the starting model becomes, the adaptable process will always create a non-zero delta table. This final delta table represents a set of calibration adjustments that are necessary in order to match the counts with a higher degree of accuracy.

This adjustment table becomes an integral part of the model. It is always added to the trip table output by the starting model, to become the final trip table for assignment purposes. The project team believes that this method of assignment calibration is superior to most other techniques and produces results that are not only more accurate in the base year, but more credible in the forecast years.

Table 6.15 presents the final delta trip tables for medium and heavy trucks, compressed to districts. The total delta (net difference) is about 24,000 trips for medium trucks and 3,400 trips for heavy trucks. The most desirable characteristic of a delta trip table is that it is small, relative to the starting table. For medium trucks, the total delta is 9% of the starting trip table; for heavy trucks, the delta is about 3%. Smaller fractions are better and these are quite acceptable. The second half of Table 6.15 shows the final truck trip tables, including the calibration adjustment.

Table 6.15
Final Delta Trip Tables

Date: 4/13/2006
Time: 14:48

Atlanta Regional Commission Travel Model
2000 Commercial Vehicle Calibration Adjustment Table

Destination District

Origin District	1	2	3	4	5	6	7	8	9	10	11	Total
1 Fulton	77681	-9562	-9054	-8408	-217	-758	-385	348	-2463	-3347	-787	43048
2 DeKalb	-8429	43745	-5496	-5740	-150	-393	-189	-562	-939	-2494	-594	18759
3 Cobb	-7808	-5582	26127	-2371	-40	-1150	584	-264	1128	-1090	-438	9096
4 Gwinnett	-8343	-4328	-2504	11425	-1415	-288	-54	-365	-186	-395	-648	-7101
5 Hall	-248	-238	-66	-1690	23492	0	0	-260	-2	-20	550	21518
6 Cherokee	-848	-433	-1123	-352	5	8276	-146	455	-41	-61	166	5898
7 NW	-475	-213	963	-75	0	6	19272	-3	187	-70	655	20247
8 NE	348	-472	-399	-179	-197	473	-8	15459	-16	765	870	16644
9 SW	1554	-1087	-88	-182	-6	-31	60	-8	36249	169	751	37381
10 SE	-4441	-3177	-993	-44	-23	-68	-47	265	429	47262	127	39290
11 External	-978	-678	-583	-742	619	201	853	867	887	105	-199	352
Total	48013	17975	6784	-8358	22068	6268	19940	15932	35233	40824	453	205132

Date: 4/13/2006
Time: 14:48

Atlanta Regional Commission Travel Model
2000 Medium Truck Calibration Adjustment Table

Destination District

Origin District	1	2	3	4	5	6	7	8	9	10	11	Total
1 Fulton	4800	2488	869	954	23	-251	5	-1	-352	-826	-28	7681
2 DeKalb	-2708	-691	-948	100	129	-157	-58	-207	-405	-624	-124	-5693
3 Cobb	-1056	-2095	3126	-848	-4	-170	172	-92	486	-444	-224	-1149
4 Gwinnett	-232	-469	-1054	11437	586	-60	-28	79	-103	-237	23	9942
5 Hall	128	137	-6	994	1295	9	1	202	-1	-10	-93	2656
6 Cherokee	-280	-148	-21	-12	10	19	17	74	3	-42	7	-373
7 NW	10	-116	1025	-35	1	4	1692	0	354	-31	281	3185
8 NE	-57	-259	-156	279	89	73	0	820	-12	27	309	1113
9 SW	-596	938	355	24	1	18	301	1	1569	-40	519	3090
10 SE	-1215	2490	-184	886	14	-29	-8	51	291	1125	421	3842
11 External	-456	-136	-190	64	-180	-2	309	411	270	236	-407	-81
Total	-1662	2139	2816	13843	1964	-546	2403	1338	2100	-866	684	24213

Date: 4/13/2006
Time: 14:48

Atlanta Regional Commission Travel Model
2000 Heavy Truck Calibration Adjustment Table

Destination District

		1	2	3	4	5	6	7	8	9	10	11	Total
O	1 Fulton	-1482	-2378	-634	-1041	-43	-155	170	-152	1484	5246	517	1532
r	2 DeKalb	-2782	-961	-868	-625	-24	-98	13	-142	19	1066	132	-4270
i	3 Cobb	-1762	-1545	1063	253	11	-216	286	-48	974	1630	521	1167
g	4 Gwinnett	-1218	854	-473	-1492	-218	-114	-16	-223	30	-47	73	-2844
i	5 Hall	-72	-49	-28	-276	-1	-4	-2	-27	1	-31	270	-219
n	6 Cherokee	-451	-252	-319	-204	-1	58	77	12	24	-23	147	-932
	7 NW	29	-102	403	25	-2	135	419	12	74	121	452	1566
D	8 NE	-273	-187	-166	-209	0	-24	2	148	-7	210	215	-291
i	9 SW	1514	188	889	-8	0	19	49	13	229	-138	259	3014
s	10 SE	1474	-161	743	-101	-30	-2	164	178	497	1112	915	4789
t	11 External	445	97	487	172	364	186	552	316	266	565	-3522	-72
	Total	-4578	-4496	1097	-3506	56	-215	1714	87	3591	9711	-21	3440

Date: 4/13/2006
Time: 14:48

Atlanta Regional Commission Travel Model
2000 Commercial Vehicle Daily Trips
With Calibration Adjustment

Destination District

		1	2	3	4	5	6	7	8	9	10	11	Total
O	1 Fulton	181251	26963	23060	10024	395	3306	1031	5657	7198	16025	1735	276645
r	2 DeKalb	28235	104121	4746	17766	317	394	249	1178	1087	11893	1012	170998
i	3 Cobb	24344	4649	98976	2445	62	7111	7639	505	6057	1910	1405	155103
g	4 Gwinnett	10039	19267	2407	82052	2367	294	83	7425	223	3243	1869	129269
i	5 Hall	382	283	70	2445	45896	81	5	1591	10	28	2934	53725
n	6 Cherokee	3179	308	7104	211	81	19698	1232	1550	82	86	925	34456
	7 NW	964	212	8144	91	4	1407	37678	35	2419	101	2326	53381
D	8 NE	5678	1328	491	7578	1551	1561	27	34713	34	2937	3818	59716
i	9 SW	11672	1101	4981	238	5	76	2341	26	86876	7205	4015	118536
s	10 SE	14926	11594	2005	3723	31	93	130	2341	7066	117716	5078	164703
t	11 External	1400	875	1228	1728	2923	956	2493	3714	4072	4882	454	24725
	Total	282070	170701	153212	128301	53632	34977	52908	58735	115124	166026	25571	1241257

Date: 4/13/2006
Time: 14:48

Atlanta Regional Commission Travel Model
2000 Medium Truck Daily Trips
With Calibration Adjustment

Destination District

		1	2	3	4	5	6	7	8	9	10	11	Total
O	1 Fulton	28086	12059	10218	7035	486	989	687	1423	2715	4995	2072	70765
r	2 DeKalb	6951	11654	2522	6841	490	170	216	303	505	3525	1136	34313
i	3 Cobb	8206	1342	18723	1186	89	1726	2010	230	2170	990	1337	38009
g	4 Gwinnett	5780	6218	1093	26864	1792	211	67	1989	192	1175	2186	47567
i	5 Hall	477	419	69	2160	4994	51	4	583	16	36	1627	10436
n	6 Cherokee	847	134	1952	238	63	1556	361	332	108	45	590	6226
	7 NW	598	90	2785	70	10	361	4328	35	825	79	1423	10604
D	8 NE	1351	373	218	2138	461	309	25	2966	20	503	2232	10596
i	9 SW	2435	1918	1857	369	22	86	782	34	10377	1899	2929	22708
s	10 SE	4454	6750	1222	2457	78	66	103	502	2178	13747	3893	35450
t	11 External	1751	1236	1404	2347	1602	600	1483	2417	2795	3763	1279	20677
	Total	60936	42193	42063	51705	10087	6125	10066	10814	21901	30757	20704	307351

Date: 4/13/2006
Time: 14:48

Atlanta Regional Commission Travel Model
2000 Heavy Truck Daily Trips
With Calibration Adjustment

Destination District

		1	2	3	4	5	6	7	8	9	10	11	Total
O	1 Fulton	14221	4957	6303	3362	271	615	1087	736	4418	11239	3895	51104
r	2 DeKalb	4422	6735	1842	3832	172	104	359	387	1109	4906	2151	26019
i	3 Cobb	4954	1166	8935	2058	112	698	1564	166	2382	3238	2681	27954
g	4 Gwinnett	3153	5485	1251	5993	446	87	167	902	476	1421	3124	22505
i	5 Hall	230	237	67	440	1221	12	4	207	42	57	2438	4955
n	6 Cherokee	379	61	763	66	24	655	349	111	114	157	989	3668
	7 NW	679	166	1528	190	7	356	1522	35	375	307	2077	7242
D	8 NE	632	361	167	870	188	115	41	847	54	604	2601	6480
i	9 SW	4381	1158	2177	352	16	118	361	83	4383	1572	3690	18291
s	10 SE	7078	3705	2401	1401	43	140	430	536	2231	9026	5806	32797
t	11 External	3009	1686	2132	2518	2122	835	1873	2331	3147	4600	10021	34274
	Total	43138	25717	27566	21082	4622	3735	7757	6341	18731	37127	39473	235289

Note:

NW = Bartow, Paulding
NE = Forsyth, Barrow, Walton
SW = Douglas, Carroll, Coweta, Fayette
SE = Clayton, Spalding, Henry, Rockdale, Newton

It is also clear from these tables that the intra-district cells are mostly positive, while many of the inter-district cells are negative. This reflects the tendency of adaptable assignment to add more short trips than long trips. 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 short trips. The reduction in longer trips suggests that those trips are contributing disproportionately to the links that are initially overestimated.

The average trip length of both types of truck trips is reduced, when the delta table is included, as shown in Table 6.16. These slight drops in average trip length are typical and are of no great concern.

Table 6.16
Starting and Final Travel Times

	COM	MTK	HTK
Starting Trip Table	27.5	33.2	41.3
Final Trip Table	23.0	31.9	39.9
Percent Change	-16%	-4%	-3%

Note: figures are in minutes and include External and X/X trips.

It should also be noted that in the delta trip matrix, the individual cell values include fractional amounts of trips and in many cases are negative. Special care must be taken in forecasting to ensure that when these delta values are added to the model's initial estimates, that the resulting value does not become negative for any cell. Such values should be re-set to zero. Also, the delta tables include all matrix cells, including I/I, I/X, X/I, and X/X values. Both the starting model and the delta tables maintain trips separately by period: AM peak, midday, PM peak, and night.

As noted above, the medium and heavy truck delta tables now become an integral part of the truck model. They must always be added to the results of the model, in order to produce the final trip table.

6.7.3 Accuracy

As the final step in the development of the truck model, the truck delta tables were added to the tables from the starting model and the resulting tables were assigned to the ARC 2000 network. The assignment procedure was modified slightly from ARC's standard process, as mentioned above, so as to include truck PCEs.

The resulting assigned volumes were compared to the new medium and heavy truck counts, producing the reports shown in Tables 6.17 and 6.18. These reports tabulate the assignment error by facility type group (1=freeway, 2=arterial, 3=collector/local) and zonal area type (1-7).

The total error is +7% for medium trucks and +15% for heavy trucks, while the %RMSE values are 37% and 64%, respectively. This is a large improvement over the starting model alone and is substantially better than the current ARC model. For comparison, the combined MTK/HTK error of the new model is +14%, with a %RMSE of 49%. The current ARC model's total truck error is -27%, with a %RMSE of 117%.

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. There is no discernable bias in the error by area type.

The project team believes that 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 should produce more logical and defensible trip patterns. This is a major improvement in accuracy and credibility, compared to the existing truck model.

Table 6.17
Assignment Report: Medium Trucks

CROSSTAB ROW=_ftg COL=ATYPE VAR=_cnt (Count)

	1	2	3	4	5	6	7	17
1 - 1	2,037	15,269	14,491	15,935	83,108	20,490	14,531	165,861
2 - 2	0	4,745	27,981	15,421	47,171	13,330	12,761	121,409
3 - 3	171	4,626	2,924	1,910	4,694	237	1,010	15,572
1 - 3	2,208	24,640	45,396	33,266	134,973	34,057	28,302	302,842

CROSSTAB ROW=_ftg COL=ATYPE VAR=MTKvol (Assigned Volume)

	1	2	3	4	5	6	7	17
1 - 1	2,169	19,130	14,271	19,792	89,467	26,696	13,646	185,171
2 - 2	0	4,878	28,564	14,918	49,323	13,338	13,588	124,609
3 - 3	167	4,602	2,823	1,494	4,791	380	1,027	15,284
1 - 3	2,336	28,610	45,658	36,204	143,581	40,414	28,261	325,064

CROSSTAB ROW=_ftg COL=ATYPE VAR=_links (Number of Counted Links)

	1	2	3	4	5	6	7	17
1 - 1	6	17	17	28	61	26	10	165
2 - 2	0	7	48	24	137	47	76	339
3 - 3	1	10	10	13	38	4	6	82
1 - 3	7	34	75	65	236	77	92	586

CROSSTAB ROW=_ftg COL=ATYPE VAR=_bad (“Bad” Links)

	1	2	3	4	5	6	7	17
1 - 1	1	4	1	4	10	6	0	26
2 - 2	0	1	2	0	6	0	5	14
3 - 3	0	0	0	3	2	0	0	5
1 - 3	1	5	3	7	18	6	5	45

Note: “bad” links are those whose error lies above the FHWA error tolerance line

CROSSTAB ROW=_ftg COL=ATYPE VAR=_sqerr (Squared Error)

1

	1	2	3	4	5	6	7	7
1 - 1	40,244	1,612,779	467,556	2,767,979	6,157,083	6,918,312	944,841	18,908,794
2 - 2	0	27,363	654,473	170,081	793,558	19,350	265,425	1,930,250
3 - 3	16	2,096	3,247	52,572	9,863	7,569	1,871	77,234
1 - 3	40,260	1,642,238	1,125,276	2,990,632	6,960,504	6,945,231	1,212,137	20,916,278

CROSSTAB ROW=_ftg COL=ATYPE COMP=MTKvol/_cnt (Assigned/Count Ratio)

	1	2	3	4	5	6	7	17
1 - 1	1.06	1.25	0.98	1.24	1.08	1.30	0.94	1.12
2 - 2	0.00	1.03	1.02	0.97	1.05	1.00	1.06	1.03
3 - 3	0.98	0.99	0.97	0.78	1.02	1.60	1.02	0.98
1 - 3	1.06	1.16	1.01	1.09	1.06	1.19	1.00	1.07

CROSSTAB ROW=_ftg COL=ATYPE COMP=_bad/_links (Proportion of “Bad” Links)

	1	2	3	4	5	6	7	17
1 - 1	0.17	0.24	0.06	0.14	0.16	0.23	0.00	0.16
2 - 2	0.00	0.14	0.04	0.00	0.04	0.00	0.07	0.04
3 - 3	0.00	0.00	0.00	0.23	0.05	0.00	0.00	0.06
1 - 3	0.14	0.15	0.04	0.11	0.08	0.08	0.05	0.08

CROSSTAB ROW=_ftg COL=ATYPE COMP=sqrt(_sqerr/_links) (RMSE)

	1	2	3	4	5	6	7	17
1 - 1	81.9	308.0	165.8	314.4	317.7	515.8	307.4	338.5
2 - 2	0.0	62.5	116.8	84.2	76.1	20.3	59.1	75.5
3 - 3	4.0	14.5	18.0	63.6	16.1	43.5	17.7	30.7
1 - 3	75.8	219.8	122.5	214.5	171.7	300.3	114.8	188.9

CROSSTAB ROW=_ftg COL=ATYPE COMP=sqrt(_sqerr/_links)/(_cnt/_links) (% RMSE)

	1	2	3	4	5	6	7	17
1 - 1	0.24	0.34	0.19	0.55	0.23	0.65	0.21	0.34
2 - 2	0.00	0.09	0.20	0.13	0.22	0.07	0.35	0.21
3 - 3	0.02	0.03	0.06	0.43	0.13	0.73	0.10	0.16
1 - 3	0.24	0.30	0.20	0.42	0.30	0.68	0.37	0.37

Rows represent facility type groups: 1 = Freeway, 2 = Arterial, 3 = Collector/Local.
Columns represent ARC zonal area type codes.

Table 6.18
Assignment Report: Heavy Trucks

CROSSTAB ROW=_ftg COL=ATYPE VAR=_cnt (Count)

	1	2	3	4	5	6	7	17
1 - 1	2,572	27,239	11,873	41,349	127,165	56,050	55,346	321,594
2 - 2	0	409	3,580	2,632	13,219	4,678	5,585	30,103
3 - 3	0	158	568	248	1,734	59	113	2,880
1 - 3	2,572	27,806	16,021	44,229	142,118	60,787	61,044	354,577

CROSSTAB ROW=_ftg COL=ATYPE VAR=HTKvol (Assigned Volume)

	1	2	3	4	5	6	7	17
1 - 1	3,171	38,157	12,822	46,201	140,598	56,945	47,549	345,443
2 - 2	0	869	11,500	5,051	23,835	7,568	9,131	57,954
3 - 3	0	483	699	285	2,725	616	434	5,242
1 - 3	3,171	39,509	25,021	51,537	167,158	65,129	57,114	408,639

CROSSTAB ROW=_ftg COL=ATYPE VAR=_links (Number of Counted Links)

	1	2	3	4	5	6	7	17
1 - 1	6	15	17	28	62	27	10	165
2 - 2	0	7	42	24	105	45	57	280
3 - 3	0	6	9	9	17	2	4	47
1 - 3	6	28	68	61	184	74	71	492

CROSSTAB ROW=_ftg COL=ATYPE VAR=_bad (“Bad” Links)

	1	2	3	4	5	6	7	17
1 - 1	3	5	6	6	15	3	0	38
2 - 2	0	4	32	12	56	18	21	143
3 - 3	0	5	2	3	7	2	4	23
1 - 3	3	14	40	21	78	23	25	204

Note: “bad” links are those whose error lies above the FHWA error tolerance line

CROSSTAB ROW=_ftg COL=ATYPE VAR=_sqerr (Squared Error)

	1	2	3	4	5	6	7	17
1 - 1	360,169	21,557,822	893,513	20,496,056	29,277,211	8,702,615	12,319,771	93,607,157
2 - 2	0	63,790	4,213,560	710,111	3,313,530	806,062	1,482,914	10,589,967
3 - 3	0	22,431	17,837	4,241	173,843	156,865	27,543	402,760
1 - 3	360,169	21,644,043	5,124,910	21,210,408	32,764,584	9,665,542	13,830,228	104,599,884

CROSSTAB ROW=_ftg COL=ATYPE COMP=HTKvol/_cnt (Assigned/Count Ratio)

	1	2	3	4	5	6	7	17
1 - 1	1.23	1.40	1.08	1.12	1.11	1.02	0.86	1.07
2 - 2	0.00	2.12	3.21	1.92	1.80	1.62	1.63	1.93
3 - 3	0.00	3.06	1.23	1.15	1.57	10.44	3.84	1.82
1 - 3	1.23	1.42	1.56	1.17	1.18	1.07	0.94	1.15

CROSSTAB ROW=_ftg COL=ATYPE COMP=_bad/_links (Proportion of “Bad” Links)

	1	2	3	4	5	6	7	17
1 - 1	0.50	0.33	0.35	0.21	0.24	0.11	0.00	0.23
2 - 2	0.00	0.57	0.76	0.50	0.53	0.40	0.37	0.51
3 - 3	0.00	0.83	0.22	0.33	0.41	1.00	1.00	0.49
1 - 3	0.50	0.50	0.59	0.34	0.42	0.31	0.35	0.41

CROSSTAB ROW=_ftg COL=ATYPE COMP=sqrt(_sqerr/_links) (RMSE)

	1	2	3	4	5	6	7	17
1 - 1	245.0	1198.8	229.3	855.6	687.2	567.7	1109.9	753.2
2 - 2	0.0	95.5	316.7	172.0	177.6	133.8	161.3	194.5
3 - 3	0.0	61.1	44.5	21.7	101.1	280.1	83.0	92.6
1 - 3	245.0	879.2	274.5	589.7	422.0	361.4	441.4	461.1

CROSSTAB ROW=_ftg COL=ATYPE COMP=sqrt(_sqerr/_links)/(_cnt/_links) (% RMSE)

	1	2	3	4	5	6	7	17
1 - 1	0.57	0.66	0.33	0.58	0.34	0.27	0.20	0.39
2 - 2	0.00	1.63	3.72	1.57	1.41	1.29	1.65	1.81
3 - 3	0.00	2.32	0.71	0.79	0.99	9.49	2.94	1.51
1 - 3	0.57	0.89	1.17	0.81	0.55	0.44	0.51	0.64

Rows represent facility type groups: 1 = Freeway, 2 = Arterial, 3 = Collector/Local.
Columns represent ARC zonal area type codes.

6.8. Commercial Vehicle Trips

Development of the Commercial (COM) vehicle trip model proceeded in exactly the same fashion as for the truck models, except that instead of actual classification counts, synthesized counts were used, as described in Section 6.5.2. The starting trip generation model was borrowed from a similar model recently developed for the Washington, DC area (Metropolitan Washington COG). The starting F factors were taken as those of the existing ARC internal light truck model.

The same protocol described above was used. The starting model was applied and the resulting assigned link volumes compared to the synthesized counts. The generation model was then adjusted so as to better match the counts and the distribution model was adjusted so as to better match an average trip length of 14.9 miles, which represents the average light truck/commercial trip length from the ARC survey. As part of this effort, the trip rate was decreased on office employment and increased on HHs. Also, area type adjustment factors were developed that decreased the trip rate in urbanized areas and increased the trip rate in suburban/rural areas. Both adjustments mirrored those made to the MTK and HTK models.

The starting COM trip generation model is shown in Table 6.19. This model estimates 1,035,000 daily COM trips: 987,000 internal and 48,000 external. It should be noted that the COM total is more than twice the total of MTK plus HTK. Since COM trips are almost all passenger cars and light duty trucks, it is important from an emissions viewpoint to clearly separate them from MTK and HTK, and important from a mode choice perspective to clearly separate them from NHB trips.

Table 6.19
Starting COM Generation Model

COM = (0.230 * INDEMP + 0.407 * RETEMP + 0.125 * OFFEMP + 0.330 * HH) * factor

INDEMP is Industrial Employment
RETEMP is Retail Employment
OFFEMP is Office Employment
HH is Households

Factor for area type:

Area Type	COM
1	0.70
2	0.80
3	0.90
4	1.00
5	1.10
6	1.20
7	1.40

The external model uses the same form as for trucks, as shown in Table 6.20 and Figure 6.4.

Table 6.20
External COM Model

Percent External (COM) = max(0.90, 1.54 * $D^{-1.2}$)

Where:
D = distance to nearest external station (via highway net), miles

The COM external shares at the cordon stations are shown in Table 6.11. These are higher than for the truck trips, since through COM trips are logically expected to be fairly low. Table 6.12 shows the COM external and through trip ends at each station.

Table 6.13 shows the F factor coefficients used for COM trips. As noted above, the existing ARC light truck F factors were used to start and were then adjusted to achieve more reasonable-looking trip patterns and average trip length. The final COM F factors are graphed in Figure 6.5.

The through trip methodology for COM trips was the same as for MTK and HTK. However, the COM X/X trips are much smaller in number: 662. COM trips are mainly local in nature and so a lot of external and through COM trips should not be expected.

COM trips are assigned in the same fashion as SOV trips – that is, they are all assumed to be single-occupant passenger cars and light trucks. The starting COM model was validated in the same manner as the MTK/HTK models. The assignment error was +27% and the %RMSE was 112%. As with the truck models, it is clear that these results can be improved upon.

The adaptable assignment procedure was applied to COM trips, producing a delta table. The sum of this table is about 205,000, which is 20% of the starting trip table's total. This is a higher percentage than is normally desirable, but various attempts to modify this figure proved unworkable (i.e., they ended up with higher overall errors). The delta table and final COM trip table are shown in Table 6.15.

As with the truck trips, the calibration adjustment process resulted in a shorter trip length. As Table 6.16 shows, the difference was more dramatic for COM trips than for the truck trips: -16%. This is typical of such analyses.

The time of day fractions assumed for COM trips are shown in Table 6.14.

The final assignment results for COM indicate an error of -1% and a %RMSE of 24%. These are both considerably better than the starting model and for the truck models. Table 6.21 presents the assignment accuracy report for COM trips.

Table 6.21
Assignment Report: Commercial Trips

CROSSTAB ROW=_ftg COL=ATYPE VAR=_cnt (Total Count)

	1	2	3	4	5	6	7	17
1 - 1	156,648	283,266	363,191	280,988	894,612	160,229	66,619	2,205,553
2 - 2	71,357	112,148	447,406	374,340	1,218,933	442,422	427,071	3,093,677
3 - 3	10,681	41,728	91,729	80,066	314,703	33,976	37,972	610,855
1 - 3	238,686	437,142	902,326	735,394	2,428,248	636,627	531,662	5,910,085

CROSSTAB ROW=_ftg COL=ATYPE VAR=COMvol (Assigned Volume)

	1	2	3	4	5	6	7	17
1 - 1	162,933	281,769	379,260	285,820	870,818	200,469	76,074	2,257,143
2 - 2	69,203	108,609	440,916	362,989	1,216,403	426,246	416,067	3,040,433
3 - 3	12,127	41,424	85,676	75,628	295,300	31,773	37,321	579,249
1 - 3	244,263	431,802	905,852	724,437	2,382,521	658,488	529,462	5,876,825

CROSSTAB ROW=_ftg COL=ATYPE VAR=_links (Number of Counted Links)

	1	2	3	4	5	6	7	17
1 - 1	21	42	66	65	194	77	46	511
2 - 2	53	85	366	334	1,373	597	921	3,729
3 - 3	32	72	178	193	613	74	112	1,274
1 - 3	106	199	610	592	2,180	748	1,079	5,514

CROSSTAB ROW=_ftg COL=ATYPE VAR=_bad (Number of “Bad” Links)

	1	2	3	4	5	6	7	17
1 - 1	0	0	3	0	0	8	0	11
2 - 2	1	7	10	9	53	28	48	156
3 - 3	3	3	21	38	70	7	9	151
1 - 3	4	10	34	47	123	43	57	318

Note: “bad” links are those whose error lies above the FHWA error tolerance line

CROSSTAB ROW=_ftg COL=ATYPE VAR=_sqerr (Squared Error)

	1	2	3	4	5	6	7	17
1 - 1	11,934,517	27,065,235	24,335,017	16,091,772	80,450,784	50,685,948	7,402,487	217,965,760
2 - 2	2,805,158	7,671,041	25,939,270	24,377,681	36,296,290	15,616,822	8,547,896	121,254,158
3 - 3	342,314	833,658	5,000,263	5,182,644	14,771,489	1,408,851	1,330,575	28,869,794
1 - 3	15,081,989	35,569,934	55,274,550	45,652,097	131,518,563	67,711,621	17,280,958	368,089,712

CROSSTAB ROW=_ftg COL=ATYPE COMP=COMvol/_cnt (Assigned/Count Ratio)

	1	2	3	4	5	6	7	17
1 - 1	1.04	0.99	1.04	1.02	0.97	1.25	1.14	1.02
2 - 2	0.97	0.97	0.99	0.97	1.00	0.96	0.97	0.98
3 - 3	1.14	0.99	0.93	0.94	0.94	0.94	0.98	0.95
1 - 3	1.02	0.99	1.00	0.99	0.98	1.03	1.00	0.99

CROSSTAB ROW=_ftg COL=ATYPE COMP=_bad/_links (Proportion of “Bad” Links)

	1	2	3	4	5	6	7	17
1 - 1	0.00	0.00	0.05	0.00	0.00	0.10	0.00	0.02
2 - 2	0.02	0.08	0.03	0.03	0.04	0.05	0.05	0.04
3 - 3	0.09	0.04	0.12	0.20	0.11	0.09	0.08	0.12
1 - 3	0.04	0.05	0.06	0.08	0.06	0.06	0.05	0.06

CROSSTAB ROW=_ftg COL=ATYPE COMP=sqrt(_sqerr/_links) (RMSE)

	1	2	3	4	5	6	7	17
1 - 1	753.9	802.8	607.2	497.6	644.0	811.3	401.2	653.1
2 - 2	230.1	300.4	266.2	270.2	162.6	161.7	96.3	180.3
3 - 3	103.4	107.6	167.6	163.9	155.2	138.0	109.0	150.5
1 - 3	377.2	422.8	301.0	277.7	245.6	300.9	126.6	258.4

CROSSTAB ROW=_ftg COL=ATYPE COMP=sqrt(_sqerr/_links)/(_cnt/_links) (%RMSE)

	1	2	3	4	5	6	7	17
1 - 1	0.10	0.12	0.11	0.12	0.14	0.39	0.28	0.15
2 - 2	0.17	0.23	0.22	0.24	0.18	0.22	0.21	0.22
3 - 3	0.31	0.19	0.33	0.40	0.30	0.30	0.32	0.31
1 - 3	0.17	0.19	0.20	0.22	0.22	0.35	0.26	0.24

Rows represent facility type groups: 1 = Freeway, 2 = Arterial, 3 = Collector/Local.
Columns represent ARC zonal area type codes.

6.9. Application

The new COM/MTK/HTK model is applied using a TP+ setup, as shown in Table 6.22. This includes trip generation, trip distribution, time of day, and assignment steps. Trip generation uses the standard ARC land use file, which for 2000 was named NWTAZ00G.PRN and the standard ARC area type file, named ZNEDAT00.DAT. Three new zonal files are needed:

1. Forecast year external trips by external station and vehicle type. ASCII file with one record per station. First field is the station number. Next 3 fields are the COM cordon total, MTK cordon total, and HTK cordon total. Data can be in any columns, but there must be at least one space between each field on each record. Values for 2000 are as shown in Table 6.12, columns "Com Veh", "Med Trk", and "Hvy Trk". During development, this file was named CMHEXT.PRN.
2. Distance to nearest external station. ASCII file with one record per internal zone and two fields per record. First field is the zone number, second field is the distance to the nearest external station in miles (via the highway network). Data can be in any columns, but there must be at least one space between each field on each record. This file can be created using the TP+ setup shown in Table 6.23. During development, this file was named EXTDIST.DAT.
3. Zonal file identifying truck zones. Currently a DBF file with one record per internal zone and two fields: ZONE and FLAG. If FLAG is non-zero, it identifies the zone as a "truck zone", having a higher heavy truck trip rate per employee than other zones. During development, this file was named "Truck Zones.DBF".

Trip distribution uses a matrix file of off-peak highway times, which include intrazonal time and O and D terminal times, as in the existing ARC model. The F factors are stored in a file called FFACTORS.PRN and are shown in Table 6.24. K factors are not used. Through trips are stored in a matrix file named CMHEE.TRP, with three tables: 1=COMEE, 2=MTKEE, 3=HTKEE. This file was developed for 2000. Forecast year versions would presumably be developed by Frataring the 2000 tables.

The time of day fractions are shown in Table 6.14 and in the TP+ setup in Table 6.22. The calibration adjustment tables are stored in four files: DELTApp.TRP, where pp is the time of day (AM, MD, PM, NT). Each of those files contains 3 tables: 1=COM, 2=MTK, 3=HTK. These files are unfortunately quite large (about 55 Mb each), since they are stored in single precision. These are matrix files that use the current 20-county zone system. If the zone system is changed, these files must be modified accordingly.

The highway assignment step shown in Table 6.22 incorporates all of the features that are used for COM/TRK assignment, including the PCEs. Each of the steps shown in Table 6.22 were incorporated into the main ARC model setup.

Table 6.22
TP+ COM/TRK Setup

```
maxzone = 2118
maxint  = 2027

run pgm=tripgen

; cmh.s
; ARC Commercial/Truck Vehicle Model

  id = "Commercial/Truck Trip Generation

; standard zonal data file
  zdati[1] = inputs\nwtaz00g.prn, z = #1, const = #2, manuf = #3, TCU = #4,
    whole = #5, retail = #6, FIRE = #7, service = #8, totpriv = #9, govt = #10,
    govt2 = #11, totemp = #12, pop = #13, hh = #14, unienr = #15, acres = #16

; external trip ends, from truck\ExternalStations.xls
  zdati[2] = cmhext.prn, z = #1, comext = #2, mtkext = #3, htkext = #4

; Zonal area type
  zdati[3] = znedat00.dat, z = #1, atype = #12

; distance to nearest external station, from above
  zdati[4] = extdist.dat, z = #1, extdist = #2

; Truck zones
  zdati[5] = "truck zones.dbf", z = ZONE

; Output P/A file:
;  1 = COM I/I  4 = COM external
;  2 = MTK I/I  5 = MTK ext
;  3 = HTK I/I  6 = HTK ext
  pao = cmhte.dat form=8.0 list= z(5.0), p[1],a[1],p[2],a[2],p[3],a[3],
    p[4],a[4],p[5],a[5],p[6],a[6],  print=y

  zones = @maxzone@


; Look up area type factors
  lookup interpolate=n, fail=1.0,1.0,1.0, name=atfac,
    lookup[1] = 1, result = 2,
    lookup[2] = 1, result = 3,
    lookup[3] = 1, result = 4,
;       AT  COM   MTK   HTK
    r = '1  0.70  0.50  0.50',
        '2  0.80  0.75  0.70',
        '3  0.90  1.00  0.75',
        '4  1.00  1.05  0.80',
        '5  1.10  1.10  0.90',
        '6  1.20  1.20  1.10',
        '7  1.40  1.30  1.30'

; Apply equation to internal zones only
  if (i <= @maxint@)

; AT-based adjustment factor.
    comfac = atfac(1,atype)
    mtkfac = atfac(2,atype)
    htkfac = atfac(3,atype)
```

```
; Sum employment by type
    indemp = const + manuf + TCU + whole
    retemp = retail
    offemp = FIRE + govt + service

; Calculate productions by type.
    com = (0.230 * indemp + 0.125 * offemp + 0.407 * retemp +
           0.330 * hh) * comfac
    mtk = (0.104 * indemp + 0.030 * offemp + 0.178 * retemp +
           0.058 * hh) * mtkfac
    htk = (0.095 * indemp + 0.028 * offemp + 0.081 * retemp +
           0.053 * hh) * htkfac

; Truck zone factor for HTK.
    if (flag > 0) htk = 3.0 * htk

;  Apply external trip end share model.
;  External share is a declining function of the zone's distance to the
;   nearest cordon station (in miles).  This particular model is an
;   amalgam of the Berks Co, PA purpose-specific models.  Limit the
;   max External share to 90%.
    extpct = 0.0
    if (extdist > 0) extpct = extdist^-1.2
    extpctc = max(min(1.54*extpct,0.9),0)
    extpctm = max(min(4.94*extpct,0.9),0)
    extpcth = max(min(8.25*extpct,0.9),0)
    intpctc = 1.0 - extpctc
    intpctm = 1.0 - extpctm
    intpcth = 1.0 - extpcth

; Apply internal trip end shares.  Set A's equal to the P's.
    p[1] = com * intpctc
    p[2] = mtk * intpctm
    p[3] = htk * intpcth
    a[1] = p[1]
    a[2] = p[2]
    a[3] = p[3]

; Define all external trip ends as "Productions" at the internal
;  zones and "Attractions" at the external stations.  Calculate
;  these (initially) for internal zones as what's left over
;  after the above calculation.
    p[4] = com * extpctc
    p[5] = mtk * extpctm
    p[6] = htk * extpcth
  endif

; External trip ends.  These were calculated externally (HAHA), in
;  ExternalStations.xls  These are defined as
;  Attractions, at the external stations.
  if (i > @maxint@)
    p[1] = 0
    p[2] = 0
    p[3] = 0
    p[4] = 0
    p[5] = 0
    p[6] = 0
    a[1] = 0
    a[2] = 0
    a[3] = 0
    a[4] = comext
    a[5] = mtkext
    a[6] = htkext
  endif
```

```
  phase = adjust

; Normalize external trips to the attractions (input at the external
;  stations).
    p[4] = p[4] * a[4][0]/p[4][0]
    p[5] = p[5] * a[5][0]/p[5][0]
    p[6] = p[6] * a[6][0]/p[6][0]
  endphase

endrun

;---------------------------------------------------------------------
run pgm=tripdist

  id = "Commercial/Truck Trip Distribution

; Skims
  mati = ff00hwy.skm

; Trip ends
  zdati = cmhte.dat z=#1,p1=#2,a1=#3,p2=#4,a2=#5,p3=#6,a3=#7,
    p4=#8,a4=#9,p5=#10,a5=#11,p6=#12,a6=#13

; Output
  mato = cmh.trp, mo=1-6, name = COMII,MTKII,HTKII,COMEXT,MTKEXT,HTKEXT,
    dec=6*S

; Set maximum iterations, unless RMSE for all purposes is met.
  maxiters = 20, maxrmse = 10

; Set productions and attractions
  setpa p[1]=p1, a[1]=a1, p[2]=p2, a[2]=a2, p[3]=p3, a[3]=a3,
        p[4]=p4, a[4]=a4, p[5]=p5, a[5]=a5, p[6]=p6, a[6]=a6

; Get skims.
  mw[10] = mi.1.Time

; Look up friction factors (see FFactors.xls).
  lookup fail=1750000,0,0, file=ffactors.prn, list=y, interpolate=y, name=ff,
    lookup[1]=1, result=2,
    lookup[2]=1, result=3,
    lookup[3]=1, result=4,
    lookup[4]=1, result=5,
    lookup[5]=1, result=6,
    lookup[6]=1, result=7

; Distribute trips on off-peak skim time w/intrazonal and terminal time.
  gravity purpose=1, los = mw[10], ffactors=ff
  gravity purpose=2, los = mw[10], ffactors=ff
  gravity purpose=3, los = mw[10], ffactors=ff
  gravity purpose=4, los = mw[10], ffactors=ff
  gravity purpose=5, los = mw[10], ffactors=ff
  gravity purpose=6, los = mw[10], ffactors=ff

; Trip end report
  report margins = 1-6

endrun
;---------------------------------------------------------------------
run pgm=matrix

  id = "Commercial/Truck TLFDs
```

```
;  Input files: trips, skims
  mati[1] = cmh.trp
  mati[2] = ff00hwy.skm

; Get trips.
  mw[1] = mi.1.COMII
  mw[2] = mi.1.MTKII
  mw[3] = mi.1.HTKII
  mw[4] = mi.1.COMEXT
  mw[5] = mi.1.MTKEXT
  mw[6] = mi.1.HTKEXT

; Sum.
  mw[9]  = mw[1] + mw[4]
  mw[10] = mw[2] + mw[5]
  mw[11] = mw[3] + mw[6]

; Time.
  mw[7] = mi.2.Distance
  mw[8] = mi.2.Time

; TLF
  frequency basemw=7, valuemw=1, range=0-50-2,
  title='Est Commercial I/I Trips vs. Off-Peak Hwy Distance'
  frequency basemw=7, valuemw=2, range=0-50-2,
  title='Est Medium Truck I/I Trips vs. Off-Peak Hwy Distance'
  frequency basemw=7, valuemw=3, range=0-50-2,
  title='Est Heavy Truck I/I Trips vs. Off-Peak Hwy Distance'
  frequency basemw=7, valuemw=4, range=0-120-5,
  title='Est Commercial Ext Trips vs. Off-Peak Hwy Distance'
  frequency basemw=7, valuemw=5, range=0-120-5,
  title='Est Medium Truck Ext Trips vs. Off-Peak Hwy Distance'
  frequency basemw=7, valuemw=6, range=0-120-5,
  title='Est Heavy Truck Ext Trips vs. Off-Peak Hwy Distance'

  frequency basemw=7, valuemw=9, range=0-120-5,
  title='Est Commercial Total Trips vs. Off-Peak Hwy Distance'
  frequency basemw=7, valuemw=10, range=0-120-5,
  title='Est Medium Truck Total Trips vs. Off-Peak Hwy Distance'
  frequency basemw=7, valuemw=11, range=0-120-5,
  title='Est Heavy Truck Total Trips vs. Off-Peak Hwy Distance'

  frequency basemw=8, valuemw=9, range=0-180-10,
  title='Est Commercial Total Trips vs. Off-Peak Hwy Time'
  frequency basemw=8, valuemw=10, range=0-180-10,
  title='Est Medium Truck Total Trips vs. Off-Peak Hwy Time'
  frequency basemw=8, valuemw=11, range=0-180-10,
  title='Est Heavy Truck Total Trips vs. Off-Peak Hwy Time'

endrun

;---------------------------------------------------------------------
run pgm=matrix

  id = "Commercial/Truck time of day

; Also add in the E/E trips, which were developed separately.

  mati[1] = cmh.trp
  mati[2] = cmhee.trp
  mati[3] = ..\adapt\deltaam.trp
  mati[4] = ..\adapt\deltamd.trp
  mati[5] = ..\adapt\deltapm.trp
  mati[6] = ..\adapt\deltant.trp
```

```
  mato[1] = com.trp, mo=5-8,   name=AMCOM,MDCOM,PMCOM,NTCOM, dec = 4*S
  mato[2] = mtk.trp, mo=17-20, name=AMMTK,MDMTK,PMMTK,NTMTK, dec = 4*S
  mato[3] = htk.trp, mo=29-32, name=AMHTK,MDHTK,PMHTK,NTHTK, dec = 4*S

; I/I trips are already balanced, so we can apply a single factor
;  to all trips.  Apply separate P/A and A/P factors to externals.
;  Assume externals are 70/30 inbound (E/I, or A/P) in the morning,
;  70/30 outbound (I/E, P/A) in the evening.  Midday/Night is 50/50.
  mw[1] = mi.1.COMII
  mw[2] = mi.1.COMEXT           ; P/A (outbound)
  mw[3] = mi.1.COMEXT.t         ; A/P (inbound)

; Also add in the E/E's.
  mw[4] = mi.2.COMEE

; Use proposed new TOD factors
  mw[5] = 0.23 * (mw[1] + 0.7 * mw[3] + 0.3 * mw[2] + mw[4])  ; AM
  mw[6] = 0.39 * (mw[1] + 0.5 * mw[3] + 0.5 * mw[2] + mw[4])  ; MD
  mw[7] = 0.27 * (mw[1] + 0.3 * mw[3] + 0.7 * mw[2] + mw[4])  ; PM
  mw[8] = 0.11 * (mw[1] + 0.5 * mw[3] + 0.5 * mw[2] + mw[4])  ; NT

; Add in calibration adjustment.
  mw[5] = max(mw[5] + mi.3.com, 0)
  mw[6] = max(mw[6] + mi.4.com, 0)
  mw[7] = max(mw[7] + mi.5.com, 0)
  mw[8] = max(mw[8] + mi.6.com, 0)

; Now for MTK
  mw[13] = mi.1.MTKII
  mw[14] = mi.1.MTKEXT           ; P/A (outbound)
  mw[15] = mi.1.MTKEXT.t         ; A/P (inbound)

; Also add in the E/E's.
  mw[16] = mi.2.MTKEE

; Use proposed new TOD factors
  mw[17] = 0.23 * (mw[13] + 0.7 * mw[14] + 0.3 * mw[15] + mw[16])  ; AM
  mw[18] = 0.39 * (mw[13] + 0.5 * mw[14] + 0.5 * mw[15] + mw[16])  ; MD
  mw[19] = 0.27 * (mw[13] + 0.3 * mw[14] + 0.7 * mw[15] + mw[16])  ; PM
  mw[20] = 0.11 * (mw[13] + 0.5 * mw[14] + 0.5 * mw[15] + mw[16])  ; NT

; Add in calibration adjustment.
  mw[17] = max(mw[17] + mi.3.mtk, 0)
  mw[18] = max(mw[18] + mi.4.mtk, 0)
  mw[19] = max(mw[19] + mi.5.mtk, 0)
  mw[20] = max(mw[20] + mi.6.mtk, 0)

; Now for HTK
  mw[25] = mi.1.HTKII
  mw[26] = mi.1.HTKEXT           ; P/A (outbound)
  mw[27] = mi.1.HTKEXT.t         ; A/P (inbound)

; Also add in the E/E's.
  mw[28] = mi.2.HTKEE

; Use proposed new TOD factors
  mw[29] = 0.22 * (mw[25] + 0.7 * mw[26] + 0.3 * mw[27] + mw[28])  ; AM
  mw[30] = 0.34 * (mw[25] + 0.5 * mw[26] + 0.5 * mw[27] + mw[28])  ; MD
  mw[31] = 0.20 * (mw[25] + 0.3 * mw[26] + 0.7 * mw[27] + mw[28])  ; PM
  mw[32] = 0.24 * (mw[25] + 0.5 * mw[26] + 0.5 * mw[27] + mw[28])  ; NT

; Add in calibration adjustment.
  mw[29] = max(mw[29] + mi.3.htk, 0)
```

```
  mw[30] = max(mw[30] + mi.4.htk, 0)
  mw[31] = max(mw[31] + mi.5.htk, 0)
  mw[32] = max(mw[32] + mi.6.htk, 0)

endrun
;---------------------------------------------------------------------

loop p = 1,4
  if (p = 1)
    per = 'AM'
    cfac= 4
  endif
  if (p = 2)
    per = 'MD'
    cfac= 5
  endif
  if (p = 3)
    per = 'PM'
    cfac= 4
  endif
  if (p = 4)
    per = 'NT'
    cfac= 11
  endif

year     = '00'
totzones = 2118
lastin   = 2027
iteration= 50

run pgm=hwyload

id = "E/E pre-load, period @per@


mati[1] = tod@per@.vtt
mati[2] = com.trp
mati[3] = mtk.trp
mati[4] = htk.trp
neti=hwy@year@ff.NET
neto=@per@_preload.tmp

zones=@totzones@
parameters maxiters=1   ;All-or-nothing assignment

phase=linkread                                    ;read in link variables from
input file
 T0=li.distance*60/li.speed
; Set Prohibitions
  if (li.prohibition==1) ADDTOGROUP=2            ;no-truck LINKS
  if (li.prohibition==2) ADDTOGROUP=3            ;HOV 2 LINKS
  if (li.factype> 49) ADDTOGROUP=4               ;transit only
  if (li.prohibition==5) ADDTOGROUP=5            ;I-285 By-Pass
; Set Fixed Toll Penalties
  if (li.toll>0)
   lw.trkaddtime=li.toll*5*2.4      ; 1 minute per dollar (Value of Time
$25/hr)
   lw.sovaddtime=li.toll*4          ; 4 minutes per dollar (Value of Time
$15/hr)
  else
   lw.trkaddtime=0
   lw.sovaddtime=0
  endif
; Add Time Penalty for Trucks at the Financial Center Tunnel (GA400)
```

```
  if ((a=8650 & b=8679) | (a=8678 & b=8651)) lw.trkaddtime=lw.trkaddtime+5
; Set Time
  lw.trktime= T0 + lw.trkaddtime
  lw.sovtime= T0 + lw.sovaddtime
endphase
phase=iloop
mw[1]=0
mw[2]=0
mw[3]=0
mw[4]=0
 jloop
  if(i>@lastin@ & j>@lastin@)
   mw[1]=mi.2.@per@COM
   mw[2]=mi.3.@per@MTK
   mw[3]=mi.4.@per@HTK
   mw[4]=mi.1.2
  endif
 endjloop
;Assign EE COM/Truck
     pathload
path=lw.trktime,vol[1]=mw[1],vol[2]=mw[2],vol[3]=mw[3],excludegrp=2,3,4,5
;Assign EE Passenger Car
     pathload path=lw.sovtime,vol[4]=mw[4],excludegrp=3,4
 endphase
endrun

;Round and rename volumes
run pgm=hwynet
filei neti=@per@_preload.tmp
fileo neto=@per@_preload.net,

Exclude=VT_1,V1T_1,V2T_1,V3T_1,V4T_1,V_1,V1_1,V2_1,V3_1,V4_1,time_1,vc_1,
           cspd_1,vdt_1,vht_1
zones= @totzones@
V_TOTEE = ROUND(V_1/10)*10           ;round total volume
V_COMEE = ROUND(V1_1/10)*10          ;round COM volumes
V_MTKEE = ROUND(V2_1/10)*10          ;round MTK volumes
V_HTKEE = ROUND(V3_1/10)*10          ;round HTK volumes
V_SOVEE = ROUND(V4_1/10)*10          ;round SOV volumes
endrun

;---------------------------------------------------------------------
run pgm=hwyload

  id = "2000 highway assignment, period @per@

  mati[1] = TOD@per@.VTT
  mati[2] = com.trp
  mati[3] = mtk.trp
  mati[4] = htk.trp
  neti=@per@_preload.net                                 ;use free-flow highway
network with preloaded EE volumes
  neto=lod@year@@per@.tmp

  parameters maxiters = @iteration@,                   ;Max numbers of
iterations allowed
  gap=0.001,aad=0, raad=0,  combine=equi               ;Equilibrium vol
combination from
                                                         ;iterations with Lamda
                                                         ; added AAD and RAAD,
citilabs instruction for optimizing toll
  phase=linkread                                     ;read in link variables
from input file
    C  = li.capacity*@cfac@
```

```
    T0 = li.distance*60/li.speed

    lw.v_sovee = li.v_sovee
    lw.v_comee = li.v_comee
    lw.v_mtkee = li.v_mtkee
    lw.v_htkee = li.v_htkee

    linkclass=li.factype+1                          ;define linkclass by
assignment group

   ; Set Prohibitions
    IF (li.prohibition==1) ADDTOGROUP=2             ;no-truck LINKS
    IF (li.prohibition==2) ADDTOGROUP=3             ;HOV 2 LINKS
    if (li.factype> 49)    ADDTOGROUP=4             ;transit only
    IF (li.prohibition==5) ADDTOGROUP=5             ;links within I-285 (for
HTK)

   ; Set Fixed Toll Penalties
   ; Truck toll = 3 * auto toll, VOT = $60/hr (1.0 min/$)
    lw.trkaddtime=(li.toll*3)*1
   ; HOV toll = 0.4 * auto toll (avg 2.5 persons/veh), VOT = $15/hr (4.0 min/$)
    lw.hovaddtime=(li.toll*0.4)*4
   ; SOV toll, VOT = $15/hr (4.0 min/$)
    lw.sovaddtime=li.toll*4

   ; Add Time Penalty for Trucks at the Financial Center Tunnel (GA400)
   ; if ((a=8650 & b=8679) | (a=8678 & b=8651)) lw.trkaddtime=lw.trkaddtime+5
;PKS Corrected 06/08/04

   ; Set Time
    lw.trktime= T0 + lw.trkaddtime
    lw.hovtime= T0 + lw.hovaddtime
    lw.sovtime= T0 + lw.sovaddtime
  endphase

;setup phase
  FUNCTION {                                          ;change TP+ default
functions
    TC[1]=   T0/CURVE@PER@(1,V/C)
    TC[2]=   T0/CURVE@PER@(2,V/C)
    TC[3]=   T0/CURVE@PER@(3,V/C)
    TC[4]=   T0/CURVE@PER@(4,V/C)
    TC[5]=   T0/CURVE@PER@(5,V/C)
    TC[6]=   T0/CURVE@PER@(6,V/C)
    TC[7]=   T0/CURVE@PER@(7,V/C)
    TC[8]=   T0/CURVE@PER@(8,V/C)
    TC[9]=   T0/CURVE@PER@(9,V/C)
    TC[10]=  T0/CURVE@PER@(10,V/C)
    TC[11]=  T0/CURVE@PER@(11,V/C)
    TC[12]=  T0/CURVE@PER@(12,V/C)
    TC[13]=  T0/CURVE@PER@(13,V/C)
    TC[14]=  T0/CURVE@PER@(14,V/C)
    TC[15]=  T0/CURVE@PER@(15,V/C)
    TC[16]=  T0/CURVE@PER@(16,V/C)
    TC[17]=  T0/CURVE@PER@(17,V/C)
    TC[18]=  T0/CURVE@PER@(18,V/C)
    TC[19]=  T0/CURVE@PER@(19,V/C)
    TC[20]=  T0/CURVE@PER@(20,V/C)
    TC[21]=  T0/CURVE@PER@(21,V/C)


; Re-label volumes:
; 1 = SOV
; 2 = HOV
```

```
; 3 = COM
; 4 = MTK
; 5 = HTK

;total volume function (with preloaded EE)
    V = vol[1] + vol[2] + vol[3] + lw.v_sovee + 1.5 * (vol[4]+lw.v_mtkee) +
        2.0 * (vol[5] + lw.v_htkee) + lw.v_comee

    COST = min(time+lw.sovaddtime, 163)              ; Use same "cost" for
paths and equilibrium
    }

  phase=iloop
   ; Congested Time with Toll Penalties
    lw.trktime= time + lw.trkaddtime
    lw.sovtime= time + lw.sovaddtime
    lw.hovtime= time + lw.hovaddtime

    mw[1]=mi.1.2           ; SOV
    mw[2]=mi.1.3           ; HOV
    mw[3]=mi.2.@per@COM         ; COM
    mw[4]=mi.3.@per@MTK         ; MTK
    mw[5]=mi.4.@per@HTK         ; HTK

;zero out EE COM/truck and passenger car from main tables -- they've
; already been loaded
    jloop
      if(i>@lastin@ && j>@lastin@)
        mw[1]=0
        mw[2]=0
        mw[3]=0
        mw[4]=0
        mw[5]=0
      endif
    endjloop

;Separate heavy trucks for I-285 Bypass
    jloop
      if(i=109,112-113,116-123,125,131-133,182-216,226-446,462-463,480-483,
        488-494,499-503,526-533,535-547,549-556,580,582,584-608,611-628,
        633,641-748,753-838,842-843,847-848,852-1321,1324-1326,1328-1645,
        1669-1671,1679,1683-2118 &&
        j=109,112-113,116-123,125,131-133,182-216,226-446,462-463,480-483,
        488-494,499-503,526-533,535-547,549-556,580,582,584-608,611-628,
        633,641-748,753-838,842-843,847-848,852-1321,1324-1326,1328-1645,
        1669-1671,1679,1683-2118)

        mw[10]=mw[5] ;Outside I-285 to outside I-285
      else
        mw[11]=mw[5] ;Origin or destination inside I-285
      endif
    endjloop

;Assign SOV, COM
    pathload path=lw.sovtime,vol[1]=mw[1],vol[3]=mw[3], excludegrp=3,4

;Assign HOV
    pathload path=lw.hovtime,vol[2]=mw[2],excludegrp=4

;Assign some Heavy Trucks to a path that does not go inside I-285
    pathload path=lw.trktime, vol[5]=mw[10], excludegrp=2,3,4,5

; Assign other Heavy Trucks and all Medium Trucks to "normal" path
    pathload path=lw.trktime, vol[4]=mw[4],vol[5]=mw[11], excludegrp=2,3,4
```

```
; Volume/delay functions, by period
    LOOKUP INTERPOLATE=T, NAME=CURVEAM,     ;eqv. to speed curves in TRANPLAN
setup
    LOOKUP[1] =1, RESULT=7,                 ;centroid connector
    LOOKUP[2] =1, RESULT=2,                 ;freeway
    LOOKUP[3] =1, RESULT=2,                 ;parkway
    LOOKUP[4] =1, RESULT=2,                 ;HOV buffer seperated
    LOOKUP[5] =1, RESULT=2,                 ;hov barrier seperated
    LOOKUP[6] =1, RESULT=2,                 ;High speed ramp
    LOOKUP[7] =1, RESULT=2,                 ;Medium speed ramp
    LOOKUP[8] =1, RESULT=2,                 ;low speed ramp
    LOOKUP[9] =1, RESULT=2,                 ;Loop Ramp
    LOOKUP[10]=1, RESULT=2,                 ;Off Ramp/with intersection
    LOOKUP[11]=1, RESULT=2,                 ;On Ramp/with intersection
    LOOKUP[12]=1, RESULT=3,                 ;Express Way
    LOOKUP[13]=1, RESULT=4,                 ;Principle Arterial - Class I
    LOOKUP[14]=1, RESULT=4,                 ;Principle Arterial - Class II
    LOOKUP[15]=1, RESULT=5,                 ;Minor Arterial - Class 1
    LOOKUP[16]=1, RESULT=5,                 ;Minor Arterial - Class 2
    LOOKUP[17]=1, RESULT=5,                 ;HOV-arterial
    LOOKUP[18]=1, RESULT=6,                 ;Collector
    LOOKUP[19]=1, RESULT=6,                 ;Other Local
    LOOKUP[20]=1, RESULT=2,                 ;Planned Ramp/with intersections
    LOOKUP[21]=1, RESULT=2,                 ;Planned directional ramp with
intersections

;   V/C  Freeway Exrswy Prin Art        Min Art Collector Cent.
 R='0.00   1.000  1.000   1.000   1.000        1.000        1.000 ',
   '0.10   0.995  0.995   0.995   0.992        0.990        0.960 ',
   '0.20   0.990  0.990   0.990   0.975        0.960        0.920 ',
   '0.30   0.950  0.950   0.950   0.935        0.920        0.880 ',
   '0.40   0.910  0.910   0.910   0.880        0.860        0.800 ',
   '0.50   0.860  0.860   0.860   0.830        0.800        0.720 ',
   '0.60   0.790  0.790   0.790   0.760        0.730        0.640 ',
   '0.70   0.670  0.670   0.670   0.650        0.630        0.560 ',
   '0.80   0.560  0.560   0.560   0.540        0.520        0.480 ',
   '0.90   0.460  0.460   0.460   0.450        0.420        0.400 ',
   '1.00   0.350  0.350   0.350   0.340        0.310        0.360 ',
   '1.10   0.240  0.240   0.240   0.230        0.210        0.320 ',
   '1.20   0.160  0.160   0.160   0.160        0.160        0.280 ',
   '1.30   0.150  0.150   0.150   0.150        0.150        0.240 ',
   '1.40   0.140  0.140   0.140   0.140        0.140        0.200 ',
   '1.50   0.130  0.130   0.130   0.130        0.130        0.160 ',
   '1.60   0.120  0.120   0.120   0.120        0.120        0.120 ',
   '1.70   0.115  0.115   0.115   0.115        0.115        0.080 ',
   '1.80   0.110  0.110   0.110   0.110        0.110        0.080 ',
   '1.90   0.105  0.105   0.105   0.105        0.105        0.080 ',
   '2.00   0.100  0.100   0.100   0.100        0.100        0.080 ',
  '99.00   0.010  0.010   0.010   0.010        0.010        0.010 '

    LOOKUP INTERPOLATE=T, NAME=CURVEMD,     ;eqv. to speed curves in TRANPLAN
setup
    LOOKUP[1] =1, RESULT=7,                 ;centroid connector
    LOOKUP[2] =1, RESULT=2,                 ;freeway
    LOOKUP[3] =1, RESULT=2,                 ;parkway
    LOOKUP[4] =1, RESULT=2,                 ;HOV buffer seperated
    LOOKUP[5] =1, RESULT=2,                 ;hov barrier seperated
    LOOKUP[6] =1, RESULT=2,                 ;High speed ramp
    LOOKUP[7] =1, RESULT=2,                 ;Medium speed ramp
    LOOKUP[8] =1, RESULT=2,                 ;low speed ramp
    LOOKUP[9] =1, RESULT=2,                 ;Loop Ramp
    LOOKUP[10]=1, RESULT=2,                 ;Off Ramp/with intersection
    LOOKUP[11]=1, RESULT=2,                 ;On Ramp/with intersection
```

```
    LOOKUP[12]=1, RESULT=3,                 ;Express Way
    LOOKUP[13]=1, RESULT=4,                 ;Principle Arterial - Class I
    LOOKUP[14]=1, RESULT=4,                 ;Principle Arterial - Class II
    LOOKUP[15]=1, RESULT=5,                 ;Minor Arterial - Class 1
    LOOKUP[16]=1, RESULT=5,                 ;Minor Arterial - Class 2
    LOOKUP[17]=1, RESULT=5,                 ;HOV-arterial
    LOOKUP[18]=1, RESULT=6,                 ;Collector
    LOOKUP[19]=1, RESULT=6,                 ;Other Local
    LOOKUP[20]=1, RESULT=2,                 ;Planned Ramp/with intersections
    LOOKUP[21]=1, RESULT=2,                 ;Planned directional ramp with
intersections

;         V/C  Freeway  Exrswy Prin Art Min Art Collector Cent.
   R=  ' 0.00  1.000  1.000  1.000  1.000  1.000  1.000 ' ,
       ' 0.10  0.995  0.995  0.995  0.992  0.990  0.960 ' ,
       ' 0.20  0.985  0.985  0.985  0.975  0.970  0.920 ' ,
       ' 0.30  0.975  0.975  0.975  0.960  0.950  0.880 ' ,
       ' 0.40  0.950  0.950  0.950  0.930  0.915  0.800 ' ,
       ' 0.50  0.920  0.920  0.920  0.900  0.870  0.720 ' ,
       ' 0.60  0.890  0.890  0.890  0.865  0.830  0.640 ' ,
       ' 0.70  0.830  0.830  0.830  0.800  0.770  0.560 ' ,
       ' 0.80  0.740  0.740  0.740  0.710  0.660  0.480 ' ,
       ' 0.90  0.500  0.500  0.500  0.500  0.500  0.400 ' ,
       ' 1.00  0.310  0.310  0.310  0.310  0.310  0.360 ' ,
       ' 1.10  0.210  0.210  0.210  0.210  0.210  0.320 ' ,
       ' 1.20  0.160  0.160  0.160  0.160  0.160  0.280 ' ,
       ' 1.30  0.150  0.150  0.150  0.150  0.150  0.240 ' ,
       ' 1.40  0.140  0.140  0.140  0.140  0.140  0.200 ' ,
       ' 1.50  0.130  0.130  0.130  0.130  0.130  0.160 ' ,
       ' 1.60  0.120  0.120  0.120  0.120  0.120  0.120 ' ,
       ' 1.70  0.115  0.115  0.115  0.115  0.115  0.080 ' ,
       ' 1.80  0.110  0.110  0.110  0.110  0.110  0.080 ' ,
       ' 1.90  0.105  0.105  0.105  0.105  0.105  0.080 ' ,
       ' 2.00  0.100  0.100  0.100  0.100  0.100  0.080 ' ,
       '99.00  0.010  0.010  0.010  0.010  0.010  0.010 '

    LOOKUP INTERPOLATE=T, NAME=CURVEPM,     ;eqv. to speed curves in TRANPLAN
setup
    LOOKUP[1] =1, RESULT=7,                 ;centroid connector
    LOOKUP[2] =1, RESULT=2,                 ;freeway
    LOOKUP[3] =1, RESULT=2,                 ;parkway
    LOOKUP[4] =1, RESULT=2,                 ;HOV buffer seperated
    LOOKUP[5] =1, RESULT=2,                 ;hov barrier seperated
    LOOKUP[6] =1, RESULT=2,                 ;High speed ramp
    LOOKUP[7] =1, RESULT=2,                 ;Medium speed ramp
    LOOKUP[8] =1, RESULT=2,                 ;low speed ramp
    LOOKUP[9] =1, RESULT=2,                 ;Loop Ramp
    LOOKUP[10]=1, RESULT=2,                 ;Off Ramp/with intersection
    LOOKUP[11]=1, RESULT=2,                 ;On Ramp/with intersection
    LOOKUP[12]=1, RESULT=3,                 ;Express Way
    LOOKUP[13]=1, RESULT=4,                 ;Principle Arterial - Class I
    LOOKUP[14]=1, RESULT=4,                 ;Principle Arterial - Class II
    LOOKUP[15]=1, RESULT=5,                 ;Minor Arterial - Class 1
    LOOKUP[16]=1, RESULT=5,                 ;Minor Arterial - Class 2
    LOOKUP[17]=1, RESULT=5,                 ;HOV-arterial
    LOOKUP[18]=1, RESULT=6,                 ;Collector
    LOOKUP[19]=1, RESULT=6,                 ;Other Local
    LOOKUP[20]=1, RESULT=2,                 ;Planned Ramp/with intersections
    LOOKUP[21]=1, RESULT=2,                 ;Planned directional ramp with
intersections

;        V/C   Freeway  Exrswy Prin Art Min Art Collector Cent.
    R=   '0.00   1.000         1.000  1.000  1.000  1.000  1.000' ,
        '0.10  0.995  0.995  0.995  0.995  0.990  0.960' ,
        '0.20  0.990  0.990  0.990  0.990  0.980  0.920' ,
        '0.30  0.970  0.970  0.970  0.960  0.950  0.880' ,
        '0.40  0.940  0.940  0.940  0.930  0.915  0.800' ,
```

```
        '0.50  0.910  0.910  0.910  0.900  0.870  0.720' ,
        '0.60  0.870  0.870  0.870  0.865  0.830  0.640' ,
        '0.70  0.820  0.820  0.820  0.800  0.770  0.560' ,
        '0.80  0.720  0.720  0.720  0.710  0.680  0.480' ,
        '0.90  0.570  0.570  0.570  0.560  0.560  0.400' ,
        '1.00  0.400  0.400  0.400  0.390  0.390  0.360' ,
        '1.10  0.280  0.280  0.280  0.280  0.280  0.320' ,
        '1.20  0.200  0.200  0.200  0.200  0.200  0.280' ,
        '1.30  0.160  0.160  0.160  0.160  0.160  0.240' ,
        '1.40  0.140  0.140  0.140  0.140  0.140  0.200' ,
        '1.50  0.130  0.130  0.130  0.130  0.130  0.160' ,
        '1.60  0.120  0.120  0.120  0.120  0.120  0.120' ,
        '1.70  0.115  0.115  0.115  0.115  0.115  0.080' ,
        '1.80  0.110  0.110  0.110  0.110  0.110  0.080' ,
        '1.90  0.105  0.105  0.105  0.105  0.105  0.080' ,
        '2.00  0.100  0.100  0.100  0.100  0.100  0.080' ,

       '99.00  0.010  0.010  0.010  0.010  0.010  0.010 '

    LOOKUP INTERPOLATE=T, NAME=CURVENT,     ;eqv. to speed curves in TRANPLAN
setup
    LOOKUP[1] =1, RESULT=7,                 ;centroid connector
    LOOKUP[2] =1, RESULT=2,                 ;freeway
    LOOKUP[3] =1, RESULT=2,                 ;parkway
    LOOKUP[4] =1, RESULT=2,                 ;HOV buffer seperated
    LOOKUP[5] =1, RESULT=2,                 ;hov barrier seperated
    LOOKUP[6] =1, RESULT=2,                 ;High speed ramp
    LOOKUP[7] =1, RESULT=2,                 ;Medium speed ramp
    LOOKUP[8] =1, RESULT=2,                 ;low speed ramp
    LOOKUP[9] =1, RESULT=2,                 ;Loop Ramp
    LOOKUP[10]=1, RESULT=2,                 ;Off Ramp/with intersection
    LOOKUP[11]=1, RESULT=2,                 ;On Ramp/with intersection
    LOOKUP[12]=1, RESULT=3,                 ;Express Way
    LOOKUP[13]=1, RESULT=4,                 ;Principle Arterial - Class I
    LOOKUP[14]=1, RESULT=4,                 ;Principle Arterial - Class II
    LOOKUP[15]=1, RESULT=5,                 ;Minor Arterial - Class 1
    LOOKUP[16]=1, RESULT=5,                 ;Minor Arterial - Class 2
    LOOKUP[17]=1, RESULT=5,                 ;HOV-arterial
    LOOKUP[18]=1, RESULT=6,                 ;Collector
    LOOKUP[19]=1, RESULT=6,                 ;Other Local
    LOOKUP[20]=1, RESULT=2,                 ;Planned Ramp/with intersections
    LOOKUP[21]=1, RESULT=2,                 ;Planned directional ramp with
intersections

;         V/C  Freeway  Exrswy Prin Art Min Art Collector Cent.
   R=  ' 0.00  1.000  1.000  1.000  1.000  1.000  1.000 ' ,
       ' 0.10  0.990  0.990  0.990  0.990  0.980  0.960 ' ,
       ' 0.20  0.940  0.940  0.940  0.930  0.920  0.920 ' ,
       ' 0.30  0.770  0.770  0.770  0.775  0.780  0.880 ' ,
       ' 0.40  0.630  0.630  0.630  0.660  0.700  0.800 ' ,
       ' 0.50  0.550  0.550  0.550  0.590  0.630  0.720 ' ,
       ' 0.60  0.500  0.500  0.500  0.550  0.600  0.640 ' ,
       ' 0.70  0.400  0.400  0.400  0.450  0.500  0.560 ' ,
       ' 0.80  0.330  0.330  0.330  0.350  0.400  0.480 ' ,
       ' 0.90  0.280  0.280  0.280  0.280  0.280  0.400 ' ,
       ' 1.00  0.220  0.220  0.220  0.220  0.220  0.360 ' ,
       ' 1.10  0.180  0.180  0.180  0.180  0.180  0.320 ' ,
       ' 1.20  0.160  0.160  0.160  0.160  0.160  0.280 ' ,
       ' 1.30  0.150  0.150  0.150  0.150  0.150  0.240 ' ,
       ' 1.40  0.140  0.140  0.140  0.140  0.140  0.200 ' ,
       ' 1.50  0.130  0.130  0.130  0.130  0.130  0.160 ' ,
       ' 1.60  0.120  0.120  0.120  0.120  0.120  0.120 ' ,
       ' 1.70  0.115  0.115  0.115  0.115  0.115  0.080 ' ,
       ' 1.80  0.110  0.110  0.110  0.110  0.110  0.080 ' ,
       ' 1.90  0.105  0.105  0.105  0.105  0.105  0.080 ' ,
       ' 2.00  0.100  0.100  0.100  0.100  0.100  0.080 ' ,
       '99.00  0.010  0.010  0.010  0.010  0.010  0.010 '
```

```
  endphase
endrun

;---------------------------------------------------------------------
run pgm=hwynet

;Round volumes

neti=lod@year@@per@.tmp
neto=new@year@@per@.lod,
  Exclude=VT_1,V1T_1,V2T_1,V3T_1,V4T_1,V5T_1,V_1,V1_1,V2_1,V3_1,V4_1,V5_1

zones= @totzones@
V_TOT@PER@ = ROUND(V_1)                         ;round total volume
V_SOV@PER@ = ROUND(V1_1 + V_SOVEE)              ;round SOV volumes
V_HOV@PER@ = ROUND(V2_1)                        ;round HOV volumes
V_COM@PER@ = ROUND(V3_1 + V_COMEE)              ;round COM volumes
V_MTK@PER@ = ROUND(V4_1 + V_MTKEE)              ;round MTK volumes
V_HTK@PER@ = ROUND(V5_1 + V_HTKEE)              ;round HTK volumes

if (Time_1>0)
 CGSTDSPD=distance/time_1*60
else
 CGSTDSPD=0
endif

endrun

endloop

;---------------------------------------------------------------------
loop t = 1,3
  if (t = 1)
    vt = 'COM'
    cf = 'COMCNT'
  endif
  if (t = 2)
    vt = 'MTK'
    cf = 'MEDTRK'
  endif
  if (t = 3)
    vt = 'HTK'
    cf = 'HVYTRK'
  endif

run pgm=hwynet

  id = "Assignment evaluation: @vt@

  neti[1] = new00am.lod
  neti[2] = new00md.lod
  neti[3] = new00pm.lod
  neti[4] = new00nt.lod
  neti[5] = comvol.net

  neto    = @vt@24.lod, exclude=v_sovam,v_sovmd,v_sovpm,v_sovnt,
    v_hovam,v_hovmd,v_hovpm,v_hovnt,v_comam,v_commd,v_compm,v_comnt,
    v_mtkam,v_mtkmd,v_mtkpm,v_mtknt,v_htkam,v_htkmd,v_htkpm,v_htknt,
    v_totee,v_comee,v_mtkee,v_htkee,v_sovee

; Recode FACTYPE as 1=frwy/expwy, 2=arterial, 3=coll.
  lookup interpolate=n, fail=0,1,1, name=ft,
    lookup[1] = 1, result = 2,
    r = '0  0',
```

```
        '1  1',
        '2  1',
        '3  1',
        '4  1',
        '5  1',
        '6  1',
        '7  1',
        '8  1',
        '9  1',
        '10 1',
        '11 1',
        '12 2',
        '13 2',
        '14 2',
        '15 2',
        '16 2',
        '17 3',
        '18 3',
        '19 1',
        '20 1'

  totvol = li.1.v_totam + li.2.v_totmd + li.3.v_totpm + li.4.v_totnt
  @vt@vol = li.1.v_@vt@am + li.2.v_@vt@md + li.3.v_@vt@pm + li.4.v_@vt@nt
  _vmt   = totvol * distance

; Tab VMT to check
  _ftg = ft(1,li.1.FACTYPE)
  crosstab var = _vmt, form=12.0c,
           col = ATYPE, range = 1-7-1, 1-7,
           row = _ftg, range = 0-3-1, 0-3

; Re-set count to what's in COMVOL.NET.
  @cf@ = li.5.@cf@

; Accuracy evaluation.  Use only links with counts.
  _bad = 0
  _cnt = li.5.@cf@
  if (_cnt > 0)

; List estimated and observed volumes for counted links
;  with a big difference.
    _err   = abs(@vt@vol - _cnt)
    _diffr = (100. * @vt@vol/_cnt)-100.
    _x     = _cnt^0.092
    _maxd  = _cnt * 1.25 * (2 - exp(0.224 * _x))

    if (_err >= _maxd)
      print form=8, list = A,B, list=@vt@vol,_cnt,_err,_diffr,_maxd
      _bad = 1
    endif

; Prep for RMSE tab.
    _sqerr  = _err * _err
    _links  = 1

; Crosstabs of count/assigned totals and error.
;  By Fac Type and Area Type:
    crosstab var = _cnt,@vt@vol, form=10.0c,
             var = _links,_bad, form=5.0c,
             var = _sqerr, form=15.0c,
             col = ATYPE, range = 1-7-1, 1-7,
             row = _ftg, range = 1-3-1, 1-3,
             comp = @vt@vol/_cnt, form=6.2,
             comp = _bad/_links, form=6.2,
```

```
            comp = sqrt(_sqerr/_links), form=8.1,
            comp = sqrt(_sqerr/_links)/(_cnt/_links), form=6.2

  endif

endrun
endloop

;---------------------------------------------------------------------
run pgm=hwynet

  id = "Assignment evaluation: Total Truck

; Need to do this, to compare with the original ARC model

  neti[1] = new00am.lod
  neti[2] = new00md.lod
  neti[3] = new00pm.lod
  neti[4] = new00nt.lod
  neti[5] = comvol.net

  neto    = tot24.lod

; Recode FACTYPE as 1=frwy/expwy, 2=arterial, 3=coll.
  lookup interpolate=n, fail=0,1,1, name=ft,
    lookup[1] = 1, result = 2,
    r = '0  0',
        '1  1',
        '2  1',
        '3  1',
        '4  1',
        '5  1',
        '6  1',
        '7  1',
        '8  1',
        '9  1',
        '10 1',
        '11 1',
        '12 2',
        '13 2',
        '14 2',
        '15 2',
        '16 2',
        '17 3',
        '18 3',
        '19 1',
        '20 1'

  mtk24 = li.1.v_mtkam + li.2.v_mtkmd + li.3.v_mtkpm + li.4.v_mtknt
  htk24 = li.1.v_htkam + li.2.v_htkmd + li.3.v_htkpm + li.4.v_htknt
  trk24 = mtk24 + htk24
  com24 = li.1.v_comam + li.2.v_commd + li.3.v_compm + li.4.v_comnt

  _ftg = ft(1,li.1.FACTYPE)

; Re-set count to what's in COMVOL.NET.
  COMCNT = li.5.COMCNT
  MEDTRK = li.5.MEDTRK
  HVYTRK = li.5.HVYTRK

; Accuracy evaluation.  Use only links with counts.
  _bad = 0
  _cnt = li.5.medtrk + li.5.hvytrk
  if (_cnt > 0)
```

```
; List estimated and observed volumes for counted links
;  with a big difference.
    _err   = abs(trk24 - _cnt)
    _diffr = (100. * trk24/_cnt)-100.
    _x     = _cnt^0.092
    _maxd  = _cnt * 1.25 * (2 - exp(0.224 * _x))

    if (_err >= _maxd)
      print form=8, list = A,B, list=trk24,_cnt,_err,_diffr,_maxd
      _bad = 1
    endif

; Prep for RMSE tab.
    _sqerr  = _err * _err
    _links  = 1

; Crosstabs of count/assigned totals and error.
;  By Fac Type and Area Type:
    crosstab var = _cnt,trk24, form=10.0c,
             var = _links,_bad, form=5.0c,
             var = _sqerr, form=15.0c,
             col = ATYPE, range = 1-7-1, 1-7,
             row = _ftg, range = 1-3-1, 1-3,
             comp = trk24/_cnt, form=6.2,
             comp = _bad/_links, form=6.2,
             comp = sqrt(_sqerr/_links), form=8.1,
             comp = sqrt(_sqerr/_links)/(_cnt/_links), form=6.2

  endif

endrun

*del *.tmp
```

Table 6.23
Nearest Station Setup

```
maxzone = 2118
maxint  = 2027
year    = '00'

run pgm=matrix

; distcor.s

  id = "Distance to nearest external station

;  input off-peak highway skim
  mati[1] = ff00hwy.skm

;  skip entire calculation for external stations
  if (i > @maxint@) continue

; get distance matrix; exclude internal zones
  mw[1] = mi.1.distance, exclude = 1-@maxint@

; Fill zero cells with large value.
  jloop
    if (mw[1] < 0.01) mw[1] = 9999.
```

```
  endjloop

; "Nearest" zone is the one with the minimum distance.
  nearest = rowmin(1)

  print list = i(5.0),nearest(7.2)  file = extdist.dat  print=n
endrun
```

Table 6.24
COM/TRK F Factors

; time	COM I/I	MTK I/I	HTK I/I	COM Ext	MTK Ext	HTK Ext
1	1572420	1615454	1648088	1750000	1750000	1750000
2	1412860	1491252	1552111	218750	298821	331563
3	1269491	1376599	1461723	64815	106262	125299
4	1140670	1270761	1376599	27344	51025	62819
5	1024921	1173060	1296432	14000	28884	36771
6	920918	1082871	1220934	8102	18145	23740
7	827469	999616	1149832	5102	12247	16398
8	743502	922762	1082871	3418	8713	11902
9	668055	851816	1019809	2401	6452	8971
10	600265	786326	960420	1750	4932	6967
11	539353	725870	904490	1315	3868	5542
12	484623	670063	851816	1013	3098	4498
13	435446	618546	802211	797	2526	3712
14	391260	570990	755493	638	2091	3107
15	351557	527090	711497	519	1754	2633
16	315883	486565	670063	427	1488	2255
17	283829	449156	631041	356	1275	1950
18	255027	414624	594292	300	1102	1700
19	229149	382746	559683	255	960	1493
20	205896	353319	527090	219	842	1320
21	185003	326154	496395	189	744	1174
22	166230	301079	467487	164	660	1050
23	149362	277930	440262	144	590	944
24	134205	256562	414624	127	529	852
25	120587	236837	390478	112	477	773
26	108350	218628	367738	100	431	703
27	97356	201819	346323	89	392	642
28	87477	186302	326154	80	357	589
29	78600	171979	307161	72	327	541
30	70624	158756	289273	65	299	499
31	63458	146551	272427	59	275	461
32	57018	135283	256562	53	254	427
33	51232	124882	241621	49	235	397
34	46034	115281	227550	45	218	369
35	41362	106418	214299	41	202	345
36	37165	98236	201819	38	188	322
37	33394	90683	190066	35	175	302
38	30005	83711	178997	32	164	283
39	26960	77275	168573	30	153	266
40	24225	71334	158756	27	144	250
41	21766	65849	149511	25	135	236
42	19558	60787	140804	24	127	222
43	17573	56113	132605	22	120	210
44	15790	51799	124882	21	113	199
45	14188	47817	117610	19	106	189
46	12748	44140	110761	18	101	179
47	11454	40747	104310	17	95	170
48	10292	37614	98236	16	90	161
49	9248	34722	92515	15	86	154

; time	COM I/I	MTK I/I	HTK I/I	COM Ext	MTK Ext	HTK Ext
50	8309	32052	87127	14	81	146
51	7466	29588	82053	13	77	140
52	6708	27313	77275	12	74	133
53	6028	25213	72775	12	70	127
54	5416	23275	68537	11	67	122
55	4866	21485	64546	11	64	116
56	4373	19833	60787	10	61	112
57	3929	18309	57247	9	58	107
58	3530	16901	53913	9	56	103
59	3172	15602	50773	9	53	98
60	2850	14402	47817	8	51	95
61	2561	13295	45032	8	49	91
62	2301	12273	42409	7	47	87
63	2068	11329	39940	7	45	84
64	1858	10458	37614	7	43	81
65	1669	9654	35423	6	42	78
66	1500	8912	33360	6	40	75
67	1348	8227	31418	6	39	73
68	1211	7594	29588	6	37	70
69	1088	7010	27865	5	36	68
70	978	6471	26242	5	35	65
71	878	5974	24714	5	33	63
72	789	5514	23275	5	32	61
73	709	5090	21919	4	31	59
74	637	4699	20643	4	30	57
75	573	4338	19441	4	29	55
76	514	4004	18309	4	28	54
77	462	3696	17242	4	27	52
78	415	3412	16238	4	26	50
79	373	3150	15293	4	25	49
80	335	2908	14402	3	25	47
81	301	2684	13563	3	24	46
82	271	2478	12773	3	23	45
83	243	2287	12030	3	22	43
84	219	2111	11329	3	22	42
85	196	1949	10669	3	21	41
86	176	1799	10048	3	20	40
87	159	1661	9463	3	20	39
88	142	1533	8912	3	19	38
89	128	1415	8393	2	19	37
90	115	1307	7904	2	18	36
91	103	1206	7444	2	18	35
92	93	1113	7010	2	17	34
93	83	1028	6602	2	17	33
94	75	949	6218	2	16	32
95	67	876	5855	2	16	31
96	61	808	5514	2	15	31
97	54	746	5193	2	15	30
98	49	689	4891	2	15	29
99	44	636	4606	2	14	28
100	39	587	4338	2	14	28
101	35	542	4085	2	14	27

; time	COM I/I	MTK I/I	HTK I/I	COM Ext	MTK Ext	HTK Ext
102	32	500	3847	2	13	26
103	29	462	3623	2	13	26
104	26	426	3412	2	13	25
105	23	394	3214	2	12	25
106	21	363	3026	1	12	24
107	19	335	2850	1	12	24
108	17	310	2684	1	11	23
109	15	286	2528	1	11	23
110	14	264	2381	1	11	22
111	12	244	2242	1	11	22
112	11	225	2111	1	10	21
113	10	207	1988	1	10	21
114	9	192	1873	1	10	20
115	8	177	1764	1	10	20
116	7	163	1661	1	10	19
117	6	151	1564	1	9	19
118	6	139	1473	1	9	19
119	5	128	1387	1	9	18
120	5	119	1307	1	9	18
121	4	109	1230	1	9	18
122	4	101	1159	1	8	17
123	3	93	1091	1	8	17
124	3	86	1028	1	8	17
125	3	79	968	1	8	16
126	2	73	912	1	8	16
127	2	68	858	1	8	16
128	2	62	808	1	7	15
129	2	58	761	1	7	15
130	2	53	717	1	7	15
131	1	49	675	1	7	15
132	1	45	636	1	7	14
133	1	42	599	1	7	14
134	1	39	564	1	7	14
135	1	36	531	1	6	13
136	1	33	500	1	6	13
137	1	30	471	1	6	13
138	1	28	444	1	6	13
139	1	26	418	1	6	13
140	1	24	394	1	6	12
141	0	22	371	1	6	12
142	0	20	349	1	6	12
143	0	19	329	1	6	12
144	0	17	310	1	5	12
145	0	16	292	1	5	11
146	0	15	275	1	5	11
147	0	14	259	1	5	11
148	0	13	244	1	5	11
149	0	12	229	1	5	11
150	0	11	216	1	5	10
151	0	10	203	1	5	10
152	0	9	192	0	5	10
153	0	8	180	0	5	10

; time	COM I/I	MTK I/I	HTK I/I	COM Ext	MTK Ext	HTK Ext
154	0	8	170	0	5	10
155	0	7	160	0	5	10
156	0	7	151	0	4	10
157	0	6	142	0	4	9
158	0	6	134	0	4	9
159	0	5	126	0	4	9
160	0	5	119	0	4	9
161	0	4	112	0	4	9
162	0	4	105	0	4	9
163	0	4	99	0	4	9
164	0	4	93	0	4	8
165	0	3	88	0	4	8
166	0	3	83	0	4	8
167	0	3	78	0	4	8
168	0	3	73	0	4	8
169	0	2	69	0	4	8
170	0	2	65	0	4	8
171	0	2	61	0	4	8
172	0	2	58	0	3	8
173	0	2	54	0	3	7
174	0	2	51	0	3	7
175	0	1	48	0	3	7
176	0	1	45	0	3	7
177	0	1	43	0	3	7
178	0	1	40	0	3	7
179	0	1	38	0	3	7
180	0	1	36	0	3	7

References

1. *Quick Response Freight Manual*, prepared by Cambridge Systematics for the Travel Model Improvement Program, September 1996
2. *Truck Trip Generation Data*, NCHRP Synthesis 298, prepared by Cambridge Systematics and Jack Faucett Associates for the Transportation Research Board, 2001
3. Allen, W.G., *Adaptable Assignment,*presented at the Sixth TRB Conference on the Application of Transportation Planning Methods, May 1997
4. List, G. and Turnquist, M., *Estimating Truck Travel Patterns in Urban Areas*, Transportation Research Record 1430, 1994

7. Airport Passenger Model

The normal travel demand models for an urban area do not estimate the number of air passengers to and from an airport very well, if at all. This is mainly because the frequency of air travel from a household is so small that most home interview never finds more than two or three air passenger trips. But travel demand can be estimated if the air passengers are interviewed at the airport and the total number of air passenger enplanements is known. There was an air passenger survey conducted at the Hartsfield-Jackson Airport in 2000. And it is possible to obtain the number of enplanements from the FAA and / or from the Airport Authority.

The air passenger model consists of a three step process. These steps are:

1. Obtain total average daily enplanements. This data is from external sources, mainly FAA information and forecasts.
2. Allocate the daily enplanements to there “ground side” trip ends. This allocation model primarily uses information on households and employment.
3. Estimate the mode used to travel between the air port and the “ground side” trip end. For this study a nested logit model has been used to develop these estimates.

The first step uses information from external sources and, in the application program, is specified by the user. The second step uses information from the normal transit demand models and, in the application program, is specified by including specific information from these models to the program. The third step required a review of air passenger models and the development of a nested logit mode choice model for the Atlanta region. In addition to developing the procedures and models to estimate air passenger travel, a computer program was written to implement all three steps.

7.1. Step One: Estimating Total Air Passengers

The initial step in estimating the air passenger travel for the region is to estimate the average daily air passengers to and from the airport. This estimates consists of estimating (or obtaining) enplanements and estimating the purpose of these enplanements. The best source of annual enplanements is the FAA. For the year 2000, the FAA estimated that the Hartsfield Airport had 39,277,901 annual enplanements. These enplanements though included transferring passengers. The Hartsfield Master Plan estimated that 59 percent of these enplanements were transferring passengers. Therefore it is estimated that of the 39,277,901 annual passengers in 2000 approximately 16,103,939 actually leave the airport. The annual enplanements then have to be converted to average weekday estimates. This is done by dividing by 365, producing 44,120 daily enplaning passengers. It is assumed that for every enplaning passenger there is one deplaining passenger, a not unreasonable assumption, producing, for the year 2000, a total of 88,240 total daily air passengers to and from the airport.

The next phase of this step is to estimate the “purpose” of the air passenger. For this model the purpose is defined in two ways; the type of air passenger and the trip purpose of the trip. The type of air passenger is either the resident of the region or a non-resident of the region. The purpose is either business or non-business.

Therefore this model has four purposes which are:

1. Residents on Business trips
2. Non-residents on Business trips
3. Residents on non-business trips
4. Non-residents on non-business trips

A review of the survey data and information form other airport surveys showed that the proportion of air passengers for the Hartsfield airport is as follows

1. Residents on Business – 22.49 percent of all air passengers
2. Non-residents on Business – 24.44 percent of all air passengers
3. Residents on non-business – 31.30 percent of all air passengers
4. Non-residents on non-business – 21.77 percent of all air passengers

Given these percentages the average daily air passengers in 2000 by purpose are:

1. Residents on Business - 9,923 trips
2. Non-residents on Business – 10,783 trips
3. Residents on non-business – 13,810 trips
4. Non-residents on non-business – 9,605 trips

These parameters need to be forecasted for future years. It is suggested that the FAA and / or the airport authority would be good sources for the total enplanements. Unless other surveys are taken the percent transfers and the percent by purpose developed in this study are adequate values for forecasting. The application computer program for this model has defaults for the percent transfers and percent by purpose, the defaults being the values presented in this section, but the user has the option to change this values. The total annual enplanements must be determined from an external source.

7.2. Step Two: Allocating Ground Side Trip Ends

In Step one, the total daily air passengers are estimated. In this step, these total air passengers are allocated to the ground side locations – either the homes of the residents or the offices, hotels, etc. for the non-residents. A review of the survey data and other studies indicated that the most appropriate allocation procedure would be to use the households by income level and total employment.

Using the survey it was found that 77.11 percent of the resident business trips had a non-airport end at a private residence and 22.89 had a non-airport trip end at a place of business – obviously people leaving from their place of business to go to the airport. These trip ends were compared to zone level data, including households by income level and employment by employment type. This comparison was performed using statistical measures, mainly regression. No significant equations, using different employment categories could be determined and the data showed that higher income households made more trips than lower incomes, once the regression analysis was constrained so that the trip rates were increasing with income. It should be noted though that these statistical relationships were not extremely significant. The possible reasons for this minor statistical relationships were: (1) the area of the measures for the non-airport end of the trip was zip code areas, of which there are only 168 in the region; (2) the employment categories were high level SIC categories which do not necessarily have any relationship to the income of the employee; (3) hotel and motel rooms or employment were not available; and (4) the survey was a sample which might have had, at the zip code level, a high degree of variability. But given the information from the survey and the analysis, a residential business trip generation model was developed. This model was an allocation model, since the total residential business trip are obtained in the first step of the model; that is the total residential business trips are 22.94 percent of total enplanements. The allocation model is a two stage model. The first stage separates the residential business trips into residential based trips and into non-residential based trips. This is a simple factoring procedure, with 77.11 percent of the trips being from residences (7,652 in 2000) and 22.89 being from businesses (2,271 in 2000). The trips from residences are then allocated to traffic analysis zones based on the number of households in the zone, by income group, with a weight assigned to each income group. Table 7.1 shows the equations used to estimate these trips ends with the coefficients of the equations adjusted so that the equations will estimate total 2000 air passenger trips correctly. In the development of these models it was found that basic model under-estimated "central" Fulton County (primarily the city of Atlanta) and over-estimated the more outlying counties of Cherokee, Forsyth, Paulding, Douglas, Coweta, Fayette, Clayton, Henry, and Rockdale. To adjust for these errors, a set of K factors were developed. There were K factors associated with the three areas (central Fulton, outlying counties, other areas), on the equations for employment related trips and on the equations for household related trips (6 K factors in all).. These K factors are shown on Table 71.

For the non-business residential trips it was found that almost all the trips originated from a private residence. Therefore the model for the non-business residential trips was to allocate the trips based upon the number of households, by income level in the traffic analysis zone. The equations for these trips are shown on Table 7.1.

For the non-residential business trips, it was found that 91.87 percent of the non-airport trip ends were employment related (with 55.15 percent being related to motels or hotels) and only 8.13 percent being related to private residences. Since the land use forecasts do not include any specific measures for hotels and motels (such as rooms), the non-residential business model was developed in the same manner as the residential business model. That is a one stage split between employment related trips and private residence trips (with the split being 91.87 and 8.13 percent). The employment related trips were than allocated to the traffic analysis zones based upon total employment and the private resident trips were allocated to the traffic analysis zones based upon households by income. Again Table 7.1 presents these equations. .

For the non-residential non-business trips, it was found that 81.65 percent of the trip ends were private residence related and 18.35 percent were employment related (with 13.85 being related to hotels or motels). Again a two stage model was used, with the first stage allocating 81.65 percent of the trip ends to residences and 18.35 percent of the trips to employment. The residence related trips were then allocated to the traffic analysis zones based on the households by income level and the employment related trips were allocated to the traffic analysis zones based on the total employment.

Table 7.1
Equations to Allocate Air Passenger Trip Ends to the Non-Airport End of the Trip

Equation to Allocate Residential Business Air Passenger Trips from Private Residents
0.001672 * low income households + 0.009965 * Medium Low Income Households
+ 0.020847* Medium High Income Households + 0.024884 * High Income Households

Equation to Allocate Residential Business Air Passenger Trips from Non-Private Residents
0.003355 * Total Employment

Equation to Allocate Residential Non-Business Air Passenger Trips
0.002648 * low income households + 0.011700 * Medium Low Income Households
+ 0.040398 * Medium High Income Households + 0.050785 * High Income Households

Equation to Allocate Non-Residential Business Air Passenger Trips
0.015928 * Total Employment

Equation to Allocate Non-Residential Non-Business Air Passenger Trips from Private Residents
0.001307 * low income households + 0.007671 * Medium Low Income Households
+ 0.023283 * Medium High Income Households + 0.026669 * High Income Households

Equation to Allocate Non-Residential Non-Business Air Passenger Trips From Employment
0.002604 * Total Employment

Adjustment Factors

Region	Factor on Employment	Factor on Households
Middle Fulton	1.23	1.13
Cobb/Gwinett/DeKalb/NF/SF	0.64	0.84
Other areas	0.08	0.34

Zone Description of Regions for Factors

1. Middle_Fulton: 1-176, 1646-1667
2. North_Fulton/South_Fulton/Cobb/Gwinett/DeKalb: 177-1204, 1668-1683
3. Others: 1205-1645, 1684-2027

Note: 1) Zones with a – between the zone numbers mean a range, for example 1-176 means from zone 1 to zone 176. The zones are the traffic analysis zones for the 2000 census model.

2) Income Groups: Low--$0~19999; Medium Low--$20000~49999; Medium High--$50000~99999; High--$100000~.

7.3. Step Three: Mode Choice Model

Since the air passengers have a wide array of modal options a relatively sophisticated approach to mode choice modeling was used. This was a nested logit model, with different structures and modal options for Resident and Non-resident air passengers, as shown in Figure 7.1.

Non-residents are assumed to have three primary modal choices: being dropped off (or picked up) by someone in a private car, using a rental car, or using one of the non-private-auto modes. Within the latter, there are two choices: public transit (regularly scheduled service) and taxi. The free hotel shuttles were considered, but the survey data did not include enough observations of this mode to support it being used as a separate mode.

Residents of the Atlanta region have a different set of choices, involving one fewer mode at the top level (they are presumed to not be car renters). Within the Private Auto mode, they can be dropped off or can drive to the airport. Within the "Non-Auto" mode, they have the same Transit and Taxi options as Non-Residents.

The model is a nested logit, as follows:

$$p(m) = e^{U(m)}/\Sigma e^{U(m)}$$

where:
p(m) = probability of choosing mode m
U(m) = disutility of mode m

The disutility equations for each mode and each model are shown in Table 7.2. The lower nest values are calculated first. For example, in the Non-resident model, the disutilities are calculated for Transit, Shuttle, and Taxi. The exponentials of these three disutilities are taken and then summed. The natural log of that sum is the "log sum" term that is used in the "top level" nest to compare the Non-Auto mode with Rental Car and Dropped Off. With this structure, trips that "leave" a mode, due to changes in cost and time, are more likely to go to other modes in the same nest, rather than modes on a different "level".

The system coefficients (on time and cost) were obtained from other air passenger models, mainly Washington and San Francisco's models. The modal bias coefficients were developed using the air passenger survey data set. In order to develop these modal bias coefficients a set of target mode shares (that is the observed mode shares) were required. Table 7.3 shows these target mode shares and the mode shares estimated by the model, using the Atlanta specific modal constants. These figures indicate that the model replicates the target mode shares with a good degree of accuracy.

The mode choice model calculates trips in the Drive Self and Dropped Off private auto modes. The model does not do a separate calculation of auto occupancy, but uses a user-entered average occupancy, which for the calibration was as follows: Drive Self = 1.0, Dropped Off = 1.1, Rental Car = 1.1, Taxi = 1.1. In the case of Dropped Off trips, it is assumed that each air passenger being dropped off generates two vehicle trips – one going and one coming. Therefore the 75,300 passenger trips, which used an automobile mode, generate approximately 88,700 vehicle trips to and from the airport on an average day.

Figure 7.1
Air Passenger Mode Choice Model Structure

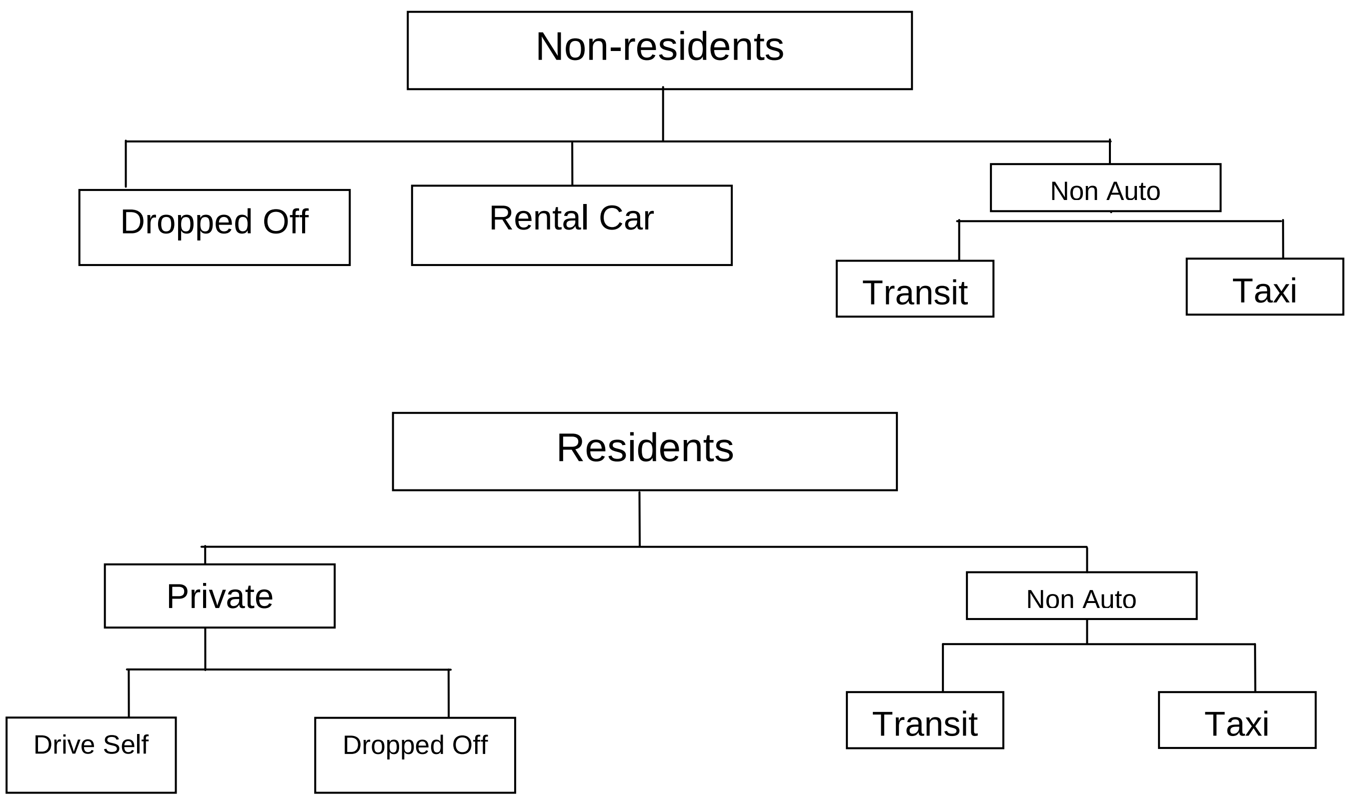


Table 7.2
Air Passenger Mode Choice Disutility Equations

<u>Business, Residents</u>

U(Drive Self) = (–0.071 * HWYTIME – 0.00277 * (HWYCOST + PCOST) + biasDS)/0.3
U(Dropped Off) = (–0.071 * HWYTIME – 0.00277 * HWYCOST)/0.3
U(Transit) = (–0.093 * WALK – 0.107 * WAIT – 0.00277 * TRFARE – 0.053 * RUN + biasTR)/0.3
U(Taxi) = (–0.071 * HWYTIME – 0.00277 * TXFARE)/0.3
NonAuto logsum = $\ln(e^{U(Transit)}+e^{U(Taxi)})$
Auto logsum = $\ln(e^{U(Dropped\ Off)}+e^{U(Drive\ Self)})$
U(Non-Auto) = 0.3 * NonAuto logsum + biasNA
U(Private Auto) = 0.3 * Auto logsum

<u>Business, Non-residents</u>

U(Dropped Off) = –0.068 * HWYTIME – 0.00256 * HWYCOST
U(Rental Car) = biasRC
U(Transit) = (–0.089 * WALK – 0.096 * WAIT – 0.00256 * TRFARE – 0.050 * RUN + biasTR)/0.3
U(Taxi) = (–0.068 * HWYTIME – 0.00256 * TXFARE)/0.3
NonAuto logsum = $\ln(e^{U(Transit)}+e^{U(Taxi)})$
U(Non-Auto) = 0.3 * NonAuto logsum + biasNA

<u>Non- Business Residents</u>

U(Drive Self) = (–0.044 * HWYTIME – 0.002105 * (HWYCOST + PCOST) + biasDS)/0.3
U(Dropped Off) = (–0.044 * HWYTIME – 0.002105 * HWYCOST)/0.3
U(Transit) =(–0.051* WALK – 0.077 * WAIT – 0.002105 * TRFARE – 0.031 * RUN + biasTR)/0.3
U(Taxi) = (–0.044 * HWYTIME – 0.002105 * TXFARE)/0.3
NonAuto logsum = $\ln(e^{U(Transit)}+e^{U(Taxi)})$
Auto logsum = $\ln(e^{U(Dropped\ Off)}+e^{U(Drive\ Self)})$
U(Non-Auto) = 0.3 * NonAuto logsum + biasNA
U(Private Auto) = 0.3 * Auto logsum

<u>Non-business, Non-residents</u>

U(Dropped Off) = –0.039 * HWYTIME – 0.001969 * HWYCOST
U(Rental Car) = biasRC
U(Transit) = (–0.045 *WALK–0.071* WAIT – 0.001969 * TRFARE – 0.029 * RUN + BiasTR)/0.3
U(Taxi) = (–0.039 * HWYTIME – 0.001969 * TXFARE)/0.3
NonAuto logsum = $\ln(e^{U(Transit)}+e^{U(Taxi)})$
U(Non-Auto) = 0.3 * NonAuto logsum + biasNA

Where:

HWYTIME = off-peak travel time from the highway network (minutes)
HWYCOST = off-peak distance from the highway network * 8.74 cents/mile
PCOST = half the daily long-term parking cost at HJAIA (cents), multiplied by the average duration of the trip in days (4 for Business, 7 for Non-business)
WALK = access + egress + sidewalk time from the AM peak transit network (minutes)
WAIT = initial wait + transfer wait time from the AM peak transit network (minutes)
RUN = total in-vehicle time from the AM peak transit network (minutes)
TRFARE = transit fare (cents)
TXFARE = taxi fare (cents); estimated, for 2000, as $1.75 plus $1.75 per mile

Note: Auto and taxi costs are <u>not</u> divided by average vehicle occupancy.

biasMM = bias coefficients by mode and purpose, as follows:

	Trip Market			
Mode (MM)	Bus., Res.	Bus., Non-Res.	Non-Bus., Res	Non-Bus., Non-Res.
Transit (TR)	-8.252	-6.133	-2.276	-4.640
Rental Car (RC)	-	-2.838	-	-2.471
Drive Self (DS)	5.427	-	4.517	-
Non-Auto Nest (NA)	8.496	8.434	2.908	3.698

Table 7.3
Observed and Estimated Air Passenger Trips by Mode

Observed Air Passenger Trips (from Survey Data)

Mode	Business, Residents	Business, Non-Residents	Non-business, Residents	Non-business, Non-Residents	Total
Dropped off	552	3,860	5,370	9,474	19,256
Drive self	15,204	-	14,936	-	30,140
Rental car	-	7,426	-	7,510	14,936
Taxi	3,066	5,866	762	1,230	10,924
Transit	1,024	4,414	6,552	996	12,986
Total	19,846	21,566	27,620	19,210	88,242

Estimated Air Passenger Trips (Model Results)

Mode	Business, Residents	Business, Non-Residents	Non-business, Residents	Non-business, Non-Residents	Total
Dropped off	551	3,849	5,365	9,474	19,239
Drive self	15,188	-	14,927	-	30,115
Rental car	-	7,396	-	7,504	14,900
Taxi	3,095	5,934	769	1,238	11,036
Transit	1,012	4,387	6,559	994	12,952
Total	19,846	21,566	27,620	19,210	88,242

Table 7.3 (continued)
Observed and Estimated Air Passenger Trips by Mode

Percent Difference (Estimated less Observed / Observed)

Mode	Business, Residents	Business, Non-Residents	Non-business, Residents	Non-business, Non-Residents	Total
Dropped off	-0.18%	-0.28%	-0.09%	0.00%	-0.09%
Drive self	-0.11%	-	-0.06%	-	-0.08%
Rental car	-	-0.40%	-	-0.08%	-0.24%
Taxi	0.95%	1.16%	0.92%	0.65%	1.03%
Transit	-1.17%	-0.61%	0.11%	-0.20%	-0.26%
Total	0.00%	0.00%	0.00%	0.00%	0.00%

Note: The air passenger trips shown are for an average day in 2000 and represent both enplaning and deplaning passengers. The 75,300 air passengers in automobiles represent 88,700 vehicles trips to and from the airport, with the drop off mode being considered two trips.

8. Assignment Model/Highway Assignment Validation

The trip generation, trip distribution and mode choice models are performed using daily trips formatted in the production to attraction direction. That is, the home-based trips are always defined as going from the home end of the trip (production) to the non-home end of the trip (attraction). For highway assignments, daily trips are split into four time periods - a morning peak (6am-10am), a mid-day period (10am-3pm), an evening peak (3pm-7pm) and an evening/night period (7pm-6am). Separate highway assignments are made for each time period. Daily volumes are computed by adding the four period assignments. Other daily statistics are also calculated from time period assignments as sums or as weighted averages. Transit assignments use daily trips that are separated by mode of access (walk to premium, walk to local, and drive to transit) and general purpose (work and non-work).

8.1. Highway Assignment Procedure

The highway assignment procedure uses a standard equilibrium technique to assign vehicle trips throughout the transportation network. Equilibrium, in the context of transportation assignments, occurs when no alternate path can be used without increasing the total travel time of all trips in the network. All-or-nothing assignments determine the desired routings and can effectively measure demand over capacity. In practice, most urban areas such as the Atlanta region, have roadway facilities which become congested at various times during the day. In order to differentiate between peak and off-peak speeds and volumes, link loading techniques are required which reflect demand (volume) and modeled capacities. Equilibrium is one such technique.

Equilibrium assignment consists of an iterative series of all-or-nothing traffic assignments with an adjustment of travel times reflecting delays encountered in the associated iteration. The load from each assignment, after the first iteration, is combined with the previous load in such a way as to minimize the impedance of each trip and thus reducing the number of iterations to find the equilibrium loads. The final congested speeds are based on the resultant total weighted assigned volumes on each link. This approach ensures the compliance with the Transportation Conformity Regulations.

The highway assignment procedures differentiate among trips in five vehicle type categories: heavy duty truck, medium duty truck, commercial vehicles, single occupancy vehicles (SOVs), and high occupancy vehicles (HOVs). Only HOVs are allowed to use the HOV lanes. Trucks are not allowed to use any truck-prohibited roadways.

There are some significant modifications to the highway assignment procedures. A passenger car equivalency (PCE) has been added to account for the greater influence of trucks on volume to capacity ratios. Also, heavy duty trucks without an origin or destination inside I-285, are prohibited from using highway facilities inside the perimeter. Finally, external to external trips are preloaded using free-flow times. This was done because people making those trips are probably not familiar with the area and therefore, less likely to divert from a predetermined path.

The highway assignment procedures include a toll diversion model to account for toll roads such as Georgia 400. The Toll Diversion Model converts toll costs to time penalties using value-of-time factors that vary by vehicle type. Table 8.1 displays the assumed parameters for the toll model.

Table 8.1
Toll Diversion Model Parameters

	Value of Time ($ / Hour)	Time Penalty (Minutes / $)
Single Occupancy Vehicles (SOV)	15	2.4
High Occupancy Vehicles (HOV)	20	3
Commercial Vehicles	25	4

The toll diversion procedures can be applied to both fixed toll and variable toll facilities. An optional assignment algorithm has been developed that assists in evaluating managed lane (often called High-Occupancy Toll (HOT) lanes) facilities. Managed lane facilities are essentially modeled as HOV lanes that can be used by SOV trips and commercial vehicles by paying a toll. The managed lane assignment algorithm varies tolls (between assignment iterations) depending on the level of congestion that exists on the subject link. As congestion increases, tolls increase. As congestion decreases, tolls decrease. The algorithm is designed to encourage managed lane facilities to operate at or near the break point between level-of-service C and D. This is done by applying a low per mile toll at low volume-to-capacity (V/C) ratios, using a relatively low but increasing per mile toll at medium V/C ratios, and using rapidly increasing per mile toll for high V/C ratios. Table 8.2 displays the assumed per mile tolls used in the managed lane assignment algorithm[9].

Table 8.2
Managed Lane Facility Assignment Parameters

V/C Ratio	SOV Toll ($ / Mile)	Commercial Vehicle Toll ($ / Mile)
0.0	0.05	0.25
0.5	0.05	0.25
0.8	0.15	0.75
1.0	1.00	5.00

8.2. Time-of-Day Model

The time-of-day model was calibrated using data from the Home Interview Survey. This data contained the beginning time of the trip and the ending time of the trip for each trip made by a traveler. This information was used to develop a series of factors showing the percent of travel made in the four time-of-day periods. These factors were stratified by trip purpose, mode and direction – with the direction being from home to non-home (production to attraction) and from non-home to home (attraction to production). These travel time factors were reviewed and updated using 1999 and 2000 hourly traffic distribution counts for the entire 13-county non-attainment area. A two-year average of the 1999 and 2000 diurnal traffic counts was used to adjust the temporal trip distribution model for the four time-of-day period assignments. Table 8.3 and Figure 8.1 represent the diurnal distribution of travel for both 1999 and 2000, as well as the two-year average used to refine the trip distribution factors. Tables 8.4-8.6 display the trip factors by purpose and mode by direction by the four time-of-day periods.

Table 8.3

[9] Tolls for intermediate V/C Ratios are interpolated. V/C Ratios higher than 1.0 are assigned the toll for V/C Ratio equal to 1.0.

Diurnal Distribution of Travel in the 13-County Non-attainment Area

Hours	2000 Sum	2000 Percent	1999 Total	1999 Percent	Two Year Total	Two Year Average
1	879,264	**1.19%**	437,089	**1.05%**	1,316,353	**1.14%**
2	547,592	**0.74%**	273,937	**0.66%**	821,529	**0.71%**
3	414,669	**0.56%**	207,875	**0.50%**	622,544	**0.54%**
4	392,431	**0.53%**	197,378	**0.47%**	589,809	**0.51%**
5	579,587	**0.78%**	295,021	**0.71%**	874,608	**0.76%**
6	1,477,073	**2.00%**	776,739	**1.86%**	2,253,812	**1.95%**
7	3,411,341	**4.62%**	1,924,335	**4.60%**	5,335,676	**4.61%**
8	4,736,415	**6.41%**	2,821,324	**6.75%**	7,557,739	**6.53%**
9	4,184,413	**5.67%**	2,554,113	**6.11%**	6,738,526	**5.83%**
10	3,575,173	**4.84%**	2,082,742	**4.98%**	5,657,915	**4.89%**
11	3,514,627	**4.76%**	1,982,420	**4.74%**	5,497,047	**4.75%**
12	3,751,041	**5.08%**	2,134,509	**5.10%**	5,885,550	**5.09%**
13	4,015,302	**5.44%**	2,333,612	**5.58%**	6,348,914	**5.49%**
14	4,134,124	**5.60%**	2,346,228	**5.61%**	6,480,352	**5.60%**
15	4,459,875	**6.04%**	2,488,118	**5.95%**	6,947,993	**6.01%**
16	4,981,794	**6.75%**	2,779,436	**6.65%**	7,761,230	**6.71%**
17	5,405,297	**7.32%**	3,070,729	**7.34%**	8,476,026	**7.33%**
18	5,708,954	**7.73%**	3,330,786	**7.97%**	9,039,740	**7.82%**
19	4,889,228	**6.62%**	2,843,429	**6.80%**	7,732,657	**6.69%**
20	3,778,137	**5.12%**	2,148,166	**5.14%**	5,926,303	**5.12%**
21	3,001,753	**4.06%**	1,667,545	**3.99%**	4,669,298	**4.04%**
22	2,563,461	**3.47%**	1,367,698	**3.27%**	3,931,159	**3.40%**
23	1,990,215	**2.70%**	1,020,471	**2.44%**	3,010,686	**2.60%**
24	1,453,605	**1.97%**	732,662	**1.75%**	2,186,267	**1.89%**
Total	73,845,371	**100.00%**	41,816,362	**100.00%**	115,661,733	**100.00%**

Figure 8.1
Diurnal Distribution of Travel in the 13-County Nonattainment Area

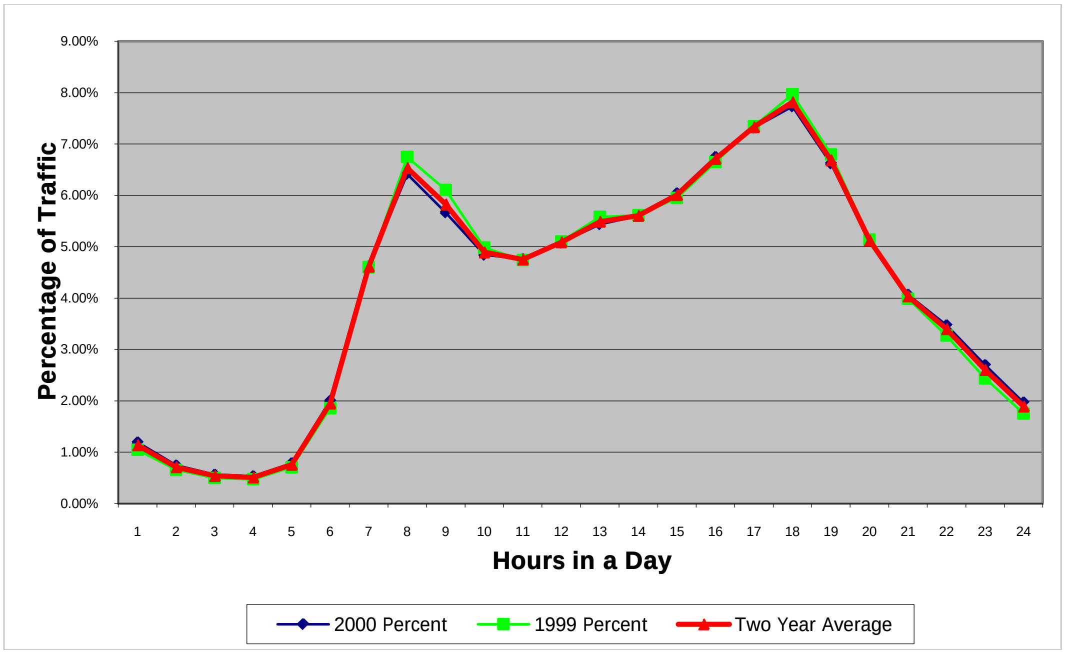


Table 8.4
Home-Based Work Distribution by Time of Day Mode and Direction

Mode	Time Period	Production to Attraction Proportion	Attraction to Production Proportion
SOV	AM Peak	0.396	0.009
"	Mid-day	0.048	0.040
"	PM Peak	0.023	0.377
"	Night	0.033	0.074
HOV	AM Peak	0.396	0.009
"	Mid-day	0.048	0.040
"	PM Peak	0.023	0.377
"	Night	0.033	0.074

Table 8.5
Home-Based Other Distribution by Time of Day Mode and Direction

Mode	Time Period	Production to Attraction Proportion	Attraction to Production Proportion
SOV	AM Peak	0.137	0.035
"	Mid-day	0.135	0.117
"	PM Peak	0.142	0.178
"	Night	0.087	0.170
HOV	AM Peak	0.137	0.035
"	Mid-day	0.135	0.117
"	PM Peak	0.142	0.178
"	Night	0.087	0.170

Table 8.6
Non-Home-Based Distribution by Time of Day Mode and Direction

Mode	Time Period	Production to Attraction Proportion	Attraction to Production Proportion
SOV	AM Peak	0.056	0.056
"	Mid-day	0.243	0.243
"	PM Peak	0.150	0.150
"	Night	0.052	0.052
HOV	AM Peak	0.056	0.056
"	Mid-day	0.243	0.243
"	PM Peak	0.150	0.150
"	Night	0.052	0.052

8.3. Volume-Delay Functions

Volume-delay functions describe the rate at which delay is added to the travel time on a roadway segment as a function of the quantity of traffic being carried. Ratios of the assigned traffic volume versus the capacity (or the V/C ratio) are used to predict how travel times (and hence, delays) increase as roadway volumes build up to and beyond the capacity of the roadway.

Revised volume-delay functions were initially developed using the results of empirical studies on roadway volume and delay distributions in urban areas over a 24-hour period. The research is published in an FHWA document entitled "Development of Diurnal Traffic Distribution and Daily, Peak and Off-peak Vehicle Speed Estimation Procedures for Air Quality Planning.[10]" This research quantifies how rural and urban roadways distribute peak

[10] Development of Diurnal Traffic Distribution and Daily, Peak and Offpeak Vehicle Speed Estimation Procedures for Air Quality Planning, Final Report, Federal Highway Administration, April, 1996.

hour traffic to other hours of the day under heavier traffic volumes, and the implications that this has on the average operating speed of the roadway. The Volpe Research Center report, “Roadway Usage Patterns: Urban Case Studies” was also used as reference during initial development of the volume-delay functions.[11] The combined research was used to extract roadway operating speed and volume distributions that match the four time period definitions of the ARC model. For each time period, hourly travel times were weighted by vehicle miles of travel during the hour to determine the overall average travel speed during that time period as a function of different volume loading levels (V/C ratios). The result was a unique set of volume-delay functions for each time period based on four general classifications of roadway – freeways, urban expressways and rural streets and highways, urban arterial streets and urban collector streets.

Once the initial volume-delay functions were developed, the functions were modified to reflect local Atlanta travel conditions using data collected from two recent speed studies conducted in the fall of 2000 and the fall of 2001, and using observed traffic counts.

8.4. Feedback Component

It is important for planning models to incorporate a feedback component to ensure the congested link travel times that result from the assignment algorithm are nearly identical to the link travel times that are used to generate the skims used in trip generation and trip distribution. The ARC regional travel demand model utilizes a feedback model option from highway assignment back to trip generation. The AM peak skims which are representative of peak travel are used in the feedback process.

The highway and transit skims are used in trip generation to determination auto importance and auto sufficiency. These skims are also used to determine accessibilities which are fed into the trip generation models which produce the productions and attractions by trip purpose. Only HBW and HB-University trips are processed through the feedback loop since these trips primarily occur during peak travel conditions.

The highway and transit skims are then used to produce a composite time which is input to the trip distribution model. The development of the composite time is based on: (1) the determination of transit services that are perceived by travelers as increasing the accessibility of zone pairs and (2) the weighting of highway and transit travel times. Only those trips that have zone pair transit access are considered eligible for increased accessibility. For those zone pairs that do not have transit access the composite time is equal to the highway time. The weighting of transit varies by the market group of the traveler. For the traveler in the market group without autos (segment #1), the availability of transit is more important than for the traveler in the market group with more cars than workers and the higher incomes (segment #4). Thus, for the first two market groups, the availability of transit increases the traffic analysis zone accessibility more than for the second two market groups.

The mode choice model is then executed using the AM skims for the peak traveling conditions and the off-peak skims for the off-peak conditions. The time of day procedure then produces AM, MD, PM and NT OD matrices. The AM assignment is executed within the feedback loop. The flows from the AM assignments in successive feedback loops are smoothed using the Method of Successive Averages (MSA). The average of the volumes for all of the iterations within the assignment are calculated and compared to the results from the average volumes in the assignment from the previous loop. Feedback closure is achieved when the percent root mean square error (%RMSE) in MSA link volumes is less than 3.5%.

[11] Roadway Usage Patterns: Urban Case Studies, Final Report, Volpe National Transportation Systems Center and Federal Highway Administration, June 9, 1994.

MSA link flows from the assignment are post-processed using the VDF curves to obtain congested travel times that are fed back into the highway and transit skimming procedures.

8.5. Adjusting Volume-Delay Functions Using Observed Speed Data

During the last several years, the Atlanta region has performed extensive speed studies to improve the highway assignment procedure and travel forecasting process. In the fall of 2000, the Georgia Regional Transportation Authority (GRTA) conducted a speed study in consultation with ARC and the Georgia Environmental Protection Division, consisting of over 1,600 speed observations around the region. The GRTA speed study consisted of obtaining speeds at 1,629 locations; some of these locations were the same physical locations at different times and days. The data was summarized by type of roadway and general location (area type). The study provided many suggestions on the development of revised free flow speeds and volume-delay curves.

In March 2001, the US Department of Transportation requested that the ARC supplement the GRTA speed study with an additional speed study that considered point-to-point travel times (e.g. average travel time over the course of a trip rather than a point speed).[12] This speed study was conducted during the fall of 2001.

The ARC speed study consisted of a series of time and delay studies for 63 routes with the routes selected to cover all facility and area types. The routes covered the entire urban area and consisted of typical movements in the region. Each route was approximately 14 miles long. Travel time runs were made on these routes for morning peak, evening peak and mid-day time periods. A floating car procedure was used to collect travel times. Using the floating car procedure, the driver attempts to drive along the route at the same speed as the majority of the traffic on the route. The travel times and check point locations were obtained using special GPS equipment. The study produced a report detailing the routes and the data collected.[13] In total 1,752 miles of highway were studied in the project and the speed runs consisted of approximately 37,000 vehicle miles. The data, consisting of miles traveled, minutes traveled and standard deviation of the travel time, were summarized by route and period of travel.

The data were initially used to revise the definition of the roadway facility types and to develop, in combination with data from the GDOT Roadway Characteristics file, a link-based roadway characteristics database which could be used to assign link-level facility types based on a number of predefined link attributes. The data were then used to develop a reasonable estimate of free flow speeds for each facility type. Free flow speed is the speed that a normal driver would drive on a highway if there were little or no congestion. The new speed data showed that the free flow speed in Atlanta was considerably higher than the speeds previously used. This is especially true for freeways where the free flow speeds ranged from 65 (in the CBD) to 75 miles per hour.

Data from both the GRTA and ARC speed studies were used to make the necessary adjustments to the volume-delay functions described in the section above, to ensure that the volume-delay functions reflect the latest available travel conditions affecting the Atlanta region. Because the volume-delay functions were developed using a common traffic flow pattern database, the delay patterns are consistent among time periods. The night-time peak period volume-delay function has a slightly different pattern than the other periods because

[12] March 8, 2001, modeling meeting held in Atlanta between ARC and USDOT modeling staff to discuss outcome of GRTA speed study and necessary updates/revisions for future model calibration.

[13] "Travel Time and Speed Study Data Collection" prepared by PBQ&D and PBS&J prepared for the ARC, November 21, 2001.

most of the traffic for this period occurs in the early evening hours. Therefore, delays (average speed) become more serious at a lower volume to capacity ratio for the total nighttime period. All of the volume-delay functions were originally capped at a volume-capacity ratio of 2.0. It was discovered that the equilibrium assignment algorithm has difficulty reducing the loaded volume on links if the resulting volume-capacity ratio in any iteration of the process exceeds the cap. This occurs because a capped curve is flat beyond the highest volume-capacity ratio in the lookup table, which makes the solution algorithm converge to a similar volume in subsequent iterations. The curves were modified to prevent this by extending the maximum volume-capacity ratio from 2.0 to 99 and including a slight slope in this range. The graphs were not revised to reflect this change because it would make them difficult to read. The volume-delay functions are illustrated in Figures 8.2 to 8.5 below.

Figure 8.2
AM Peak Period Speed Flow Curves by Facility Type

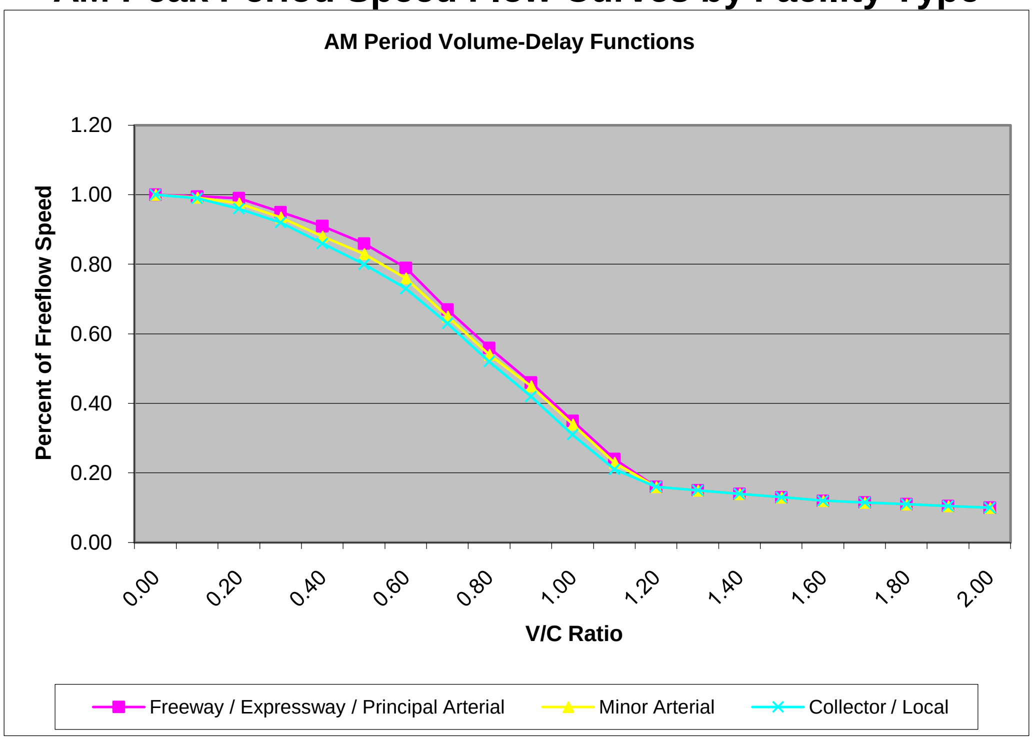


Figure 8.3
Mid-day Period Speed Flow Curves by Facility Type

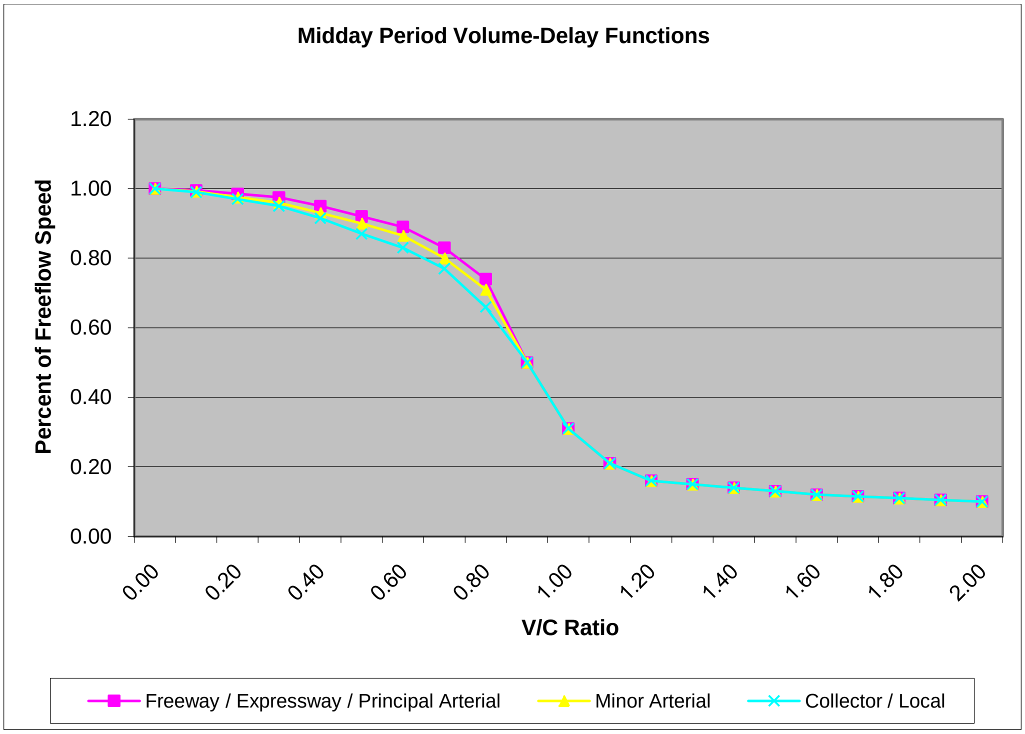


Figure 8.4
PM Peak Period Speed Flow Curves by Facility Type

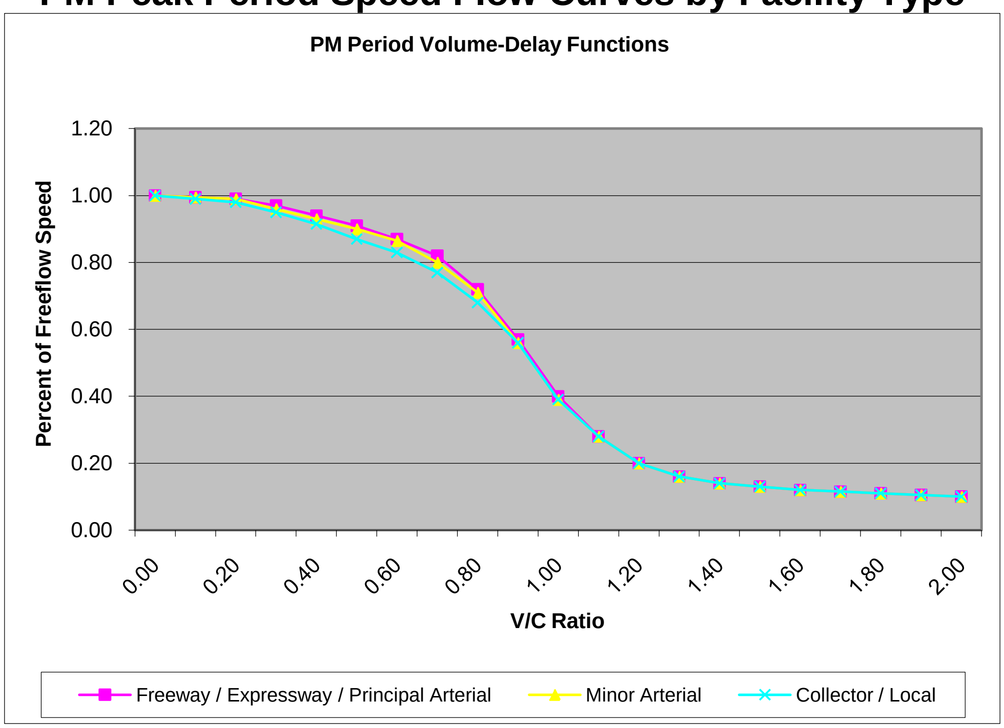
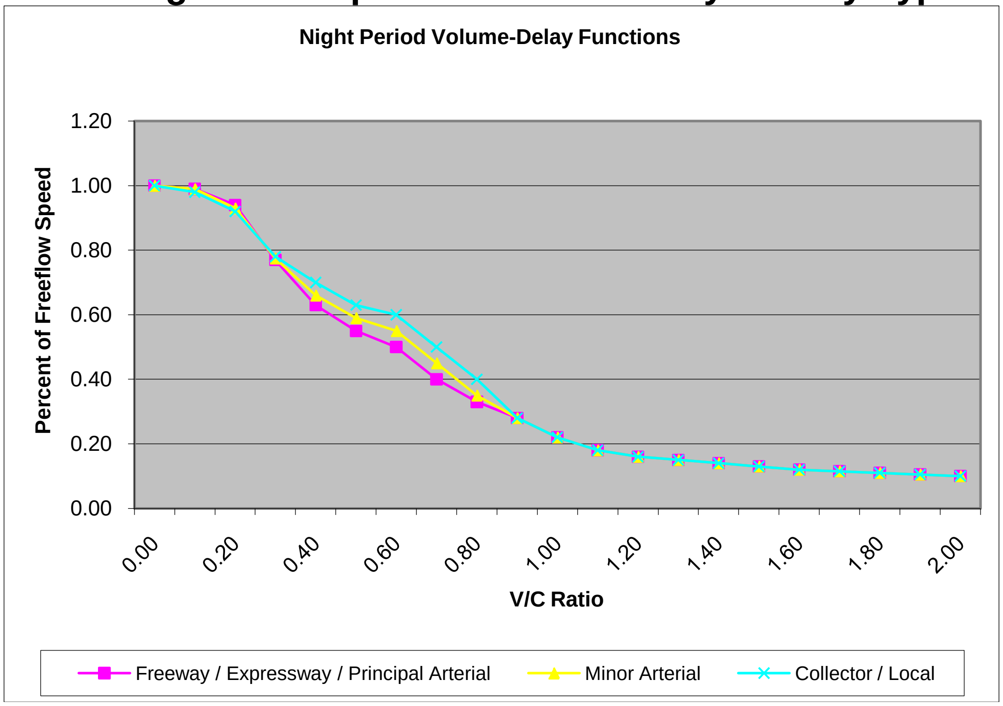


Figure 8.5
Evening Period Speed Flow Curves by Facility Type



8.6. Highway Assignment Validation - Speeds

Once the initial free flow speeds and the volume-delay functions were developed, highway trips were assigned to the network using initially estimated volume-delay functions. Adjustments were made to the free flow speeds, the lane capacity values and the volume delay functions until a reasonable match was made of both speeds and traffic volumes on the roadways.

Table 8.7 displays a general comparison of the modeled speeds to the ARC speed study results. The table indicates that the travel demand model produces considerable consistency with observed speeds by time-of-day.

Table 8.7
Summary of Observed and Estimated Speeds from ARC Speed Study

Period	Observed Speed	Estimated Speed	Percent Difference
AM	33.0	34.7	5.3%
Mid-day	36.3	34.0	-6.3%
PM	32.1	33.8	5.2%
Total	33.7	35.1	4.2%

The average GRTA speeds, by facility type and general location, were compared to the total average estimated speed for all links by facility type and general location. In general the observed GRTA speeds and the estimated speeds were compatible. Of the 16 categories (four facility types and four general locations), there were 9 categories where the estimated speeds were lower and 7 categories where the estimated speeds were higher. The difference in the average speed ranged from a low of –14.0 for suburban freeways, to a high of 7.3 for rural freeways, but speeds for most other categories were considerably closer. This information is shown on Table 8.8.

Table 8.8
Summary of Observed and Estimated Speeds from GRTA Speed Study

Area Type	Period	Facility Type	Observed Speed	Estimated Speed[22]	Difference
CBD	AM	Freeway	31.9	27.1	-4.8
Urban	AM	Freeway	40.1	33.5	-6.6
Suburban	AM	Freeway	54.4	40.4	-14.0
Exurban/Rural	AM	Freeway	40.9	48.2	7.3
CBD	AM	Class I Arterial	19.6	18.8	-0.8
Urban	AM	Class I Arterial	24.1	22.4	-1.7
Suburban	AM	Class I Arterial	31.7	29.6	-2.1
Exurban/Rural	AM	Class I Arterial	38.4	38.6	0.2
CBD	AM	Class II Arterial	17.4	15.6	-1.8
Urban	AM	Class II Arterial	24.8	18.2	-6.6
Suburban	AM	Class II Arterial	27.3	23.8	-3.5
Exurban/Rural	AM	Class II Arterial	39.9	32.8	-7.1
CBD	AM	Class III Arterial	14.3	15.6	1.3
Urban	AM	Class III Arterial	25.7	19.8	-5.9
Suburban	AM	Class III Arterial	21.5	25.8	4.3
Exurban/Rural	AM	Class III Arterial	28.6	35.3	6.7

Note: Observed Speeds are for selected locations while estimated speeds are for all roadways in the area.

8.7. Trip Assignment Validation – Counts

To ensure the accuracy of the travel demand model, the highway assignments were validated using several widely used measures. The primary validation measures were comparisons of modeled Vehicle Miles Traveled (VMT) data to Highway Performance Monitoring System (HPMS) data, comparisons of modeled volumes to traffic counts along screenlines, and modeled volume to traffic count Root Mean Square Errors (RMSE) by various volume groups.

Transit assignments were verified using the latest available boarding (un-linked) transit trip data from the MARTA system, in addition to data derived from the 2001/2002 Transit On-Board Travel Survey.

8.6.2 Highway Validation

The highway assignment process was conducted for the AM Peak, PM Peak, Mid-Day and Night-Time periods as discussed in Section 8.2. Highway loadings from all four time periods were aggregated to obtain total daily volumes and total daily VMT, and compared to average daily HPMS VMT derived from GDOT's HPMS report for the year 2000. The year 2000 HPMS functional classification was coded into each highway link using the study results from the GRTA speed study conducted in 2000[14] enabling a more accurate summary of travel model VMT by functional classification, and therefore a more accurate comparison of estimated and observed average daily VMT.

Table 8.9 reflects estimated and observed VMT for the year 2000. Results indicate a less than 1% difference between total daily VMT estimated by the travel demand model and daily 2000 HPMS VMT.

Table 8.9
Comparison Between Estimated and Observed VMT Year 2000

HPMS Code	HPMS Functional Class	2000 GDOT Report	2000 Model Results
1	Rural Interstate Principal Arterial	7,469,623	11,002,580
2	Rural Principal Arterial	4,336,905	4,879,487
6	Rural Minor Arterial	4,951,523	5,086,453
7	Rural Major Collector	6,008,641	5,444,211
8	Rural Minor Collector	1,590,285	1,402,498
9	Rural Local	5,067,398	7,843,858
	RURAL TOTAL	**29,424,375**	**35,659,087**
11	Urban Interstate Principal Arterial	38,395,472	37,537,921
12	Urban Freeway and Expressway	5,789,202	2,741,098
14	Urban Principal Arterial	13,556,016	17,353,073
16	Urban Minor Arterial	24,832,465	21,011,009
17	Urban Collector	8,164,787	6,327,547
19	Urban Local	17,017,080	16,083,765
	URBAN TOTAL	**107,755,022**	**101,054,413**
1,11,12	Interstate/Freeway/Expresway	51,654,297	51,281,599
2,6,14,16	Arterial	47,676,909	48,330,022
7,8,17	Collector	15,763,713	13,174,256
9,19	Local	22,084,478	23,927,623
	TOTAL	**137,179,397**	**136,713,500**

Although there are some minor differences in observed versus modeled VMT for specific functional classes, when the data are aggregated into major facility types (removing urban / rural designations), as the statistics in the bottom portion of Table 8.9 indicate, the model closely matches observed VMT.

[14] Assignment of HPMS Functional Classification and Posted Speed Limit Attributes to Atlanta Regional Commission Highway Network, GRTA, May 2001

Table 8.10
Number of Counts by Facility Type

Facility Type	No. of Counts
Interstate/Freeway	597
Principal Arterial	1,577
Minor Arterial	2,357
Collector	1,180
Total	5,711

Table 8.11
Percent Error Between Estimated and Observed Counts Year 2000

Facility Type	2000 Modeled	FHWA Targets[15]
Interstate/Freeway	0.3%	+/-7%
Principal Arterial	-6.5%	+/-10%
Minor Arterial	2.4%	+/-15%
Collector	20.6%	+/-25%
Total	-0.3%	-

Numerous traffic counts were coded in the model highway network for highway assignment validation. Table 8.10 shows the number of counts by facility in the base year highway network.

Table 8.11 shows the percent error between the observed counts and the model estimated counts by facility type. The percent error between the observed counts and model estimated counts is less than one percent for the interstate/freeway facilities that carry over a third of the daily vehicle miles traveled. The largest percent error occurs on collector facilities which accommodate for approximately 11 percent of the daily vmt. Overall, the model is producing reasonable volumes when compared to the observed traffic counts.

Once regional VMT estimates were validated, modeled volumes from the highway assignment were compared to observed traffic counts. As part of the model expansion, a significant amount of work was done to put more traffic counts into the network for assignment validation. The first major comparison to traffic counts was done for screenlines. Since the model area was expanded, several new screenlines were added for validation. Screenlines are a means of comparing major traffic flows in the model. The term screenline is often used generically to refer to three types of comparisons:

1. Cordon – A cordon forms an enclosed boundary, which is intended to determine the traffic flows into and out the enclosed area. Cordons are often used to determine if traffic flows into

[15] FHWA percent difference standards are available in MODEL VALIDATION AND REASONABLENESS CHECKING MANUAL, Travel Model Improvement Program, Federal Highway Administration, February 1997.

and out of a Central Business District are being modeled accurately. An example of a cordon line used in the Atlanta model validation is the "Outside of I-285" screenline.

2. Cutline – A cutline captures the flows through a major corridor. The "I-85 Corridor north of Norcross" is an example of a cutline. This cutline compares modeled volumes to observed counts on I-85 and other parallel facilities such as Peachtree Industrial Boulevard, Buford Highway, and Lawrenceville Highway.
3. Screenline – a "true" screenline captures all flows from one side of the region to the other. The "Chattahoochee River" screenline does this by comparing all bridge crossing traffic counts with the modeled volumes.

A set of screenlines displayed in Figure 8.6 were developed for the ARC region to assist with the evaluation of the performance of the model.

Figure 8.6
ARC Year 2000 Model Screenlines

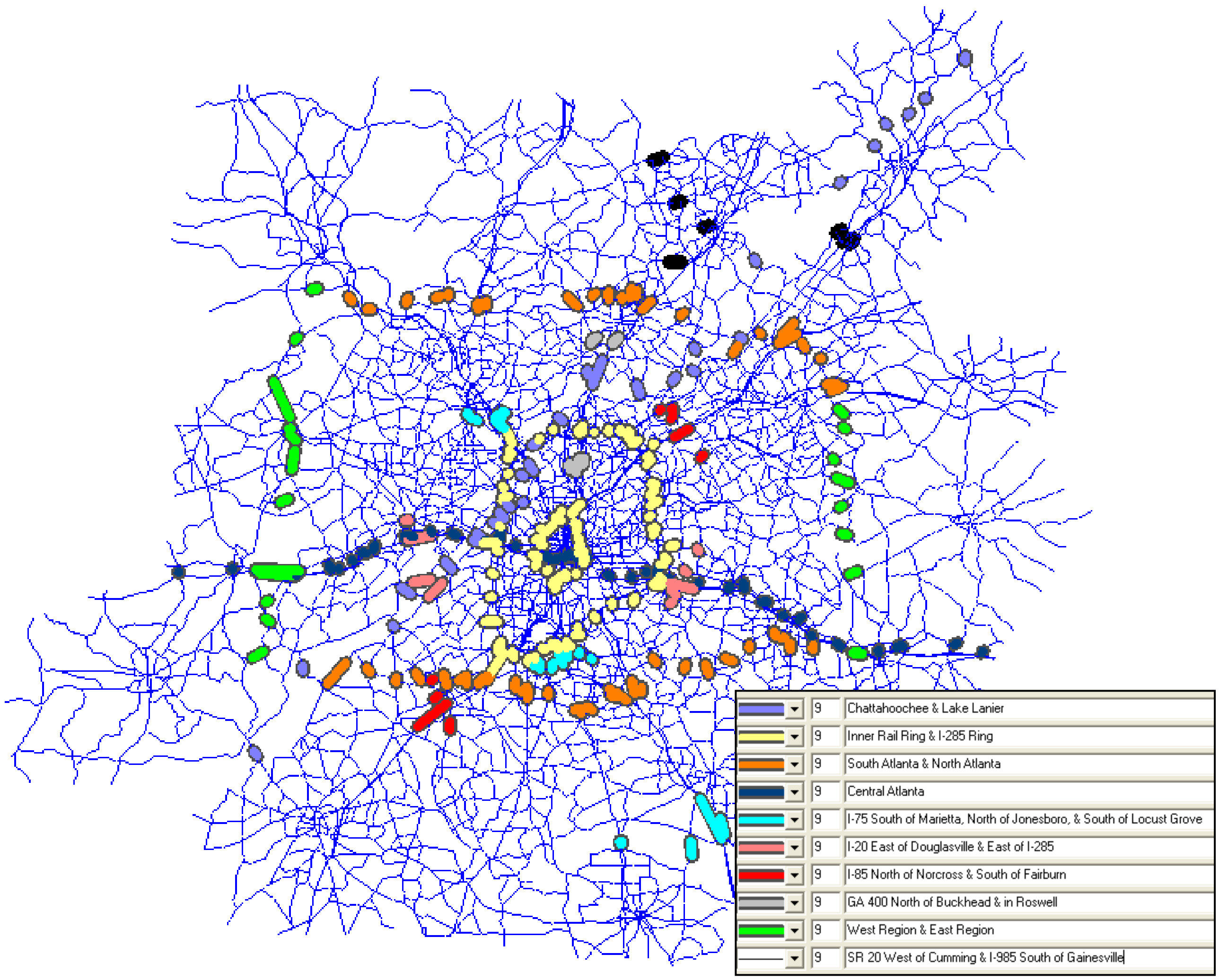


Table 8.12 displays the comparisons for screenlines that were used in the ARC 2000 model validation. Maximum desirable deviation[16] standards are commonly used to evaluate assignment models. Maximum desirable deviation standards require higher levels of accuracy for higher volume corridors and lower levels of accuracy for lower volume corridors. The standards are designed to insure that modeled deviations from observations are limited such that potential transportation improvements that are considered for meeting future travel demands will be in the correct scale (two additional lanes of capacity versus four lanes). The modeled percent deviations in Table 8.12 indicate that the assignment model is generally within desirable standards. The only exception to this is the Georgia 400 corridor in Roswell, where the modeled volumes are much lower than traffic counts. Since the Georgia 400 corridor's modeled volumes are significantly lower than counts, special attention should be paid to future travel demands in the corridor, considering that the model demands will likely be lower than actual demands.

Table 8.12
ARC Year 2000 Model Screenline Summary

Screenline	Assigned Volume	Traffic Count	Volume / Count Ratio	Percent Deviation	Maximum Desirable Deviation (+/-)
Chattahoochee River	1,371,296	1,299,756	1.06	5.50%	8.27%
Inner Rail Ring	1,537,742	1,489,970	1.03	3.21%	7.83%
Outside of I-285	2,769,930	2,778,592	1.00	-0.31%	6.13%
South Atlanta - East/West	683,089	656,921	1.04	3.98%	10.83%
North Atlanta - East/West	621,623	571,619	1.09	8.75%	11.44%
Central Atlanta - north of I-20	1,358,561	1,313,793	1.03	3.41%	8.23%
Corridor south of Marietta	402,583	374,168	1.08	7.59%	13.52%
I-20 Corridor east of Douglasvill	144,106	137,303	1.05	4.95%	20.09%
I-75 Corridor north of Jonesboro	305,607	303,223	1.01	0.79%	14.69%
I-85 Corridor north of Norcross	401,453	375,894	1.07	6.80%	13.50%
GA 400 Corridor north of Buckhead	148,050	159,613	0.93	-7.24%	18.93%
I-20 Corridor east of I-285	226,171	230,181	0.98	-1.74%	16.38%
GA 400 Corridor in Roswell	157,985	197,000	0.80	-19.80%	17.42%
SR 20 Corridor west of Cumming	36,448	32,894	1.11	10.80%	35.33%
I-85 Corridor south of Fairburn	135,972	115,800	1.17	17.42%	21.49%
Lake Lanier	82,811	88,276	0.94	-6.19%	23.92%
I-985 South of Gainesville	82,862	66,900	1.24	23.86%	26.69%
West Region N/S	149,852	133,013	1.13	12.66%	20.35%
East Region N/S	129,794	133,145	0.97	-2.52%	20.34%
I-75 South of Locust Grove	150,441	137,733	1.09	9.23%	20.07%
Alcovy River	153,929	159,708	0.96	-3.62%	18.93%
Flint River	218,479	196,692	1.11	11.08%	17.43%
Totals	**11,268,784**	**10,952,194**	**1.03**	**2.89%**	**3.56%**

Another common validation measure for assignment are Root Mean Squared Errors (RMSE). RMSE statistics for the 2000 assignment were calculated for all links with traffic counts, and were grouped by several categories. RMSE statistics should generally decrease as traffic volumes increase. The Atlanta 2000 assignment RMSE is 29.7%, which is under the common standard for regional RMSE (30%). Comparisons were made with other urban area travel models which included the Mid-Ohio Regional Planning Commission (MORPC), Baltimore Metropolitan Council (BMC), and Metropolitan Washington Council of Governments (WASHCOG). The RMSE were split by volume groups, facility types, and area types and are shown in Tables 8.13 through

[16] Maximum Desirable Deviation standards for screenlines and individual count locations are available in NCHRP 255 HIGHWAY TRAFFIC DATA FOR URBANIZED AREA PROJECT PLANNING AND DESIGN, Transportation Research Board, National Research Council.

8.15. As shown in these tables, the error estimates for ARC are comparable with those for models used in other urban areas.

Table 8.13
Percent Root Mean Square Error Comparison by Volume Group for the 2000 Atlanta Regional Model

Volume Group	MORPC[17]	ARC 2000
0 - 499	220%	306%
499 - 1,499	90%	122%
1,500 - 2,499	58%	80%
2,500 - 3,499	50%	57%
3,500 - 4,499	45%	47%
4,500 - 5,499	44%	44%
5,500 - 6,999	42%	40%
7,000 - 8,499	34%	41%
8,500 - 9,999	36%	38%
10,000 - 12,499	32%	35%
12,500 - 14,999	30%	31%
15,000 - 17,499	26%	25%
17,500 - 19,999	23%	23%
20,000 - 24,999	23%	24%
25,000 - 34,999	16%	14%
35,000 - 54,999	15%	12%
> 55,000	17%	10%
Total	40%	30%

Table 8.14
Percent Root Mean Square Error Comparison by Facility Type for the 2000 Atlanta Regional Model

Facility Type	WASHCOG 2000[18]	ARC 2000
Freeways	27.54%	12.66%
Major Arterials	46.72%	31.61%
Minor Arterials	65.64%	48.77%
Collectors	75.34%	54.49%
Total	47.21%	29.72%

[17] "MORPC Model Validation - Summary", David Schmitt, AECOM Consult Inc, Robert M. Donnelly, PB Consult, Rebekah S. Anderson, Ohio Department of Transportation

[18] "COG/TPB Travel Forecasting Modal Version 2.1 D #50 Calibration Report", Metropolitan Washington Council of Governments

Table 8.15
Percent Root Mean Square Error Comparison by Area Type for the 2000 Atlanta Regional Model

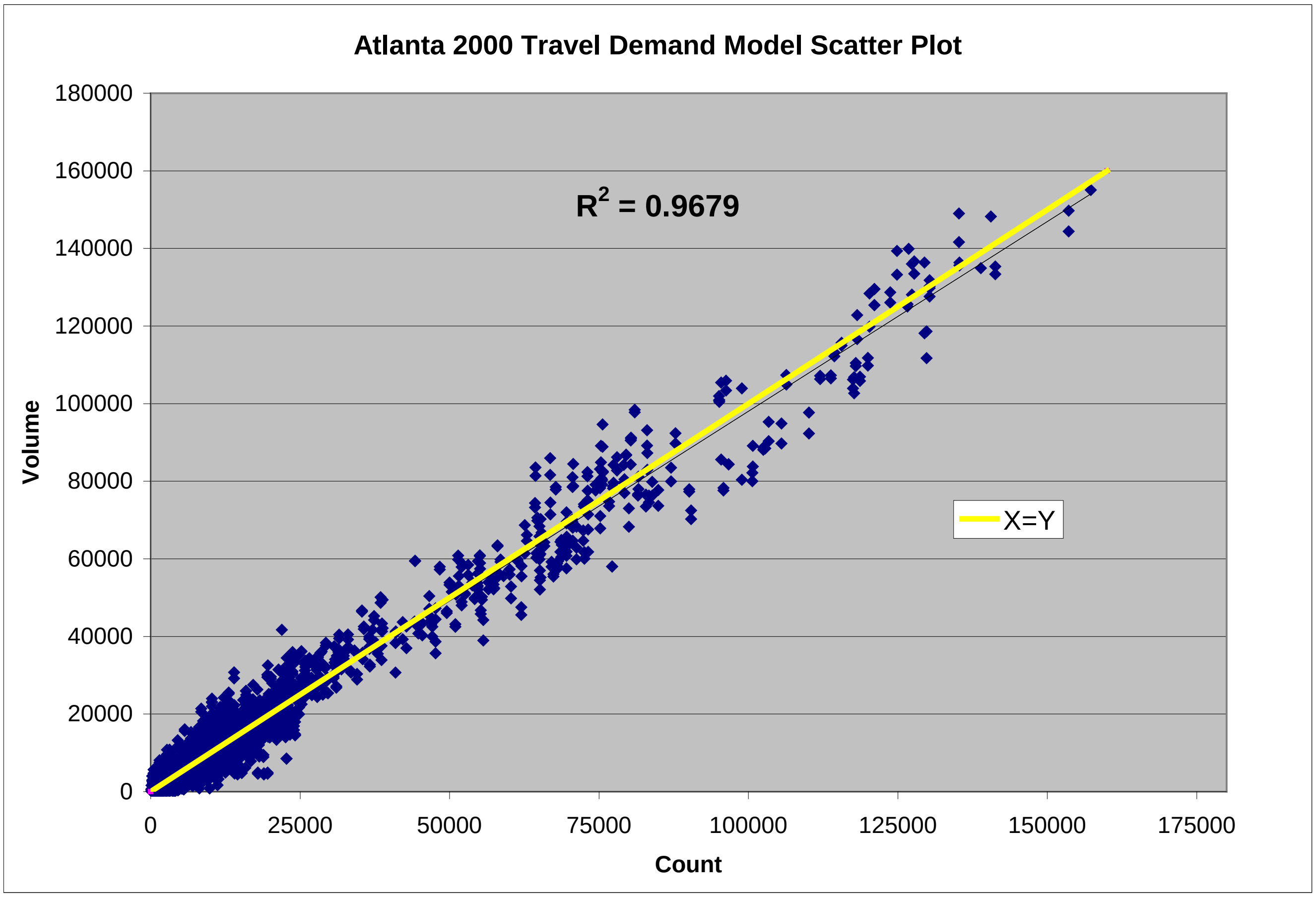
BMC 2000[19]			
Area Type	Freeway	Other Roads	Total
1(rural)	21.0%	42.4%	33.3%
2	20.9%	37.0%	28.3%
3	32.9%	38.9%	45.6%
4	28.5%	47.6%	41.7%
5	19.4%	49.0%	45.1%
6	-	34.4%	34.4%
7	123.3%	51.5%	82.3%
8	45.3%	52.2%	51.1%
9 (cbd)	42.0%	62.3%	61.0%
Total	25.8%	43.6%	37.6%

ARC 2000			
Area Type	Freeway	Other Roads	Total
7(rural)	15.3%	62.2%	46.2%
6	16.1%	44.8%	34.3%
5	12.5%	37.6%	28.1%
4	10.9%	32.7%	23.0%
3	13.5%	37.9%	27.6%
2	10.0%	36.2%	18.7%
1(CBD)	10.0%	39.0%	18.0%
Total	12.7%	41.6%	29.7%

The highway assignment validation process generally proceeds from regional checks, to checks on groups of links (screenlines, RMSE groups, etc.), and finally to link specific checks. Figure 8.7 displays a scatter plot of the ARC 2000 model count locations. Ideally all of the data points on the graph would fall on a line where x = y (i.e., count = volume). The coefficient of determination (R^2) is shown on the graph. The generally accepted value regionwide is 0.88 (closer to 1 is better). The ARC 2000 model had an R^2 of 0.97 which is well above the target value. The graph indicates that the assignment model is accurately modeling specific links, in most cases.

[19] "Baltimore Region Travel Demand Model for Base Year 2000 Task Report 04-01", Baltimore Metropolitan Council

Figure 8.7



8.6.2 Transit Validation

Refer to Section 4, Mode Choice model for the validation results.

9. Networks

9.1 Highway Networks

This file represents all zones, nodes, and links for the peak and off-peak highway network in TP+ format. TP+ allows unlimited data fields for highway network files. For the ARC model, the required data fields are listed in Table 9.1. Other fields typically exist in networks and are listed in Tables 9.3 and 9.4.

Table 9.1
Required Data Fields for Initial Highway Network

Variable	Definition	Units
A	Beginning node	
B	Ending node	
Distance	Link distance	Miles
Prohibition	Link restriction parameters 0 = No Restrictions 1 = Trucks Prohibited 2 = HOV Lanes 3 = Managed Lanes 4 = Truck Only Lanes 5 = Truck prohibition inside I-285	
Lanes	Number of through lanes in one direction	
Auxlane	Number of auxiliary lanes	
Factype	0 Centroid Connectors 1 Interstate / Freeway 2 Parkway 3 HOV Buffer Separated 4 HOV Barrier Separated 5 High Speed Ramp / CD Road 6 Medium Speed Ramp 7 Low Speed Ramp 8 Loop Ramp 9 Off Ramp w/ Intersection 10 On Ramp w/ Intersection 11 Expressway 12 Principal Arterial - Class I 13 Principal Arterial - Class II 14 Minor Arterial - Class I 15 Minor Arterial - Class II 16 HOV - Arterial (all classes) 17 Major Collector 18 Minor Collector / Other Local 19 Planned Ramps w/ Intersections 20 Planned Directional Ramps 50 Transit Only Link: Neighborhood Local 51 Transit Only Link: Local Roads and Collectors 52 Transit Only Link: Park-n-ride lot connector 53 Transit Only Link: Transfer links between rail and bus 54 Transit Only Link: Bus Rapid Transit	

Facility Type (Factype) is a required link attribute. Many Atlanta highway networks include the attributes that are listed in Table 9.2. This is a result of an effort to develop a consistent process for assigning facility type codes. A TP+ script was developed to base facility type coding on Georgia DOT's Road Characteristics File (RC File) attributes. The attributes in Table 9.2 were integrated into a base year highway network and the TP+ script assisted in assigning facility types to the network.

Table 9.2
Data Fields Used for Facility Type Estimation

Variable	Definition	Units
Speed_Limit	Posted Speed Limit from the GDOT RC file	
Median	Median Type D = Divided T = Two-way left turn lane U = Undivided	
Shoulder	Shoulder Type Blank=Paved N=Not Paved	
Access	Access Control F=Full control P=Partial control N=No control	
Strategic	ARC Strategic Arterial Code	

Although not required for the core modeling system to run, the link attributes listed in Table 9.3 should be maintained.

Table 9.3
Other Recommended Data Fields for Initial Highway Network

Variable	Definition	Units
Name	Name of facility	
COUNTSTA	GDOT Count Station Identifier	
DIRCOUNT	Average Daily Directional Traffic Count (2000)	
Screenline	Screenline Code	
FCLASS	HPMS Functional Classification (Used for Emissions Post-Processors)	

After the highway network building module executes several additional link attributes will be added to peak and off-peak highway networks. Additional variables include:

Table 9.4
Link Attributes Added In the Highway Network Building Module

Variable	Definition	Units
Zone	Nearest Traffic Analysis Zone	
AType	Link Area Type 1 – CBD / Very High Density Urban 2 – High Density Urban 3 – Medium Density Urban 4 – Low Density Urban 5 – Suburban 6 – Exurban 7 – Rural	
Capacity	Total Link Capacity (1 Hr -LOS E)	
Toll	Fixed Toll Cost	Dollars
Speed	Free-Flow Speed	
BusSpd	Bus Speed	Mph
Bustime	Bus time	Minutes

Several TP+ functions add data fields to the highway links within the highway network for toll cost, speed and capacity. The speed and capacity values have been recently modified to accommodate the 2001 model panel review comments and validated with two speed studies.

The peak and free-flow speed and capacity tables are listed in Tables 9.5 through 9.7. Transit only links are not included the highway assignment process. Therefore, capacities are not necessary. Transit only speeds are assigned fixed values as follows:

Facility Type	Link type	Speed
50	Neighborhood Local	12 mph
51	Local or Collector	20 mph
52	Park-n-ride Lot Connector	20 mph
53	Rail / bus Transfer	20 mph
54	BRT Separate Facility	

Table 9.5
Free-flow Speed by Area Type and Facility Type

		Area Type								
	Facility Type	Urban Very High Density	Urban High Density	Urban Medium Density	Urban Low Density	Suburban	Exurban	Rural		Metered Ramps
0	Zone Centroid Connectors	7	11	11	11	11	14	14		
1	Interstate / Freeway Free Flow	55	58	58	61	61	63	65		
2	Parkway	50	50	55	55	57	60	60		
3	HOV Buffer Separated	55	58	58	61	61	63	65		
4	HOV Barrier Separated	55	58	58	61	61	63	65		
5	High Speed Ramp / CD Road	50	50	55	55	57	60	60		15
6	Medium Speed Ramp	50	50	50	50	50	50	50		10
7	Low Speed Ramp	40	40	40	40	40	40	40		10
8	Loop Ramp	30	30	30	30	30	30	30		10
9	Off Ramp w/ Intersection	25	25	25	25	25	25	25		
10	On Ramp w/ Intersection	40	40	40	40	40	40	40		5
11	Expressway	40	42	45	48	52	55	60		
12	Principal Arterial - Class I	26	30	33	36	42	46	55		
13	Principal Arterial - Class II	24	27	30	34	40	44	48		
14	Minor Arterial - Class I	22	25	28	31	38	42	45		
15	Minor Arterial - Class II	20	23	26	29	34	38	42		
16	HOV - Arterial (all classes)	20	27	30	33	36	39	42		
17	Major Collector	18	22	25	28	31	34	38		
18	Minor Collector	15	18	21	24	27	30	35		
19	Planned Ramps w/ Intersections	30	30	30	30	30	30	30		5
20	Planned Directional Ramps	45	45	45	45	45	45	45		10

Table 9.6
Free-flow Capacity by Area Type and Facility Type

	Facility Type	Urban Very High Density	Urban High Density	Urban Medium Density	Urban Low Density	Suburban	Exurban	Rural		Auxiliary Lanes	Metered Ramps
		Area Type									
0	Zone Centroid Connectors	10,000	10,000	10,000	10,000	10,000	10,000	10,000		-	-
1	Interstate / Freeway Free-flow	1,600	1,650	1,700	1,750	1,800	1,800	1,800		1,200	-
2	Parkway	1,600	1,600	1,600	1,700	1,700	1,800	1,800		900	-
3	HOV Buffer Separated	1,400	1,400	1,600	1,600	1,600	1,800	1,800		900	-
4	HOV Barrier Separated	1,600	1,650	1,700	1,750	1,800	1,800	1,800		900	-
5	High Speed Ramp / CD Road	1,600	1,600	1,600	1,700	1,700	1,800	1,800		900	1,200
6	Medium Speed Ramp	1,600	1,600	1,600	1,650	1,650	1,700	1,700		-	900
7	Low Speed Ramp	1,400	1,400	1,400	1,400	1,400	1,400	1,400		-	900
8	Loop Ramp	1,200	1,200	1,200	1,200	1,200	1,200	1,200		-	900
9	Off Ramp w/ Intersection	1,200	1,200	1,200	1,200	1,200	1,200	1,200		-	-
10	On Ramp w/ Intersection	1,200	1,200	1,200	1,200	1,200	1,200	1,200		-	600
11	Expressway	1,200	1,300	1,400	1,500	1,600	1,600	1,600		600	-
12	Principal Arterial - Class I	1,000	1,050	1,100	1,150	1,200	1,250	1,350		300	-
13	Principal Arterial - Class II	900	900	950	1,000	1,000	1,050	1,100		300	-
14	Minor Arterial - Class I	800	800	850	900	900	950	1,000		300	-
15	Minor Arterial - Class II	650	700	750	750	800	850	900		300	-
16	HOV - Arterial (all classes)	600	600	650	700	700	750	800		-	-
17	Major Collector	550	600	600	650	650	700	700		-	-
18	Minor Collector	400	400	450	450	500	550	600		-	-
19	Planned Ramps w/ Intersections	1,200	1,200	1,200	1,200	1,200	1,200	1,200		-	600
20	Planned Directional Ramps	1,600	1,600	1,600	1,700	1,700	1,800	1,800		-	900

Table 9.7
Peak Speed by Area Type and Facility Type

		Area Type								
	Facility Type	Urban Very High Density	Urban High Density	Urban Medium Density	Urban Low Density	Suburban	Exurban	Rural		Metered Ramps
0	Zone Centroid Connectors	7	11	11	11	11	14	14		
1	Interstate / Freeway Peak	40	45	50	55	55	55	60		
2	Parkway	40	45	50	55	55	55	60		
3	HOV Buffer Separated	40	45	50	55	55	55	60		
4	HOV Barrier Separated	40	45	50	55	55	55	60		
5	High Speed Ramp / CD Road	30	35	35	40	45	45	45		15
6	Medium Speed Ramp	30	35	35	40	40	40	40		10
7	Low Speed Ramp	25	30	30	35	35	35	35		10
8	Loop Ramp	20	20	20	20	20	20	20		10
9	Off Ramp w/ Intersection	20	20	20	20	20	20	20		
10	On Ramp w/ Intersection	30	30	30	30	30	30	30		5
11	Expressway	35	40	40	45	45	50	55		
12	Principal Arterial - Class I	25	27	30	33	35	40	50		
13	Principal Arterial - Class II	20	20	20	25	30	35	40		
14	Minor Arterial - Class I	20	20	23	25	30	30	35		
15	Minor Arterial - Class II	15	20	20	22	25	30	35		
16	HOV - Arterial (all classes)	20	20	20	25	30	35	40		
17	Major Collector	15	18	18	20	23	25	30		
18	Minor Collector	10	10	10	15	20	20	25		
19	Planned Ramps w/ Intersections	25	25	25	25	25	25	25		5
20	Planned Directional Ramps	30	35	35	40	40	40	40		10

9.2. Transit Networks

Transit networks are similar to highway networks but more data files are required to build a transit network. A transit network contains lines and support links. Lines are user defined transit routes. Support links provide connectivity between transit lines and between zone centroids and transit lines. Typical support link types are walk, park/ride and transfer links. The highway network provides the location of the nodes and basic information regarding the distance and speeds between links. Transit lines that utilize the highway links obtain the speeds from the highway network that are factored based on the area type and facility type. Fixed guideway speeds are obtained from the input train link file.

A variety of support links are automatically built to provide connectivity within the network. These links are used for walking to, from and between transit stop nodes, and for driving from zones to transit. To provide greater control over how support links are automatically generated, the transit route files and park/ride files are each separated into two files.

The following files are text or ASCI files that are created by the user to create a transit network. Routes files (Troute*{year}x*.txt) are created using Viper's Transit Line Manager. Train link and park/ride lot data files are created using a text editor.

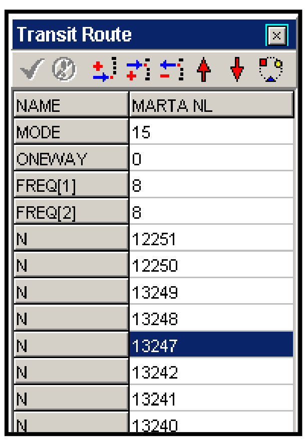
Transit routes are specified in two files. Fixed guideway routes (typically rail lines and BRT) are specified in Troute{year}1.txt. Other transit routes are specified in Troute{year}2.txt. Transit routes are separated into two route files to assist in representing differences in service areas for fixed guideway stations versus bus stops.

Route Information – Troute{year}1.txt and Troute{year}2.txt

Field	Description
Name	Name of the Route – No longer than 12 characters
Mode	Mode of the Route
OneWay	Directional indicator (T = one way and F = two way)
Freq[1]	Peak Period Frequency or Headway
Freq[2]	Off-Peak Period Frequency or Headway
N	Nodes List of links that the line follows. Each node is followed by another. Each node is automatically considered a stop unless it is coded as a negative number. Nodes may be separated by spaces, a comma or a dash (if using a text editor)

Sample Transit Route File (Text File and Viper Transit Line Editor)

```
LINE NAME="MARTA NL", MODE=15, ONEWAY=F, FREQ[1]=8, FREQ[2]=8,
N=12251, 12250, 13249, 13248, 13247, 13242, 13241, 13240,
22116, 13238, 13237, 23003, 13325, 13326, 13327, 13328, 13329,
13330, 22115
```



Speed and distance information for routes that use links that are not in the highway network (currently most rail lines), is specified in a train link file (Trainlnk{year}.txt).

Fixed Guideway Information – Trainlnk{year}.txt

Field	Description
Link Nodes	Anode and Bnode
Mode	Mode of the Route
Dist	Distance (Miles with two implied decimal places)
Speed	Average Speed traveled over this link
OneWay	Directional indicator (T = one way and F = two way)

Sample Train link File

```
LINK  NODES=12251-12250  MODES= 15  DIST= 110  SPEED= 33   ONEWAY=T
LINK  NODES=13249-12250  MODES= 15  DIST= 90  SPEED= 27   ONEWAY=T
LINK  NODES=12250-12251  MODES= 15  DIST= 110  SPEED= 33   ONEWAY=T
LINK  NODES=13080-23003  MODES= 15  DIST= 40  SPEED= 24   ONEWAY=T
LINK  NODES=13089-23003  MODES= 15  DIST= 40  SPEED= 24   ONEWAY=T
```

Park/Ride lots are represented by two nodes coded in the highway network, and a list of zones that have the potential to drive to the lot. The first node is the location of the lot itself. The second node is the transit station or stop. The park-ride lots specified in Pnrcode*{year}*1.txt represent the premium facilities (see below for further information). The remainder of the park/ride lots are specified in pnrcode{*year}*2.txt. Generally all internal zones are listed as having access to park/ride lots. Procedures in the support link building process attempt to insure that no unreasonable park/ride support links are produced in the final transit networks. The procedure to build the support links for premium park/ride lot has been refined to select zones that focus on the appropriate market.

Park/Ride Lots – Pnrcode*{year}*1.txt and Pnrcode{year}2.txt

Field	Description
PNR NODE	TP+ Park/ride lot command
A	Park/Ride lot node number
B	Park/Ride station/stop node number
Zones	Potential range of zones eligible to use the par/ride lot

Sample Park/Ride lot data file:

```
PNR NODE=19100-23002,ZONES=1-1683
PNR NODE=19099-13245,ZONES=1-1683
PNR NODE=19098-13244,ZONES=1-1683
PNR NODE=19105-12251,ZONES=1-1683
PNR NODE=19102-13249,ZONES=1-1683
```

“Premium” Coding Considerations:

MARTA rail lines are the only “premium” transit mode that currently exists in the Atlanta area, with a few “premium” park/ride lots. However, future planned projects include other premium transit modes and additional “premium” park/ride lots. Below are issues that may need some clarification regarding potential "premium" transit coding. Note: detailed transit coding guidelines are contained in the ARC Model Users Guide. All rail modes should be coded as premium. Professional judgment, however, is required in deciding whether to code some transit facilities as "premium." The following are most likely cases that require professional judgment.

- Particular care should be taken when designating park-n-ride lots as " premium." Premium lots are coded in pnrcode{year}1.txt. All premium lot nodes must also be added to the list of nodes for the expected market direction within the main TP+ script itself. Premium park-n-ride lots should exhibit several key attributes: walk access to a premium transit mode, direct or near-direct access from freeways, and a large (1000+ spaces) parking supply.
- Bus Rapid Transit (BRT) may or may not be considered a premium mode depending on the attributes of the proposed project. BRT routes should be coded as express bus routes unless they includes most of the following "premium" attributes:
    - Right-of-way: A majority of the route operates on reliable high-speed facilities provided either by dedicated right-of-way or managed lanes.
    - Stations: Boarding / Alighting opportunities are limited to permanent stations that are "subway like." Bus shelters do not qualify as a "premium" station.
    - Vehicles: Advanced vehicles that provide "rail-like" access such as doublewide doors and floors that align with the platform.
    - Fare Collection: Fares are collected before entering the platform to minimize station dwell time.
    - Service/Capacity: All-day frequent service is provided to insure on-demand high-capacity service.

9.2.1 Development of Bus Speed Model

ARC has developed an empirical model to connect bus speed to highway congested speed. In the previous model, bus speeds were determined using a lookup table related to the area type and facility type that the transit link was associated with. These speeds did not change in relation to the highway speed. The objective of the bus speed model was to add highway congested speed into the lookup table and change each cell of the table into a dynamic function. This approach enabled bus speeds to closely resemble the observed operation speed.

The bus speed model was calibrated by statistically fitting a set of bus speed curves linking bus speed to congested highway speed. Different curves were developed for each area type and facility type combination. The resulting functions are somewhat linear, following the equation below:

Bus speed = ***a*** (congested highway speed) + ***b***

Where both **a** and **b** are parameters resulting from the calibration of the bus speed model. These parameters are closely related to bus cruise speed, frequency of stops and dwell times at stations. Bus schedules from MARTA and CCT were used to generate a and b factors. The a and b factors were entered into two lookup tables added into the TP+ transit build module, enabling the bus speed to change based on the congested highway speed of the link. With the revised bus speed model, bus speeds will change with every model iteration. Therefore, the model feedback loop is modified to reflect bus path building within every iteration. The output from the model provides details for each bus route including distance, time and speed. This information was compared, for each bus line, to the applicable bus schedule. Several rounds of calibration took place until the resulting bus speed resembled the bus operation speed with an average error level below 5%. The calibrated bus speed table is shown in Tables 9.9 and 9.10.

Table 9.9
Calibrated Bus Speed Table –Factor a

Area Type	Centroid Connectors	Freeway	Principal Arterial 1	Principal Arterial 2	Minor Arterials	Collector
1	1.0000	0.9000	0.3605	0.5376	0.5923	0.7379
2	1.0000	0.9000	0.4405	0.4668	0.5385	0.5290
3	1.0000	0.9000	0.4085	0.4569	0.4899	0.5067
4	1.0000	0.9000	0.4290	0.4807	0.5356	0.5449
5	1.0000	0.7000	0.5861	0.6116	0.6267	0.6783
6	1.0000	0.9000	0.5477	0.6030	0.6085	0.6287
7	1.0000	0.9000	0.5385	0.6697	0.7105	0.6926

Table 9.10
Calibrated Bus Speed Table –Factor b

Area Type	Centroid Connectors	Freeway	Principal Arterial 1	Principal Arterial 2	Minor Arterials	Collector
1	0.0000	0.0000	5.9993	2.6072	2.0696	0.6383
2	0.0000	0.0000	5.6740	5.1127	3.5933	3.7366
3	0.0000	0.0000	6.5819	5.5321	4.9054	4.3896
4	0.0000	0.0000	5.9857	4.8842	3.8184	3.4951
5	0.0000	0.0000	4.6927	4.1883	3.7634	2.7144
6	0.0000	0.0000	5.7155	4.4121	4.2765	3.6284
7	0.0000	0.0000	9.4463	4.4402	3.1615	3.6658

9.2.2. Transit Modes and Transit Fare Coding

The transit fare structure used to develop the previous 2025 RTP was developed in 1995, using a fare matrix on a zone to zone level with a universal fare structure of $1.50 (flat fare) for all bus and rail lines. With the MARTA fare change implemented in 2002, the addition of new transit operators providing regional transit services and the need to plan for future transit modes such as commuter rail and light rail in future years, more specific transit coding was needed to accurately reflect the transit levels of service. Several factors were taken into account when developing the fare structure: (1) accuracy, (2) ease of coding (3) flexibility for future fare structure changes (4) easy summarization by mode and by owner.

TP+ enables 255 modes to be used in the model stream. Taking advantage of this new feature, ARC has developed the mode numbering structure as shown in Table 9.2.2 below. Walk and drive to transit, and transfer between transit lines was kept intact and remained the same for all modes of transit. A separate mode was reserved for each transit provider and each mode they operate. Up to 10 modes are reserved for each operator and 25 operators can be accommodated in this manner. For easy summarization, all local bus mode numbers end with 4, heavy rail with 5, express bus with 6, commuter rail with 7, light rail and BRT with 8 and intercity rail with 9. This coding system can be easily expanded for future modes and providers. The coding approach enables most of the fares to be coded universally for each mode and all providers are allowed to have different fares. In addition, a protocol was established in the model stream to allow transit fare to be coded by transit link (i.e. between stations for Commuter Rail mode). The fare skim calculated using this approach has replaced the static fare matrix from the previous model.

The fare structure coded for 2000 reflects the current fare structure.

Table 9.11
Transit Modes and Fare Approaches

Operator	Mode	Mode Number	Fare Coding Approach	Fare
All	Transfer	1	N/A	N/A
All	Drive to Transit	2	N/A	N/A
All	Walk to Transit	3	N/A	N/A
All	All Park and Ride Lots	4	Link Fare	Parking fee if applicable
N/A	Shuttle Bus	10	N/A	Free
MARTA				
	Local bus	14	Mode Fare	$1.75
	Heavy rail	15	Mode Fare	$1.75
	Express Bus	16	Mode Fare	$1.75
	Light Rail/BRT	18	Mode Fare	$1.75
CCT				
	Local Bus	24	Mode Fare	$1.75
	Express Bus	26	Mode Fare	$1.75
	Light Rail/BRT	28	Mode Fare	$1.75
Clayton County				
	Local bus	34	Mode Fare	$1.75
	Express Bus	36	Mode Fare	$1.75
	Light Rail/BRT	38	Mode Fare	$1.75
Gwinnett County				
	Local bus	44	Mode Fare	$1.75
	Express Bus	46	Mode Fare	$1.75
	Light Rail/BRT	48	Mode Fare	$1.75
State Owned				
	Local bus	54	Mode Fare	$1.75
	Express Bus	56	Mode Fare	$1.75
	Commuter Rail	57	Link Fare	TBD
	Light Rail/BRT	58	Mode Fare	$1.75
	Intercity Rail	59	Link Fare	TBD
Greyhound	Express Bus	66	TBD	TBD
Hall County				
	Local bus	74	Mode Fare	$1.00
	Express Bus	76	Mode Fare	N/A
	Commuter Rail	77	Link Fare	TBD
	Light Rail/BRT	78	Mode Fare	N/A
	Intercity Rail	79	Link Fare	TBD

APPENDICES

APPENDIX A – Setup to Synthesize Commercial Vehicle Counts

```
run pgm=hwynet

; comvol.s

  id = "Synthesize 2000 COM link counts

  neti = hwy00ff.net
  neto = temp.net

; Model to synthesize COM "counts" is as calibrated in ComVeh.xls.
;  Use the "AT4/FT" logit model, with count-based adjustment.

; Lookup tables for bias constants.  First set are based on
;  County, grouped by density into 3 classes.  Higher values = lower %COM.
  lookup interpolate = n, fail = 0,0,0, name = biasco,
        lookup[1] = 1, result = 2,
        r = ' 13   1.1674',
            ' 15   1.1674',
            ' 45   1.1674',
            ' 57   1.1674',
            ' 63   1.2383',
            ' 67   1.2383',
            ' 77   1.1674',
            ' 89   1.2279',
            ' 97   1.1674',
            '113   1.1674',
            '117   1.1674',
            '121   1.2279',
            '135   1.2383',
            '139   1.1674',
            '151   1.1674',
            '217   1.1674',
            '223   1.1674',
            '247   1.1674',
            '255   1.1674',
            '297   1.1674'

; Look up fac type group.
  lookup interpolate = n, fail = 0,0,0, name = ftg,
        lookup[1] = 1, result = 2,
;            ft ftg
        r = ' 0  0',
            ' 1  1',
            ' 2  2',
            ' 3  1',
            ' 4  1',
            ' 5  1',
            ' 6  1',
            ' 7  1',
            ' 8  1',
            ' 9  1',
            '10  1',
            '11  3',
            '12  4',
            '13  5',
            '14  6',
            '15  7',
            '16  4',
```

```
            '17  8',
            '18  9'

; Look up area type group.
  lookup interpolate = n, fail = 0,0,0, name = atg,
        lookup[1] = 1, result = 2,
;            at atg
        r = ' 1  1',
            ' 2  2',
            ' 3  2',
            ' 4  2',
            ' 5  3',
            ' 6  4',
            ' 7  4'

; Second set of bias coeffs are based on FT group and AT group codes.
;  Values for cells that don't exist in 2000 are estimated
;  by analogy by WGA based on the other values.
  lookup interpolate = n, fail = 0,0,0, name = biasfgag,
        lookup[1] = 1, result = 2,
        lookup[2] = 1, result = 3,
        lookup[3] = 1, result = 4,
        lookup[4] = 1, result = 5,
;                     AG
;            FG       1        2        3        4
        r = ' 1  0.1770,  0.0810, -0.0052,  0.5626',
            ' 2  0.20,    0.3593,  0.1048, -0.4918',
            ' 3  0.20,    0.10,    0.0204,  0.4811',
            ' 4  0.20,    0.1125,  0.1384,  0.1092',
            ' 5  0.1967,  0.1195,  0.1606, -0.1238',
            ' 6  0.20,   -0.0595,  0.0052, -0.13  ',
            ' 7  0.20,    0.2776,  0.0415, -0.1460',
            ' 8  0.7717,  0.2890, -0.0409, -0.15  ',
            ' 9  0.75,    0.2412,  0.2828, -0.15  '

; If this is an external station, whose COM count was
;  posted previously by PBS&J, use it as is.
  if (A = 2028-2118 || B = 2028-2118)
    COMCNT = COMVEH
    break
  endif

; If the link has a COM count derived directly from the COM
;  manual count data and there is no total count, then use
;  the posted COM count as is.
  if (COMVEH > 0 && DIRCOUNT = 0)
    COMCNT = COMVEH
    break
  endif

; Else, if there's no weekday count, can't estimate a Commercial
;  count for this link, so skip it.
  if (DIRCOUNT = 0) break

; Skip further processing for centroid connectors and HOV lanes.
  if (FACTYPE = 0 || PROHIBITION = 2) break

; Look up the county group bias constant based on COUNTY.
  _cJur = biasco(1,COUNTY)

; Look up the FGroup based on FTYPE.
```

```
  _fg   = ftg(1,FACTYPE)

; Look up the ATGroup based on ATYPE.
  _ag   = atg(1,ATYPE)

; Use FGroup and ATGroup to look up the FGroup/ATGroup bias constant.
  if (_fg > 0) _cFA  = biasfgag(_ag,_fg)

; COM utile for the logit model.
  _lncnt = ln(DIRCOUNT)
  _u = _cJur + _cFA + 0.1290*_lncnt - 0.0655*LANES

; Percent COM.
  _p = 1/(1+exp(_u))

; Apply count-based adjustment.
  _p = 11.0686 * _p / _lncnt

; Estimated COM link volume
  _cnt = round(_p * DIRCOUNT)

; If this was a surveyed link, compare the estimated count to the
;  actual count.  If they're within 50%, use the actual.
;  Otherwise, use the estimated.
  if (COMVEH > 0)

    _diff = abs(_cnt/COMVEH - 1)
    if (_diff <= 0.5)
      COMCNT = COMVEH
    else
      COMCNT = _cnt
    endif

  else

    COMCNT = _cnt

  endif

; But there are a few exceptions to that rule...
  if (A= 8644       && B= 8646      ) COMCNT=COMVEH
  if (A= 8647       && B= 8645      ) COMCNT=COMVEH

; List every link, for checking.
  print form=12.4, list=a(6),b(6),_cJur(8.4),_fg(3),_ag(3),_cFA(8.4),
    LANES(3),DIRCOUNT(6),_lncnt(8.4),_u,_p,COMCNT(6)
  print form=6, list=a,b,_p(12.4), file=comvol.dat

; After the initial run, some links were found to have inconsistent
;  or illogical-looking counts.  Remove such counts.
  if (A=44065,44066 && B=44065,44066) COMCNT=0
  if (A=44059,44060 && B=44059,44060) COMCNT=0
  if (A=44238,44239 && B=44238,44239) COMCNT=0
  if (A=44275,44277 && B=44275,44277) COMCNT=0
  if (A=44175,44176 && B=44175,44176) COMCNT=0
  if (A=44389,44390 && B=44389,44390) COMCNT=0
  if (A=44394,44395 && B=44394,44395) COMCNT=0
  if (A=43598       && B=43599      ) COMCNT=0
  if (A=43608       && B=43609      ) COMCNT=0
  if (A=44008,44010 && B=44008,44010) COMCNT=0
  if (A=44000,44001 && B=44000,44001) COMCNT=0
```

```
if (A=11902,11912 && B=11902,11912) COMCNT=0
if (A=11929,31964 && B=11929,31964) COMCNT=0
if (A=29279,29280 && B=29279,29280) COMCNT=0
if (A=17116       && B=11917      ) COMCNT=0
if (A=10478       && B=17525      ) COMCNT=0
if (A=13498       && B=13497      ) COMCNT=0
if (A=13499       && B=11909      ) COMCNT=0
if (A=11901,11914 && B=11901,11914) COMCNT=0
if (A= 9802,11914 && B= 9802,11914) COMCNT=0
if (A= 9802,11942 && B= 9802,11942) COMCNT=0
if (A=28576,28577 && B=28576,28577) COMCNT=0
if (A=10910,10911 && B=10910,10911) COMCNT=0
if (A=10918,10927 && B=10918,10927) COMCNT=0
if (A=10930,10980 && B=10930,10980) COMCNT=0
if (A=10921,10933 && B=10921,10933) COMCNT=0
if (A=58488,58489 && B=58488,58489) COMCNT=0
if (A=58402,58403 && B=58402,58403) COMCNT=0
if (A=58389,58390 && B=58389,58390) COMCNT=0
if (A=57230,57231 && B=57230,57231) COMCNT=0
if (A=58699,58700 && B=58699,58700) COMCNT=0
if (A=57137       && B=57138      ) COMCNT=0
if (A=57139       && B=57140      ) COMCNT=0
if (A=58649,58650 && B=58649,58650) COMCNT=0
if (A=58970,58971 && B=58970,58971) COMCNT=0
if (A=58967,58968 && B=58967,58968) COMCNT=0
if (A=57692,58972 && B=57692,58972) COMCNT=0
if (A=57690,57691 && B=57690,57691) COMCNT=0
if (A=57686,57687 && B=57686,57687) COMCNT=0
if (A=57771,57772 && B=57771,57772) COMCNT=0
if (A=57348,57349 && B=57348,57349) COMCNT=0
if (A=57378,57379 && B=57378,57379) COMCNT=0
if (A=57388,57389 && B=57388,57389) COMCNT=0
if (A=57968,57969 && B=57968,57969) COMCNT=0
if (A=46506       && B=46507      ) COMCNT=0
if (A=46502       && B=46503      ) COMCNT=0
if (A=46839,46840 && B=46839,46840) COMCNT=0
if (A=46655,46656 && B=46655,46656) COMCNT=0
if (A=46697,46698 && B=46697,46698) COMCNT=0
if (A=46717,46718 && B=46717,46718) COMCNT=0
if (A=46711,46712 && B=46711,46712) COMCNT=0
if (A=46762,46763 && B=46762,46763) COMCNT=0
if (A=46762,46761 && B=46762,46761) COMCNT=0
if (A=46758,46759 && B=46758,46759) COMCNT=0
if (A=46754,46755 && B=46754,46755) COMCNT=0
if (A=46752,46753 && B=46752,46753) COMCNT=0
if (A=46775,46776 && B=46775,46776) COMCNT=0
if (A=46885       && B=46886      ) COMCNT=0
if (A=46866       && B=46867      ) COMCNT=0
if (A=46915,46916 && B=46915,46916) COMCNT=0
if (A=46589,46590 && B=46589,46590) COMCNT=0
if (A=34640,34641 && B=34640,34641) COMCNT=0
if (A=34643,34644 && B=34643,34644) COMCNT=0
if (A=34694,34696 && B=34694,34696) COMCNT=0
if (A=34690,34691 && B=34690,34691) COMCNT=0
if (A=34831,34832 && B=34831,34832) COMCNT=0
if (A=34823,34824 && B=34823,34824) COMCNT=0
if (A=34994,34995 && B=34994,34995) COMCNT=0
if (A=35009,35010 && B=35009,35010) COMCNT=0
if (A=34980,34987 && B=34980,34987) COMCNT=0
if (A=34985,34986 && B=34985,34986) COMCNT=0
if (A=34952,34955 && B=34952,34955) COMCNT=0
```

```
if (A=34957,34958 && B=34957,34958) COMCNT=0
if (A=34948,34950 && B=34948,34950) COMCNT=0
if (A=40898       && B=40547      ) COMCNT=0
if (A=40897       && B=40548      ) COMCNT=0
if (A=40544       && B=40542      ) COMCNT=0
if (A=40893       && B=40543      ) COMCNT=0
if (A=40576,40577 && B=40576,40577) COMCNT=0
if (A=40576,40578 && B=40576,40578) COMCNT=0
if (A=40576,40575 && B=40576,40575) COMCNT=0
if (A=40583,40575 && B=40583,40575) COMCNT=0
if (A=40594,40595 && B=40594,40595) COMCNT=0
if (A=40601,40602 && B=40601,40602) COMCNT=0
if (A=40606,40607 && B=40606,40607) COMCNT=0
if (A=40626,40627 && B=40626,40627) COMCNT=0
if (A=40638,40637 && B=40638,40637) COMCNT=0
if (A=37827       && B=11892      ) COMCNT=0
if (A=11892       && B=11889      ) COMCNT=0
if (A=11888       && B=37826      ) COMCNT=0
if (A=37826       && B=37828      ) COMCNT=0
if (A=11878       && B=11856      ) COMCNT=0
if (A=11859       && B=11879      ) COMCNT=0
if (A=37818,37819 && B=37818,37819) COMCNT=0
if (A=37816,37817 && B=37816,37817) COMCNT=0
if (A=37556,37557 && B=37556,37557) COMCNT=0
if (A=37695,37696 && B=37695,37696) COMCNT=0
if (A=37697,37698 && B=37697,37698) COMCNT=0
if (A=37692,37694 && B=37692,37694) COMCNT=0
if (A=37690,37693 && B=37690,37693) COMCNT=0
if (A=37686,37927 && B=37686,37927) COMCNT=0
if (A=37633,37634 && B=37633,37634) COMCNT=0
if (A=37658,37678 && B=37658,37678) COMCNT=0
if (A=37659,37660 && B=37659,37660) COMCNT=0
if (A=37639,37640 && B=37639,37640) COMCNT=0
if (A=37583,37584 && B=37583,37584) COMCNT=0
if (A=37578,37587 && B=37578,37587) COMCNT=0
if (A=37575,37576 && B=37575,37576) COMCNT=0
if (A=37588,37589 && B=37588,37589) COMCNT=0
if (A=11726,11718 && B=11726,11718) COMCNT=0
if (A=11710,11713 && B=11710,11713) COMCNT=0
if (A=31993,11702 && B=31993,11702) COMCNT=0
if (A=11723,11676 && B=11723,11676) COMCNT=0
if (A=11716,11705 && B=11716,11705) COMCNT=0
if (A=11703,11693 && B=11703,11693) COMCNT=0
if (A=11703,11699 && B=11703,11699) COMCNT=0
if (A= 8919,11698 && B= 8919,11698) COMCNT=0
if (A=11695,29221 && B=11695,29221) COMCNT=0
if (A=11677,29219 && B=11677,29219) COMCNT=0
if (A=29207,29206 && B=29207,29206) COMCNT=0
if (A=29205,29206 && B=29205,29206) COMCNT=0
if (A= 8984,28482 && B= 8984,28482) COMCNT=0
if (A=31986,11549 && B=31986,11549) COMCNT=0
if (A=11537,11490 && B=11537,11490) COMCNT=0
if (A=51325,51326 && B=51325,51326) COMCNT=0
if (A=52148,52149 && B=52148,52149) COMCNT=0
if (A=51687,51688 && B=51687,51688) COMCNT=0
if (A=51640,51641 && B=51640,51641) COMCNT=0
if (A=51644,51645 && B=51644,51645) COMCNT=0
if (A=51568,51569 && B=51568,51569) COMCNT=0
if (A=51562,51563 && B=51562,51563) COMCNT=0
if (A=51560,51561 && B=51560,51561) COMCNT=0
if (A=51677,51678 && B=51677,51678) COMCNT=0
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if (A=51668,51669 && B=51668,51669) COMCNT=0
if (A=51658,51657 && B=51658,51657) COMCNT=0
if (A=51781,51782 && B=51781,51782) COMCNT=0
if (A=51070       && B=51071      ) COMCNT=0
if (A=51078       && B=51079      ) COMCNT=0
if (A=51061       && B=51062      ) COMCNT=0
if (A=51087       && B=51088      ) COMCNT=0
if (A=51368,51369 && B=51368,51369) COMCNT=0
if (A=51368,51241 && B=51368,51241) COMCNT=0
if (A=51246,51249 && B=51246,51249) COMCNT=0
if (A=51242,51243 && B=51242,51243) COMCNT=0
if (A=51237,51239 && B=51237,51239) COMCNT=0
if (A=28807,28808 && B=28807,28808) COMCNT=0
if (A=10613,10617 && B=10613,10617) COMCNT=0
if (A=10542,10554 && B=10542,10554) COMCNT=0
if (A=10557,10554 && B=10557,10554) COMCNT=0
if (A=10557,10559 && B=10557,10559) COMCNT=0
if (A=10533,10553 && B=10533,10553) COMCNT=0
if (A=10583,32025 && B=10583,32025) COMCNT=0
if (A=10586,32025 && B=10586,32025) COMCNT=0
if (A=43952,43953 && B=43952,43953) COMCNT=0
if (A=43941,43942 && B=43941,43942) COMCNT=0
if (A=44076,44077 && B=44076,44077) COMCNT=0
if (A=44500,44501 && B=44500,44501) COMCNT=0
if (A=43663       && B=43664      ) COMCNT=0
if (A=43544       && B=43665      ) COMCNT=0
if (A=8794        && B=9048       ) COMCNT=0
if (A=6321        && B=8795       ) COMCNT=0
if (A=7549        && B=7751       ) COMCNT=0
if (A=7540        && B=7541       ) COMCNT=0
if (A=7716        && B=7547       ) COMCNT=0
if (A=13503       && B=7716       ) COMCNT=0
if (A=2798        && B=2799       ) COMCNT=0
if (A=3155        && B=2852       ) COMCNT=0
if (A=2774        && B=2775       ) COMCNT=0
if (A=2836        && B=3140       ) COMCNT=0
if (A= 3546, 3643 && B= 3546, 3643) COMCNT=0
if (A= 6287       && B=17057      ) COMCNT=0
if (A= 8988       && B= 6286      ) COMCNT=0
if (A= 8601       && B= 6289      ) COMCNT=0
if (A= 6291       && B= 8602      ) COMCNT=0
if (A=11852       && B=11849      ) COMCNT=0
if (A=11850       && B=11853      ) COMCNT=0
if (A=11433,11450 && B=11433,11450) COMCNT=0
if (A=11419,22139 && B=11419,22139) COMCNT=0
if (A=10482       && B=11443      ) COMCNT=0
if (A=11440       && B= 8945      ) COMCNT=0
if (A= 6940       && B= 6941      ) COMCNT=0
if (A= 6956       && B= 6957      ) COMCNT=0
if (A= 3812       && B= 3817      ) COMCNT=0
if (A= 3993       && B= 3816      ) COMCNT=0
if (A= 4836       && B= 8591      ) COMCNT=0
if (A= 8591       && B= 4837      ) COMCNT=0
if (A= 4844       && B= 4845      ) COMCNT=0
if (A= 5211       && B= 5212      ) COMCNT=0
if (A= 4972       && B= 4973      ) COMCNT=0
if (A= 3964       && B= 9175      ) COMCNT=0
if (A= 9176       && B= 3297      ) COMCNT=0
if (A= 3389, 9373 && B= 9373, 3389) COMCNT=0
if (A= 3475, 3761 && B= 3761, 3475) COMCNT=0
if (A= 3663       && B= 3664      ) COMCNT=0
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if (A= 3676       && B= 3673      ) COMCNT=0
if (A= 3566, 3567 && B= 3566, 3567) COMCNT=0
if (A= 3858       && B= 3860      ) COMCNT=0
if (A= 3847       && B= 3848      ) COMCNT=0
if (A= 3794, 9697 && B= 3794, 9697) COMCNT=0
if (A= 6738, 6739 && B= 6738, 6739) COMCNT=0
if (A= 6700, 6701 && B= 6700, 6701) COMCNT=0
if (A=27603,27604 && B=27603,27604) COMCNT=0
if (A=27603,27602 && B=27603,27602) COMCNT=0
if (A=51874,51875 && B=51874,51875) COMCNT=0
if (A=51882,51883 && B=51882,51883) COMCNT=0
if (A=51746,51748 && B=51746,51748) COMCNT=0
if (A=51223,51224 && B=51223,51224) COMCNT=0
if (A=51228,51229 && B=51228,51229) COMCNT=0
if (A=51399,51400 && B=51399,51400) COMCNT=0
if (A=10654,10664 && B=10654,10664) COMCNT=0
if (A= 7623,31478 && B= 7623,31478) COMCNT=0
if (A= 7524,31525 && B= 7524,31525) COMCNT=0
if (A= 7489,10394 && B= 7489,10394) COMCNT=0
if (A= 7063,31611 && B= 7063,31611) COMCNT=0
if (A=57126       && B=57127      ) COMCNT=0
if (A=57150       && B=57151      ) COMCNT=0
if (A=57073       && B=57074      ) COMCNT=0
if (A=57203       && B=57204      ) COMCNT=0
if (A=57054       && B=57055      ) COMCNT=0
if (A=57222       && B=57223      ) COMCNT=0
if (A= 7034       && B=57052      ) COMCNT=0
if (A=57225       && B= 7290      ) COMCNT=0
if (A= 9468       && B= 7030      ) COMCNT=0
if (A= 7031       && B= 9470      ) COMCNT=0
if (A= 7006       && B= 9795      ) COMCNT=0
if (A= 9792       && B= 7001      ) COMCNT=0
if (A= 7000       && B= 9774      ) COMCNT=0
if (A= 9786       && B= 6994      ) COMCNT=0
if (A= 9774       && B= 9770      ) COMCNT=0
if (A= 6989       && B= 9598      ) COMCNT=0
if (A= 9599       && B= 6962      ) COMCNT=0
if (A= 5263       && B= 5264      ) COMCNT=0
if (A= 5469       && B= 5472      ) COMCNT=0
if (A=17812       && B= 8998      ) COMCNT=0
if (A= 3167       && B= 2875      ) COMCNT=0
if (A= 5660,31357 && B= 5660,31357) COMCNT=0
if (A=11952,31969 && B=11952,31969) COMCNT=0
if (A= 7836,28215 && B= 7836,28215) COMCNT=0
if (A=11905,13498 && B=11905,13498) COMCNT=0
if (A=10944,10955 && B=10944,10955) COMCNT=0
if (A=29292,29293 && B=29292,29293) COMCNT=0
if (A=27156,27157 && B=27156,27157) COMCNT=0
if (A= 5897       && B= 5950      ) COMCNT=0
if (A= 5960       && B= 6141      ) COMCNT=0
if (A= 5953       && B= 5954      ) COMCNT=0
if (A= 6138       && B= 5958      ) COMCNT=0
if (A= 6317,31852 && B= 6317,31852) COMCNT=0
if (A= 6157,27410 && B= 6157,27410) COMCNT=0
if (A=11843,11854 && B=11843,11854) COMCNT=0
if (A= 8063,11891 && B= 8063,11891) COMCNT=0
if (A=37827       && B=11892      ) COMCNT=0
if (A=37826       && B=37828      ) COMCNT=0
if (A=37719,37722 && B=37719,37722) COMCNT=0
if (A=11427,11428 && B=11427,11428) COMCNT=0
if (A=11503       && B=11508      ) COMCNT=0
```

```
  if (A=51465,51466 && B=51465,51466) COMCNT=0
  if (A= 6605, 6606 && B= 6605, 6606) COMCNT=0
  if (A=10813,10819 && B=10813,10819) COMCNT=0
  if (A=22102       && B=22101      ) COMCNT=0
  if (A=22101       && B= 8346      ) COMCNT=0
  if (A= 8346       && B=10804      ) COMCNT=0
  if (A= 8356,10791 && B=10791, 8356) COMCNT=0
  if (A=11446,11447 && B=11446,11447) COMCNT=0
  if (A=11427,11428 && B=11427,11428) COMCNT=0
  if (A=37763,37764 && B=37763,37764) COMCNT=0
  if (A=11883,37870 && B=11883,37870) COMCNT=0
  if (A=37765,37871 && B=37765,37871) COMCNT=0
  if (A=11843,11854 && B=11843,11854) COMCNT=0
  if (A= 9652, 9660 && B= 9652, 9660) COMCNT=0
  if (A= 6189, 9652 && B= 6189, 9652) COMCNT=0
  if (A= 6277,27458 && B= 6277,27458) COMCNT=0
  if (A= 6326, 6328 && B= 6326, 6328) COMCNT=0
  if (A= 3362, 9237 && B= 3362, 9237) COMCNT=0

endrun

;---------------------------------------------------------------------
run pgm=hwynet

  id = "Screen truck counts

  neti = temp.net
  neto = comvol.net

; Delete bogus Heavy and Medium Truck counts, based on manual review.
  _bad = 0
  if (A=44223,44224 && B=44223,44224) _bad = 1
  if (A=11902,11912 && B=11902,11912) _bad = 3
  if (A=57614,57615 && B=57614,57615) _bad = 3
  if (A=57952,57953 && B=57952,57953) _bad = 3
  if (A=57378,57379 && B=57378,57379) _bad = 3
  if (A=11695,29221 && B=11695,29221) _bad = 3
  if (A=11677,29219 && B=11677,29219) _bad = 3
  if (A= 3332, 3333 && B= 3332, 3333) _bad = 3
  if (A= 2750       && B= 2751      ) _bad = 1
  if (A= 3236       && B=17886      ) _bad = 1
  if (A=11468,11484 && B=11468,11484) _bad = 1
  if (A=11510,11517 && B=11510,11517) _bad = 1
  if (A= 5537,31666 && B= 5537,31666) _bad = 1
  if (A= 8407,31666 && B= 8407,31666) _bad = 2

  if (_bad = 1) MEDTRK = 0
  if (_bad = 2) HVYTRK = 0
  if (_bad = 3)
    MEDTRK = 0
    HVYTRK = 0
  endif

; Delete tiny counts that are NOT on an external station.
  if (A > 2118 && B > 2118)
    if (MEDTRK < 10) MEDTRK = 0
    if (HVYTRK < 10) HVYTRK = 0
  endif

; Re-balance some counts that were way out of balance.  If
;  summed volume would be odd, make it even.
```

```
  if (A= 6573, 6589 && B= 6590, 6591) MEDTRK = (1494+3226)/2

  if (A= 2938, 2722 && B= 2939, 2723) MEDTRK = (1391+2063)/2
  if (A=40892,40540 && B=40541,40539) MEDTRK = ( 598+ 828)/2
  if (A= 3679, 3658 && B= 3981, 3680) MEDTRK = (1379+2113)/2
  if (A= 9334, 7026 && B= 7015, 9333) MEDTRK = ( 806+1190)/2

  if (A= 7470, 7471 && B= 7470, 7471) HVYTRK = ( 131+ 227)/2
  if (A= 2938, 2722 && B= 2939, 2723) HVYTRK = ( 826+1478)/2
  if (A= 7031, 9468 && B= 9470, 7030) HVYTRK = (1095+1391)/2

endrun
*del temp.net
```

APPENDIX B– Processing of Vehicle Classification Data

Memorandum

TO: ARC Model Support Project Files

FROM: Florence Ngai, PB
Jun Yao, PB

DATE: January 15, 2006

RE: ARC Truck Count Data Collection and Processing

In the effort to support the development of the new ARC commercial vehicle/truck model, vehicle classification count data was collected and processed. This memorandum describes (1) the collected data, (2) the data processing, and (3) the data delivery.

2.1.4.1 Vehicle Classification

The current ARC commercial vehicle model uses gross weight to categorize commercial vehicles into light-duty, medium-duty, and heavy-duty vehicles/trucks. Any commercial vehicles less than 8,000 lb are considered light-duty. These light-duty vehicles/trucks can include passenger vehicles, 2-axle 4-tire single unit trucks (e.g. pickup truck), and 2-axle 6-tire single unit trucks.

The new ARC commercial vehicle/truck model will reclassify commercial vehicles/trucks according to the FHWA 13 vehicle classes, as shown in the following table.

FHWA Vehicle Class		light-duty	Medium-duty	Medium heavy-duty	Heavy-duty
1	motor cycle	--			
2	passenger car	x			
3	2-axle 4-tire single unit (including pickup trucks)	x			
4	buses		x		
5	2-axle 6-tire single unit		x		
6	3-axle single unit			x	
7	4-axle single unit			x	
8	3/4-axle trailer				x
9	5-axle trailer				x
10	6-axle trailer				x
11	5-axle multi trailer				x
12	6-axle multi-trailer				x
13	7-axle multi-trailer				x

2.1.4.1 Vehicle Classification Count Database

Five years of permanent counts (ATR) data (2000, 2002-2005) and 3 years of portable counts data (2002-2004) by hour of day were obtained from the Office of Transportation Data, GDOT in Microsoft Access file format. The database covers the entire State of Georgia. Records with count data collected within the ARC 20 counties were extracted from the statewide database. Disregarding some ATR data were collected at the same count stations, the database provides a total of 736 count data (224 ATR count data and 206 portable count data). 262 unique count stations were identified. The following table summarizes the numbers of count stations by county by year.

# of Stations		**Permanent**					**Portable**		
cty_name	CTY	2000	2002	2003	2004	2005	2002	2003	2004
Barrow	013			1	1	1	1	4	
Bartow	015			2	3	3		4	
Carroll	045						2	5	8
Cherokee	057			1	1	1		3	
Clayton	063	2	2	4	8	9	3	4	
Cobb	067		1	5	7	6	3	9	
Coweta	077						2	6	5
Dekalb	089		2	8	17	15	2	12	
Douglas	097			1	2	2		2	
Fayetta	113		1	2	2	2	1	5	1
Foryth	117			2	2	2	1	3	
Fulton	121	2	4	12	25	21	3	20	32
Gwinnett	135		2	3	5	3	4	9	
Hall	139			3	4	4	1	7	9
Henry	151		1	2	1			5	5
Newton	217			1	1	1	1	4	
Paulding	223						1	3	
Rockdale	247						1	3	2
Spalding	255				1	1	1	5	
Walton	297			2	4	3		4	
	Total	**4**	**13**	**49**	**84**	**74**	**27**	**117**	**62**
		Total 91 Unique Permanent count locations							

Total # of unique locations 262

The GDOT vehicle classification count data system contains the following 15 classes. (Note that Vehicle Classes 14 and 15 are not included in the FHWA 13 vehicle types).

Vehicle Class 1.	Motor-cycle
Vehicle Class 2.	Passenger car
Vehicle Class 3.	Pick up truck (including 2-axle 4-tire single unit truck)
Vehicle Class 4.	Bus
Vehicle Class 5.	2-axle dual-tire single unit truck
Vehicle Class 6.	3-axle single unit truck
Vehicle Class 7.	4-axle single unit truck
Vehicle Class 8.	3- or 4-axle single trailer combination
Vehicle Class 9.	5-axle single trailer combination
Vehicle Class 10.	6-axle single trailer combination
Vehicle Class 11.	5-axle multi-trailer combination
Vehicle Class 12.	6-axle multi-trailer combination
Vehicle Class 13.	7-axle multi-trailer combination
Vehicle Class 14.	Other combinations
Vehicle Class 15.	Pulpwood

As shown in the following table, each count station is identified by a county code number and TC number (CTY+TC). Each data entry includes the information of direction of travel, day of week, and hour of day.

Field Name	Data Type
County Name	Text
County Code	Text
TCNumber	Text
Route Type Name	Text
Route Type	Number
Month Name	Text
Month Of Data	Number
DayOfWeek	Text
Day Of Week	Number
Day Of Month	Number
Travel Driection Name	Text
Direction Of Travel	Number
Hour OF Day	Number
Date Collected	Date/Time
FCType	Text
FC Desc	Text
Functional Class	Number
Motorcycles	Number
Passenger Cars	Number
Pick Up Trucks	Number
Buses	Number
2 Axle Trucks	Number
3 Axle Trucks	Number
4 Axle Trucks	Number
3/4 Axle Trailer Trucks	Number
5 Axle Trailer Trucks	Number
6 Axle Trailer Trucks	Number
5 Axle Multi Trailer Trucks	Number
6 Axle Multi Trailer Trucks	Number
7 Axle Multi Trailer Trucks	Number
Other Multi Trailer Trucks	Number
Pulpwood Trucks	Number

Weekday traffic data by vehicle type, direction, time of day was extracted and summarized according to the following classification scheme.

Motorcycles (MC)	**Category 1**
Passenger Cars (PC)	
Pick Up Trucks (Pickup)	
Buses	**Category 2**
2 Axle Trucks (SU2)	**Category 3**
3 Axle Trucks (SU3)	**Medium Duty Trucks (MDT)**
4 Axle Trucks (SU4)	
¾ Axle Trailer Trucks (ST34)	**Heavy Duty Trucks (HDT)**
5 Axle Trailer Trucks (ST5)	
6 Axle Trailer Trucks (ST6)	
5 Axle Multi Trailer Trucks (MT5)	
6 Axle Multi Trailer Trucks (MT6)	

7 Axle Multi Trailer Trucks (MT7)	

2.1.4.1 Data Processing

Data Aggregation

The extracted database was maintained in Access. A series of SQL queries was performed to aggregate data (by "station + hour ending + direction"). For each count station, the data collected from Monday to Thursday was summarized by Hour Ending by Direction by 5 Vehicle Classes. For those stations that have multiple entries (or days of records), the average volumes were calculated. In general, the ATR data has about 100-200 entries for a specific "station + hour ending + direction". The portable data has about 1-2 entries for a specific "station + hour ending + direction". The following table is a typical summary table for a station.

	North					South				
HOUR	PV	CV	LDT	MDT	HDT	PV	CV	LDT	MDT	HDT
1	313	44	4	1	14	648	77	5	3	7
2	191	31	3	2	11	398	50	4	3	7
3	152	25	3	2	11	249	32	3	2	8
4	184	36	4	2	13	188	28	3	2	8
5	320	73	7	3	17	171	26	5	2	9
6	927	226	21	5	27	219	36	8	2	11
7	1916	426	42	9	38	456	108	18	5	16
8	2422	447	53	15	42	834	193	34	11	21
9	2157	376	49	15	41	1002	221	39	17	24
10	1718	332	47	14	48	982	225	41	18	27
11	1513	305	44	14	46	1069	248	41	17	31
12	1451	295	43	13	44	1232	274	42	16	34
13	1528	302	42	13	41	1449	302	43	16	34
14	1584	304	43	14	39	1594	326	43	17	33
15	1643	307	44	14	35	1766	364	46	16	33
16	1585	287	43	12	36	2090	436	52	17	30
17	1520	260	37	9	29	2414	465	53	15	25
18	1509	244	30	6	26	2670	443	45	12	21
19	1451	233	28	4	22	2475	379	40	11	18
20	1283	220	27	3	23	2021	317	35	10	16
21	1042	185	22	3	23	1656	256	27	8	13
22	873	144	15	3	24	1466	201	19	6	11
23	769	114	10	2	20	1174	149	12	6	9
24	531	71	7	2	17	920	112	9	5	9

2.1.4.1 Data quality screening

The data that GDOT provided is raw data; thus, a screening process was developed and implemented to ensure the quality of data. The objective of the screening process is to identity outliners (or abnormalities). A technique called Box Plot was used.

A box plot uses the median, and the lower and upper quartiles (defined as the 25th and 75th percentiles). In this discussion, the lower quartile is referred to as Q1 and the upper quartile is referred to as Q2. The difference (Q2 - Q1) is called the inter-quartile range or IQ. A box plot is constructed by drawing a box between the upper and lower quartiles with a solid line drawn across the box for the median. Fences (or whiskers) were calculated for identifying outliners.

1. lower inner fence: Q1 - 1.5*IQ
2. upper inner fence: Q2 + 1.5*IQ
3. lower outer fence: Q1 - 3*IQ
4. upper outer fence: Q2 + 3*IQ

A point beyond an inner fence on either side is considered a mild outlier. A point beyond an outer fence is considered an extreme outlier. The multipliers of 1.5 and 3.0 to IQ are typical factors used to define the maximum distances from the lower and upper quartiles.

This technique was only applied to assess the ATR data. In addition, some extreme values were observed while aggregating data and they include 99 for Pulp, 999 for MC, and less than 10 for PC in the peak hour. The Box Plot technique was able to identify these extreme values as outliners, in addition to other outliners. A total of 15 box plots (one for each vehicle class) were drawn for each hour of the entry. An entry was removed from the database if an outliner was identified.

The Box Plot technique cannot be applied to the portable station data because generally only 1 to 2 entries are available for a station. The data for each station was visually checked for any abnormalities. The original dataset would be examined for reasons of abnormalities, which would then be used to determine whether the entry should be removed from the database.

2.1.4.1 Data Delivery

The final traffic volumes, aggregated by 5 vehicle classes by direction, were geo-coded to the ARC 20-county highway network provided by PBS&J. Only data of the latest available year was geo-coded. Several stations could not be located. The following table summarizes the geo-coding effort. Traffic data of 227 stations were successfully geo-coded.

Status	**# Stations Not Found In Network**		**# Stations Found In Network**		**Grand Total**
	Portable	**ATR**	**Portable**	**ATR**	
Geo-coded	6	1	148	72	227
Can't be geo-coded	16	5			21
Direction error	6	10			16
Grand Total	28	16	148	72	264

Note: The Projected Coordinate System for the ARC highway network: NAD_1983_StatePlane_Georgia_West_FIPS_1002_Feet

Once the data was geo-coded, a highway map was plotted with volumes and percent share of vehicle class. These numbers were visually checked against nearby stations for consistency. Unexplainable inconsistent data was removed from the network.

APPENDIX C – Recoding of Transit Bus Stops

MEMO

To: Patti Schropp, Chris Simons
From: Jeff Bruggeman
Date: October 18, 2005
Subject: Recoding of ARC Model Bus Stops

As you know, I pulled together a revised version of bus stopping patterns for the 2000 ARC network back at the end of August. This was as a somewhat exploratory activity. Since then, I have tried to develop a more rigorous and highly automated process which is presented in this memo. The resulting process has been re-applied to the 2000 network as well as to the 2030 "baseline" network you provided. The resulting 2000 network is slightly different from that produced earlier, but probably would not have a huge impact on model calibration. If a situation presents itself to do an update, it might be worth doing just for consistency.

The process proceeds in several steps, again making things as automated as I can. The process includes three fairly simply stand-alone Fortran programs, plus a simple TP+ script to dump highway link and node files at the outset and an optional manual intervention in between the steps to override "decisions" based on a review of network geometry. The steps are as follows:

1) Extracted ACSII link and node files

In the prior version, I did a quick conversion to Tranplan and dumped the ASCII files using Tranplan utilities. I also use the "assignment group" field to separate limited access facilities from local streets. Following a discussion with Chris, I revised the procedure to dump the ASCII file directly from a simple TP+ script and to use the "facility type" field as a more accurate determinant of limited access facilities. The latter resulted in a few changes in the listing of "eligible" nodes as the "assignment group" coding is apparently not being maintained and a few errors exist. The simple script, HDUMP.S, is invoked by me in a one-line batch file, HDUMP.BAT. You may well have a procedure already that does something similar or a better way to invoke your TP+ scripts.

2) Common file names

A simple ASCII file, STOPS2.CTL, was created to contain all of the input and output file names used by the various special-purpose programs. The file includes a "token" in columns 1-20 which is read by each program and identified with the specific files. The actual file names used are included in columns 21-60. At this point, they are common for the 2000 and 2030 runs, which would be done in different directories, except for the input and output network file names.

3) Input networks

At Chris's suggestion, I have limited the analysis to the "second" of the two files that are created for each alternative and assumed that the "first" file, that contains MARTA lines and other "premium" transit services, has been coded correctly. In the 2030 network, I found one small apparent typo in the coded network which prevented my being able to parse the text. I have included the corrected file (in a modified name) in the materials I am transmitting.

4) Scanning process

The first of the special-purpose programs, SCAN2, was written to convert the network files into a format which could be easily processed and to examine the patterns of stop nodes and non-stop nodes on a route-by-route basis. The program first reads the input network and does a quick conversion to a similar NAMELIST format to make further processing somewhat easier. In order to do this, it notes some special coding in the network. The original version of the program simply deleted this coding and required the user to manually re-insert it at the end of the process. This version attempts to automate this process, but it is designed strictly for special coding that appears in the networks reviewed to date and will almost surely "die" if other special coding is used. The first of the special coding, the use of an "OWNER" field in two routes, could probably have been treated as an alternate header variable. The second coding, using the "ACCESS" feature to control board-only and alight-only nodes, was noted only in the 2000 network (so far) and was much more difficult to process and is subject to "blowing up" if a different logic is applied in future networks.

After noting the special codes on a data set and the route file in a NAMELIST format, the program re-reads the line file and writes it out again in a simplified ACSII format to make further processing simpler. The program then processes each route and checks each node to identify whether three or more transit "legs" exist at that node, indicating the potential for a transfer to occur at that location. The program also checks against an assumed approximate boundary of the CBD from coordinate geometry and produces a summary file (TROUTE2.SUM) which is currently not used in further processing.

Next, the program examines the highway network file to flag any node which serves as a centroid connector in the highway network. Since the access control logic used in the ARC model builds over the highway centroid connectors, they are very important part of the modeling system. Unless some special situation exists, it is assumed that any local bus which passes a centroid connector should probably stop there. At the same point in the logic, the program scans for nodes which fall on freeways, ramps, or other limited access facilities. In this case, it is assumed that, barring a special situation, buses do not normally stop along these facilities or at most ramp junctions with local streets, as such locations are typically an unsafe location for a bus stop, with autos weaving through the interchanges and other challenging geometric constraints.

The program produces special files for the ramp nodes, the centroid nodes, and a data set which flags each stop based on whether or not three or more "legs" are connected.

5) Line comparisons

A second simpler special-purpose program, "HITS2", is run immediately after the scanning program. It reads the ASCII version of the line file produced by the SCAN2 program together with the centroids, ramps, and legs files also produced by that program. The program then creates a series of "hits" (stop nodess) and "misses" (non-stop nodes) for the system as a whole. A couple of summary report files are produced which are not used directly in the third stage, but may be examined for confirmation as to what has been coded in the network. The most useful of these files, "NODE2.PRN", produces a summary to the route numbers with "hits" and the route numbers with "misses", for every node in the network which has both "hits" and "misses",.

The program also reads in a file which contains prior assessments of whether individual nodes should be flagged for consistent stopping or not stopping. This file is denoted at the moment as "NODE2.Y00" for the year 2000 network and would normally be blank for an initial year 2000 application but based on the 2000 results and used as a "seed" for a future year network. The file, when completed, includes a "use as a stop node" flag of "2" in column 1 and a "use as a non stop node" flag of "1" in column 1, followed by the node umber in columns 2-9. The remaining columns in the file include the flag value from the previous application and the status of the "legs" and "ramp" flags. A fragment of the file is shown below:

```
 Mixed:
Def  Node     Y00     Leg    Ramp


2    2505       0       2       0
2    2527       0       2       0
2    2539       0       2       0
2    2545       0       2       0
1    2547       0       1       0
2    2550       0       2       0
1    2554       0       1       0
2    2556       0       2       0
2    2558       0       2       0
1    2572       0       1       0
1    2573       0       1       1
2    2576       0       2       0
1    2585       0       1       0
2    2586       0       2       0
```

For all nodes where both stops and non-stops occur, a record is produced in the file. At the current point, a "default" estimate is made based on the prior year file (if available), the centroid connector flag, the ramp flag, and the number of legs flag. If the centroid is used, the node is given the "all stop" code of "2". If a ramp is involved, the node is given the "no stop" code of "1". If three or more legs are present, the node is given the "all stop" code.

6) Manual review

A manual procedure was used to review the codes of interest in the 2000 networks and subsequently in the 2030 network. The defaults were generally accepted with three exceptions:

- If the node served as the exit from a “driveway” at a MARTA station, it was recoded as a non-stop node since it is highly unlikely that buses would stop at this location for safety and operational reasons
- If a node that only had two legs, such as “shape point” on a route that had other nearby stops, it was usually left as a “non-stop” code. However, if the node could serve as access from a centroid that may have been otherwise not well served by the route or other surrounding routes, then an “all-stop” code would have been substituted. This is the most arbitrary part of the process.
- Occasionally, a “non-stop” node was converted to a stop node if some other unusual situation occurred, such as a location with only two legs but served as the starting or ending point for one or more of the routes.

Procedurally, the “NODE2.TXT” file produced from the previous program was copied into a new name, “NODE2.LST” and this file was edited using the manual process. It should be noted that any node which had been consistently coded with all routes serving it either stopping or not-stopping, no changes were made.

7) Recoding of route files

The third and final special purpose program, “RESTOP2”, is run after the manual intervention. Of course, as a default mode of operation, the manual intervention could be ignored and the “rules” in the previous programs assumed to produce a reliable set of stops.

As discussed earlier, the program produces two sets of revised line files. The first set limits the creation of stop nodes to the resolution of the conflicts noted above. The second set assumes that all stops are stop nodes unless specifically “turned off” by the process above. It is understood that the first set is being used at this point.

In addition to applying the stop and non-stop rules, the bulk of the third program is consumed by re-insertion of the special codes found in the original network for the “OWNER” flag and far more importantly the “ACCESS” codes. As noted above, an attempt has been made to automate this process, but no warranties are implied or given.