Appendix A

Regional travel forecasting models:
A survey of the modeling practice at
11 medium-sized Metropolitan Planning Organizations
in the U.S.

Findings as of October 20, 2003

Regional travel forecasting models: A survey of the modeling practice at 11 medium-sized Metropolitan Planning Organizations in the U.S.

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A technical working paper

National Capital Region Transportation Planning Board

Metropolitan Washington Council of Governments

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Executive summary

The Transportation Research Board (TRB) is currently in the process of reviewing the regional travel forecasting model used by the National Capital Region Transportation Planning Board (TPB). The TPB serves as the metropolitan planning organization (MPO) for the Washington, D.C. area. Under the guidelines of the proposed review, which was requested in a May 8, 2002 letter from the TPB to the TRB, the TRB would deliver two reports. The first report, which was delivered on September 8, 2003, was a review of the current TPB travel model and emissions postprocessor model. The second report, which is due in early 2004, will provide guidance on the TPB's proposed direction of future travel demand model upgrades and on travel surveys and other data needed to accomplish future model upgrades. In the first of the two reports, the TRB Committee stated that "there are few universally accepted guidelines or standards of practice for these models or their application" (TRB letter report 1 of 2, 2003, p. 2) and that it was not within the scope of the TRB study "to conduct a thorough review of practices of MPOs around the country" (ibid, p. 8). In the absence of such a benchmark, the TRB Committee stated that it had to rely "primarily on members' experience and judgment" (ibid, p. 8).

Given this lack of an agreed-upon state of the practice, the goal of the work described in this paper was to help define the state of the practice in regional travel forecasting models. To do this, TPB staff attempted to survey the travel modeling practice at a series of medium-sized MPOs that were of comparable size to the TPB. In its first of two reports, the TRB Committee suggested six urban areas that could serve as members of a peer group of MPOs for the TPB: Boston, Chicago, Dallas/Fort Worth, Miami, Philadelphia, and Phoenix (TRB letter report 1 of 2, 2003, p. 7). TPB staff has added five additional areas to the list of potential peer MPOs for the Washington area, based on the criterion of being similar in size to the Washington, D.C. area: Detroit, Houston, Atlanta, San Francisco, and Seattle. These 11 proposed peer MPOs are shown in Table 1.

Table 1 Eleven proposed peer MPOs for MWCOG

	City	MPO
1	Atlanta, GA	Atlanta Regional Commission (ARC)
2	Boston, MA	Boston MPO, Central Transportation Planning Staff (CTPS)
3	Chicago, IL	Chicago Area Transportation Study (CATS)
4	Dallas/Fort Worth, TX	North Central Texas Council of Governments (NCTCOG)
5	Detroit, MI	Southeast Michigan Council of Governments (SEMCOG)
6	Houston, TX	Houston-Galveston Area Council (H-GAC)
7	Miami, FL	Miami-Dade Metropolitan Planning Organization
8	Philadelphia, PA	Delaware Valley Regional Planning Commission (DVRPC)
9	Phoenix, AZ	Maricopa Association of Governments (MAG)
10	San Francisco	Metropolitan Transportation Commission (MTC)
11	Seattle, WA	Puget Sound Regional Council (PSRC)

The survey conducted by TPB staff involved collecting information about ten key areas of modeling practice, defined below. The focus of this survey was the current, production-use travel demand model used at each MPO, not a model that is under development. The survey was based on only published, off-the-shelf models documentation. In some cases, the documentation was available on the MPO's Web site for free, as is the case with TPB's model documentation.

In other cases, TPB staff had to make a special request and/or purchase the documentation. To date, TPB staff has obtained model documentation from nine of the 11 MPOs (all but Boston and Miami). A staff member from the Boston MPO indicated that there is currently no off-the-shelf documentation on the travel model, only internal technical memos. The Miami-Dade MPO has yet to respond to a TPB staff request for documentation. Below is a summary of the key findings for each of the major topics in the survey.

Size of modeled area versus nonattainment area: Although the TPB modeled area is much larger than its nonattainment area (22 jurisdictions versus 12 jurisdictions), most MPOs have a modeled area that is roughly equal to their air quality nonattainment or maintenance area. Of the nine peer MPOs, six have modeled areas that are roughly or exactly the same size as their air quality nonattainment or maintenance area (ARC, CATS, NCTCOG, SEMCOG, H-GAC, MTC). One (DVRPC) has a modeled area that is smaller than its nonattainment area. One (PSRC) had a modeled area bigger than its maintenance area. And for one MPO (MAG), the size of the modeled area could not be determined (the nonattainment area is one county).

Trip purposes for passenger and commercial travel: The TPB travel model uses four trip purposes for resident, passenger travel (home-based work, home-based shop, home-based other, and non-home based) and two trip purposes for commercial travel (medium truck and heavy truck). As for passenger travel, each of the nine peer MPOs used more trip purposes than TPB, with the exception of DVRPC, which uses three. Typically, six or seven passenger trip purposes are used. Some MPOs used a large number of trip purposes initially, say in trip generation, which is then collapsed later in the process. For example, CATS uses 11 passenger trip purposes in trip generation, but collapses the number down to three for trip distribution and mode choice. As for commercial travel, we have information from eight MPOs (no information for ARC). Only three of the eight MPOs have a more detailed representation of commercial travel than is used in the TPB model (CATS uses four commercial trip categories, DVRPC uses five, and MAG uses three). We have found three examples of MPOs modeling light-duty trucks as a separate trip purpose: CATS, Baltimore, and MAG.

Trip generation: Special generators and adjustment factors: Special generators are zones that have unique trip generation characteristics where the standard regional production and/or attraction model does a poor job of replicating the observed travel to and from these zones. Examples of such special generators are commercial airports, military bases, universities, and, possibly, regional shopping centers. There are two general approaches to modeling special generator zones. First, one can create explicit "special generator" models for one or more zones. Second, one can use production modification factors ("p-mods") and/or attraction modification factors ("a-mods") to account for this special trip generation. The TPB travel model (Version 2.1C) makes use of p-mods and a-mods, but does not use explicit special generator models. TPB staff was able to obtain information about special generator models for five peer MPOs. All five of these MPOs use special generator models in one form or another. For six of the nine peer MPOs, it could not be determined whether p-mods and a-mods were used. Of the remaining three MPOs, two use p-mods and a-mods (ARC and MTC) and one does not (CATS).

Trip distribution: Income stratification and K-factors: The TPB Version 2.1C trip distribution model is a gravity model that uses income stratification for the three home-based trip purposes (HBW, HBS, and HBO by four income quartiles) and a series of K-factors. All of the peer MPOs use gravity model trip distribution models, with the exception of CATS, which uses an intervening opportunities model. Three MPOs use income-stratified trip distribution (ARC, NCTCOG, and MTC – the latter two for HBW only). Four MPOs do not use income-stratified trip distribution (SEMCOG, H-GAC, DVRPC, and PSRC). It was not apparent from available documentation whether MAG uses income stratification or not. Of the nine peer MPOs, five use K-factors (NCTCOG, SEMCOG, H-GAC, MTC, PRTC) and two use adjustments that are analogous to K-factors (CATS and DVRPC). Only two MPOs (ARC and MAG) state that they do not use K-factors or other similar adjustments, such as jurisdiction-level time penalties.

Mode choice: Use of jurisdiction-level adjustment factors: The mode choice model for the Version 2.1C model is a sequential multinomial logit (S-MNL) model. There is a separate model for each of the four passenger trip purposes. The model was estimated using disaggregate, household-level data, but is applied at the aggregate zone-to-zone trip interchange level. The model also uses jurisdiction-level post mode choice model adjustment factors to ensure that the disaggregately estimated models can replicate observed mode choice behavior at the aggregate level. With the exception of DVRPC, none of the nine peer MPOs mention using such post-mode choice factors in their documentation. This could mean that either such factors are not used, or they are used but not documented. As of 1997, the date of the most recent models documentation we have for the agency, SEMCOG did not model its transit network, so it did not perform mode choice in the typical fashion. Instead, it used a series of county-to-county transit mode split factors.

Changing bus speeds as a function of link congestion: In the TPB Version 2.1C travel model, bus speeds in the transit network are determined by the published bus schedules, which, in the near term, take into account congestion of the roads over which the route travels, stop spacing, and other similar issues. However, there is no direct feedback mechanism between increasing congestion on highway links and bus speeds for future years. Based on the documentation we have obtained for nine MPOs, two (CATS and MTC) do not mention whether they change bus speeds with link congestion; two (DVRPC and SEMCOG) do not change bus speeds with link congestion; and five (ARC, NCTCOG, H-GAC, MAG, and PSRC) do change bus speeds with link congestion.

Validation results: Transit estimates: The TPB Version 2.1C model was validated for both 1994 and 2000. At the regional level, the ratio of estimated transit trips to observed transit trips was 1.03 for 1994 and 0.95 for 2000. Based on the available documentation from the nine peer MPOs, five did not provide the information necessary to compute this metric: CATS, NCTCOG, SEMCOG, H-GAC, and MAG. Atlanta had an estimated-to-observed transit ratio of 0.92 for 2000. MTC had an estimated-to-observed transit ratio, for HBW trips, of 1.08. PSRC had an estimated-to-observed transit ratio of 0.91 using a 1998 estimate and 1999 observed data. DVRPC had an estimated-to-observed transit ratio for 1990 of 0.93 before recalibration and 1.01 after recalibration of the mode choice model.

Speed feedback into mode choice model: The TPB Version 2.1C travel model ensures travel time consistency between model steps by including a speed feedback process, where speeds from traffic assignment are fed back into trip distribution. The feedback process includes four iterations, which are called "pump prime," "base," "first," and "second." Each iteration includes running the trip distribution step and the traffic assignment step. The full mode choice model is executed in only one of the four iterations: the base iteration. We can assume that any of the peer MPOs that are nonattainment areas use some form of speed feedback. However, using the available documentation, it was hard to determine which MPOs included mode choice in each iteration. Four of the eight MPOs – DVRPC, MAG, MTC, and PSRC - appear to run the mode choice model during each iteration of speed feedback, but further follow up is needed to confirm the details of the speed feedback methodologies used by the MPOs. The TPB model documentation was the only one with a detailed description of how it performs speed feedback.

Validation results: Highway assignment: One goodness-of-fit measure for the traffic assignment step is the regional percent root mean squared error (%RMSE) between the estimated and observed link volumes. For the Version 2.1C TPB travel model, the regional %RMSE for traffic assignment was about 55% for the 1994 base year and 52% for the 2000 validation year. Only three of the nine peer MPOs (ARC, DVRPC, and MAG) reported the %RMSE for regional highway assignment of volumes in their documentation. ARC reported a %RMSE of 50% for 1995 and 47% for 2000. DVRPC reported a %RMSE of 39% for a 1990 simulation using its "existing" travel model. MAG reports a regional %RMSE of 37% in its conformity documentation for a validation year of 1998.

Introduction

The Transportation Research Board (TRB) is currently in the process of reviewing the regional travel forecasting model used by the National Capital Region Transportation Planning Board (TPB). The TPB serves as the metropolitan planning organization (MPO) for the Washington, D.C. area. Under the guidelines of the proposed review, which was requested in a May 8, 2002 letter from the TPB to the TRB, the TRB would deliver two reports. The first report, which was delivered on September 8, 2003, was a review of the current TPB travel model and emissions postprocessor model. The second report, which is due in early 2004, will provide guidance on the TPB's proposed direction of future travel demand model upgrades and on travel surveys and other data needed to accomplish future model upgrades. In the first of the two reports, the TRB Committee stated that "there are few universally accepted guidelines or standards of practice for these models or their application" (TRB letter report 1 of 2, 2003, p. 2) and that it was not within the scope of the TRB study "to conduct a thorough review of practices of MPOs around the country" (ibid, p. 8). In the absence of such a benchmark, the TRB Committee stated that it had to rely "primarily on members' experience and judgment" (ibid, p. 8).

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TPB staff surveyed each of the 11 proposed peer MPOs to find out similarities and differences in modeling practice. The focus of this survey is the current, production-use travel demand model, not a model that is under development. The first step was to visit the Web site of each MPO and obtain any relevant documentation on the travel models. For those MPOs where models documentation could not be found on the Web site, TPB staff contacted either the library or a travel demand modeler to ask for current documentation. To date, TPB staff has obtained models documentation, in one form or another, from nine of the 11 MPOs. Below is a summary of the findings to date.

Table 2 Eleven proposed peer MPOs for TPB, shown in the context of the 25 largest urbanized areas in the U.S., based on total population in 2000

Rank	State	Urbanized Area	Population	Density
1	NY	New York--Newark, NY--NJ--CT	17,799,861	5,309
2	CA	Los Angeles--Long Beach--Santa Ana, CA	11,789,487	7,068
3	**IL**	**Chicago, IL--IN**	**8,307,904**	**3,914**
4	**PA**	**Philadelphia, PA--NJ--DE--MD**	**5,149,079**	**2,861**
5	**FL**	**Miami, FL**	**4,919,036**	**4,407**
6	**TX**	**Dallas--Fort Worth--Arlington, TX**	**4,145,659**	**2,946**
7	**MA**	**Boston, MA--NH--RI**	**4,032,484**	**2,323**
8	**DC**	**Washington, DC--VA--MD**	**3,933,920**	**3,401**
9	**MI**	**Detroit, MI**	**3,903,377**	**3,094**
10	**TX**	**Houston, TX**	**3,822,509**	**2,951**
11	**GA**	**Atlanta, GA**	**3,499,840**	**1,783**
12	**CA**	**San Francisco--Oakland, CA**	**3,228,605**	**6,130**
13	**AZ**	**Phoenix--Mesa, AZ**	**2,907,049**	**3,638**
14	**WA**	**Seattle, WA**	**2,712,205**	**2,844**
15	CA	San Diego, CA	2,674,436	3,419
16	MN	Minneapolis--St. Paul, MN	2,388,593	2,671
17	MO	St. Louis, MO--IL	2,077,662	2,506
18	MD	Baltimore, MD	2,076,354	3,041
19	FL	Tampa--St. Petersburg, FL	2,062,339	2,571
20	CO	Denver--Aurora, CO	1,984,889	3,979
21	OH	Cleveland, OH	1,786,647	2,761
22	PA	Pittsburgh, PA	1,753,136	2,057
23	OR	Portland, OR--WA	1,583,138	3,340
24	CA	San Jose, CA	1,538,312	5,914
25	CA	Riverside--San Bernardino, CA	1,506,816	3,434

Source: Federal Transit Administration (http://www.fta.dot.gov/library/planning/census/uza.html).

Table 3 Eleven proposed peer MPOs for MWCOG

	City	MPO	Web Site
1	Atlanta, GA	Atlanta Regional Commission (ARC)	http://www.atlantaregional.com/
2	Boston, MA	Boston MPO, Central Transportation Planning Staff (CTPS)	http://www.ctps.org/bostonmpo/
3	Chicago, IL	Chicago Area Transportation Study (CATS)	http://www.catsmpo.com/
4	Dallas/Fort Worth, TX	North Central Texas Council of Governments (NCTCOG)	http://www.nctcog.dst.tx.us/
5	Detroit, MI	Southeast Michigan Council of Governments (SEMCOG)	http://www.semcog.org/
6	Houston, TX	Houston-Galveston Area Council (H-GAC)	http://www.h-gac.com/
7	Miami, FL	Miami-Dade Metropolitan Planning Organization	http://www.co.miami-dade.fl.us/mpo/
8	Philadelphia, PA	Delaware Valley Regional Planning Commission (DVRPC)	http://www.dvrpc.org/
9	Phoenix, AZ	Maricopa Association of Governments (MAG)	http://www.mag.maricopa.gov/
10	San Francisco	Metropolitan Transportation Commission (MTC)	http://www.mtc.ca.gov/
11	Seattle, WA	Puget Sound Regional Council (PSRC)	http://www.psrc.org/
	Washington, D.C.	Metropolitan Washington Council of Governments (MWCOG)	http://www.mwcog.org/home.asp

Modeling issues

Documentation

TPB staff provides documentation of its current travel model, Version 2.1C, on its Web site.[1] Of the 11 peer MPOs, seven provide models documentation on their Web sites. Of these seven, three had their models documentation in the form of a stand-alone models report (NCTCOG, MTC, and PSRC), and four had their models documentation in the form of an appendix to another document, such as a regional transportation plan or air quality conformity documentation (ARC, CATS, H-GAC, and MAG). Models documentation was obtained for two MPOs (SEMCOG and DVRPC) by contacting the agency and requesting it, since it was not available on their Web page. In the case of SEMCOG, its library mailed several documents to TPB staff for no charge. In the case of DVRPC, TPB staff had to pay about $170 for 11 documents. Despite e-mail requests, TPB staff has been unable to obtain models documentation from two MPOs - Miami-Dade and Boston - so they are, for the most part, excluded from the remaining discussion, reducing the set of peer MPOs from 11 to 9.

The PSRC models documentation refers to two model sets: the “current” model and the “new” model. The “current” model is the one that is used for current production work. The “new” model has not yet been adopted into practice (CSI 2001, Current Model Documentation, p. 1-4). DVRPC has both its “existing” travel forecasting model, which performs traffic assignments using a time period of an average day, and a new, “enhanced” model, that performs traffic assignments in three time-of-day periods. In most regional travel models, this time-of-day disaggregation occurs after the mode choice step, but, in the enhanced DVRPC model, it occurs in trip generation and continues through trip distribution, mode choice, and traffic assignment (DVRPC 2000, p. 79). It is not clear whether the current, production use model for DVRPC is the “existing” model or the “enhanced” model.

Size of modeled area versus nonattainment area

The TPB air quality nonattainment area includes 12 jurisdictions (ten counties and two cities - Washington, D.C. and Alexandria, Virginia), but the TPB modeled area covers 22 jurisdictions. Thus, the TPB modeled area is ten jurisdictions (one city and nine counties) larger than the nonattainment area. Eight of the 11 peer MPOs are nonattainment areas, and the remaining three are air quality maintenance areas (Detroit, Miami, and Seattle). Of the nine peer MPOs, six have modeled areas that are roughly or exactly the same size as their air quality nonattainment or maintenance area (ARC, CATS, NCTCOG, SEMCOG, H-GAC, MTC). One, DVRPC, has a modeled area that is <u>smaller</u> than its nonattainment area.[2] One, PSRC, had a modeled area bigger than its maintenance area. And for one MPO (MAG), the size of the modeled area could not be determined (the nonattainment area is one county). The MPO with the fewest transportation analysis zones (TAZ) is Seattle (850). The MPO with the most is Dallas (5,999).

The reason that TPB staff chose to have a modeled area significantly larger than the nonattainment area was to improve the quality of the traffic assignment in the nonattainment

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[1] (http://www.mwcog.org/transportation/committee/committee/documents.asp?COMMITTEE_ID=43)

[2] The complete ozone nonattainment area for the Philadelphia region encompasses the nine county DVRPC region, as well as Salem and Cumberland Counties, New Jersey; New Castle and Kent Counties, Delaware; and Cecil County, Maryland.

area, by moving the modeling "noise" beyond the nonattainment area. One of the drawbacks with the TPB approach, however, is that traffic assignment goodness-of-fit measures, such as the regional root mean square error (RMSE), will be worse, since they include many outer counties where zone sizes are large and the grain of the highway network is coarse. It is also more difficult to get and maintain modeling data from the more distant jurisdictions, which are not TPB member jurisdictions.

Trip purposes for passenger and commercial travel
The TPB travel model uses four trip purposes for resident, passenger travel (home-based work, home-based shop, home-based other, and non-home based) and two trip purposes for commercial travel (medium truck and heavy truck). The four passenger trip purposes are used for all four steps of the modeling chain. As for passenger travel, each of the nine peer MPOs used more trip purposes than TPB, with the exception of DVRPC, which uses three. Typically, six or seven passenger trip purposes are used. CATS uses 11 passenger trip purposes in trip generation, but collapses the number down to three for trip distribution and mode choice. ARC uses eight passenger trip purposes for trip generation, which get collapsed to six for trip distribution and mode choice.

As for commercial travel, we have information from eight MPOs (no information for ARC). Only three of the eight MPOs have a more detailed representation of commercial travel than is used in the TPB model (CATS uses four commercial trip categories, DVRPC uses five, and MAG uses three). We have found examples of three MPOs modeling light-duty trucks as a separate trip purpose: CATS, Baltimore, and MAG. CATS models four commercial trip purposes: B plate truck,[3] light truck, medium truck, and heavy truck (CATS 2003, pp. 18, 28). MAG uses three commercial vehicle trip purposes: light truck, medium truck, and heavy truck. Four of the MPOs - NCTCOG, H-GAC, MTC, and PSRC - use only one truck category. NCTCOG uses one "other" trip purpose to include internal-to-external trips, external-to-internal trips, through trips, truck trips, and taxi trips (NCTCOG 2003, p. 11). MTC uses only one commercial trip purpose, entitled, "commercial" (Purvis June 1997, p. 8). According to the latest documentation we could obtain, SEMCOG has no truck model, but uses a post-traffic assignment adjustment procedure to add in the effect of truck traffic (SEMCOG 1997, Background Paper No. 2, pp. 22-23). Baltimore, which is not one of the peer MPOs, has developed a light-duty commercial vehicle model using truck counts and synthetic trip tables (Allen 2002, Development of Commercial Vehicle Travel Model). DVRPC uses two categories of trucks, light and heavy, but it was not clear what definition was used for each category.

Trip generation: Special generators and adjustment factors
Special generators are zones that have unique trip generation characteristics, where the standard regional production and/or attraction model does a poor job of replicating the observed travel to and from these zones. Examples of special generators are commercial airports, military bases, universities, and, possibly, regional shopping centers. There are two general approaches to modeling special generator zones. First, one can create explicit "special generator" models for one or more zones. Second, one can use production modification factors ("p-mods") and/or attraction modification factors ("a-mods") to account for this special trip generation. The TPB travel model makes use of p-mods and a-mods, but does not use explicit special generator

[3] A B-Plate truck is a pickup truck registered for commercial use.

models. TPB staff was able to obtain information about special generator models for five peer MPOs. All five of these MPOs use special generator models in one form or another.

The TPB travel model, Version 2.1C, uses a series of post-trip generation p-mods and a-mods at the superdistrict level (36 superdistricts). These factors are used to ensure that estimated production and attractions match observed productions and attractions. These factors are needed because the trip production models are developed using disaggregate household-level data. In the Version 2.1C model, there is a set of adjustment factors for each of the four trip purposes (HBW, HBS, HBO, and NHB), stratified by superdistrict (36) and income quartile. For six of the nine peer MPOs, it could not be determined whether similar factors were used. Of the remaining three MPOs, two use p-mods and a-mods (ARC and MTC) and one does not (CATS). The values for the ARC p-mods and a-mods vary from 0.67 to 1.41 (ARC 2002, Section 5, Trip Generation, p. 5-34). MTC uses p-mods and a-mods at the district level (34 districts), by income quartile (Purvis May 8, 1996 memo, Tables A2 and A3). Chicago does not use p-mods and a-mods, but uses special generators instead (CATS 2003, p. 28). Dallas also uses special generators, but it is unclear whether Dallas uses p-mods and a-mods (NCTCOG 2000, pp. 13, 28, 32, 33, 35). PSRC, in its current travel model, uses four special generators: Seattle Center (a park containing various entertainment venues and the Space Needle), SeaTac Airport, King Dome, and Tacoma Dome (CSI, Urban Analytics 2001, Current Model Documentation, p. 7-9). No mention was found of p-mods or a-mods in the PSRC documentation.

Trip distribution: Income stratification and K-factors

The gravity model trip distribution technique is an adaptation of Newton's law of gravitational attraction and is the most common technique used to distribute trips in regional travel models. Other approaches include "intervening opportunities" and "destination choice" models. As applied in transportation planning, the gravity model theory states that the number of trips between two transportation analysis zones will be 1) directly proportional to the number of productions in the production zone and attractions in the attraction zone; and 2) inversely proportional to the spatial separation between the zones.

Every gravity model uses a series of friction factors and some also use a series of K-factors. A friction factor is actually a function – an inverse function of the impedance between two zones, where the impedance can be defined as the travel time, cost, distance, or some combination of these. K-factors are zone-to-zone or district-to-district adjustment factors that fine tune the model, so as to better fit observed trip patterns. K-factors are used in gravity models to account for various socio-economic phenomena that are not adequately captured in the gravity model formula. For example, a gravity model without K-factors would tend to send school trips to the nearest school, even though it is more likely that school trips would remain in the jurisdiction of residence. A K-factor greater than one will increase the number of trips in a zone-to-zone or district-to-district interchange. A K-factor less than one will decrease the number of trips in that interchange. K-factors neither increase nor decrease the total number of trips; they simply redistribute them from one interchange to another. Modelers generally try to strike a balance between a model with no K-factors that has a poor fit with observed data and a model with multitudes of K-factors that has a high degree of fit with observed data. Another way to help model performance is income-stratified trip distribution.

All of the peer MPOs use gravity model trip distribution models, with the exception of CATS, which uses an intervening opportunities model. Three MPOs use income-stratified trip distribution (ARC, NCTCOG, and MTC – the latter two for HBW only). Four MPOs do not use income-stratified trip distribution (SEMCOG, H-GAC, DVRPC, and PSRC). It was not apparent from available documentation whether MAG uses income stratification or not.

The TPB Version 2.1C trip distribution model is income stratified for the three home-based trip purposes (HBW, HBS, and HBO). The model also uses K-factors: 68 in total for the four resident, passenger trip purposes (HBW, HBS, HBO, and NHB) and 114 for the two truck trip purposes (medium-weight and heavy-weight trucks).

Of the nine peer MPOs, five use K-factors and two (CATS and DVRPC) use adjustments that are analogous to K-factors. Only two MPOs (ARC and MAG) state that they do not use K-factors or other similar adjustments, such as jurisdiction-level time penalties. As for the percent of zonal trip interchanges that are affected by K-factors, we were able to obtain estimates for this metric from only two of the six MPOs using K-factors: PSRC applies K-factors to about 35% of interchanges and MTC applies K-factors to about 50% of interchanges (See additional information below). In the TPB Version 2.1C model, K-factors are applied to between 9 and 20 percent of zonal trip interchanges, depending on the trip purpose.

ARC uses K-factors in neither its home-based work trip distribution model nor its five non-work trip distribution models (ARC 2002, Section 6, Trip Distribution, pp. 6-2 and 6-3). According to draft documentation obtained from MAG, K-factors were not required in the work trip distribution model (MAG 2002, Model Documentation, p. 8-1).[4] This draft model documentation states that the 1988/89 home interview survey did not have enough observations to calibrate separate work trip distribution models for each stratification of household income and auto ownership. Consequently, the HBW trip distribution model was calibrated using the 1990 Census Transportation Planning Package (CTPP).

CATS does not use K-factors, per se, but does use some other adjustments to validate its trip distribution model. CATS uses an intervening opportunity (IO) trip distribution model, which is a member of the gravity model family of trip distribution models. Calibrating an IO model involves calculating a series of "L-values." The L-value can be thought of as a measure of how selective trip makers are toward accepting an opportunity. The lower the L-value is, the more selective the person is in accepting an opportunity and, therefore, the longer the trip length is for a set of given opportunities. For the current travel model used by CATS, L-values were calibrated for 13 subareas. During calibration, it was found that trip lengths for person trips to the central Chicago areas were too short. Two adjustments were made to improve trip distribution: 1) Highway costs to the central area were increased and transit costs to the central area were decreased, as shown in Table 4;[5] and 2) The combined transit-highway cost, after the log sum is taken, was increased by 0.3 for all trip interchanges across the Illinois-Indiana state

[4] This documentation was not available on the Web. Per a TPB staff request, it was sent to TPB staff in February 2003.

[5] After these additions and subtractions, the combined transit-highway generalized cost roughly ranges between 4.0 and 12.0 cost units. Cost values are in the same dimensionless units as the mode choice model's weighted sum of costs and times.

line for all trip purposes, regardless of direction. In its documentation, CATS states that, “It can be argued that the state line is an additional barrier to movement that cannot be correctly represented in the F_{ij} impedance.” (CATS 2003, p. 57).

Table 4 Transit and highway bias adjustment for CATS trip distribution model

Trip Purpose	Transit Cost Reduction	Auto Cost Increase
Home production to work attractions	1.0	1.1
Home production to non-work attractions	1.0	2.0
Non-home productions to non-home attractions	1.0	2.0

Note: Values are in the same dimensionless units as the mode choice model’s weighted sums of costs and times.
Source: CATS, Conformity Analysis Documentation for the 2030 Regional Transportation Plan and the FY 2004-2009 Transportation Improvement Program. Appendix B, Travel Demand Modeling for the Conformity Process in Northeastern Illinois.

NCTCOG applies what it calls “K-factors” to adjust home-based non-work (HBNW) trips and non-home-based (NHB) trips going to/from the Dallas/Fort Worth International Airport (NCTCOG 2000, pp. 67-70). The NCTCOG modeled area includes 57 “jurisdictions” (cities and counties). These trip interchange factors are applied before mode choice to the HBNW and NHB person trip tables. The trip tables are affected only for those HBNW and NHB trips that have DFW Airport as a trip end. Values range from 0.2 to 99.

SEMCOG uses K-factors in its gravity model trip distribution model. It uses 93 K-factors for home-based work (HBW); 61 for non-home-based work (NHBW); 27 for home-based other (HBO); 22 for non-home-based other (NHBO); 23 for home-based shopping (HBSh); and 20 for home-based school (HBSc) (SEMCOG 1997, Background Paper No. 2, pp. 16-19).

MTC appears to apply over two thousand K-factors in its HBW trip distribution model. MTC uses income-stratified trip distribution. For calibration, it uses 34 superdistricts. There are 1,156 (= 34 * 34) superdistrict trip interchanges and 4,624 (= 1,156 * 4) superdistrict trip interchanges by income quartile. Based on a review by TPB staff, over 50% of these have non-unitary K-factor values (Purvis memo, January 23, 1997, p. A-27 to A-39), which would imply over 2,300 K-factors, by income level, for HBW. For the three non-work trip distribution models – home-based shop/other (HBsh/oth), home-based social/recreation (HBsoc/rec), and non-home-based (NHB) – K-factors were calculated at the intra-county level (There are nine counties in the modeled area). K-factors were not estimated for inter-county movements (Purvis memo, January 27, 1997, p. 2), consequently there were 9 intra-county-level K-factors for each of these three non-work purposes. Values ranged from 0.82 to 1.76. As for the three home-based school trip distribution models (HB grade school, HB high school, and HB college), K-factors were calculated for both inter-county and intra-county movements (Purvis memo, January 28, 1997, p. 1). The number of K-factors is 25 for HB grade school trips, 25 for HB high school trips, and 15 for HB college trips.

HGAC uses K-factors. According to recent documentation (HGAC 2001, p. 4-7):

> K-factors historically, have been used to improve model performance in addressing two natural barriers within the Houston-Galveston TMA: the Houston Ship Channel and the separation

> between Galveston Island and the mainland. These physical barrier K-factors are included in the 1990 model for both work and non-work trip purposes. Distinct socio-economic and land use characteristics that require introduction of K-factors are the under-representation of both HBW attractions to the Houston CBD and intra-county HBW trips for the surrounding seven counties. In addition to the CBD, three other major activity centers, (Greenway area, Galleria-Post Oak, and Texas Medical Center) also required K- factors. In the current 1990 model, the original 1985 model K-factors have been retained except in Brazoria County. Additional K-factors refinements were subsequently made for Brazoria County in conjunction with a county roadway planning effort.

The values of the HGAC K-factors do not seem to be part of the models documentation.

DVRPC does not use K-factors, but uses a series of river penalties – a 10-minute time penalty for movements across the Delaware River - and other "inter-area" time penalties (DVRPC 1997, pp. 118, 128-130). The inter-area time penalties, which range from –3 minutes to +10 minutes, are added to or subtracted from the travel time skims, just before the terminal and intrazonal travel times are added to the skims. There are about 134 zonal interchange groups to which inter-area time penalties are applied. For example, the first zonal interchange group is from TAZ 1-54 to TAZ 55-101, and the time penalty is +3 minutes. It would be difficult to calculate the percent of zonal interchanges to which the time penalties are applied.

PSRC appears to use K-factors in both their work and non-work trip distribution models. Approximately 35% of origin-destination pairs have non-unitary K-factors applied. The model documentation states that one of the reasons for having K-factors is that "gravity models do not perform as well in areas where there are multiple centers of activity" as exists in several of the counties in the Seattle modeled area (CSI, Urban Analytics 2001, Current Model Documentation, p. 7-5). The "new" model has no K-factors, but the consultant report says that PSRC should consider adding K-factors to improve model fit (CSI, Urban Analytics 2001, New Model Validation, p. 5-4).

Mode choice: Use of jurisdiction-level adjustment factors

The mode choice model for the Version 2.1C model is a sequential multinomial logit (SMNL) model. There is a separate model for each of the four passenger trip purposes. The Version 2.1C mode choice model also uses jurisdiction-level post mode choice model adjustment factors. The rationale for using these adjustment factors is that each of the four mode choice models is a discrete choice model, estimated from disaggregate, household-level data from the most recent household travel survey. When disaggregate models are applied at the aggregate, zone-to-zone level, there is no assurance that estimated trips by mode will match the observed trips by mode. The adjustment factors are used to help ensure a good match between estimated and observe data at the aggregate level. With the exception of DVRPC (discussed below), none of the nine peer MPOs mention using such factors in their documentation. This could mean that either such factors are not used, or they are used but not documented. One may need to actually interview modelers at each MPO to get a complete answer to this question. As of 1997, the date of the most recent models documentation we have for the agency, SEMCOG did not have a transit network, so it did not perform mode choice in the typical fashion. Instead, it used a series of county-to-county transit mode split factors.

DVRPC does use mode choice adjustment factors, but they are not jurisdiction-based. In the DVRPC travel model, the mode choice model is made up of two models: a mode choice model and a car occupancy model. The mode choice model is a binary probit model, also known as a diversion curve, which apportions motorized person trips to either transit person trips or highway person trips. The auto occupancy model estimates the share of highway person trips that are auto driver person trips (i.e., vehicle trips). The mode choice model is applied at the trip interchange level after trip distribution and is composed of 18 diversion curves, one for each stratum:

- Trip purpose (3)
  - Home-based work
  - Home-based non-work
  - Non-home based
- Transit submode (3)
  - Commuter rail
  - Subway-elevated
  - Surface trolley/bus
- Auto ownership (2)
  - Trip interchanges by auto-less households
  - Trip interchanges by car-owning households

The DVRPC travel model uses six area types:

1 CBD
2 Fringe
3 Urban
4 Suburban
5 Rural
6 Open Rural

The mode choice model includes nine inter-area-type penalties or adjustment factors, that are included as coefficients on dummy variables representing the 9 travel markets (area-type-to-area-type interchanges) shown in Table 5.

Table 5 Area interchange factors/coefficients used in DVRPC's mode choice model

From, Area Type	To, Area Type	Factor
1 (CBD)	1 (CBD)	-100
1 (CBD)	2, 3 (Urban)	-45
1 (CBD)	4, 5, 6 (Suburban/rural)	0
2, 3 (Urban)	1 (CBD)	+20
2, 3 (Urban)	2, 3 (Urban)	-15
2, 3 (Urban)	4, 5, 6	+30

4, 5, 6 (Suburban/rural)	1 (CBD)	+5
4, 5, 6 (Suburban/rural)	2, 3 (Urban)	+5
4, 5, 6 (Suburban/rural)	4, 5, 6 (Suburban/rural)	+100

Source: DVRPC 1997, p. 147.

According to the DVRPC documentation, examination of the Delaware River crossings from the preliminary highway assignment indicated that the average occupancy for interstate travel was underestimated. Consequently, the interstate occupancies predicted by the model were increased by 18% for HBW trips, 30% for HBNW trips, and 14% for NHB trips. Based on data from the 1987-88 home interview survey, auto occupancies in Pennsylvania were higher than those in New Jersey (1.41 vs. 1.33). Consequently, "state factors were introduced into the auto occupancy model to correct for this difference." Because the model also tended to underestimate the auto occupancy for trips to the center city area of Philadelphia, "CBD occupancies were increased by 10 percent for all trip purposes." (DVRPC 1997, p. 149)

Changing bus speeds as a function of link congestion

In the TPB Version 2.1C travel model, bus speeds in the transit network are determined by the published bus schedules, which, in the near term, take into account congestion of the roads over which the route travels, stop spacing, and other similar issues. So, when developing a 1994 transit network, the bus speeds are based on the 1994 bus schedules. For a future-year network, say 2005, the bus speeds are based on the latest available bus schedules (e.g., 2003). In the TPB Version 2.1C model, there is no direct feedback mechanism between increasing congestion on highway links and bus speeds for future years.

Based on the documentation we have obtained for nine MPOs, two (CATS and MTC) do not mention whether they change bus speeds with link congestion; two (DVRPC and SEMCOG) do not change bus speeds with link congestion; and five (ARC, NCTCOG, H-GAC, MAG, and PSRC) do change bus speeds with link congestion. As of 1997, SEMCOG did not use a transit network and DVRPC states that it does not make bus speeds a function of highway congestion (DVRPC 2000, p. 77).

Validation results: Transit estimates

The TPB Version 2.1C model was validated for both 1994 and 2000. At the regional level, the ratio of estimated transit trips to observed transit trips was 1.03 for 1994 and 0.95 for 2000. Based on the available documentation from the nine peer MPOs, five did not provide the information necessary to compute this metric: CATS, NCTCOG, SEMCOG, H-GAC, and MAG. Atlanta had an estimated-to-observed transit ratio of 0.92 for 2000. MTC had an estimated-to-observed transit ratio, for HBW trips, of 1.08. PSRC had an estimated-to-observed transit ratio of 0.91 using a 1998 estimate and 1999 observed data. DVRPC had an estimated-to-observed transit ratio for 1990 of 0.93 before recalibration and 1.01 after recalibration of the mode choice model (DVRPC 1997, p. 141). When the transit trips were assigned to the transit network, the 1990 estimated-to-observed ratio was 1.04 (DVRPC 1997, p. 185) and the %RMSE for the assigned transit line volumes was 61.5% (p. 188), based on 145 observations. For a 1997 simulation, DVRPC had an estimated-to-observed ratio for transit volumes of 1.06.

Speed feedback into mode choice model
The TPB Version 2.1C travel model ensures travel time consistency between model steps by including a speed feedback process, where speeds from traffic assignment are fed back into trip distribution. The feedback process includes four iterations, which are called “pump prime,” “base,” “first,” and “second.” Each iteration includes running the trip distribution step and the traffic assignment step. The full mode choice model is executed in only one of the four iterations: the base iteration. The full mode choice model run uses speeds from the pump prime traffic assignment. Peak period speeds are used for home-based work and off-peak period speeds are used for the other three trip purposes (HBS, HBO, NHB). In the “first” and “second” iterations, instead of running the full mode choice model, the transit and HOV trips produced from the initial full mode choice model run are preserved and are subtracted from total person trips (Note that HOV trips includes only those HOV trips traveling on HOV facilities). Revised LOV trips are computed by applying LOV auto driver percents, again, from the initial mode choice model run, to the remaining balance of person trips (COG 2002, Calibration Report, p. 1-7).

We can assume that any of the peer MPOs that are nonattainment areas use some form of speed feedback. However, using the available documentation, it was hard to determine which MPOs included mode choice in each iteration. Four of the eight MPOs – DVRPC, MAG, MTC, and PSRC - appear to run the mode choice model during each iteration of speed feedback, but further follow up is needed to confirm the details of the speed feedback methodologies used by these MPOs. As an indication of the difficulty of obtaining an answer to this question using only published documentation, we have included a paragraph of text from the PSRC model documentation:

> There are four feedback loops between the trip assignment model and the trip distribution model to equilibrate travel times between these models. The highway travel time is the variable that is fed back into the trip distribution model following each of four iterations of the trip assignment model. There is no separate feedback to the mode choice model, but this model is run during each of the four iterations of the feedback to trip distribution and will, therefore, provide different results based on these updated highway travel times. The initial assignment in each of the new base years and in each forecast year is based on the most recent highway network from a previous year.
>
> (CSI 2001, Current Model Documentation, p. 2-3).

Validation results: Highway assignment
One goodness-of-fit measure for the traffic assignment step is the regional percent root mean squared error (%RMSE) between the estimated and observed link volumes. For the Version 2.1C TPB travel model, the regional %RMSE for traffic assignment was about 55% for the 1994 base year and 52% for the 2000 validation year, based on 13,708 links with counts in 1994 and 11,377 links with counts in 2000. Atlanta, reported a similar regional %RMSE: 50% for 1995 and 47% for 2000 (ARC 2002, p. 10-2). In the CATS documentation, there is a table showing %RMSE for arterial roads, grouped by directional volume (from a 1996 traffic assignment). Values range from 27% for a directional volume of 5,000 to 5% for a directional volume of 25,000 (25,000+ ?), but there is no overall %RMSE for all arterials. There is also no mention of the regional %RMSE for all road segments - readers are directed to see CATS working papers for more information. SEMCOG does not report RMSE, but lists the percent difference in volume at the regional level between estimated and observed values as –16.7%. MAG reports a

regional %RMSE of 37% in its conformity documentation for a validation year of 1998 (MAG 2002, Conformity Analysis, p. 3-1). MTC does not report the regional %RMSE, but reports the r-squared value of 0.8882 (MTC 1998, p. 203). PSRC also does not report the regional %RMSE for traffic assignment, but reported a percent difference in assigned traffic volume of –0.4% compared to observed counts (CSI 2001, Current Model Validation, p. 4-5). DVRPC reported a %RMSE of 39.4% and an r-squared of 0.88 for a 1990 simulation using its "existing" travel model, based on 355 screenline and/or cutline locations (DVRPC 1997, p. 182). Using its "enhanced" travel model for a 1997 validation, DVRPC reported an r-squared of 0.84 and percent difference of –3.7% when comparing estimated and observed volumes over 355 links on 14 screenlines. In summary, only three of the nine peer MPOs (ARC, DVRPC, and MAG) reported the %RMSE for regional highway assignment in their documentation.

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Matrix of 11 MPOs: Comparison of travel modeling practice
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		Wash., DC COG/TPB	Atlanta ARC	Boston Boston MPO	Chicago CATS	Dallas NCTCOG	Detroit SEMCOG
1	Models documentation on Web site?	Yes	Yes	No (1)	Yes	Yes	No (3)
2	Model documentation found in . . .	Own report	RTP & Conformity	Not currently available	Conformity	Own report	Conform. (1997) & own report (2000)
3	Name of travel model	Version 2.1, Rel. C	2025 RTP & FY01-03 TIP ?	?	2030 RTP & FY04-09 TIP ?	Dallas-Fort Worth Regional Travel Model	?
4	Household travel survey used	1994 HTS	1990 HIS		1970, 79, 91 HIS	1984 HIS	1994 HTS
5	Validation year(s)	1994, 2000	1990, 95, 2000		1996	1980, 84, 86, 95	
6	No. of jurisdict. in non-attainment area vs. modeled area	Model: 22 Nonatt: 12	Model: 13 Nonatt: 13	Model: ? Nonatt: 12	Model: 10 Nonatt: 10	Model: 4 Nonatt: 4	Model: 7 Maint: 7
7	No. of zones in modeled area	2,191	948		1,640	721 RAAs, 2,331 LADs, 5,999 TSZs	1,505
8	Trip purposes used in travel model	HBW, HBshop, HBO, NHB, MedTrk, HvyTrk	HBW, HBshop, HBgradeSch, HBuniv, HBO, NHBJTW, NHBJAW, NHBNW		7 for workers, 3 for non-working adults, 1 for children age 12-15; 4 for trucks	HBWinc1(low inc.) … HBWinc4 (high income), HBnonWk, NHB, Other (IX, XI, XX, truck, taxi)	HBW, HBshopping, HBschool, HBO, NHBW, NHBO
9	Number of trip purposes for passenger (resident) travel	4	8 for TG; 6 for TD & MC (3 NHB purps become 1)		11 TG; 3 for TD & MC	6	6
10	Number of trip purposes for commercial travel	2	?		4 (B-plate, light, med, hvy)	1	No truck model (post-TA adj proc)
11	Trip Generation: Use p-mods & a-mods?	Yes	Yes. Values range from 0.67 to 1.41		No	?	?
12	Trip Generation and Distribution: Use special generators?	No	Yes, for Hartsfield Airport		Yes	Yes	?
13	Trip Distribution: Income stratified?	Yes	Yes		Intervening opportunities	Yes, for HBW	No
14	Trip Distribution: Use any adjustment factors?	Yes	No		Yes, adjustment assoc. w/ Illinois /Indiana state line	Yes, "K-factors" applied before MC for airport trips	Yes, K-factors
15	Trip Distribution: How many K-factors	68 for resident travel; 114 for trucks	None		N/A	About 40, affecting only trips that have DFW Airport as a trip end	93 for HBW; 61 for NHBW; 27 for HBO; 22 for NHBO; 23 for HBSH; 20 for HBSC
16	Trip Distribution: What % of interchanges have K-factors	9 to 20 percent, varies by purp.	0		N/A	?	?
17	Mode Choice: Use jurisdiction-level adjustment factors?	Yes	?		?	?	No. MC is not logit (uses county-level factors)
18	Are bus speeds a function of link speeds?	No	Yes		?	Yes	No. No transit network used.
19	Estimate of transit trips	Work & non-work	Work & non-work		Work & non-work	Work & non-work	Work & non-work
20	Est. of transit trips: Est/Obs	1994: 1.03; 2000: 0.95	2000: 0.92		?	?	?
21	Speed feedback?	Yes	?		Yes	Yes	Sort of
22	Speed feedback: Is mode choice run for each iteration?	No, only 1st of 4	?		?	?	?
23	Traffic Assignment: Regional %RMSE for link volumes	1994: 55%; 2000: 52%	1995: 50%; 2000: 47%		"See working papers"	?	Not reported (%diff vol: -4%)

Notes:

(1) Not for production model. An e-mail was sent on 9/23/03 to Karl Quackenbush requesting documentation.
He responded that there is no off-the-shelf documentation available now.

(2) B-Plate Truck: GW <= 8000 lbs, regardless of whether used for commercial or private (residential) purposes.

(3) A request has been made (10/2/03) for the relevant documentation (Structure and Implementation of the Regional Travel Forecasting Model for SE Michigan)

(4) "There is no separate feedback to the mode choice model, but this model is run during each of the four iterations…" (CSI 2001, Current Model Doc., p. 2-3)

(5) PSRC's "new" travel model uses a destination-choice model for HBW trips. Model segments trips by income and veh. avail. (CSI 2001, New Model Doc., p. 2-6)

(6) An e-mail was sent to Frank Baron on 9/23/03 requesting model docum. As of 10/2/03, no response has been received.

(7) The highway network covers 7 counties. As of 1997, there was no transit network, but work had just begun to develop one.

Matrix of 11 MPOs: Comparison of travel modeling practice
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		Houston H-GAC	Miami Miami-Dade MPO	Philadel. DVRPC	Phoenix MAG	San Fran. MTC	Seattle PSRC
1	Models documentation on Web site?	Yes	No (6)	For purchase only	Yes, limited	Yes	Yes, detailed
2	Model documentation found in . . .	Conformity, 2022 MTP		Own report	Conformity	Own report	Own reports
3	Name of travel model			1997 (24 hr assignment)		BAYCAST-90	"Current model"
4	Household travel survey used	1984 & 1995 HTSs		1987-88 HIS	1989 HITS	1990 HTS	
5	Validation year(s)	1995			1989, 95, 98	1990, 1998	1990, 95, 97, 98
6	No. of jurisdict. in non-attainment area vs. modeled area	Model: 8 Nonatt: 8	Model: ? Maint: 3	Model: 9 Nonatt: 14	Model: ? Nonatt: 1	Model: 9 Nonatt: 9	Model: 4 Maint: 3
7	No. of zones in modeled area	2,680		1,509	1541 (3715 sq mi)	1,099	850
8	Trip purposes used in travel model	HBW, HBsch, HBshop, HBO, NHB, Truck-Taxi (TRTX), External local veh (EXTL), Ext. through veh (EXTHR)		HBW, HBnonWork, NHB, Light truck, Heavy truck, Taxi, Freeway XI, Arterial XI	HBW, HBshop, HBsch, HBuniv1, HBuniv2, HBO, NHB, LightTrk, MedTrk, HvyTrk	HBW, HBshopOther, HBsocRec, HBgrSch, HBhiSch, HBcoll, NHB, IX, Commercial	HBW, HBshop, HBsch, HBcoll, HBO, NHB, Commercial
9	Number of trip purposes for passenger (resident) travel	5 (3 for MC)		3	7	7	6; 5 for TD; 3 for MC
10	Number of trip purposes for commercial travel	1		5	3	1	1
11	Trip Generation: Use p-mods & a-mods?	?		?		Yes	?
12	Trip Generation and Distribution: Use special generators?	?		?	Yes?	?	Yes
13	Trip Distribution: Income stratified?	No		No	?	Yes, for HBW	No (5)
14	Trip Distribution: Use any adjustment factors?	Yes, K-factors		Yes, river penalties amd inter-area time penalties	No K-factors for HBW; Non-work: ???	Yes, K-factors	Yes, K-factors
15	Trip Distribution: How many K-factors	?		No K-factors. Inter-area time penalties: 134 zonal interchange groupings		HBW: over 2300; HBsh: 9; HBrec: 9; NHB: 9; HBsch: 65	?
16	Trip Distribution: What % of interchanges have K-factors	?		?		HBW: Over 50%	Approx. 35%
17	Mode Choice: Use jurisdiction-level adjustment factors?			Yes, 9 adj. factors between some area types		?	?
18	Are bus speeds a function of link speeds?	Yes		No	Yes	?	Yes
19	Estimate of transit trips	Work & non-work				Work & non-work	Work & non-work
20	Est. of transit trips: Est/Obs			1990: 1.01 1997: 1.06		HBW: 1.08	1998est/1999obs: 0.91
21	Speed feedback?	?		Yes, for enh. model	Yes	?	Yes
22	Speed feedback: Is mode choice run for each iteration?	?		Yes, for enh. model	Yes	Appears to be	Yes (4)
23	Traffic Assignment: Regional %RMSE for link volumes	Not shown		1990: 39%	37%	Not reported (r-squared 0.8882)	Not reported (%diff vol: -0.4%)

Ref: mpoSvyMatrix_08.xls

Appendix B

Highway and Transit Validation

- ❖ Maryland Inter County Connector (ICC) Corridor – Base Year 2000 Validation Using Version 2.1C Travel Demand Model.

- ❖ October 7, 2003 letter from Thomas Harrington (Washington Metropolitan Area Transit Authority) to Ronald Kirby, regarding comments on TRB review of MWCOG travel demand modeling procedures.

December 12, 2003

Maryland Inter County Connector (ICC) Corridor
Base Year 2000 Validation Using Version 2.1C Travel Demand Model

I. INTRODUCTION

A. Overview

This memo documents the first application of the Version2.1C travel demand model in a major corridor study in the Washington region. This writeup is adapted from a project documentation memo prepared for, and approved by, the ICC Travel Demand Task Force in August 2003.

A first step in such a corridor or subarea planning effort is to review in detail and validate the performance of the travel demand model in the corridor to provide quality assurance for the work and to minimize the need for later traffic refinement of forecasts / alternatives. This work performed in the ICC corridor illustrates that significant improvements can be realized in the regional model's 'goodness of fit' statistics, such as estimated-to-observed travel volumes, when more detailed validation procedures are executed.

To illustrate this point, staff computed regional root mean squared error (RMSE) statistics to assess the overall impact of these corridor validation refinements. As reported in summary statistics contained in the memo, the overall regional percent RMSE improves from 52% in the original model to 47% with the model validated for the ICC corridor. Some of this improvement is due to use of updated regional speed and capacity lookup tables, i.e., a one time statistical improvement. However, much of the improvement results from updates specific to the ICC corridor, e.g., centroid loading locations, for which the ICC corridor represents probably less than 20% of the regional total. In other words, forthcoming work in other corridors / subareas, or execution of a specific work program element to perform similar analysis throughout the rest of the Washington region, would yield additional improvement to these regional statistics.

B. Background

As part of the Maryland technical assistance element of the FY2003 Unified Planning Work Program (UPWP), in the second half of fiscal year 2003 COG staff carried out project planning activities in the ICC corridor of Montgomery and Prince George's counties. Staff from SHA's consultants, BMI/SG and Associates, and members of the ICC Travel Demand Task Force provided assistance with this effort, which was conducted as part of the draft environmental impact statement (DEIS) for the project. This memorandum documents the first phase of the travel forecasting process: procedures and results of corridor level model validation.

The COG/TPB Travel Forecasting Model, Version 2.1 / TP+ Release C, Calibration Report, December 2002, documented on COG's web site (www.mwcog.org), represented the starting point for the corridor level validation. COG staff produced this model set over the past several years as part of its continuing model development work program. It has now been used to provide travel demand forecasts (and associated mobile source emissions inventories using an emissions post-processor) for the Washington region's state air quality implementation plan (SIP) as a severe ozone nonattainment area. It is also currently being used to test air quality conformity of the region's 2003 Constrained Long Range Plan (CLRP) and FY2004 - 09 Transportation Improvement Program (TIP).

II. ICC VALIDATION

The first step in preparing travel forecasts for the ICC DEIS is to validate the currently adopted Version 2.1/TP+ Release C model for the study area. As part of this ICC corridor validation, staff first reviewed the regional model's performance in the study corridor. These results are documented in the December 2002 report: travel was somewhat over-simulated regionwide and in the ICC corridor. Staff then systematically applied updated land use inputs and a number of model and network refinements to improve the overall performance of the modeling process at both the regional and corridor levels. Staff utilized a standard set of evaluation statistics to assess the impacts of each change. Tables 1 - 5 present these statistics, including regional and corridor vehicle trips, vehicle miles traveled (VMT), screenline results, and RMSE. The three primary sets of simulated data in the columns within each table include: I. Preliminary Base, II. ICC Base, and III. ICC Validation results (the end result of over two dozen model runs). These model runs, updates, and evaluation statistics are described below.

A. Land Activity

At the first meeting of the ICC Travel Demand Task Force, the group indicated the importance of using the latest land activity inputs for the project. While Baltimore Metropolitan Council's Round 6 Cooperative Forecasts are not yet available for use, staff obtained and utilized their Round 5D estimates. The summary statistics portrayed in the tables for I. Preliminary Base represent these inputs, in combination with COG's Round 6.2 inputs. Validation work initially proceeded with this Preliminary Base estimation; staff subsequently received and incorporated COG's year 2000 Round 6.3 estimates (which reflect data from the US Census and also local employment census statistics). These simulation results comprise the ICC Base, and represent the starting point for comparisons of travel demand validation iterations. As seen in Tables 2 and 3, however, even with the refined land use inputs, travel to and through the ICC corridor remained substantially over-simulated in comparison to traffic counts.

B. Speed and Capacity Parameters

1. Table Lookup Values

The Version 2.1C table lookup values for speeds and capacities by facility type and area type (a value based on population and employment density) are based upon the Parsons Brinckerhoff Quade and Douglas model set originally used in the Dulles rail and I-66 corridors of northern Virginia. As part of the work performed in developing the draft SIP for the Washington area, COG staff researched and prepared an updated set of speed and capacity values for use in the mobile source emissions post-processor. These updated speed and capacity values are based on the Highway Capacity Manual and data collected locally. To achieve consistency between the travel demand and emissions post-processor elements and to reflect the newly available data, staff substituted these updated speeds and capacities into the ICC validation. The final tables of speeds and capacities used in developing the ICC Validation results are contained in the Appendix to this memo.

2. Volume Delay Function (VDF)

While the above values improved the simulation, there were still instances of over-simulated volumes on freeways for which very little restraint, or travel speed reduction, occurred. Accordingly, staff prepared and tested a modified VDF which further improved results. Documentation of this change is contained in the Appendix to this memo.

3. Freeway Overrides in Corridor

Following review of operating characteristics on the freeway system in the corridor, staff identified and tested some overrides to free-flow speeds and capacities. This included capacity reductions on I-270 to reflect the operation of the collector - distributor roadways, and capacity increases on the Capital Beltway to reflect higher peak and off-peak ‘capacities’ associated with lower peaking characteristics on that facility. The final values are contained in Figure 1. All of the above-specified parameter updates are reflected in the ICC Validation results.

C. Trip Distribution

As the ICC Base runs indicated a substantial over-simulation between Montgomery County and Frederick County and between Montgomery County and Howard County, staff tested the application of K-factors and additional impedance penalties for nonwork trip purposes between these areas to reduce that over-simulation. The results showed a better fit between estimated and observed volumes through the use of a 0.2 K-factor between Montgomery County and Frederick County, a 2.0 to 2.8 range of K-factors for home-based-shop, home-based-other, and non-home-based purposes within Howard County, and the use of a 10 minute penalty for nonwork purpose trips between Montgomery and Frederick counties and between Montgomery and Howard counties. These updates are reflected in the ICC Validation results.

D. Network Updates

Staff performed a series of network updates to improve the simulation in the ICC corridor, as described below.

1. Project Team Review

Following staff's distribution of network plots to local agencies at the May Task Force meeting, staff received a host of recommended updates, primarily from Montgomery County DOT and MNCPPC. For ‘number of lanes’ information, staff made the network changes to the ICC networks. In the case of route type changes, however, staff did not reflect all recommended changes to the TPB networks since route type definitions often vary by agency. Further study team review resulted in the addition of Glenallen Avenue and Plyers Mill Road in Montgomery County. These network updates, including facilities, number of lanes, and route types, are shown in the project computer plots.

2. Zone Centroid Connectors

Staff review of specific centroid loading points onto the networks yielded a number of instances in which additional connections needed to be added, or where modifications were appropriate. The project computer plots identify the updated centroid connections.

3. Area Types

The area type code, based upon land use associated with each zone, is designed to reflect a facility's speed and capacity according to the density of development which is in the vicinity. These codes are assigned based upon a mechanical computation and in practice can result in anomalous results, e.g., a facility may be assigned different codes by direction. Through a review of computer plots of assigned values in conjunction with aerial photos, staff identified and applied a number of updates at the link level. The updated area type designations are contained in project computer plots.

4. Traffic Counts

Staff made a number of additions and updates to the observed data values at many locations in the corridor. These resulted from additional counts received from BMI or SHA or corrections made to the values originally coded in the regional network. The traffic counts applied in the ICC Validation are contained in the project computer plots.

III. RESULTS

The results of the ICC Validation work can be seen in Tables 1 - 5 and in the project computer plots of estimated and observed volumes and volume differences, respectively.

Table 1, the Regional Tracking Sheet, documents the statistics for land use, vehicle trips by purpose and mode, and VMT. It also shows that while vehicle trips increase by just over 1%, VMT decreases by just under 7% from the ICC Base case to the ICC Validation case.

Table 2 presents VMT statistics for the modeled area, the MSA and by county. It illustrates substantial improvement in the ICC Validation case for both the ICC corridor and regionwide.

Table 3 presents regional screenline results and indicates substantial improvement in the ICC corridor and regionwide.

Table 4 presents a summary of estimated to observed results at 5 'critical link' locations within the study area. This table identifies 5 freeway locations which, at the start of the validation, were outside of the acceptable tolerances for estimated to observed comparisons. The table indicates significant progress and acceptable comparisons for the ICC Validation case.

Table 5A through 5C presents regional RMSE statistics which document the overall improvement from the original 52% revised with the ICC model to 47%.

IV. RECOMMENDATIONS

This memo documents the status of model validation activities / evaluation in the ICC corridor. Some additional traffic counts may still be obtained and reflected in the analysis, and some additional changes to the model are still possible, pending review by the project team. However, it appears that the validation work has reached an acceptable level for use in forecasting. The recommendation that the validation work receive signoff and be used as the basis for proceeding to the forecast year analysis was approved by the ICC Travel Demand Task Force.

Following:

5 Tables, 2 Figures

Attachment

Table 1. Regional Tracking Sheet
Version 2.1C Model; 2,191 Zones

		Prelim. Base	ICC Base	ICC Validation	Validation against ICC Base	
		COG 6.2+BMC5.D	COG 6.3	COG 6.3	Difference	Difference (%)
Land Use						
	Households	2,107,233	2,144,161	2,144,161	0	0.00%
	Employment	3,455,264	3,482,427	3,482,427	0	0.00%
	Population	5,637,342	5,746,598	5,746,598	0	0.00%
Motorized Trips/Trip Rates						
Motorized Person Travel	HBW	4,095,142	4,157,440	4,162,892	5,452	0.13%
(Internal & External)	HBS	3,060,657	3,105,722	3,113,213	7,491	0.24%
	HBO	9,299,063	9,477,771	9,499,749	21,978	0.23%
	NHB	6,816,299	6,916,575	6,940,914	24,339	0.35%
	Total Person Trips	23,271,161	23,657,508	23,716,768	59,260	0.25%
Non-Motorized HBW Trips		174,444	183,170	183,455	285	0.16%
Auto Driver Travel	HBW	3,161,733	3,211,876	3,153,256	-58,620	-1.83%
(Internal & External)	HBS	2,389,571	2,418,600	2,450,241	31,641	1.31%
(No HOV)	HBO	6,320,413	6,440,572	6,595,802	155,230	2.41%
	NHB	5,329,927	5,402,871	5,473,040	70,169	1.30%
	Total Auto Driver	17,201,644	17,473,919	17,672,339	198,420	1.14%
Auto Passenger Travel	HBW	417,229	424,902	404,069	-20,833	-4.90%
(Internal & External)	HBS	635,591	650,440	629,005	-21,435	-3.30%
	HBO	2,811,879	2,865,635	2,740,901	-124,734	-4.35%
	NHB	1,350,539	1,378,642	1,330,681	-47,961	-3.48%
	Total Auto Passenger	5,215,238	5,319,619	5,104,656	-214,963	-4.04%
Auto Occupancies	HBW	1.12	1.12	1.12	0.00	0.00%
(Internal & External)	HBS	1.27	1.27	1.26	-0.01	-0.79%
	HBO	1.44	1.44	1.42	-0.02	-1.39%
	NHB	1.25	1.26	1.24	-0.02	-1.59%
Transit Travel	HBW	516,180	520,662	605,567	84,905	16.31%
(Internal Only)	HBS	35,495	36,682	33,967	-2,715	-7.40%
	HBO	166,771	171,564	163,046	-8,518	-4.96%
	NHB	135,833	135,062	137,193	2,131	1.58%
	Total Internal Transit	854,279	863,970	939,773	75,803	8.77%
Transit Percentage	HBW	12.60%	12.52%	14.55%	2.02%	16.15%
	HBS	1.16%	1.18%	1.09%	-0.09%	-7.62%
	HBO	1.79%	1.81%	1.72%	-0.09%	-5.18%
	NHB	1.99%	1.95%	1.98%	0.02%	1.22%
	Total Transit Pct.	3.67%	3.65%	3.96%	0.31%	8.50%
Truck Travel	Medium Weight	303,513	304,862	304,869	7	0.00%
	Heavy Weight	160,427	157,976	157,937	-39	-0.02%
Miscellaneous & Through	Misc. Auto Driver	583,921	583,921	583,921	0	0.00%
	Through Auto Driver	40,706	40,706	40,706	0	0.00%
	Through Trucks	32,752	32,752	32,752	0	0.00%
	Airport Auto Drivers.	22,612	22,612	22,612	0	0.00%
Total Vehicle Trips		18,345,575	18,616,748	18,815,136	198,388	1.07%
Vehicle-Miles-Traveled						
Regional VMT		129,548,000	129,778,000	120,803,000	-8,975,000	-6.92%

Table 2. 2000 VMT Comparison in ICC Study: 2000 Counts, Base Years Vs. Base Year Validation (in 000s)
Version 2.1C Model; 2191 Zones

					Comparison with 2000 Counts					
		Prelim. Base	ICC Base	ICC Validation	Prelim. Base		ICC Base		ICC Validation	
Jurisdiction	2000 Counts	COG 6.2+BMC5.D	COG 6.3	COG 6.3	Diff.	% Diff.	Diff.	% Diff.	Diff.	% Diff.
District of Columbia	5,849	6,821	6,970	6,170	972	16.62%	1,121	19.17%	321	5.49%
Montgomery Co., MD	15,234	17,192	17,148	15,446	1,958	12.85%	1,914	12.56%	212	1.39%
Prince George's Co., MD	19,692	19,030	19,033	18,018	-662	-3.36%	-659	-3.35%	-1,674	-8.50%
Arlington Co., VA	3,555	3,583	3,620	3,317	28	0.79%	65	1.83%	-238	-6.69%
City of Alexandria, VA	1,279	1,517	1,550	1,402	238	18.61%	271	21.19%	123	9.62%
Fairfax Co., VA	23,078	24,256	24,427	22,577	1,178	5.10%	1,349	5.85%	-501	-2.17%
Loudoun Co., VA	3,821	3,653	3,649	3,374	-168	-4.40%	-172	-4.50%	-447	-11.70%
Prince William Co., VA	6,317	6,661	6,717	6,214	344	5.45%	400	6.33%	-103	-1.63%
Frederick Co., MD	6,528	7,404	7,309	6,896	876	13.42%	781	11.96%	368	5.64%
Howard Co., MD	8,048	8,874	8,722	8,016	826	10.26%	674	8.37%	-32	-0.40%
Anne Arundel Co., MD	11,486	12,679	12,608	12,413	1,193	10.39%	1,122	9.77%	927	8.07%
Charles Co., MD	2,742	2,208	2,120	2,011	-534	-19.47%	-622	-22.68%	-731	-26.66%
Carroll Co., MD	2,496	2,752	2,732	2,435	256	10.26%	236	9.46%	-61	-2.44%
Calvert Co., MD	1,690	1,390	1,417	1,194	-300	-17.75%	-273	-16.15%	-496	-29.35%
St. Mary's Co., MD	1,628	1,558	1,492	1,412	-70	-4.30%	-136	-8.35%	-216	-13.27%
King George Co., VA	567	589	620	622	22	3.88%	53	9.35%	55	9.70%
City of Fredericksburg, VA	534	303	315	329	-231	-43.26%	-219	-41.01%	-205	-38.39%
Stafford Co., VA	3,151	3,550	3,749	3,567	399	12.66%	598	18.98%	416	13.20%
Spotsylvania Co., VA	1,803	1,551	1,585	1,560	-252	-13.98%	-218	-12.09%	-243	-13.48%
Fauquier Co., VA	2,372	2,344	2,351	2,267	-28	-1.18%	-21	-0.89%	-105	-4.43%
Clarke Co., VA	579	713	718	696	134	23.14%	139	24.01%	117	20.21%
Jefferson Co., WVA	673	920	926	867	247	36.70%	253	37.59%	194	28.83%
MSA										
DC	5,849	6,821	6,970	6,170	972	16.62%	1,121	19.17%	321	5.49%
VA	41,201	43,220	43,712	40,451	2,019	4.90%	2,511	6.09%	-750	-1.82%
MD	45,886	47,224	47,027	43,565	1,338	2.92%	1,141	2.49%	-2,321	-5.06%
MSA Total	**92,936**	**97,265**	**97,709**	**90,186**	**4,329**	**4.66%**	**4,773**	**5.14%**	**-2,750**	**-2.96%**
Total	**123,122**	**129,548**	**129,778**	**120,803**	**6,426**	**5.22%**	**6,656**	**5.41%**	**-2,319**	**-1.88%**

Table 3. Year 2000 Screenline Volume Comparison in ICC Study: 2000 Counts, Base Years Vs. Base Year Validation (in 000s)*
Version 2.1C Model; 2191 Zones

						Comparison with 2000 Counts				
			Prelim. Base	ICC Base	ICC Validation	Prelim. Base		ICC Base		ICC Va
Screenline	Location	2000 Counts	COG 6.2+BMC5.D	COG 6.3	COG 6.3	Diff.	% Diff.	Diff.	% Diff.	Diff.
1	Ring 1, Virginia	642	584	588	534	-58	-9.03%	-54	-8.41%	-108
2	Ring 1, DC	680	903	928	799	223	32.79%	248	36.47%	119
3	Ring 3, Virginia	648	642	658	607	-6	-0.93%	10	1.54%	-41
4	Ring 3, DC	766	979	998	860	213	27.81%	232	30.29%	94
5	Beltway, Virginia	854	1,118	1,125	1,054	264	30.91%	271	31.73%	200
6	Beltway, Maryland	1,378	1,628	1,634	1,541	250	18.14%	256	18.58%	163
7	Ring 5, Virginia	1,022	1,104	1,106	1,042	82	8.02%	84	8.22%	20
8	Ring 5, Maryland	1,169	1,413	1,401	1,294	244	20.87%	232	19.85%	125
9	Ring 7, Virginia	632	745	762	695	113	17.88%	130	20.57%	63
10	Eastern Loudoun Co.	218	346	358	330	128	58.72%	140	64.22%	112
11	US 15, Loudoun / Pr. William Co.	148	163	158	149	15	10.14%	10	6.76%	1
12	Central Montgomery Co. Radial	390	432	431	399	42	10.77%	41	10.51%	9
13	Eastern Montgomery Co. Radial	329	406	405	333	77	23.40%	76	23.10%	4
14	NE. Pr.Geo. Co. Radial	297	329	334	297	32	10.77%	37	12.46%	0
15	Central Pr.George's Co. Radial	269	300	298	266	31	11.52%	29	10.78%	-3
16	Southern Pr.George's Co. Radial	200	251	252	225	51	25.50%	52	26.00%	25
17	Southern Fairfax / Pr. Wm. Radial	269	448	448	300	179	66.54%	179	66.54%	31
18	Central Fairfax Co. Radial	594	671	660	613	77	12.96%	66	11.11%	19
19	VA Route 7 Radial	408	499	501	456	91	22.30%	93	22.79%	48
20	Beltway & 'Inner' Potomac River Crossings	904	1,131	1,144	1,039	227	25.11%	240	26.55%	135
22	Central Mtg./P.G. Radial	1,060	1,265	1,265	1,161	205	19.34%	205	19.34%	101
23	NE Montgomery Co. Radial	144	196	193	164	52	36.11%	49	34.03%	20
24	Montgomery / Pr.Geo. Co. border	430	399	399	377	-31	-7.21%	-31	-7.21%	-53
25	Montgomery/ Frederick Co. border	92	129	119	93	37	40.22%	27	29.35%	1
26	Montgomery / Howard Co. border	298	398	386	331	100	33.56%	88	29.53%	33
27	Pr.Geo. / Anne Arundel Co. Border	298	329	326	359	31	10.40%	28	9.40%	61
28	Charles / Pr.Geo. Co. Border	164	156	150	129	-8	-4.88%	-14	-8.54%	-35
31	Frederick / Carroll Co. Border	82	144	143	117	62	75.61%	61	74.39%	35
32	Western Loudoun Co. Border	64	113	113	106	49	76.56%	49	76.56%	42
33	'Outer' Southwestern Circumferential	226	330	336	320	104	46.02%	110	48.67%	94
34	'Outer' Southeastern Circumferential	100	114	113	96	14	14.00%	13	13.00%	-4
35	South of Baltimore City	886	905	901	882	19	2.14%	15	1.69%	-4
36	'Outer' Northwestern Radial	42	94	94	87	52	123.81%	52	123.81%	45
37	'Outer' Western Circumferential	32	36	35	34	4	12.50%	3	9.38%	2
38	'Outer' I-95 (South) Radial	173	151	185	172	-22	-12.72%	12	6.94%	-1
Total		**15,908**	**18,851**	**18,947**	**17,261**	**2,943**	**18.50%**	**3,039**	**19.10%**	**1,353**

Table 4. 2000 Counts vs. Validation on Critical Select Links in the ICC Study (in 000s)*
Version 2.1C Model; 2,191 Zones; COG Land Use 6.3

							ICC Base			ICC Validation		
No.	**Facility**	**Direction**	**Location**	**A node**	**B node**	**2000 Counts**	**Volume**	**Diff.**	**% Diff.**	**Volume**	**Diff.**	**% Diff.**
1	I-270	NB	North of I-370	3776	12586	104	138	34	32.69%	116	11.954	11.49%
	I-270	SB	North of I-370	12589	3729	104	138	34	32.69%	116	11.86	11.40%
2	I-270	NB	North of Montrose Road	3768	12542	108	156	48	44.44%	131	23.075	21.37%
	I-270	SB	North of Montrose Road	12545	3713	108	157	49	45.37%	130	22.15	20.51%
3	I-495	EB	Colesville Road &George Avenue	3426	3460	125	118	-7	-5.60%	111	-13.531	-10.82%
	I-495	WB	Colesville Road &George Avenue	3704	3698	124	114	-10	-8.06%	115	-9.068	-7.31%
4	I-495	EB	US 1 &BW Parkway	4489	4437	115	96	-19	-16.52%	100	-15.066	-13.10%
	I-495	WB	US 1 &BW Parkway	4514	4624	115	96	-19	-16.52%	104	-11.143	-9.69%
5	I-95	NB	Old Gunpowder Road &Van Dusen Road	4626	4907	86	111	25	29.07%	91	5.331	6.20%
	I-95	SB	Old Gunpowder Road &Van Dusen Road	4255	4492	86	112	26	30.23%	92	5.656	6.58%

*HOV volumes are added

Table 5A
2000 Base Version 2.1/TP+, C RMSE Report

Facility Type	Volume Range	Links Count	Ave Obs Volume	Ave Est Volume	Diff. (Obs-Est)	Pct Diff.	RMSE	Pct RMSE
Freeways	1.00-9.99K	23	8.04	18.35	-10.30	-128.11	14.04	174.54
	10.00-19.99K	144	15.72	32.47	-16.76	-106.63	20.32	129.30
	20.00-29.99K	64	25.14	39.98	-14.84	-59.04	17.99	71.56
	30.00-39.99K	200	35.17	44.82	-9.65	-27.43	15.70	44.63
	40.00-49.99K	162	43.87	55.74	-11.87	-27.06	21.02	47.92
	50.00-59.99K	119	54.21	67.03	-12.82	-23.66	19.11	35.26
	60.00-69.00K	137	64.67	72.98	-8.31	-12.84	19.06	29.47
	70.00-79.00K	104	73.88	79.92	-6.04	-8.17	21.59	29.22
	80.00-89.99K	90	84.60	87.84	-3.24	-3.84	20.83	24.62
	90.00-99.99K	127	95.09	96.51	-1.42	-1.49	19.10	20.08
	100.00-109.99K	85	104.68	110.48	-5.80	-5.54	18.89	18.05
	110.00-119.99K	47	115.36	121.53	-6.17	-5.35	25.01	21.68
	120.00-129.99K	36	125.06	111.97	13.08	10.46	26.47	21.17
	130.00-139.99K	28	137.86	110.29	27.57	20.00	34.30	24.88
	Subtotal:	***1,366***	***61.18***	***69.05***	***-7.87***	***-12.87***	***20.08***	***32.82***
Maj Arterials	1.00-9.99K	1,315	6.53	10.83	-4.30	-65.91	7.41	113.51
	10.00-19.99K	2,615	14.32	18.06	-3.74	-26.16	7.91	55.24
	20.00-29.99K	1,289	23.67	24.43	-0.76	-3.20	7.36	31.10
	30.00-39.99K	312	32.30	28.36	3.94	12.21	9.31	28.83
	40.00-49.99K	24	42.75	36.21	6.54	15.30	18.02	42.14
	50.00-59.99K	12	52.67	33.00	19.67	37.34	22.99	43.65
	Subtotal:	***5,567***	***15.86***	***18.52***	***-2.66***	***-16.77***	***7.89***	***49.78***
Minor Arterials	1.00-9.99K	1,732	4.91	5.87	-0.95	-19.40	3.48	70.80
	10.00-19.99K	398	12.74	9.88	2.85	22.39	5.41	42.49
	20.00-29.99K	37	22.70	12.65	10.05	44.29	13.08	57.60
	30.00-39.99K	8	35.00	21.00	14.00	40.00	16.67	47.62
	Subtotal:	***2,175***	***6.76***	***6.77***	***-0.01***	***-0.22***	***4.35***	***64.37***
Collectors	1.00-9.99K	1,634	3.76	4.91	-1.15	-30.51	3.23	85.85
	10.00-19.99K	201	12.33	10.34	2.00	16.18	5.59	45.36
	20.00-29.99K	32	21.69	14.78	6.91	31.84	12.12	55.90
	Subtotal:	***1,867***	***4.99***	***5.66***	***-0.67***	***-13.45***	***3.87***	***77.63***
Expressways	1.00-9.99K	26	6.85	11.85	-5.00	-73.03	6.64	97.06
	10.00-19.99K	90	15.44	20.23	-4.79	-31.01	8.22	53.22
	20.00-29.99K	128	24.50	30.52	-6.02	-24.59	9.66	39.42
	30.00-39.99K	86	34.37	33.98	0.40	1.15	9.20	26.76
	40.00-49.99K	44	44.77	33.64	11.14	24.87	13.90	31.04
	50.00-59.99K	28	54.29	34.54	19.75	36.38	21.75	40.06
	Subtotal:	***402***	***27.74***	***28.37***	***-0.63***	***-2.29***	***10.95***	***39.47***
Grand Total		***11,377***	***18.20***	***20.58***	***-2.38***	***-13.09***	***9.44***	***51.91***

Note:

$$RMSE = \sqrt{\frac{\sum (ObsCount - SimCount)^2}{n}}$$

where n= the number of observations in each facility type / volume range group

Source: rmse.s

Table 5B
2000 ICC RMSE Report

Facility Type	Volume Range	Links Count	Ave Obs Volume	Ave Est Volume	Diff. (Obs-Est)	Pct Diff.	RMSE	Pct RMSE
Freeways	1.00-9.99K	24	7.83	18.88	-11.04	-140.96	13.86	176.91
	10.00-19.99K	132	15.76	32.03	-16.27	-103.27	20.92	132.75
	20.00-29.99K	60	24.82	38.93	-14.12	-56.88	18.30	73.73
	30.00-39.99K	225	35.24	41.24	-6.00	-17.01	12.80	36.33
	40.00-49.99K	198	44.09	50.73	-6.64	-15.06	16.31	36.99
	50.00-59.99K	136	54.24	60.38	-6.14	-11.32	14.14	26.07
	60.00-69.00K	135	64.93	66.58	-1.64	-2.53	17.22	26.51
	70.00-79.00K	107	73.93	74.71	-0.78	-1.05	17.49	23.66
	80.00-89.99K	99	84.93	82.28	2.65	3.12	14.58	17.17
	90.00-99.99K	107	94.97	83.37	11.60	12.21	18.78	19.78
	100.00-109.99K	97	104.46	98.62	5.85	5.60	16.68	15.96
	110.00-119.99K	49	115.63	107.61	8.02	6.94	21.13	18.27
	120.00-129.99K	32	124.34	101.34	23.00	18.50	30.41	24.45
	130.00-139.99K	20	139.50	99.35	40.15	28.78	42.96	30.80
	Subtotal:	***1,421***	***60.24***	***62.40***	***-2.15***	***-3.58***	***17.72***	***29.41***
Maj Arterials	1.00-9.99K	1,337	6.54	10.07	-3.53	-53.94	6.58	100.64
	10.00-19.99K	2,679	14.30	16.74	-2.44	-17.08	6.88	48.11
	20.00-29.99K	1,231	23.64	22.28	1.36	5.76	6.94	29.35
	30.00-39.99K	289	32.20	26.58	5.62	17.45	10.30	31.98
	40.00-49.99K	22	42.73	31.55	11.18	26.17	19.42	45.46
	50.00-59.99K	8	53.00	30.75	22.25	41.98	23.03	43.46
	Subtotal:	***5,566***	***15.60***	***16.95***	***-1.35***	***-8.68***	***7.18***	***46.05***
Minor Arterials	1.00-9.99K	1,769	4.93	5.78	-0.85	-17.26	3.40	68.90
	10.00-19.99K	394	12.61	9.78	2.84	22.49	5.34	42.37
	20.00-29.99K	28	22.36	11.61	10.75	48.08	12.81	57.29
	30.00-39.99K	10	33.50	20.90	12.60	37.61	16.22	48.43
	Subtotal:	***2,201***	***6.66***	***6.64***	***0.02***	***0.27***	***4.20***	***63.14***
Collectors	1.00-9.99K	1,572	3.84	3.71	0.13	3.37	2.77	72.29
	10.00-19.99K	175	12.63	7.35	5.27	41.76	7.08	56.07
	20.00-29.99K	29	21.72	14.00	7.72	35.56	12.29	56.58
	Subtotal:	***1,776***	***4.99***	***4.23***	***0.76***	***15.22***	***3.77***	***75.48***
Expressways	1.00-9.99K	18	7.00	9.78	-2.78	-39.68	4.00	57.14
	10.00-19.99K	76	15.00	17.41	-2.41	-16.05	6.78	45.17
	20.00-29.99K	106	24.52	28.96	-4.44	-18.12	9.41	38.38
	30.00-39.99K	46	33.61	33.11	0.50	1.49	8.52	25.36
	40.00-49.99K	6	43.67	39.00	4.67	10.69	6.63	15.19
	50.00-59.99K	10	53.60	46.20	7.40	13.81	8.34	15.56
	Subtotal:	***262***	***23.70***	***25.91***	***-2.21***	***-9.33***	***8.16***	***34.45***
Ramp	1.00-9.99K	1	9.00	13.00	-4.00	-44.44	4.00	44.44
	10.00-19.99K	3	17.00	33.00	-16.00	-94.12	19.66	115.67
	20.00-29.99K	4	24.00	42.00	-18.00	-75.00	18.01	75.06
	30.00-39.99K	1	33.00	13.00	20.00	60.61	20.00	60.61
	40.00-49.99K	1	46.00	43.00	3.00	6.52	3.00	6.52
	Subtotal:	***10***	***23.50***	***33.60***	***-10.10***	***-42.98***	***16.98***	***72.25***
Grand Total		***11,236***	***18.01***	***18.89***	***-0.88***	***-4.89***	***8.53***	***47.36***

Note:

$$RMSE = \sqrt{\frac{\sum (ObsCount - SimCount)^2}{n}}$$

where n= the number of observations in each facility type / volume range group

Source: rmse.s

Table 5C
2000 RMSE Difference Statistics
(ICC - Base)

Facility Type	Volume Range	Links Count	Ave Obs Volume	Ave Est Volume	Diff. (Obs-Est)	Pct Diff.	RMSE	Pct RMSE
Freeways	1.00-9.99K	1	-0.21	0.53	-0.74	-12.85	-0.18	2.37
	10.00-19.99K	-12	0.04	-0.44	0.49	3.36	0.60	3.45
	20.00-29.99K	-4	-0.32	-1.05	0.72	2.16	0.31	2.17
	30.00-39.99K	25	0.07	-3.58	3.65	10.42	-2.90	-8.30
	40.00-49.99K	36	0.22	-5.01	5.23	12.00	-4.71	-10.93
	50.00-59.99K	17	0.03	-6.65	6.68	12.34	-4.97	-9.19
	60.00-69.00K	-2	0.26	-6.40	6.67	10.31	-1.84	-2.96
	70.00-79.00K	3	0.05	-5.21	5.26	7.12	-4.10	-5.56
	80.00-89.99K	9	0.33	-5.56	5.89	6.96	-6.25	-7.45
	90.00-99.99K	-20	-0.12	-13.14	13.02	13.70	-0.32	-0.30
	100.00-109.99K	12	-0.22	-11.86	11.65	11.14	-2.21	-2.09
	110.00-119.99K	2	0.27	-13.92	14.19	12.29	-3.88	-3.41
	120.00-129.99K	-4	-0.72	-10.63	9.92	8.04	3.94	3.28
	130.00-139.99K	-8	1.64	-10.94	12.58	8.78	8.66	5.92
	Subtotal:	**55**	**-0.94**	**-6.65**	**5.72**	**9.29**	**-2.36**	**-3.41**
Maj Arterials	1.00-9.99K	22	0.01	-0.76	0.77	11.97	-0.83	-12.87
	10.00-19.99K	64	-0.02	-1.32	1.30	9.08	-1.03	-7.13
	20.00-29.99K	-58	-0.03	-2.15	2.12	8.96	-0.42	-1.75
	30.00-39.99K	-23	-0.10	-1.78	1.68	5.24	0.99	3.15
	40.00-49.99K	-2	-0.02	-4.66	4.64	10.87	1.40	3.32
	50.00-59.99K	-4	0.33	-2.25	2.58	4.64	0.04	-0.19
	Subtotal:	**-1**	**-0.26**	**-1.57**	**1.31**	**8.09**	**-0.71**	**-3.73**
Minor Arterials	1.00-9.99K	37	0.02	-0.09	0.10	2.14	-0.08	-1.90
	10.00-19.99K	-4	-0.13	-0.10	-0.01	0.10	-0.07	-0.12
	20.00-29.99K	-9	-0.34	-1.04	0.70	3.79	-0.27	-0.31
	30.00-39.99K	2	-1.50	-0.10	-1.40	-2.39	-0.45	0.81
	Subtotal:	**26**	**-0.10**	**-0.13**	**0.03**	**0.49**	**-0.15**	**-1.23**
Collectors	1.00-9.99K	-62	0.08	-1.20	1.28	33.88	-0.46	-13.56
	10.00-19.99K	-26	0.30	-2.99	3.27	25.58	1.49	10.71
	20.00-29.99K	-3	0.03	-0.78	0.81	3.72	0.17	0.68
	Subtotal:	**-91**	**0.00**	**-1.43**	**1.43**	**28.67**	**-0.10**	**-2.15**
Expressways	1.00-9.99K	-8	0.15	-2.07	2.22	33.35	-2.64	-39.92
	10.00-19.99K	-14	-0.44	-2.82	2.38	14.96	-1.44	-8.05
	20.00-29.99K	-22	0.02	-1.56	1.58	6.47	-0.25	-1.04
	30.00-39.99K	-40	-0.76	-0.87	0.10	0.34	-0.68	-1.40
	40.00-49.99K	-38	-1.10	5.36	-6.47	-14.18	-7.27	-15.85
	50.00-59.99K	-18	-0.69	11.66	-12.35	-22.57	-13.41	-24.50
	Subtotal:	**-140**	**-4.04**	**-2.46**	**-1.58**	**-7.04**	**-2.79**	**-5.02**
Ramp	1.00-9.99K	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	10.00-19.99K	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	20.00-29.99K	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	30.00-39.99K	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	40.00-49.99K	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Subtotal:	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Grand Total		**-141**	**-0.19**	**-1.69**	**1.50**	**8.20**	**-0.91**	**-4.55**

Note:

$$RMSE = \sqrt{\frac{\sum (ObsCount - SimCount)^2}{n}}$$

where n= the number of observations in each facility type / volume range group

Source: rmse.s

Note: The Grand total includes Ramps.

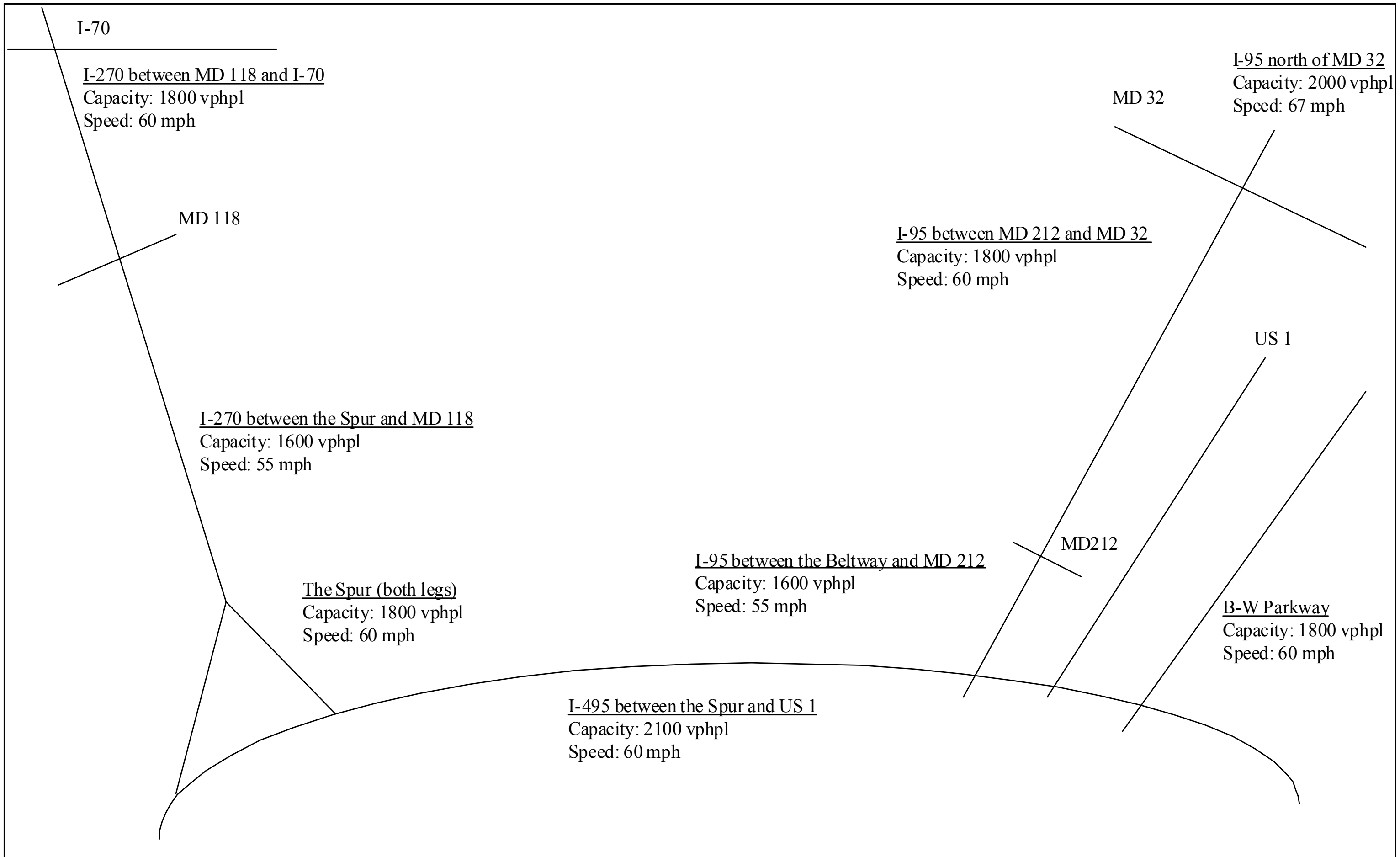


Figure 1. Freeway Speed and Capacity Assumptions in 2000 ICC Validation

ATTACHMENT

Table 1. Version 2.1/TP+ Freeflow Speed (mph) Table

	Facility Type						
	Centroids	Freeway	Major Art	Minor Art	Collector	Expressway	Ramp
Area Type	(FT=0)	(FT=1)	(FT=2)	(FT=3)	(FT=4)	(FT=5)	(FT=6)
1	15	65	35	30	25	60	65
2	15	65	40	35	35	60	65
3	20	70	40	35	35	65	70
4	25	70	45	40	35	65	70
5	30	70	50	40	40	65	70
6	30	70	50	45	40	65	70
7	35	70	50	45	40	65	70

Table 2. Final Freeflow Speed (mph) Table for ICC Study

	Facility Type						
	Centroids	Freeway	Major Art	Minor Art	Collector	Expressway	Ramp
Area Type	(FT=0)	(FT=1)	(FT=2)	(FT=3)	(FT=4)	(FT=5)	(FT=6)
1	15	55	25	20	15	45	55
2	15	55	25	20	15	45	55
3	20	60	35	30	20	50	60
4	25	60	35	30	20	50	60
5	30	67	40	35	25	50	67
6	30	67	45	40	30	55	67
7	35	67	45	40	30	55	67

*I-270 between the Spur and MD 118 has a special speed code 71 with 55 mph
**I-270 between MD 118 and I-70 has a special speed code 72 with 60 mph
***BW Parkway has a special speed code 72 with 60 mph
****I-95 between I-495 and MD 212 has a special code 73 with 55 mph

Table 3. Version 2.1/TP+ LOS 'E' Capacity (veh/lane/hr) Table

	Facility Type						
	Centroids	Freeway	Major Art	Minor Art	Collector	Expressway	Ramp
Area Type	(FT=0)	(FT=1)	(FT=2)	(FT=3)	(FT=4)	(FT=5)	(FT=6)
1	3,150	1,500	800	400	300	900	1,500
2	3,150	1,600	900	500	400	1,000	1,600
3	3,150	2,000	1,000	700	500	1,000	2,000
4	3,150	2,000	1,200	800	700	1,200	2,000
5	3,150	2,100	1,500	900	700	1,500	2,100
6	3,150	2,100	1,500	900	700	1,500	2,100
7	3,150	2,200	1,500	1,000	800	1,500	2,200

Table 4. Final LOS 'E' Capacity (veh/lane/hr) Table for ICC Study

	Facility Type						
	Centroids	Freeway	Major Art	Minor Art	Collector	Expressway	Ramp
Area Type	(FT=0)	(FT=1)	(FT=2)	(FT=3)	(FT=4)	(FT=5)	(FT=6)
1	3,150	1,500	800	500	300	900	1,500
2	3,150	1,600	800	600	400	1,000	1,600
3	3,150	1,800	960	700	500	1,000	1,800
4	3,150	1,800	960	840	700	1,200	1,800
5	3,150	2,000	1,260	1,000	700	1,500	2,000
6	3,150	2,000	1,260	1,000	700	1,500	2,000
7	3,150	2,100	1,260	1,000	800	1,500	2,100

*I-270 between spur and MD 118 has a special capacity code 71 with 1,600 vphpl

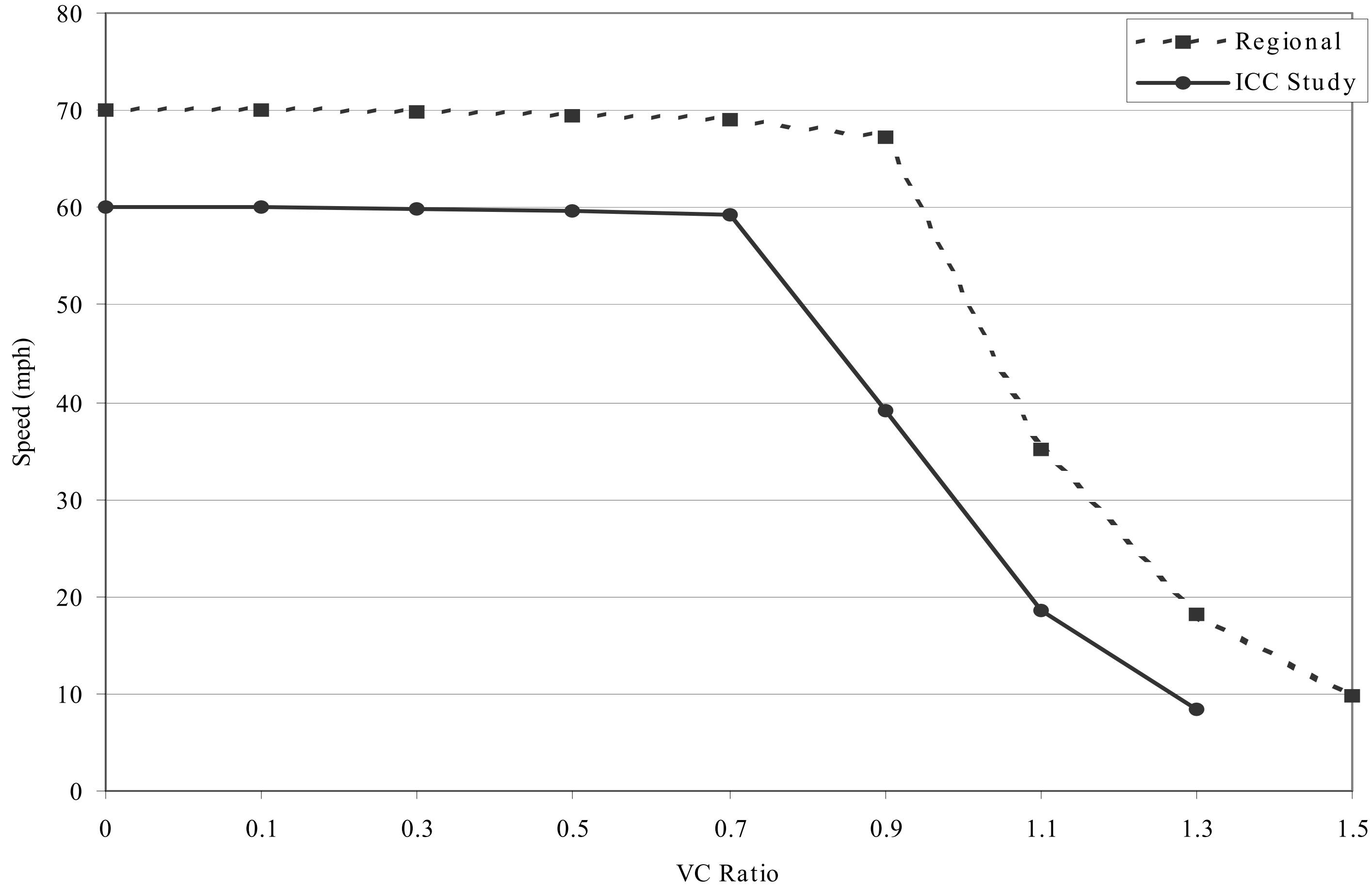
**I-270 between MD 118 and I-70 has a special capacity code 72 with 1,800 vphpl

***I-95 between I-495 and MD 32 and BW Parkway have a special capacity code 72 with 1,800 vphpl

****I-495 from the Spur to US 1 has a special capacity code 92 with 2,100 vphpl

*****I-95 between I-495 and MD 212 has a special code 73 with 1,600 vphpl

Figure 2. Speed/VC Ratio Relationship: Regional Vs. ICC Study
Freeway, Area Type 3



Appendix B
(continued)

Highway and Transit Validation

- October 7, 2003 letter from Thomas Harrington (Washington Metropolitan Area Transit Authority) to Ronald Kirby, regarding comments on TRB review of MWCOG travel demand modeling procedures.

October 7, 2003

Mr. Ron Kirby
Director, Department of Transportation Planning
Metropolitan Washington Council of Governments
777 N. Capitol Street, N.E., Suite 300
Washington, DC 20002

RE: Comments on TRB Review of MWCOG Travel Demand Modeling Procedures

Dear Mr. Kirby:

WMATA has received a copy of the report released September 8, 2003 by the TRB review committee on travel demand modeling in the Washington region, as well as the accompanying response letter by TPB staff on issues raised in the review. As an important stakeholder in the TPB process, WMATA appreciates this opportunity to comment on the findings of the review committee and the overall structure of the COG/TPB Version 2.1C travel demand model.

There are two areas that WMATA believes should have received more attention in the TRB review:

1. Travel modeling procedures for transit forecasts and validation.

2. Application of the model for corridor studies, especially as part of the FTA Project Planning process.

These two areas are discussed in more detail below. In general, the TPB model development process needs to focus more attention on supporting project planning studies conducted around the region

1. <u>Transit Modeling</u>

The TRB Committee provided observations on a number of features of the Version 2.1 model including model validation, representation of travel times including feedback, the use of adjustment factors, and post-processing procedures for estimating mobile emissions. However, the Committee did not discuss one significant omission of the current model – the lack of a transit assignment component or any working procedures for forecasting transit ridership at the corridor, route, and station level.

Your comments at the September 26th Travel Forecasting Subcommitte meeting suggest that this is a priority area for further improvement of the model. WMATA requests that the development of working transit assignment procedures be among the first refinements to be made to the model in your work plan.

The next few sections provide specific aspects of the model that WMATA believes may need to be reviewed and refined for the purpose of improving transit forecasts.

A. Representation of Transit Service

The TRB letter did provide some comments on the representation of transit service in the model, specifically the calculation of bus travel times using fixed speeds (Principal Observation #6). WMATA supports further investigation of this practice and agrees that the model should attempt to account for the impact of highway congestion on bus speeds. WMATA will gladly coordinate with TPB staff to review assumptions and provide inputs for transit network coding.
There are other issues related to the representation of transit service levels and travel times that were not raised in the TRB review but WMATA would like to see considered in the model improvement work plan:

- Consistent treatment of travel time weights through all steps of the model;
- Updated procedures for calculation of bus and rail fare matrices to allow for analysis of current and proposed fare structures and policies;
- More sophisticated treatment of auto access to rail including:

% The ability to constrain parking at park-and-ride lots, including Metrorail stations;
% Inclusion of parking costs at park-and-ride lots; and
% More flexible coding of drive-access links from traffic zones to rail

stations. Rail station access connectors are currently coded for set distance rings from the station, but survey data show that end-of the line stations serve a bigger travel shed than the 5-mile and 8-mile limits imposed by the TPB model. In general, the use of constraints ("cliffs") as a method for designing auto access to rail connections is not as desirable as the use of continuous impedance functions.

B. Mode Choice Model and Sub-Models

The current model structure does not allow for explicit calibration of transit trips by sub-mode and mode of access. Previous versions of the TPB model on the MINUTP platform included sub-mode-choice models that are missing from the latest Version 2.1 release on the TP+ platform. These sub-models include:

- Sub-mode choice model to split transit into Metrorail and non-Metrorail by access type (walk- and auto- access); and
- Mode of arrival model used to apportion Metrorail trips by arrival modes (walk, bus, auto-pass., and auto-driver) and stations.

In the short-term, WMATA supports the implementation of these procedures in TP+ for use in estimating rail and bus trips. A lonF-term plan for improving the mode choice model should consider a nested model structure that would explicitly break out rail from bus trips to better reflect modal characteristics in the mode choice step. WMATA realizes that making structural changes to the mode choice model would require a significant level of effort. A further challenge is representing new modes, such as BRT, that have characteristics somewhere between rail and local bus.

C. Model Validation

The December 2002 Calibration Report for the Version 2.1C model does not provide sufficient detail to assess the ability of the model to estimate and forecast demand for transit service. On page 11 of the TRB letter, the Committee notes *"The goodness of fit for transit passenger volumes is normally conducted in more detail than systemwide averages and cordon crossings. Additional comparisons by subarea, district interchange, corridor, and rail line* *and station are typically performed to ensure that usage, trip distribution, and travel patterns by transit are reliably replicated by the model for regional planning purposes. The committee is concerned with the performance of the model with respect to transit estimates and validation."*

WMATA agrees with the Committee's finding that there is a need for more detailed validation of the model's ability to replicate transit demand. This will require the region to collect additional base year data on transit usage for detailed market segments. Recent technological improvements such as the use of electronic fare media and GPS on bus routes will allow for easier collection of data on bus boardings and transfers.

2. <u>Application for Corridor Studies</u>

A number of upcoming corridor studies of interest to WMATA will need to produce transit ridership and user benefits forecasts including the D.C. Alternatives Analysis, Bi-County Transitway DEIS, and the Columbia Pike Transitway study. It is imperative that the review agencies and the public have confidence in the ability of the travel models to forecast demand for new facilities. To that end, WMATA would welcome the opportunity to provide assistance to TPB staff to improve transit forecasting capabilities.

The calculation of accurate estimates of travel times and person trips is more important than ever now that FTA has endorsed the use of the SUMMIT post-processing tool for New Starts evaluation. Implementation of SUMMIT does not necessarily require structural changes to the TPB model, but it does place increased scrutiny on the underlying assumptions and procedures. For example, calculation of travel time savings depends on the ability of the model to produce reliable estimates of bus travel times.

In presentation materials prepared for the 2003 Transportation Users Benefits Workshops, FTA lists a number of common issues with models that have lead to problems with calculating user benefits including:

- Accuracy of bus running times;
- Stability of highway assignment results; and
- Counter-intuitive trip table changes.

The TRB letter provided examples of measures that should be used in testing future transportation scenarios to assess the model's ability to predict future travel. Measures listed on page 8 of the TRB report include:

- *Rates of change in transit boardings by line compared with historical rates of change,*
- *Rates of change in highway link volumes and speeds compared to historic rates of change,*
- *Changes in mode shares compared with historic mode shares, and*
- *Transit line volumes and park-and-ride lot usage compared with estimated capacities.*

Further investigation is needed to determine the sensitivity of the TPB model to changes in transit service, especially sensitivity to changes in bus speeds, headways, and fares. The calibration report should be expanded to include a range of sensitivity tests. One possibility would be to show how the model responds when a major fixed-guideway transit project is added to the regional transportation network.

Next Steps

The TRB review process has been helpful in focusing attention on critical assumptions inherent to the modeling process that may not have been understood by the public. The review has also highlighted a number of aspects of the current travel forecasting process that are commendable, particularly the participation of local agencies in the Travel Forecasting Subcommittee.

The second phase of the TRB review, which will produce a work plan for travel model improvements, presents an excellent opportunity to improve transit forecasting capabilities. Development of travel forecasting procedures for the Washington region that are responsive to the needs of member agencies will require a continuous dialogue about the structure and performance of the models.

We look forward to working with you on improving the region's travel forecasting models.

Sincerely,

Thomas K. Harrington, Program Manager
Office of Business Planning and Project Development

cc: Jim Hogan, MWCOG/TPB
Ron Milone, MWCOG/TPB

Appendix C

An executive summary for each of the following reports is included in this appendix:

Development of Commercial Vehicle Travel Model; and

Development of Truck Models.

Both were prepared for the Baltimore Metropolitan Council by William G. Allen, Jr., P.E. on July 29, 2002. Full documentation of each is being transmitted separately.

Development of Commercial Vehicle Travel Model

Prepared for

Baltimore Metropolitan Council
Baltimore, Maryland

Prepared by

William G. Allen, Jr., P.E.
Transportation Consultant
Mitchells, Virginia

29 July 2002

Executive Summary

This report documents the development of a new set Commercial trip forecasting model for the Baltimore Metropolitan Council (BMC). BMC, along with many other agencies, has included trucks in its regional modelling for many years. However, it has not specifically included a fairly important category of non-personal travel that uses passenger cars, light trucks, and other vehicles not included in the "Truck" model. BMC recently retained a consultant to develop a new set of Medium and Heavy Truck trip models. As part of this effort, a completely new Commercial trip model has also been developed.

The principal challenge in estimating Commercial trips is to define them and obtain any kind of data on observed trip patterns. Traditional surveys are unlikely to be useful, so the consultant and staff devised an innovative way to estimate Commercial vehicle counts at those locations where Maryland DOT classification count data already existed.

The consultant has refined the practical application of a methodology to synthesize a trip table from count data. Working "backwards" from the count data, the consultant not only created such a trip table, but then used it to develop a Commercial trip forecasting model that would produce link-level volumes with reasonable accuracy.

BMC staff conducted new manual counts at a representative sample of locations throughout the region. They used this to create a database of various link characteristics. The consultant used this database to calibrate a "count model", which was then applied to synthesize daily Commercial counts at the 550+ classification count locations for 2000.

A Commercial model from the Lehigh Valley (PA) was adapted as a starting point. The consultant then applied a procedure called "adaptable assignment" to systematically adjust the interim model so as to better match the counts. This process resulted in a number of changes to the interim model and also produced a calibration adjustment table. This adjustment table is then multiplied by the output of the model, producing a new table whose assignment comes much closer to matching the count data.

The result is a process that both exhibits reasonable sensitivities to the key input variables (employment by type and households) and has been shown to match the synthesized counts to a fairly high degree of accuracy. A 2025 forecast was made with this new process and the results found to be reasonable. The consultant has also provided the staff with a set of TP+ setups with which to apply the new model.

Development of Truck Models

Prepared for

Baltimore Metropolitan Council
<u>Baltimore, Maryland</u>

Prepared by

William G. Allen, Jr., P.E.
Transportation Consultant
Mitchells, Virginia

29 July 2002

Executive Summary

This report documents the development of a new set of regional truck trip forecasting models for the Baltimore Metropolitan Council (BMC). BMC, along with many other agencies, has been using truck trip estimates that are based on data that is more than 30 years old. Given a renewed interest in air quality, and goods movement as part of intermodal planning, the agency has decided to update its truck models.

The difficulty in truck modelling is that good data on observed trip patterns is very rare. A truck survey recently conducted jointly with the Metropolitan Washington Council of Governments did not produce the kind of information that is usable for model development.

However, there were some fairly reliable Maryland DOT counts of truck volumes on numerous links in the Baltimore region. BMC engaged the services of a consultant who has pioneered the practical application of a methodology to synthesize a trip table from count data. Working "backwards" from the count data, the consultant not only created such a trip table, but then used it to develop a truck trip forecasting model that would produce link-level truck volumes with much improved accuracy. This effort was aided by extensive nationwide truck trip research recently published by the Transportation Research Board and USDOT's Travel Model Improvement Program.

BMC staff assembled year 2000 medium and heavy truck counts on a few hundred links across the modelled region. The consultant researched the literature to develop a new, interim set of generation/distribution/assignment models for both truck types. The consultant then applied a procedure called "adaptable assignment" to systematically adjust the interim model so as to better match the counts. This process resulted in a number of changes to the interim model and also produced a set of "calibration adjustment" factors. These adjustment factors are then multiplied by the output of the model, producing a new table whose assignment comes much closer to matching the count data. In addition, the consultant developed an improved method of modelling external and through truck travel. Separate models were developed for medium and heavy truck trips. The consultant also created a new model to estimate commercial light-duty vehicle trips, as documented in a separate report.

The result is a process that both exhibits reasonable sensitivities to the key input variables (employment by type and households) and has been shown to match 2000 counts to a fairly high degree of accuracy. A 2025 forecast was made with this new process and the results found to be reasonable. The consultant has also provided the staff with a set of TP+ setups with which to apply the new models.

Appendix D

Use of Adjustment Factors in the Version 2.1C Model

Use of Adjustment Factors in the Version 2.1C Model

Introduction

December 12, 2003

This document describes some background information regarding the use and rationale of the technical adjustments employed in the Version 2.1/TP+, Release C model, currently under review by the TRB model review committee.
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The TRB Committee has commented in its first letter report that, "TPB's extensive use of adjustment factors in trip generation, trip distribution, and mode choice to enhance the match between simulated and observed base-year data undermines the fundamental behavioral logic of the four-step modeling process…" Given that models are only an approximation of reality, modeling adjustments are a requirement of the model development process. TPB staff is in agreement with the TRB committee that the extent to which adjustments are utilized is, in the committee's words, "a subject of active, continuing debate among modeling professionals."

TPB staff has recently begun a review of travel demand modeling practices at eleven major MPOs to assess the extent of modeling adjustments elsewhere. While the investigation is incomplete at this time, it is clear that a vast majority of the MPOs employ adjustment factors of one or more types in their travel demand modeling, and some apply them to a greater degree than is practiced in the TPB models.

The Version 2.1/TP+ model uses adjustments in the trip generation, trip distribution, and mode choice modeling steps. The reasons for using modeling adjustments are as follows:

1) Underreporting – In trip generation non-work person trip rates are factored by 1.50 to ensure that observed VMT will be matched by the simulation. The factor was determined by assigning observed vehicle trips from the survey to the network together with other travel markets (trucks, external, through vehicles, etc.) and comparing simulated vehicle miles with observed vehicle miles. Past experience has shown that surveyed trips require upward adjustments to account for underreporting in order to achieve a reasonable match with observed ground counts.

2) Aggregation error – TPB's trip production (cross-classification) models are developed at the sampled household level. When disaggregate rates are applied to aggregate zonal households, there is no guarantee that modeled productions will match weighted person trips. Therefore, sub-area adjustments are both common and necessary. The mode choice models are also subject to aggregation error. TPB has historically treated this type of error with adjustments to superdistrict-based or jurisdiction-based interchanges.

3) Limitations of Explanatory Variables - No model can adequately describe human behavior when the means to do so essentially is limited to depictions of travelers' time and cost. To more adequately represent behavior, it is necessary to account for other factors through adjustment of travel demand models. K-factors and time penalties (both of which are used in the trip

distribution process) address this problem. The trip patterns in Washington are difficult to capture within a gravity model framework even when the trip distribution model is applied on an income-stratified basis. The trip patterns are influenced by location decisions which reflect housing prices, job locations of two-income households, the desire to locate near an HOV lane or transit line, and other factors. Trip patterns are also affected by numerous special generators that exist in the region, including military installations, three major airports, and large-scale retail centers. Most problematic is the presence of the Baltimore region just to the northeast of the modeled study area.

4) Limited Geographic Scope of the Household Travel Survey

The COG/TPB 1994 Household Travel Survey (HTS) was the primary travel survey supporting the Version 2.1 model. The survey area comprised 13 of the 22 major jurisdictions in the modeled area, including TPB member governments. A variety of alternate data sources were consulted to arrive at observed highway and transit data for areas beyond the HTS area, including the 1993 Baltimore Household Travel Survey (BTS) and available transit counts. Given the size and complexity of the study area, and the fact that observed data was assembled in a 'patchwork' manner, staff anticipated that model adjustments would need be necessary. The sections which follow describe the rationale TPB employed in developing travel demand models to meet the needs of the EPA-designated non-attainment region.

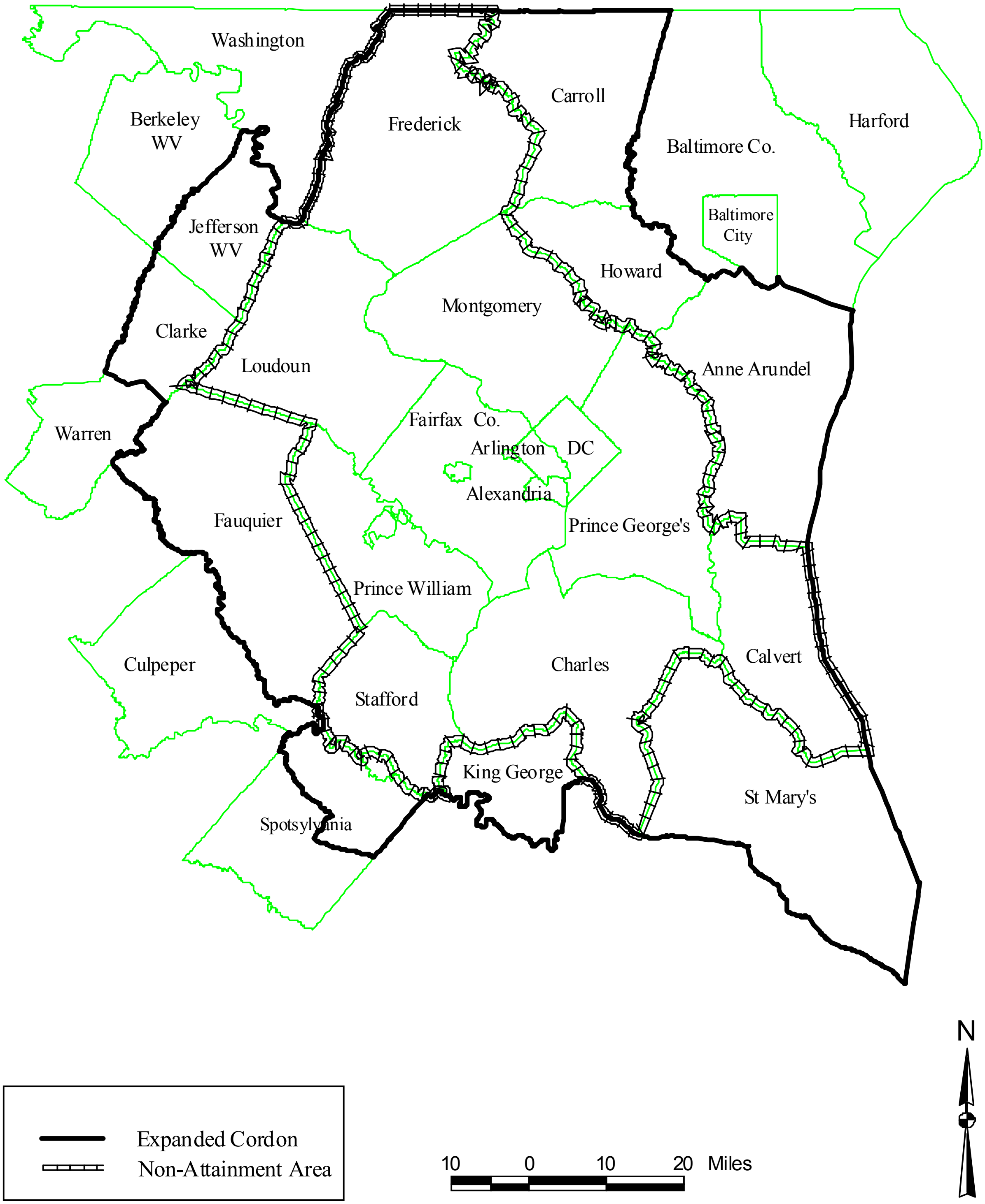
EPA-mandated non-attainment boundary and the TPB expanded cordon

Shown in Figure 1 is a map depicting both the EPA-mandated non-attainment boundary and the TPB expanded cordon for travel demand modeling. In addition to the TPB member governments the non-attainment boundary includes Calvert County in Maryland and Stafford County in Virginia. When performing updates to the TIP and Plan, estimates of vehicle miles of travel and levels of mobile emissions are required for travel within this boundary, even though the two added counties are outside the TPB boundary.

The boundary for the expanded cordon was constructed to provide a buffer between the external boundary of the modeling area and the EPA-mandated non-attainment boundary. The logic is that modeling "noise" increases near the boundary of any area being modeled, and TPB staff sought to minimize the noise occurring within the non-attainment area boundary. With the concurrence of the TPB Travel Forecasting Subcommittee the expanded cordon for travel demand modeling depicted in Figure 1 was adopted in 1994. It is noted during the TPB staff's review of modeling in eleven major metropolitan areas that, with the possible exception of Seattle, no other region in the group of eleven investigated appears to have adopted this "expanded cordon" approach to travel demand modeling.

TPB staff has found that some adjustment of the travel demand model, calibrated largely with data from within the TPB member jurisdictions, is required to both simulate and forecast travel

Figure 1
Expanded Cordon Region



within the expanded cordon. Adjustments to the travel demand model have occurred in four distinct areas: 1) application of trip generation rates developed at the sampled household level to produce aggregated estimates; 2) the use of superdistrict level time penalties in the trip distribution model estimation to account for income bias in travel patterns; 3) the use of K-factors in trip distribution model application to account for historical patterns and special generators, as well as the influence of jurisdictions in the Baltimore region; and 4) the adjustment needed to apply the disaggregate mode choice models in production mode. Each of these sets of adjustments is described in the sections which follow.

Trip Generation Calibration

The TPB Version 2.1C travel demand model employs a series of post-trip generation production modification factors and attraction modification (p-mod and a-mod) factors based on a 36 superdistrict system shown as Figure 2. An adjustment of some type was deemed necessary after applying the model (unfactored) and reviewing estimated and observed productions and attractions at the county level. Given that the distribution model is applied on an income-level basis, a factoring scheme based on income levels and superdistricts was decided to be optimal. Attempts were made to keep factors between 0.5 and 2.0, but in some rare cases this range was violated. Adjustment factors for HBW, HBS, HBO, and NHB trip purposes are displayed in Tables 1-4, respectively.

It should be pointed out that the factors were not produced in a mechanical way, but rather were developed after several iterations of the trip generation model were executed and analyzed.

Figure 2
Superdistrict Area System
Used in the
Version 2.1/TP+, Release C
Trip Generation Calibration

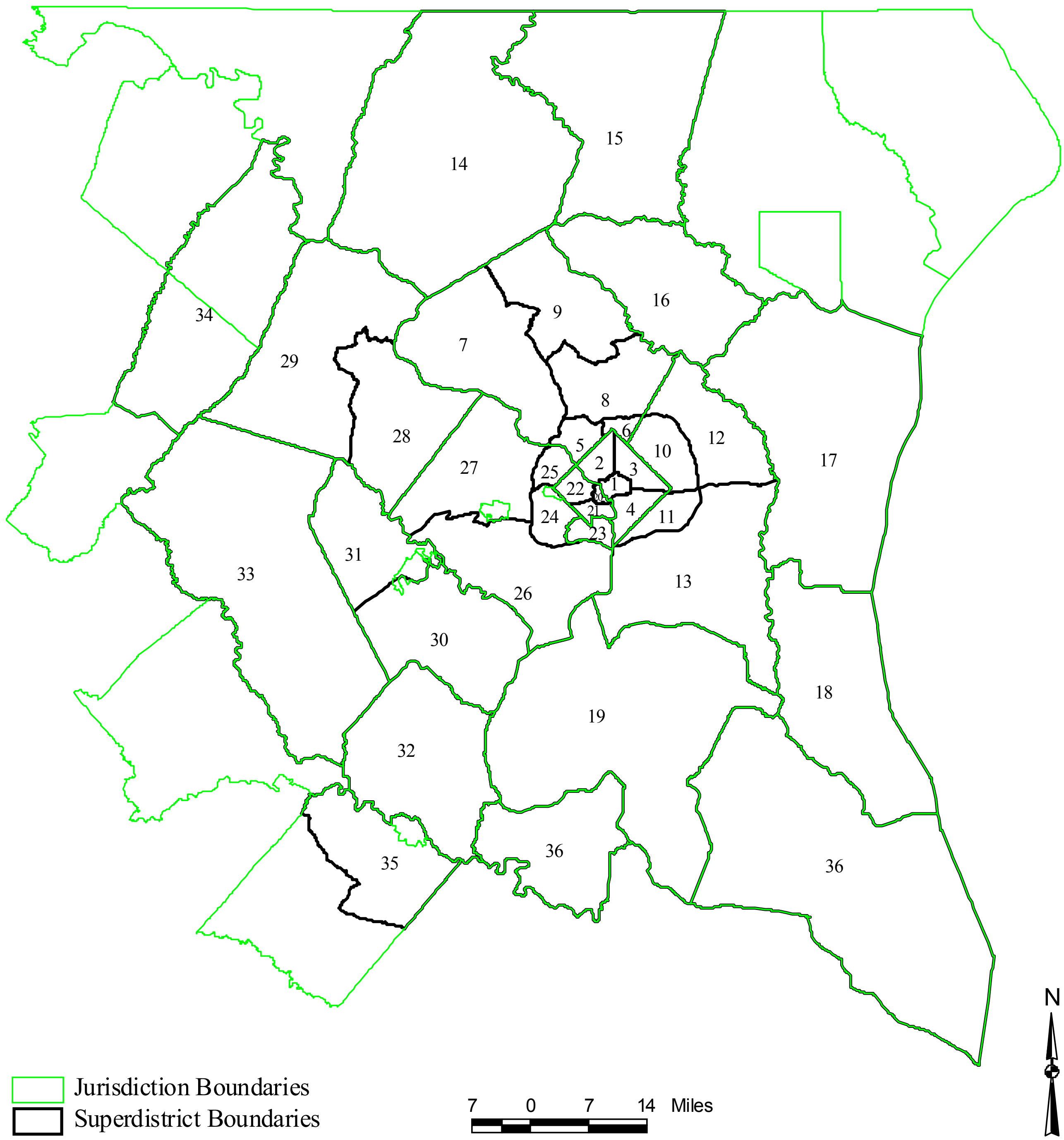


Table 1

HBW Trip Generation Adjustment Factors by Income Group

Superdistrict Number	Superdistrict Area	Production				Attraction			
		Income 1	Income 2	Income 3	Income 4	Income 1	Income 2	Income 3	Income 4
1	DC core	1.51	1.00	1.00	2.85	1.14	1.00	1.05	1.08
2	DC ncore NW	1.00	1.00	1.00	2.82	1.84	1.00	1.00	1.00
3	DC ncore NE	1.00	0.58	1.00	1.65	1.58	1.00	0.59	0.51
4	DC ncore SW	0.61	0.40	1.00	1.42	1.27	1.29	1.27	1.35
5	Mtg. IBelt W.	1.00	1.00	1.00	0.91	1.00	0.80	0.72	0.87
6	Mtg. IBelt E.	1.00	0.50	1.54	2.02	1.00	1.00	0.37	1.00
7	Mtg. OBelt W.	1.00	0.64	1.00	1.00	0.51	1.00	1.00	1.00
8	Mtg. OBelt E.	1.00	0.63	0.92	0.95	0.54	0.67	0.87	0.83
9	Mtg. OBelt N.	0.61	1.27	1.63	1.34	0.38	0.61	0.68	1.00
10	PG IBelt N.	0.71	0.81	1.00	1.00	1.00	1.00	1.00	0.54
11	PG IBelt S.	1.32	0.68	1.00	1.00	1.00	1.28	0.43	0.54
12	PG OBelt N.	1.17	1.58	1.35	0.77	1.00	0.80	1.00	0.61
13	PG OBelt S.	1.11	1.00	1.49	1.00	1.27	1.00	1.00	1.00
14	Frederick	0.75	1.00	1.46	1.00	1.00	1.30	1.24	1.00
15	Carroll	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
16	Howard	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
17	Anne Arundel	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
18	Calvert	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
19	Chs/StM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	Arl. core	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.54
21	Arl. ncore S.	1.00	0.66	1.00	1.00	0.37	1.44	1.33	1.18
22	Arl. ncore N.	1.77	1.00	1.22	1.89	1.00	1.00	1.00	1.32
23	Alexandria	1.37	0.71	1.25	1.64	1.00	1.00	1.00	1.00
24	FFX IBelt S.	1.00	0.70	0.81	1.00	1.00	1.00	0.71	1.00
25	FFX IBelt N.	1.00	1.00	0.41	1.00	1.00	1.00	1.00	2.03
26	FFX OBelt S.	0.75	0.78	1.28	1.25	1.00	1.00	1.00	1.36
27	FFX OBelt N.	1.82	0.78	1.13	1.19	0.83	0.78	0.86	1.24
28	Loudoun E.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.91
29	Loudoun W.	2.47	1.00	1.00	1.00	1.00	1.00	1.00	1.00
30	PW S.	1.00	1.00	1.14	1.24	1.00	1.00	1.00	1.00
31	PW N.	1.00	1.00	0.53	1.00	0.30	1.00	0.44	0.67
32	Stafford	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
33	Fauquier	1.00	0.59	1.00	1.00	1.00	1.00	1.00	1.00
34	Clk./Jeff.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
35	Spots./Frbg.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
36	KGeo.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
37	Ext./Unused	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 2

HBS Trip Generation Adjustment Factors by Income Group

Superdistrict Number	Superdistrict Area	Production				Attraction			
		Income 1	Income 2	Income 3	Income 4	Income 1	Income 2	Income 3	Income 4
1	DC core	0.32	0.29	1.00	1.00	1.00	1.00	0.60	0.39
2	DC ncore NW	1.08	0.71	1.15	2.08	1.00	1.00	1.00	2.04
3	DC ncore NE	0.76	0.52	1.00	1.00	1.00	0.34	0.29	0.12
4	DC ncore SW	1.00	0.34	0.50	1.00	1.00	1.00	0.39	0.43
5	Mtg. IBelt W.	2.31	1.00	2.01	1.00	1.00	1.00	1.00	2.29
6	Mtg. IBelt E.	1.00	1.00	3.09	1.00	1.00	1.00	1.00	1.00
7	Mtg. OBelt W.	1.00	1.00	1.00	1.00	1.00	1.00	1.47	1.97
8	Mtg. OBelt E.	1.93	0.57	1.47	1.00	1.59	0.64	1.53	1.27
9	Mtg. OBelt N.	1.73	1.96	1.55	1.00	1.43	2.27	1.37	1.00
10	PG IBelt N.	1.00	1.00	1.00	1.00	1.60	1.00	0.63	0.35
11	PG IBelt S.	0.69	0.56	1.00	0.10	1.00	1.00	0.62	0.13
12	PG OBelt N.	1.49	1.88	1.53	0.75	1.00	2.18	1.00	1.00
13	PG OBelt S.	1.00	0.65	1.68	1.00	1.00	1.00	1.56	0.50
14	Frederick	1.00	0.85	1.00	1.00	1.00	1.00	1.00	1.00
15	Carroll	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
16	Howard	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
17	Anne Arundel	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
18	Calvert	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
19	Chs/StM	1.00	1.00	1.00	1.00	1.00	0.67	1.00	1.00
20	Arl. core	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
21	Arl. ncore S.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00
22	Arl. ncore N.	1.00	1.00	1.00	1.00	2.10	2.55	1.36	2.48
23	Alexandria	1.00	1.00	1.00	1.56	1.00	1.00	1.00	1.00
24	FFX IBelt S.	1.00	1.00	1.00	1.00	1.00	1.00	0.65	0.78
25	FFX IBelt N.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
26	FFX OBelt S.	0.40	1.00	1.73	1.03	0.47	1.00	1.42	1.54
27	FFX OBelt N.	1.00	1.00	1.74	1.54	0.44	0.82	1.00	1.49
28	Loudoun E.	1.00	0.72	1.00	1.00	1.00	1.00	1.00	1.00
29	Loudoun W.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
30	PW S.	0.37	1.00	1.54	1.36	0.31	1.00	1.53	1.00
31	PW N.	1.00	1.00	1.00	1.00	1.00	1.00	0.62	0.68
32	Stafford	1.00	1.00	1.00	1.48	1.00	1.00	0.49	1.00
33	Fauquier	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
34	Clk./Jeff.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
35	Spots./Frbg.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
36	KGeo.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
37	Ext./Unused	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 3

HBO Trip Generation Adjustment Factors by Income Group

Superdistrict Number	Superdistrict Area	Production				Attraction			
		Income 1	Income 2	Income 3	Income 4	Income 1	Income 2	Income 3	Income 4
1	DC core	1.00	0.38	0.49	0.67	1.07	0.63	0.62	0.76
2	DC ncore NW	1.00	1.00	1.45	2.95	1.29	1.68	1.10	1.76
3	DC ncore NE	1.00	0.61	1.00	1.00	1.88	1.19	0.50	0.44
4	DC ncore SW	1.00	0.33	1.00	1.00	1.51	1.00	0.51	0.34
5	Mtg. IBelt W.	1.00	1.46	1.40	1.00	1.00	1.16	1.81	1.91
6	Mtg. IBelt E.	1.00	1.00	1.00	1.00	1.00	1.00	0.86	0.78
7	Mtg. OBelt W.	1.00	0.65	1.00	1.48	1.00	1.00	0.73	1.61
8	Mtg. OBelt E.	1.35	0.49	1.20	1.00	1.00	0.72	1.17	1.10
9	Mtg. OBelt N.	1.00	1.42	1.98	1.00	1.00	1.55	1.67	1.33
10	PG IBelt N.	0.86	0.76	1.00	1.00	2.02	1.47	0.66	0.50
11	PG IBelt S.	0.81	0.57	1.00	0.35	1.00	1.00	0.69	0.27
12	PG OBelt N.	0.71	1.00	1.37	0.86	1.00	1.00	1.32	0.65
13	PG OBelt S.	1.00	1.08	1.54	0.67	1.36	1.31	1.28	0.70
14	Frederick	1.00	0.65	1.38	1.00	1.43	1.00	1.28	0.61
15	Carroll	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
16	Howard	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
17	Anne Arundel	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
18	Calvert	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
19	Chs/StM	1.00	0.82	1.00	1.00	1.00	1.41	1.14	0.76
20	Arl. core	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.68
21	Arl. ncore S.	1.00	0.48	1.00	1.88	1.00	1.00	0.61	0.85
22	Arl. ncore N.	3.22	0.70	1.00	1.68	2.35	1.00	1.00	1.83
23	Alexandria	1.00	0.50	1.00	1.00	0.50	1.00	1.15	0.89
24	FFX IBelt S.	1.00	0.41	1.00	1.33	1.55	1.00	1.00	1.20
25	FFX IBelt N.	1.00	1.00	0.38	1.00	1.00	1.00	1.00	1.88
26	FFX OBelt S.	1.00	0.45	1.24	1.00	0.49	0.59	1.13	1.35
27	FFX OBelt N.	1.00	0.72	1.10	1.21	0.57	0.64	0.82	1.69
28	Loudoun E.	1.00	1.00	0.70	1.00	1.00	1.00	1.00	1.55
29	Loudoun W.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
30	PW S.	1.00	0.63	1.00	1.39	1.00	1.00	1.00	1.00
31	PW N.	0.43	0.83	0.75	1.00	1.00	1.00	0.71	0.56
32	Stafford	1.00	0.69	0.74	1.00	1.00	1.00	1.00	0.72
33	Fauquier	0.42	1.00	0.68	1.00	1.00	1.00	0.57	0.55
34	Clk./Jeff.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
35	Spots./Frbg.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
36	KGeo.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
37	Ext./Unused	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 4

NHB Trip Generation Adjustment Factors by Income Group

Superdistrict Number	Superdistrict Area	Production				Attraction			
		Income 1	Income 2	Income 3	Income 4	Income 1	Income 2	Income 3	Income 4
1	DC core	1.06	1.00	1.00	1.00	1.06	1.00	1.00	1.00
2	DC ncore NW	1.11	1.00	1.00	1.00	1.11	1.00	1.00	1.00
3	DC ncore NE	0.74	1.00	1.00	1.00	0.74	1.00	1.00	1.00
4	DC ncore SW	0.65	1.00	1.00	1.00	0.65	1.00	1.00	1.00
5	Mtg. IBelt W.	1.08	1.00	1.00	1.00	1.08	1.00	1.00	1.00
6	Mtg. IBelt E.	0.78	1.00	1.00	1.00	0.78	1.00	1.00	1.00
7	Mtg. OBelt W.	1.25	1.00	1.00	1.00	1.25	1.00	1.00	1.00
8	Mtg. OBelt E.	1.14	1.00	1.00	1.00	1.14	1.00	1.00	1.00
9	Mtg. OBelt N.	1.34	1.00	1.00	1.00	1.34	1.00	1.00	1.00
10	PG IBelt N.	0.90	1.00	1.00	1.00	0.90	1.00	1.00	1.00
11	PG IBelt S.	0.69	1.00	1.00	1.00	0.69	1.00	1.00	1.00
12	PG OBelt N.	1.05	1.00	1.00	1.00	1.05	1.00	1.00	1.00
13	PG OBelt S.	1.22	1.00	1.00	1.00	1.22	1.00	1.00	1.00
14	Frederick	1.13	1.00	1.00	1.00	1.13	1.00	1.00	1.00
15	Carroll	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
16	Howard	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
17	Anne Arundel	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
18	Calvert	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
19	Chs/StM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	Arl. core	0.76	1.00	1.00	1.00	0.76	1.00	1.00	1.00
21	Arl. ncore S.	0.88	1.00	1.00	1.00	0.88	1.00	1.00	1.00
22	Arl. ncore N.	1.35	1.00	1.00	1.00	1.35	1.00	1.00	1.00
23	Alexandria	1.10	1.00	1.00	1.00	1.10	1.00	1.00	1.00
24	FFX IBelt S.	1.07	1.00	1.00	1.00	1.07	1.00	1.00	1.00
25	FFX IBelt N.	1.24	1.00	1.00	1.00	1.24	1.00	1.00	1.00
26	FFX OBelt S.	1.04	1.00	1.00	1.00	1.04	1.00	1.00	1.00
27	FFX OBelt N.	1.07	1.00	1.00	1.00	1.07	1.00	1.00	1.00
28	Loudoun E.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
29	Loudoun W.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
30	PW S.	0.93	1.00	1.00	1.00	0.93	1.00	1.00	1.00
31	PW N.	1.10	1.00	1.00	1.00	1.10	1.00	1.00	1.00
32	Stafford	0.62	1.00	1.00	1.00	0.62	1.00	1.00	1.00
33	Fauquier	0.63	1.00	1.00	1.00	0.63	1.00	1.00	1.00
34	Clk./Jeff.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
35	Spots./Frbg.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
36	KGeo.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
37	Ext./Unused	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Trip Distribution Adjustments

Two sets of adjustment factors were applied to the trip distribution model. The first set was a series of time penalties applied sparingly to a matrix of twelve superdistricts depicted in Figure 3. Time penalties were developed as an integrated part of the F-factor calibration process, using HTS data. These superdistricts generally represent one or more jurisdictions, excepting those defining the District of Columbia and Arlington County in which there are core and non-core delineations. The calibration involved running the model for several iterations, using a gamma distribution fitting technique to arrive at a 'smoothed' F-function, which allowed observed trip length profiles to be matched. Time penalties are used to address physical barrier effects on trip patterns and to address jurisdictional effects (e.g., school trips and shopping trips tend to remain in a given traveler's residence jurisdiction). The percentage of interchanges receiving time penalties applied by trip purpose were as follows:

HBW 7 to 12 percent
HBS 1 to 6 percent
HBO 8 to19 percent
NHB 32 percent

The listings of these time penalties for HBW, HBS, HBO, and NHB trip purposes are presented in Tables 5-8, respectively. The time penalties were not developed in a mechanical process' but were developed after running and rerunning the calibration process with different time penalty sets. An analysis of the results was conducted in between iterations.

A second set of adjustment factors was introduced during model application. Commonly referenced as K-factors, 68 individual values were introduced in the Version 2.1C model. Shown in Table 9 is a listing of these factors, and the breakdown by trip purpose is as follows:

HBW - 31 factors
HBS - 11 factors
HBO - 17 factors
NHB - 9 factors

K-factors were developed in the *application* of the model for the entire modeled area, after the F-factor calibration was completed. The K-factors were developed separately for each purpose, after several application iterations. Several points should be noted about these 68 factors. First, 18 are applied to jurisdictions which are within the modeled cordon but which lie outside the non-attainment boundary, principally, Anne Arundel, Howard, and Carroll Counties in the Baltimore suburbs. These counties were added together with others in Maryland, Virginia, and West Virginia for the express purpose of modeling an area greater than the non-attainment area. The network grain is much coarser in these outer jurisdictions compared to the grain within the non-attainment area.

Second, the remaining 50 K-factors encompass 26 unique jurisdictional interchanges, all of which lie within the non-attainment boundary. There are 13 x 13 = 169 possible jurisdictional interchanges which lie within the non-attainment boundary. These 26 unique interchanges receiving a K-Factor represent approximately 15 percent of the jurisdictional interchanges within the non-attainment boundary.

Third, nine of the 26 unique jurisdictional K-factors involve intra-jurisdictional adjustments, reflecting policy goals and programs in several jurisdictions aimed at attracting and retaining a mix of land activities that will encourage their residents to work, shop, and conduct other activities within their jurisdiction of residence. Of the remaining 17 unique K-factor interchanges, all but two are interchanges where either the D.C. Core or the D.C. Non-Core is involved. (The two exceptions are a Charles County to Prince George's County K-factor for HBW trips and a Fairfax County to Arlington Non-Core K-Factor for HBW trips.)

There is a behavioral pattern present in trip distribution involving the District of Columbia which simple time and cost variables in modeling cannot explain. The D.C. Core has several major nodes of development and encompasses a larger "downtown" than many other cities of similar size. There is a very large federal government presence in the D.C. Core, the Arlington Core, and in recent years, the Ballston corridor in the Arlington Non-Core.

Another pattern which is evident in the application of K-factors is the influence of Baltimore at the northern external boundary. Nearly all of the K-factors involving jurisdictions outside the non-attainment boundary for Washington are for Carroll, Howard, and Anne Arundel Counties or for external stations on the Baltimore County boundary with these jurisdictions. These factors are uniformly less than 1.0 for interchanges beginning in either Montgomery County or Prince George's County to discourage travel northward into the Baltimore region. Both Montgomery County and Prince George's County receive K-factors which are greater than 1.0 for interchanges heading southward into the District of Columbia. This has the effect of forcing the gravity model to distribute trips southward in both Montgomery County and Prince George's County toward the District of Columbia instead of sending them to jobs in Anne Arundel and Howard Counties based on network times alone. This reflects a growing pattern of travel from households in the Baltimore region to employment in the Washington region which is likely to increase in the future given the disparity in housing costs in the two regions.

Fairfax County illustrates an additional behavioral pattern which simple time and cost variables in modeling cannot explain. The county has experienced substantial growth in employment during the past two decades, and is projected to continue this trend. However, there remains a significant amount of interaction with the District of Columbia and Arlington County, largely in terms of commutation to government employment and to other jobs related to government employment. Given the large growth in employment projected within Fairfax County in the future, a gravity model will likely understate this commutation into the central jurisdictions unless K-factors are applied.

Figure 3
Superdistrict Area System
Used in the
Version 2.1/TP+, Release C
Internal Trip Distribution Calibration
(12 Superdistricts)

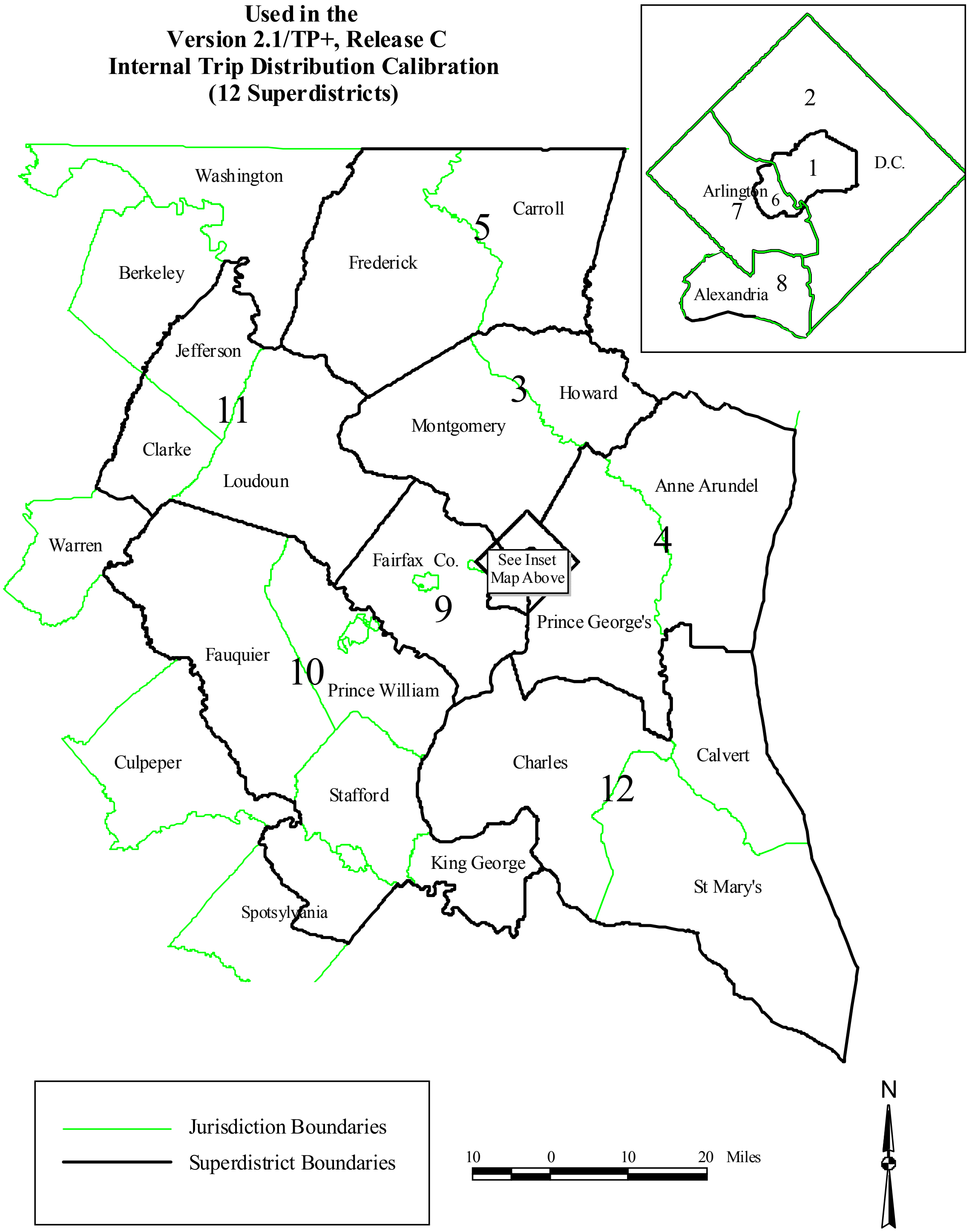


Table 5
Time Penalities (in minutes) for 12 Superdistrict Interchange System Purpose: HBW

Origin	Destination	Income Level 1	Income Level 2	Income Level 3	Income Level 4
2	1	0	0	0	3
2	3	5	0	0	0
2	4	0	3	3	10
2	6	0	0	0	9
2	7	0	0	5	9
3	4	0	5	7	7
3	7	0	0	0	7
3	9	0	0	3	0
4	1	5	5	5	5
4	2	3	3	5	7
4	3	0	2	3	3
4	6	0	0	0	7
4	7	3	0	10	0
4	8	5	3	10	7
4	9	5	0	0	0
7	1	0	0	3	0
7	9	7	0	0	0
8	1	3	0	0	0
8	7	0	0	0	3
8	9	0	3	0	0
9	1	2	2	3	5
9	2	3	2	0	5
9	3	0	0	0	7
9	4	0	0	3	10
9	10	0	0	0	5
9	11	0	3	0	0
10	8	0	0	5	0
10	9	0	3	0	0
12	1	0	0	5	0

Table 6
Time Penalities (in minutes) for
12 Superdistrict Interchange System
Purpose: HBS

Origin	Destination	Income Level 1	Income Level 2	Income Level 3	Income Level 4
2	3	0	0	3	3
2	4	3	3	0	0
2	7	0	0	0	3
3	2	0	0	0	3
3	4	0	5	3	3
3	9	0	0	0	5
4	2	3	3	3	0
4	3	0	3	0	3
9	7	0	0	0	3
9	10	0	0	5	3
10	9	0	0	3	0

Table 7

Time Penalities (in minutes) for

12 Superdistrict Interchange System

Purpose: HBO

Origin	Destination	Income Level 1	Income Level 2	Income Level 3	Income Level 4
2	1	0	0	0	3
2	4	7	3	3	9
2	7	7	0	5	3
2	9	5	0	0	7
3	1	0	0	0	3
3	7	0	0	0	7
3	9	0	3	7	10
4	1	3	3	7	9
4	7	0	3	7	7
4	8	0	0	5	7
4	9	3	0	10	3
5	3	0	0	5	0
7	1	0	0	3	5
7	2	5	0	7	5
7	3	3	0	3	7
7	4	3	0	3	0
7	8	0	3	5	3
7	9	3	3	3	5
8	1	0	0	3	5
8	2	3	0	0	3
8	4	3	0	0	0
8	7	3	0	3	3
9	2	3	9	3	10
9	3	0	5	5	5
9	4	0	5	5	3
9	7	3	0	5	0
9	8	0	0	0	3
9	10	0	5	7	9
9	11	0	0	3	5
10	9	3	5	5	5
11	9	0	0	0	3

Table 8
Time Penalities (in minutes) for
12 Superdistrict Interchange System
Purpose: NHB

Origin	Destination	Time Pen.
2	1	5
2	3	7
2	4	7
2	6	5
2	7	9
2	8	9
2	9	10
3	1	5
3	2	7
3	4	7
3	5	3
3	6	3
3	7	10
3	8	7
3	9	10
4	1	7
4	2	9
4	3	7
4	7	10
4	8	10
4	9	9
5	3	5
5	11	5
6	2	3
7	1	7
7	2	9
7	3	10
7	4	10
7	8	5
7	9	7
8	1	7
8	2	7
8	3	5
8	4	10
8	7	5
8	9	3
9	1	5
9	2	10
9	3	10
9	4	9
9	7	7
9	8	3
9	10	9
9	11	3
10	4	3
10	9	10

Table 9
K-Factor Listing

HBW	Interchange	HBS	Interchange	HBO	Interchange	NHB	Interchange
2.2	dc cr- dc cr	1.3	dcncr – dcncr	2.0	dcncr-dc cr	2.0	mtg - mtg
2.5	dc cr- dcncr	1.2	dcncr- dc cr	1.3	dcncr – dcncr	0.2	mtg - how
3.0	dcncr- dc cr	2.0	dcncr - mtg	0.5	dcncr – ffx	2.0	pg - pg
2.5	dcncr – dcncr	2.8	mtg – mtg	2.0	mtg – dc cr	0.2	pg - aa
0.1	dcncr – extls	1.8	pg – pg	2.5	mtg – mtg	2.0	arlncr - arlncr
2.9	mtF- dc cr	2.6	arlncr - arlncr	0.2	mtg – how	2.0	Alx – alx
2.4	mtF- dcncr	2.3	alx – alx	2.0	pg – dc cr	2.0	ffx – ffx
2.0	mtg – mtg	1.1	ffx – ffx	2.5	pg – pg	2.5	frd – frd
0.2	mtF- how	2.8	frd – frd	0.5	how – mtg	2.5	Chs – chs
0.2	mtF- aa	2.5	chs – chs	2.5	aa – aa		
1.8	pg – dc cr	0.5	car – car	0.6	aa – pg		
1.8	pg – dcncr			1.6	arlncr – arlncr		
2.5	pg – pg			1.9	alx – alx		
0.2	pg – aa			2.0	ffx – dc cr		
0.2	pg – how			2.0	ffx – ffx		
0.2	PF- extls			2.5	frd – frd		
2.5	arl cr- dc cr			2.5	chs – chs		
2.0	arl cr- dcncr						
2.5	arlncr- dc cr						
2.8	alx- dc cr						
2.5	how- pg						
2.5	how- extls/balt						
0.5	aa- aa						
2.8	ffx – dc cr						
2.3	ffx – dcncr						
1.2	ffx – ffx						
1.3	ffx – arlncr						
0.2	frd- aa						
0.2	frd- how						
2.2	chs – dc cr						
2.2	chs – pg						

Charles County exhibits another behavioral pattern which is not fully described using time and cost variables in modeling. Many residents in the county commute to employment in the District of Columbia and in Prince George's County. There are military installations and other government agencies in these two jurisdictions, and a significant number of military and other government workers reside in Charles County. This has been a pattern going back decades, and it is likely to continue into the future. The non-work pattern for Charles County tends to be more intra-county in orientation however. Therefore, there are intra-county K-factors for each of the non-work trip purposes and two inter-jurisdictional K-factors (Charles to D.C. Core and Charles to Prince George's County) for the HBW purpose.

Mode Choice Model Adjustments

Each of the four mode choice models (HBW, HBS, HBO, NHB) is a discrete choice model, estimated from disaggregate, household-level data in the HTS. When disaggregate models are applied at the aggregate, zone-to-zone level, there is no assurance that estimated trips by mode will match the observed trips by mode. The adjustment factors are therefore used to help ensure a reasonable match between estimated and observed data at the aggregate level. A 20-superdistrict system shown in Figure 4 served as the mechanism for adjusting the four discrete choice models to better match aggregate observed data. The factors were developed in two groups: 1) transit percent adjustment factors (TPAFs) and 2) Car Occupancy Adjustment Factors (COAFs). These are presented for the HBW, HBS, HBO, and NHB models in Tables 10-13, respectively.

The aggregate adjustment factors are developed in the final phase of the model development process, i.e., after estimation and after system-wide adjustments are made to bias coefficients and mode-specific constants. The aggregate factors were developed over several iterations with attention paid to the number and magnitude of adjustment factors and to confront shortcomings in the observed data.

Figure 4
Area System (Superdistricts) used for
Transit Percent Adjustment Factors (TPAFs) and
Car Occupancy Adjustment Factors (COAFs)

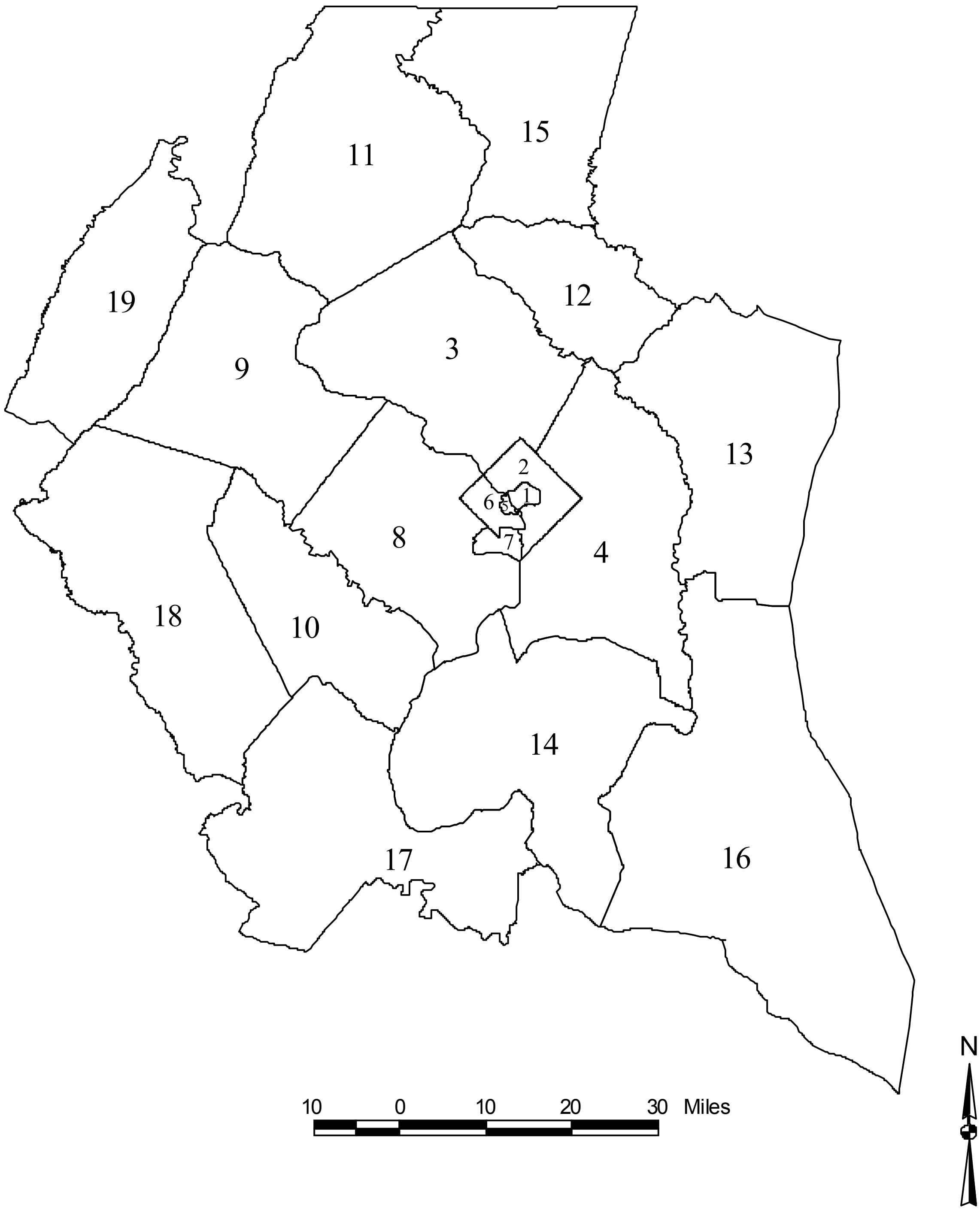


Table 10
HBW Final TPAF and COAF values

HBW **TPAF** mctf_hbw.asc

	1 dc cr	2 dcncr	3 mtg	4 pg	5 arlcr	6 arlnc	7 alx	8 ffx	9 ldn	10 pw	11 frd	12 how	13 aa	14 chs	15 carrl	16 ca/sm	17 s. va	18 fauq	19 w. va	20 ext
1	1.4040	1.0961	1.0248	1.0000	1.0000	0.4703	7.0000	7.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	1.1586	1.0217	0.9939	0.8619	1.2648	0.4883	0.2500	0.7480	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
3	1.1179	0.6916	0.4039	1.0000	1.5787	2.7915	1.0000	2.1418	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
4	1.4031	0.7839	1.4231	0.6471	1.5682	0.6010	1.0000	1.0000	1.0000	1.0000	1.0000	7.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
5	1.7511	1.2262	1.0000	1.0000	7.0000	0.7957	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
6	1.3190	2.3341	1.1795	1.0000	0.7241	0.5435	1.0000	0.2500	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
7	1.0854	3.0568	1.0000	1.0000	2.1966	0.5500	0.4447	1.3549	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
8	1.0724	0.5971	1.0000	1.0000	2.7542	1.1033	0.4062	0.8614	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
9	7.0000	3.2556	1.8841	1.0000	1.4039	1.0031	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
10	7.0000	3.2111	3.6305	1.0000	1.4621	1.2289	0.4847	1.7906	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
11	2.7032	3.5464	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
12	7.0000	1.6057	0.6499	1.0000	1.7389	1.4009	1.0000	1.0000	1.0000	1.0000	1.0000	1.4976	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
13	2.9147	1.0204	0.5178	1.0000	0.6231	0.4168	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	7.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
14	1.4455	1.0000	1.0000	1.0000	4.5245	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
15	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
16	1.1090	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
17	7.0000	7.0000	7.0000	1.0000	3.5056	2.3139	1.8229	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
18	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
19	7.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
20	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	Min	0.2500		Max	7.0000		Ave	1.2581		Std dev	1.0977		Count	400						

HBW **COAF** mccf_hbw.asc

	1 dc cr	2 dcncr	3 mtg	4 pg	5 arlcr	6 arlnc	7 alx	8 ffx	9 ldn	10 pw	11 frd	12 how	13 aa	14 chs	15 carrl	16 ca/sm	17 s. va	18 fauq	19 w. va	20 ext
1	1.9217	1.0130	2.6803	0.8074	1.0000	0.5647	0.6545	0.7337	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	1.7078	1.2488	1.6972	1.1470	2.2535	1.3895	0.7657	0.2500	1.0000	0.4615	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
3	1.0655	0.5700	1.0736	0.2878	0.8377	0.8286	2.5187	0.8836	1.0000	1.0000	0.8436	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
4	1.9099	0.9847	0.3581	0.8175	1.0676	0.6074	0.9269	0.2500	1.0000	1.0000	1.0000	1.0000	1.0000	2.3041	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
5	0.7675	1.0000	0.8506	1.0000	1.0000	2.6752	0.9245	0.9253	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
6	0.7217	0.3242	0.8523	0.8919	1.0338	0.6249	1.2398	0.4220	0.7120	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
7	1.2580	1.7953	0.7123	1.9508	0.6818	0.5824	1.0627	0.2500	0.5731	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
8	1.2526	0.5265	0.5108	0.3791	1.7822	0.4215	0.8593	0.6191	1.0232	1.0697	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
9	0.7034	0.4758	0.6057	0.4879	0.2647	0.5775	0.5069	0.3435	1.3208	0.5405	0.9201	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	2.6173	1.0000	1.0000
10	0.8805	0.3964	0.4117	0.4118	0.4541	1.5248	0.9735	0.8583	0.9259	1.7435	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8345	0.9690	1.0000	1.0000
11	1.3909	0.5265	0.5276	1.6452	0.4774	1.0029	1.0000	1.7203	0.7574	1.0000	0.9353	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
12	1.2469	1.6793	0.4504	1.5431	1.0000	1.0000	1.0000	0.7374	1.0000	1.0000	1.0000	0.5374	0.2500	1.0000	0.9878	1.0000	1.0000	1.0000	1.0000	1.0000
13	1.1596	1.5697	1.9307	0.7007	1.0000	1.0000	1.0000	0.5988	1.0000	1.0000	1.0000	0.5421	1.2563	0.6477	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
14	0.9169	1.5447	0.5195	0.2957	1.2720	1.1806	0.7436	0.6463	1.0000	1.0000	1.0000	1.0000	1.0000	0.7008	1.0000	0.8411	1.0000	1.0000	1.0000	1.0000
15	1.0000	1.0000	0.6685	0.6927	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8476	0.4437	1.0000	2.4452	1.0000	1.0000	1.0000	1.0000	1.0000
16	0.4788	0.6260	0.4978	0.2500	1.0000	0.4757	0.5962	0.5384	1.0000	1.0000	1.0000	1.0000	1.0000	0.8822	1.0000	1.6701	1.0000	1.0000	1.0000	1.0000
17	0.9436	0.2921	0.3085	1.0000	1.0000	0.4143	0.3748	0.4057	1.0000	0.8918	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	2.5493	0.7676	1.0000	1.0000
18	1.0000	1.0000	0.5386	1.0000	1.0000	0.3454	1.0000	0.4950	1.4547	0.9459	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8295	1.1352	1.0000	1.0000
19	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
20	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	Min	0.2500		Max	2.6803		Ave	0.9719		Std dev	0.3473		Count	400						

Table 11
HBS Final TPAF and COAF values

HBS **TPAF** `mctf_hbs.asc`

	1 dc cr	2 dcncr	3 mtg	4 pg	5 arlcr	6 arlnc	7 alx	8 ffx	9 ldn	10 pw	11 frd	12 how	13 aa	14 chs	15 carrl	16 ca/sm	17 s. va	18 fauq	19 w. va	20 ext
1	1.7603	3.4089	4.8084	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	1.6067	0.6785	0.2513	0.4466	1.0000	0.4472	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
3	1.0000	1.0000	0.8379	1.0000	12.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
4	4.4419	1.0000	2.2184	0.7757	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
5	7.4164	1.0000	1.0000	1.0000	12.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
6	1.8014	1.0000	1.0000	1.0000	1.0000	0.6428	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
7	2.5674	1.0000	1.0000	1.0000	1.0000	1.0000	1.1287	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
8	1.0000	1.0000	1.0000	1.0000	1.0000	3.4493	1.0000	0.4702	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
9	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
10	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
11	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
12	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
13	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
14	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
15	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
16	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
17	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
18	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
19	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
20	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Min 0.2513 Max 12.0000 Ave 1.1054 Std dev 0.9003 Count 400

HBS **COAF** `mccf_hbs.asc`

	1 dc cr	2 dcncr	3 mtg	4 pg	5 arlcr	6 arlnc	7 alx	8 ffx	9 ldn	10 pw	11 frd	12 how	13 aa	14 chs	15 carrl	16 ca/sm	17 s. va	18 fauq	19 w. va	20 ext
1	1.9801	1.7354	7.4554	1.3320	1.6487	1.6120	1.0000	1.3006	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	1.1894	0.9434	0.5487	0.9004	1.0000	2.6877	2.0645	1.0406	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
3	1.0000	1.2533	0.9215	1.0007	1.3299	1.0882	1.0000	1.0318	1.0000	1.0000	0.8954	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
4	1.1268	1.0000	1.1866	0.8812	1.0000	1.0000	1.0000	0.6890	1.0000	2.9583	1.0000	1.0000	1.0000	1.0622	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
5	1.0000	1.0000	1.0000	1.0000	12.0000	1.7474	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
6	1.0000	1.2652	1.3131	1.0000	1.3307	1.5793	0.9999	0.2500	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
7	1.0000	1.1736	1.0000	1.0917	1.0000	1.2717	1.0078	1.0560	1.0000	0.9864	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
8	3.3281	1.0000	1.6969	1.0000	1.9404	1.1192	1.4437	0.9096	1.5156	1.0305	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
9	1.0000	1.0000	0.7492	1.0000	1.0000	1.0000	1.0000	0.8962	0.8465	0.9294	1.6479	1.0000	1.0000	1.0000	1.0000	0.5302	1.0000	1.0000	1.0000	1.0000
10	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.2500	0.9190	1.5071	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9652	1.0000	1.0000
11	1.0000	1.0000	1.0380	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.2542	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
12	1.0000	1.0000	0.9970	1.0933	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	2.1246	2.0503	1.0000	0.7699	1.0000	1.0000	1.0000	1.0000	1.0000
13	1.0000	1.0000	0.8436	0.8618	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0446	1.3473	1.4569	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
14	1.0000	1.0000	1.0000	0.5295	1.0000	1.0000	1.0000	0.6497	1.0000	1.0000	1.0000	1.0000	1.0000	1.7706	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
15	1.0000	1.0000	0.7722	1.5924	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.6477	1.0000	1.5740	1.0000	1.0000	1.0000	1.0000	1.0000
16	1.0000	0.7007	1.0000	1.0935	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9095	1.0000	1.2803	1.0000	1.0000	1.0000	1.0000
17	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	2.7032	1.0000	0.9407	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	2.0256	1.0000	1.0000	1.0000
18	1.0000	1.0000	1.0000	0.6419	1.0000	1.0000	1.0000	0.7855	1.0000	1.2231	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	8.3996	1.0000	1.0000
19	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
20	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Min 0.2500 Max 12.0000 Ave 1.1132 Std dev 0.7794 Count 400

Table 12
HBO Final TPAF and COAF values

HBO **TPAF** `mctf_hbo.asc`

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	dc cr	**dcncr**	**mtg**	**pg**	**arlcr**	**arlnc**	**alx**	**ffx**	**ldn**	**pw**	**frd**	**how**	**aa**	**chs**	**carrl**	**ca/sm**	**s. va**	**fauq**	**w. va**	**ext**
1	0.8867	1.0258	0.2674	1.0000	1.0000	0.6180	2.4696	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	0.7205	1.3610	0.6442	0.3235	0.5145	0.6153	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
3	1.4792	0.8370	0.2571	1.0000	1.0000	0.7881	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
4	0.6983	0.2629	0.9887	0.3407	1.0000	1.0545	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
5	1.0000	1.5910	1.0000	1.0000	1.0000	0.7401	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
6	1.1299	1.1003	1.0000	1.0000	1.1897	0.2839	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
7	0.8967	1.2302	0.8460	1.0000	7.2040	1.0000	0.6734	0.6262	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
8	1.6943	1.3461	1.0000	1.0000	1.0000	0.5450	1.0000	0.2605	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
9	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
10	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	5.1966	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
11	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
12	1.0000	1.0000	1.0000	2.7613	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
13	1.0000	1.0000	1.0000	3.0890	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
14	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
15	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
16	12.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
17	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
18	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
19	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
20	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	Min	0.2571		Max	12.0000		Ave	1.0514		Std dev	0.6931		Count	400						

HBO **COAF** `mccf_hbo.asc`

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	dc cr	**dcncr**	**mtg**	**pg**	**arlcr**	**arlnc**	**alx**	**ffx**	**ldn**	**pw**	**frd**	**how**	**aa**	**chs**	**carrl**	**ca/sm**	**s. va**	**fauq**	**w. va**	**ext**
1	2.0062	0.6492	1.8778	1.1898	1.0000	0.9704	0.7521	1.9444	1.0000	0.9401	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	0.8000	1.3098	0.7735	0.8157	0.8394	0.7846	1.0633	0.5423	0.8009	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.7471	1.0000	1.0000	1.0000	1.0000
3	0.4624	0.6104	1.2819	0.7270	1.0000	0.8462	1.0660	0.2534	1.0000	0.7823	0.7993	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
4	0.7589	0.8494	0.8966	1.2197	0.8494	0.8336	1.4286	0.2546	1.1214	1.5486	1.0000	1.0000	1.0000	1.4248	1.0000	0.8163	1.0000	1.0000	1.0000	1.0000
5	1.0000	1.0000	1.0000	1.0000	1.0000	1.1946	1.0329	1.9216	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
6	0.4078	0.6356	0.9188	0.8558	0.3079	1.3815	0.8064	0.7421	0.8378	0.8362	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
7	0.9024	1.1788	0.5377	1.5274	0.3937	0.6635	1.4017	0.5454	0.8241	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
8	0.7000	0.8684	0.7181	0.8001	0.8433	1.0325	0.7517	1.1681	0.6000	1.1339	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0984	1.0000	1.0000	1.0000
9	0.8257	0.7883	0.5582	0.8411	1.0000	2.5452	0.8064	0.8240	1.7623	1.1709	1.3540	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	5.3836	1.0000	1.0000
10	0.8227	0.9968	0.7322	0.7891	1.0000	0.8208	1.5562	0.8414	0.9508	1.6214	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.3173	0.6189	1.0000	1.0000
11	0.5384	1.0000	0.4902	0.9359	1.0000	1.0000	1.0000	0.7898	0.7832	1.0000	2.0860	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
12	1.0000	1.0000	1.0444	1.2450	1.0000	1.0000	1.0000	0.8062	1.0000	1.0000	1.0000	7.2328	0.6091	1.0000	0.7446	1.0000	1.0000	1.0000	1.0000	1.0000
13	1.0000	1.0000	0.9441	0.9410	1.0000	1.0000	1.0000	1.4799	1.0000	1.0000	1.0000	0.4375	1.7183	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
14	1.1887	1.4958	0.7891	0.6222	1.0000	0.8329	0.7907	0.7937	1.0000	1.0000	1.0000	1.0000	1.0000	8.6164	1.0000	0.8134	1.0000	1.0000	1.0000	1.0000
15	1.0000	1.0000	0.7813	0.9228	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.4333	0.7915	1.0000	12.0000	1.0000	1.0000	1.0000	1.0000	1.0000
16	0.8113	0.7950	1.5050	0.6376	1.0000	0.8466	1.0000	1.2878	1.3959	1.0000	1.0000	1.0000	1.0000	0.8985	1.0000	1.6039	1.0000	1.0000	1.0000	1.0000
17	1.0000	1.0000	1.0000	0.7727	1.0000	0.8080	1.0000	0.5534	1.0000	0.8765	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	12.0000	1.5760	1.0000	1.0000
18	1.0000	1.0000	1.0000	1.0000	1.0000	0.8125	1.0000	0.3201	0.3815	0.7257	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.5751	12.0000	1.0000	1.0000
19	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
20	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	Min	0.2534		Max	12.0000		Ave	1.1100		Std dev	1.1144		Count	400						

Table 13
NHB Final TPAF and COAF values

NHB **TPAF** `mctf_nhb.asc`

	1 dc cr	2 dcncr	3 mtg	4 pg	5 arlcr	6 arlnc	7 alx	8 ffx	9 ldn	10 pw	11 frd	12 how	13 aa	14 chs	15 carrl	16 ca/sm	17 s. va	18 fauq	19 w. va	20 ext
1	0.6334	0.8832	0.9808	1.3909	1.7413	0.6552	0.3434	1.6976	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	0.3911	0.4685	0.2539	0.8552	0.3324	0.5383	0.5674	0.2988	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
3	0.5759	0.2650	0.2500	0.6848	0.3790	0.3535	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
4	0.5924	0.6880	0.4413	0.2500	1.0000	0.3430	1.0000	1.5155	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
5	0.6848	0.4037	0.4434	1.0000	1.0000	0.3990	1.0236	0.6784	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
6	0.5007	0.6976	0.4146	0.6720	0.3931	0.2500	1.0000	1.1083	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
7	0.2500	0.5416	1.0000	1.0000	0.7561	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
8	0.7374	0.2500	1.0000	1.9604	0.3673	0.6417	1.0000	0.2500	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
9	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
10	5.8414	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
11	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
12	1.0000	1.0000	1.2482	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
13	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
14	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
15	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
16	7.5389	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
17	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
18	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
19	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
20	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Min 0.2500 Max 7.5389 Ave 0.9836 Std dev 0.4502 Count 400

NHB **COAF** `mccf_nhb.asc`

	1 dc cr	2 dcncr	3 mtg	4 pg	5 arlcr	6 arlnc	7 alx	8 ffx	9 ldn	10 pw	11 frd	12 how	13 aa	14 chs	15 carrl	16 ca/sm	17 s. va	18 fauq	19 w. va	20 ext
1	1.5000	1.0000	0.8167	0.6473	0.6725	0.6161	1.0718	0.6723	1.0771	1.1751	0.7384	1.0000	1.0000	1.2352	1.0000	0.4537	10.8608	1.0000	1.0000	1.0000
2	1.0000	1.1283	0.5672	0.5742	0.7845	0.2838	0.6740	0.3350	0.8160	0.7586	0.7017	1.0000	1.0000	1.0689	1.0000	0.6680	1.0000	1.0000	1.0000	1.0000
3	0.8213	0.5668	1.0453	0.5353	0.7886	0.2500	0.7801	0.3603	1.1131	0.4074	0.7771	1.0000	1.0000	0.8502	1.0000	0.7472	1.0000	1.0000	1.0000	1.0000
4	0.6488	0.5749	0.5340	0.8444	0.7829	0.2500	0.3928	0.5346	0.7719	1.0000	0.7788	1.0000	1.0000	0.3643	1.0000	1.1315	1.0000	1.0000	1.0000	1.0000
5	0.6734	0.7983	0.7960	0.7732	2.4356	0.8963	0.7932	1.2891	0.8171	1.4814	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
6	0.6174	0.2831	0.2500	0.2500	0.9071	0.9173	0.4038	0.7782	0.2500	0.5393	0.7926	1.0000	1.0000	1.5053	1.0000	0.7086	1.0000	1.0000	1.0000	1.0000
7	1.0731	0.6697	0.7813	0.3883	0.7970	0.3987	1.0518	0.8724	0.7310	0.7602	1.0000	1.0000	1.0000	0.7002	1.0000	1.0000	0.7473	1.0000	1.0000	1.0000
8	0.6726	0.3377	0.3617	0.5313	1.3043	0.7817	0.8729	0.7813	0.2500	0.6950	0.6910	1.0000	1.0000	0.2818	1.0000	1.0000	0.2500	0.9021	1.0000	1.0000
9	1.1298	0.8057	1.1126	0.7386	0.7654	0.2500	0.7800	0.2503	0.8984	1.4082	0.7412	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.7246	1.0000	1.0000
10	1.1650	0.7607	0.4172	1.0000	1.4827	0.5439	0.7595	0.6933	1.4136	1.4326	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.3381	0.7140	1.0000	1.0000
11	0.7333	0.7707	0.7725	0.7553	1.0000	0.7346	0.7858	0.7509	0.7373	1.0000	1.6310	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
12	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
13	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
14	1.2497	0.9953	0.7477	0.3632	1.0000	1.5320	0.7767	0.3353	1.0000	1.0000	1.0000	1.0000	1.0000	2.1464	1.0000	1.8037	1.0000	1.0000	1.0000	1.0000
15	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
16	0.4410	0.7342	0.7403	1.1239	1.0000	0.7060	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.7974	1.0000	1.1071	1.0000	1.0000	1.0000	1.0000
17	8.7250	1.0000	1.0000	1.0000	1.0000	1.0000	0.7288	0.2500	1.0000	0.3362	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	3.1221	1.0000	1.0000	1.0000
18	1.9515	0.7547	1.0000	1.0000	1.0000	1.0000	1.0000	0.9666	0.7423	0.7134	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	2.0518	1.0000	1.0000
19	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
20	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Min 0.2500 Max 10.8608 Ave 0.9728 Std dev 0.6913 Count 400

Appendix E

Running the Version 2.1/TP+ C Model With Additional Iterations

Running the Version 2.1/TP+ C Model With Additional Iterations

Introduction

One of the concerns expressed by the TRB model review committee about the TPB travel model was that the feedback of highway times bypasses mode choice. This document provides a brief description of the feedback process in the Version 2.1/C model and contains the results of applying the model with additional iterations, including a re-running of the mode choice model.

The Version 2.1 model application involves four separate executions of the traffic assignment process occuring in sequential modeling 'cycles' or iterations. Travel models are executed in this iterative fashion to ensure that congested highway time used in trip distribution is consistent with that resulting from the traffic assignment. In other words, highway time functions as both an input and an output of the travel model. A stable estimate of demand is therefore dependent on an equilibrated highway time condition.

The four sequential iterations of the model are generally referred to as the *pump-prime*, *base*, *first*, and *second* iterations. The pump-prime iteration functions to develop an initial set of traffic assignment-based highway skims (peak and off-peak) that will support the trip distribution and mode choice models in the subsequent (base) iteration. The base iteration includes the running of the mode choice model and another traffic assignment execution. The first and second iterations include re-runs of the trip distribution and traffic assignment process using recycled highway skims within each pass.

The pump-prime iteration involves an application of the entire four-step process using 'initial' peak and off-peak highway speeds for the beginning trip distribution process and 'initial' zonal mode choice percentages (in lieu of an explicit mode choice model execution). The highway speeds are provided by facility type and zone (as a table lookup) and were developed from a base year (1994) traffic assignment process. In application, this particular speed lookup table is used for all model runs. The mode choice percentages, however, do vary for a given model year. The percentages are taken from a pre-existing mode choice model run that is deemed to be appropriate for the year/alternative being modeled.

The base iteration involves a second execution of the four-step process where restrained times are recycled into the trip distribution and mode choice models. The restrained highway times resulting from the pump-prime iteration are also used to update the speeds of auto access links in the transit network. The mode choice model is executed during the base iteration, but is not re-run in subsequent model iterations. Instead, the transit and priority facility/HOV trips produced by the mode choice model in the base iteration are held constant during the latter (first and second) iterations. As person trip patterns change in the first and second iterations, there are special matrix operations that must be undertaken when transit and HOV trips are held constant. First, a check is made to ensure that the revised number of person trips is greater than or equal to the fixed number of transit and HOV trips. For rare cases when person trips are less than the transit /HOV trips, the number of person trips is updated to equal the transit/HOV total. Next, auto driver trips must be re-estimated by applying the base iteration car occupancy to the current iteration residual (non-transit/HOV) person trips. Given the necessity of the two operations, it is currently accepted that a small difference in the total number of vehicle trips will typically occur between iterations.

Testing Additional Iterations

To assess the effect of re-running the mode choice model after the base iteration, the model was applied with additional iterations. Table 1 lists model iterations that are executed in a 'standard' run as well as added iterations that were tested in this analysis. The standard execution consists of steps 1-4 while the additional iterations tested are shown as steps 5-7 (a re-running of the base, first, and second iteration). The mode choice model (step 5) was executed using person trips and highway skims resulting from step 4, the point at which the standard model terminates. Steps 1-7 were applied for the years 1994, 2005, and 2025.

Table 1
Version 2.1/TP+, C Iteration Summary
'Standard' and Additional (in Shade) Iteration Steps

Iteration No./Name		Outputs Passed to Following Iteration
1	**Pump Prime Iteration** Generation/Distribution/Synthetic Mode Choice/ Assignment	Person Trips, Highway Skims
2	**Base Iteration** Generation/Distribution/Mode Choice / Assignment	Person Trips, Transit/HOV trips(priority facilities), Highway Skims
3	**First Iteration** Distribution/ transit, HOV trips maintained / Assignment	Person Trips, Highway Skims
4	**Second Iteration** Distribution/ transit, HOV trips maintained / Assignment	Person Trips, Highway Skims
5	**Base Iteration Rerun** Generation/Distribution/Mode Choice / Assignment	Person Trips, Transit/HOV trips(priority facilities), Highway Skims
6	**First Iteration Rerun** Distribution/ transit, HOV trips maintained / Assignment	Person Trips, Highway Skims
7	**Second Iteration Rerun** Distribution/ transit, HOV trips maintained / Assignment	Person Trips, Highway Skims

Test Results

A global summary of VMT and link speeds by iteration and time period is shown on Table 2. The table indicates that the highway speeds are generally declining over time as would be expected, particularly during peak periods. The AM speed of 41 mph in 1994 declines to about 34 mph in 2025 (a 17% decrease) while the off-peak speed declines from 47 to 43 mph (a 9% decrease). The systemwide speed is ultimately stabilized by the feedback process. Highway speeds are generally in equilibrium by the end of the 2nd iteration (step 4). Little change in the highway speeds occurs with added model iterations.

Table 2

Regional VMT and Speed Summary by Year, Iteration, and Time Period
(Additional Iteration Results are in Shade)

		Time Period							
		AM		PM		Off Peak		Daily	
Year	Iteration	VMT	Speed	VMT	Speed	VMT	Speed	VMT	Speed
1994									
	1_Pump Prime	25,452,157	41	35,631,948	35	69,304,066	48	130,388,172	43
	2_Base	26,522,164	40	37,859,961	33	74,816,807	46	139,198,933	41
	3_First Iteration	26,135,241	41	36,950,734	34	72,891,266	47	135,977,241	42
	4_Second Iteration	26,159,953	41	36,965,492	34	72,858,685	47	135,984,130	42
	5_Base	25,885,024	41	36,698,842	34	72,184,039	47	134,767,905	43
	6_First Iteration	26,132,805	41	36,978,941	34	72,737,593	47	135,849,340	42
	7_Second Iteration	26,129,559	41	36,964,119	34	72,743,753	47	135,837,432	42
2005									
	1_Pump Prime	33,352,505	38	46,493,136	31	90,263,496	46	170,109,138	40
	2_Base	30,929,189	41	43,831,574	33	87,508,954	46	162,269,718	42
	3_First Iteration	32,249,096	40	45,558,848	32	90,390,879	46	168,198,823	41
	4_Second Iteration	32,130,577	40	45,304,344	32	89,897,554	46	167,332,475	41
	5_Base	31,582,380	41	44,511,057	33	88,239,935	47	164,333,372	42
	6_First Iteration	32,195,997	40	45,364,007	32	89,719,358	46	167,279,362	41
	7_Second Iteration	32,145,008	40	45,246,942	32	89,559,666	46	166,951,616	41
2025									
	1_Pump Prime	48,200,423	29	65,529,644	23	127,041,423	39	240,771,490	33
	2_Base	36,434,277	39	51,480,135	32	106,569,534	45	194,483,945	41
	3_First Iteration	42,728,549	34	59,350,805	26	119,945,666	42	222,025,020	36
	4_Second Iteration	42,184,277	34	58,554,028	27	118,334,467	42	219,072,772	37
	5_Base	40,775,280	35	56,664,129	28	114,399,125	43	211,838,533	38
	6_First Iteration	42,202,614	34	58,645,850	27	118,188,810	42	219,037,274	36
	7_Second Iteration	41,905,550	34	58,229,791	27	117,431,480	43	217,566,822	37

Source:jurisitr_BM_itr2_Ron.xls

More detailed iteration summaries at the jurisdiction level are shown for the three modeled years on Tables 3, 4, and 5.

Table 3

1994 AM Jurisdictional Speeds by Iteration

	'Standard' Iterations				Additional Iterations		
Juris	**1_PP Itr**	**2_Base Itr**	**3_1st Itr**	**4_2nd Itr**	**5_Base Itr**	**6_1st Itr**	**7_2nd Itr**
DC	31	30	30	30	31	30	30
Mtg	37	36	37	37	37	37	37
Pg	43	40	42	42	42	42	42
Arl	36	34	35	35	36	35	35
Alx	32	30	30	30	31	30	31
Ffx	39	36	37	37	38	37	37
Ldn	41	40	41	41	41	41	41
Pw	45	44	45	45	45	45	44
Frd	55	55	55	55	55	55	55
How	40	46	44	44	44	44	44
AA	41	44	43	43	43	43	43
Chs	42	42	42	42	42	42	42
Car	38	42	41	41	41	41	41
Cal	48	48	48	48	48	48	48
StM	43	43	43	43	43	43	43
Kg	44	43	43	43	43	43	43
Fbg	57	57	57	57	57	57	57
Stf	58	57	58	57	58	57	57
Spt	59	59	59	59	59	59	59
Fau	52	52	52	52	52	52	52
Clk	44	44	44	44	44	44	44
Jef	45	46	45	45	45	45	45
Total	41	40	41	41	41	41	41

Source:jurisitr_BM_itr2_Ron.xls

Table 4
2005 AM Jurisdictional Speeds by Iteration

Juris	'Standard' Iterations				Additional Iterations		
	1_PP Itr	2_Base Itr	3_1st Itr	4_2nd Itr	5_Base Itr	6_1st Itr	7_2nd Itr
DC	28	31	30	30	31	30	30
Mtg	35	37	36	36	36	36	36
Pg	39	40	40	40	41	40	40
Arl	32	36	33	34	36	33	33
Alx	28	31	29	29	31	29	29
Ffx	33	36	34	34	35	34	34
Ldn	42	45	44	44	44	43	43
Pw	41	42	42	42	43	42	42
Frd	49	52	51	51	50	50	50
How	42	50	47	47	47	47	47
AA	40	45	43	43	43	43	43
Chs	41	41	41	41	41	41	41
Car	36	42	40	40	39	39	39
Cal	46	46	46	46	46	46	46
StM	39	39	39	39	40	39	39
Kg	42	43	42	42	42	42	42
Fbg	51	52	51	52	52	52	52
Stf	50	51	51	51	51	51	51
Spt	57	57	57	57	57	57	57
Fau	51	51	51	51	51	51	51
Clk	42	43	42	42	42	42	42
Jef	43	45	45	45	44	44	44
Total	38	41	40	40	41	40	40

Source:jurisitr_BM_itr2_Ron.xls

Table 5

2025 AM Jurisdictional Speeds by Iteration

	'Standard' Iterations				Additional Iterations		
Juris	**1_PP Itr**	**2_Base Itr**	**3_1st Itr**	**4_2nd Itr**	**5_Base Itr**	**6_1st Itr**	**7_2nd Itr**
DC	23	32	27	28	29	27	27
Mtg	26	37	30	31	33	31	31
Pg	29	40	34	34	35	34	34
Arl	26	40	30	32	36	31	32
Alx	22	31	26	27	29	26	27
Ffx	27	38	31	32	34	32	32
Ldn	26	37	33	32	33	32	32
Pw	36	43	40	40	39	40	40
Frd	32	43	39	39	39	38	39
How	26	44	35	35	35	35	35
AA	24	34	30	30	31	29	30
Chs	36	40	39	39	39	38	38
Car	29	38	34	34	34	34	34
Cal	42	43	43	43	42	42	42
StM	38	37	37	37	37	37	37
Kg	36	41	39	40	40	39	39
Fbg	41	44	43	43	43	43	43
Stf	34	42	40	40	39	40	40
Spt	46	47	46	46	46	46	46
Fau	45	48	47	47	47	47	47
Clk	33	38	37	37	37	37	37
Jef	38	43	41	41	41	41	41
Total	29	39	34	34	35	34	34

Source:jurisitr_BM_itr2_Ron.xls

The time series results of the ‘base’ (step 2) mode choice model run using pump-prime highway speeds and the ‘tested’ (step 5) mode choice model run using equilibrated highway speeds are shown on Table 6. Jurisdictional summaries of the transit trips are also attached, as follows:

Table 7 – 1994 Base Total Transit Trips
Table 8 – 1994 Base_Rerun Total Transit Trips
Table 9 – Difference 1994 Total Transit Trips (Base - Rerun- Base)

Table 10 – 2005 Base/SIP Total Transit Trips
Table 11 – 2005 Base/SIP_Rerun Total Transit Trips
Table 12 – Difference 2005 Total Transit Trips (Base/SIP - Rerun- Base)

Table 13 – 2025 Base Total Transit Trips
Table 14 – 2025 Base_Rerun Total Transit Trips
Table 15 – Difference 2025 Total Transit Trips (Base - Rerun- Base)

Conclusions

The Version 2.1, C Model was executed with additional iterations, including the execution of the mode choice model using equilibrated speeds. The highway speeds resulting from added iterations did not substantially change from speeds resulting from the second iteration (where the existing model currenly terminates in application). A re-running of the mode choice model, using final highway speeds as opposed to pump-prime speeds, resulted in a somewhat lower number of estimated transit trips, particularly in 2025 where the pump-prime input speeds were significantly different from the final traffic assignment speeds. There are two possible adjustments to the model application that could be implemented in response to this finding:

1) The initial speed lookup table used in the pump-prime trip distribution could be updated for forecast years so that the pump-prime input speed is closer to the final speed.

2) The model set could be executed with additional iterations to ensure that the speeds used in mode choice are within close tolerances of the speeds output from the final assignment.

Table 6

Comparison of 1994, 2005, and 2025 Trips by Mode
Base and Base Rerun iterations

		1994 Base	1994 with Final Hwy Skims and Person trip tables	1994 Difference (Test - Base)	2005 used for SIP with Prelim. LU 6.3	2005 with Finla (itr 2) Hwy Skims and Person trip tables	2005 Difference (Test-Base/SIP)	2025 Base	2025 with Final Hwy Skims and Person trip tables	2025 Difference (Test - Base)
Motorized Trips / Trip Rates	HBW	3,689,242	3,689,215	-27	4,553,106	4,553,047	-59	5,799,792	5,799,536	-256
Motorized Person Travel	HBS	2,763,003	2,763,043	40	3,382,448	3,382,467	19	4,156,120	4,155,964	-156
(Internal & External)	HBO	8,457,680	8,457,673	-7	10,256,892	10,256,937	45	12,512,344	12,512,055	-289
	NHB	6,155,306	6,155,437	131	7,534,994	7,534,948	-46	9,199,601	9,199,628	27
	Total Person Trips	**21,065,231**	**21,065,368**	**137**	**25,727,440**	**25,727,399**	**-41**	**31,667,857**	**31,667,183**	**-674**
Auto Driver Travel	HBW	2,854,183	2,846,329	-7,854	3,519,045	3,528,567	9,522	4,419,263	4,469,755	50,492
(Internal & External)	HBS	2,163,139	2,165,604	2,465	2,646,818	2,645,798	-1,020	3,240,868	3,236,306	-4,562
	HBO	5,792,871	5,785,655	-7,216	6,979,381	6,974,347	-5,034	8,535,097	8,507,449	-27,648
	NHB	4,813,152	4,809,988	-3,164	5,887,331	5,883,989	-3,342	7,219,167	7,213,332	-5,835
	Total Auto Dr.	**15,623,345**	**15,607,576**	**-15,769**	**19,032,575**	**19,032,701**	**126**	**23,414,395**	**23,426,842**	**12,447**
Auto Passenger Travel	HBW	358,497	358,920	423	423,070	427,188	4,118	548,830	560,997	12,167
(Internal & External)	HBS	566,999	564,534	-2,465	694,025	695,152	1,127	863,452	867,899	4,447
	HBO	2,511,417	2,518,747	7,330	3,076,784	3,082,208	5,424	3,741,005	3,768,350	27,345
	NHB	1,213,576	1,215,740	2,164	1,491,448	1,495,544	4,096	1,793,626	1,801,216	7,590
	Total Auto Pass.	**4,650,489**	**4,657,941**	**7,452**	**5,685,327**	**5,700,092**	**14,765**	**6,946,913**	**6,998,462**	**51,549**
Auto Occupancies	*HBW*	*1.13*	*1.13*	*0.00*	*1.12*	*1.12*	*0.00*	*1.12*	*1.13*	*0.00*
(Internal & External)	*HBS*	*1.26*	*1.26*	*0.00*	*1.26*	*1.26*	*0.00*	*1.27*	*1.27*	*0.00*
	HBO	*1.43*	*1.44*	*0.00*	*1.44*	*1.44*	*0.00*	*1.44*	*1.44*	*0.00*
	NHB	*1.25*	*1.25*	*0.00*	*1.25*	*1.25*	*0.00*	*1.25*	*1.25*	*0.00*
	Total Auto Occ.	***1.30***	***1.30***	***0.00***	***1.30***	***1.30***	***0.00***	***1.30***	***1.30***	***0.00***
Transit Travel	HBW	476,562	483,966	7,404	610,991	597,292	-13,699	831,699	768,784	-62,915
(Internal Only)	HBS	32,865	32,905	40	41,605	41,517	-88	51,800	51,759	-41
	HBO	153,392	153,271	-121	200,727	200,382	-345	236,242	236,256	14
	NHB	128,578	129,709	1,131	156,215	155,415	-800	186,808	185,080	-1,728
	Total Int'l Transit	**791,397**	**799,851**	**8,454**	**1,009,538**	**994,606**	**-14,932**	**1,306,549**	**1,241,879**	**-64,670**
Transit Percentage	*HBW*	*12.92%*	*13.12%*	*0.20%*	*13.42%*	*13.12%*	*-0.30%*	*14.34%*	*13.26%*	*-1.08%*
	HBS	*1.19%*	*1.19%*	*0.00%*	*1.23%*	*1.23%*	*0.00%*	*1.25%*	*1.25%*	*0.00%*
	HBO	*1.81%*	*1.81%*	*0.00%*	*1.96%*	*1.95%*	*0.00%*	*1.89%*	*1.89%*	*0.00%*
	NHB	*2.09%*	*2.11%*	*0.02%*	*2.07%*	*2.06%*	*-0.01%*	*2.03%*	*2.01%*	*-0.02%*
	Total Transit Pct.	***3.76%***	***3.80%***	***0.04%***	***3.92%***	***3.87%***	***-0.06%***	***4.13%***	***3.92%***	***-0.20%***

Source: v2tptab_trb_mcitr2_rev.xls

Table 7
1994 BaseTotal Transit

Simulation - Year: 1994 Alternative: base
Purpose: ALL   MODE: Transit

ORIGIN | DESTINATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	TOTAL
1 DC CR	40507	19542	8027	6374	3976	6142	2458	7344	0	2	0	0	29	21	0	0	0	0	0	0	0	0	0	94422
2 DC NC	112140	70414	12442	4626	4105	5324	3053	3170	0	4	0	0	120	83	0	0	0	0	0	0	0	0	0	215481
3 MTG	68723	11934	23679	3140	3640	8158	1496	2392	0	1	1	0	18	12	0	0	0	0	0	0	0	0	0	123194
4 PG	44677	6779	7882	8238	3850	2878	1143	1464	0	0	0	0	217	60	0	0	0	0	0	0	0	0	0	77188
5 ARLCR	6556	1420	509	347	746	1195	774	683	0	2	0	0	1	2	0	0	0	0	0	0	0	0	0	12235
6 ARNCR	39932	7050	2559	982	3496	6866	3619	3710	1	3	0	0	13	16	0	0	0	0	0	0	0	0	0	68247
7 ALX	15510	3579	1399	483	4398	4367	5725	3429	0	1	0	0	6	4	0	0	0	0	0	0	0	0	0	38901
8 FFX	56286	4121	3244	1062	13709	19487	4048	11378	7	0	0	0	18	19	0	0	0	0	0	0	0	0	0	113379
9 LDN	2660	423	368	12	354	424	50	507	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4806
10 PW	9066	1143	914	46	972	1697	321	1457	0	4338	0	0	0	3	0	0	0	0	0	0	0	0	0	19957
11 FRD	940	273	482	4	41	78	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1825
12 CAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 HOW	4275	372	279	606	138	168	34	12	0	0	0	0	422	12	0	0	0	0	0	0	0	0	0	6318
14 AAR	4903	546	326	1268	158	189	86	43	0	0	0	0	16	284	3	0	0	0	0	0	0	0	0	7822
15 CAL	692	55	18	35	30	58	1	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	903
16 STM	44	1	1	0	0	5	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	56
17 CHS	1435	42	21	6	160	69	2	1	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	1743
18 FAU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19 STA	1416	325	263	6	359	451	217	46	0	1	0	0	0	1	0	0	0	0	0	0	3	0	0	3088
20 CL/JF	120	9	149	2	3	6	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	291
21 SP/FB	578	167	109	3	205	263	159	45	0	0	0	0	0	1	0	0	0	0	6	0	5	0	0	1541
22 KGEO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23 EXTL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	410460	128195	62671	27240	40340	57825	23192	35683	16	4352	2	0	860	518	17	0	12	0	6	0	8	0	0	791397

Table 8
1994 Base_Rerun Total Transit

Simulation - Year: 1994 Alternative: base
Purpose: ALL MODE: Transit

ORIGIN \ DESTINATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	TOTAL
1 DC CR	41432	19746	7856	6327	4236	6318	2418	7390	0	0	0	0	41	31	0	0	0	0	0	0	0	0	0	95795
2 DC NC	112906	70901	12481	4653	4260	5358	2903	3101	0	0	0	0	82	77	0	0	0	0	0	0	0	0	0	216722
3 MTG	68270	11924	24272	3098	3606	8026	1439	2440	0	0	0	0	10	12	0	0	0	0	0	0	0	0	0	123097
4 PG	45549	7020	7783	8492	3985	2960	1182	1459	0	0	0	0	232	56	0	0	0	0	0	0	0	0	0	78718
5 ARLCR	6724	1411	490	332	791	1241	783	681	0	1	0	0	1	3	0	0	0	0	0	0	0	0	0	12458
6 ARNCR	40505	7036	2462	947	3612	7013	3690	3673	0	0	0	0	11	6	0	0	0	0	0	0	0	0	0	68955
7 ALX	15944	3619	1303	478	4539	4421	5911	3402	0	1	0	0	4	7	0	0	0	0	0	0	0	0	0	39629
8 FFX	57999	4116	3211	1032	14254	20098	4167	12221	6	2	0	0	12	10	0	0	0	0	0	0	0	0	0	117128
9 LDN	2443	439	424	12	365	462	63	589	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4804
10 PW	8948	1108	817	40	920	1703	401	1709	0	4443	0	0	2	4	0	0	0	0	0	0	0	0	0	20095
11 FRD	851	263	490	7	35	71	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1724
12 CAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 HOW	4380	342	249	592	131	162	30	14	0	0	0	0	299	12	0	0	0	0	0	0	0	0	0	6211
14 AAR	4902	517	307	1202	156	173	79	41	0	0	0	0	18	283	3	0	0	0	0	0	0	0	0	7681
15 CAL	687	63	16	35	32	67	1	3	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	921
16 STM	46	4	0	0	3	6	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	62
17 CHS	1503	49	23	11	173	79	3	3	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	1848
18 FAU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19 STA	1244	247	166	6	258	358	215	53	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	2550
20 CL/JF	107	8	146	0	2	5	0	1	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	272
21 SP/FB	468	116	65	2	132	186	146	51	0	2	0	0	0	0	0	0	0	0	6	0	7	0	0	1181
22 KGEO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23 EXTL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	414908	128929	62561	27266	41490	58707	23436	36833	13	4449	2	0	712	502	20	0	7	0	7	0	9	0	0	799851

Table 9
1994 Difference in Total transit
(Base_Rerun – Base)

MODE CHOICE COMPARISON   Difference (Test - Base)
Purpose: ALL   MODE: Transit

ORIGIN | DESTINATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	TOTAL
1 DC CR	925	204	-171	-47	260	176	-40	46	0	-2	0	0	12	10	0	0	0	0	0	0	0	0	0	-1373
2 DC NC	766	487	39	27	155	34	-150	-69	0	-4	0	0	-38	-6	0	0	0	0	0	0	0	0	0	-1241
3 MTG	-453	-10	593	-42	-34	-132	-57	48	0	-1	-1	0	-8	0	0	0	0	0	0	0	0	0	0	97
4 PG	872	241	-99	254	135	82	39	-5	0	0	0	0	15	-4	0	0	0	0	0	0	0	0	0	-1530
5 ARLCR	168	-9	-19	-15	45	46	9	-2	0	-1	0	0	0	1	0	0	0	0	0	0	0	0	0	-223
6 ARNCR	573	-14	-97	-35	116	147	71	-37	-1	-3	0	0	-2	-10	0	0	0	0	0	0	0	0	0	-708
7 ALX	434	40	-96	-5	141	54	186	-27	0	0	0	0	-2	3	0	0	0	0	0	0	0	0	0	-728
8 FFX	1713	-5	-33	-30	545	611	119	843	-1	2	0	0	-6	-9	0	0	0	0	0	0	0	0	0	-3749
9 LDN	-217	16	56	0	11	38	13	82	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
10 PW	-118	-35	-97	-6	-52	6	80	252	0	105	0	0	2	1	0	0	0	0	0	0	0	0	0	-138
11 FRD	-89	-10	8	3	-6	-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	101
12 CAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 HOW	105	-30	-30	-14	-7	-6	-4	2	0	0	0	0	-123	0	0	0	0	0	0	0	0	0	0	107
14 AAR	-1	-29	-19	-66	-2	-16	-7	-2	0	0	0	0	2	-1	0	0	0	0	0	0	0	0	0	141
15 CAL	-5	8	-2	0	2	9	0	3	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	-18
16 STM	2	3	-1	0	3	1	0	0	0	0	0	0	0	0	0	0	-2	0	0	0	0	0	0	-6
17 CHS	68	7	2	5	13	10	1	2	0	0	0	0	0	0	0	0	-3	0	0	0	0	0	0	-105
18 FAU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19 STA	-172	-78	-97	0	-101	-93	-2	7	0	-1	0	0	0	-1	0	0	0	0	1	0	-1	0	0	538
20 CL/JF	-13	-1	-3	-2	-1	-1	-1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	19
21 SP/FB	-110	-51	-44	-1	-73	-77	-13	6	0	2	0	0	0	-1	0	0	0	0	0	0	2	0	0	360
22 KGEO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23 EXTL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	4448	734	-110	26	1150	882	244	1150	-3	97	0	0	-148	-16	3	0	-5	0	1	0	1	0	0	8454

Table 10
2005 Base/SIP Total transit

Simulation - Year: 2005 Alternative: base
Purpose: ALL MODE: Transit

ORIGIN \ DESTINATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	TOTAL
1 DC CR	49422	23253	9943	9488	4265	7075	2912	10080	21	68	0	0	170	79	1	0	3	0	0	0	0	0	0	116780
2 DC NC	128023	77912	17571	6968	4462	5989	3133	4241	48	63	1	0	309	251	5	0	8	0	0	0	0	0	0	248984
3 MTG	73058	12396	32789	3978	3732	8615	1639	5403	10	34	2	0	40	35	1	0	1	0	0	0	0	0	0	141733
4 PG	66465	10958	12010	12006	5388	4491	2031	3114	6	46	0	0	514	58	2	0	4	0	0	0	0	0	0	117093
5 ARLCR	6550	1384	612	423	904	1426	908	1015	2	17	0	0	7	4	0	0	0	0	0	0	0	0	0	13252
6 ARNCR	43816	7662	3620	1348	4249	9322	4826	5940	26	87	0	0	28	35	0	0	1	0	0	0	0	0	0	80960
7 ALX	19987	4338	1918	769	5880	6156	7945	6382	7	70	0	0	11	12	2	0	0	0	0	0	0	0	0	53477
8 FFX	62458	4600	4686	1608	16836	27688	7027	26813	232	141	0	0	13	12	0	0	5	0	0	0	0	0	0	152119
9 LDN	3079	421	743	29	373	657	83	2694	2420	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10499
10 PW	9673	1376	1408	170	1380	2805	1105	5448	0	24345	0	0	0	0	0	0	0	0	0	0	0	0	0	47710
11 FRD	544	153	517	6	22	51	8	3	0	0	255	0	0	0	0	0	0	0	0	0	0	0	0	1559
12 CAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 HOW	5051	418	390	598	179	253	39	47	0	0	0	0	711	32	0	0	0	0	0	0	0	0	0	7718
14 AAR	4760	508	284	987	137	185	66	73	0	0	0	0	66	741	2	0	0	0	0	0	0	0	0	7809
15 CAL	841	101	43	28	54	119	17	14	0	0	0	0	0	0	27	0	0	0	0	0	0	0	0	1244
16 STM	125	23	9	6	9	20	6	3	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	214
17 CHS	3832	199	144	152	500	259	29	33	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	5156
18 FAU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19 STA	863	223	127	13	307	499	334	191	0	13	0	0	0	0	0	0	0	0	2	0	3	0	0	2575
20 CL/JF	24	3	67	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	97
21 SP/FB	138	35	12	0	44	79	92	92	0	8	0	0	0	0	0	0	0	0	10	0	10	0	0	520
22 KGEO	18	7	0	1	3	1	4	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	39
23 EXTL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	478727	145970	86893	38579	48724	75691	32204	71590	2772	24894	258	0	1869	1259	40	0	43	0	12	0	13	0	0	1009538

Table 11
2005 Base/SIP_Rerun Total transit

Simulation - Year: 2005 Alternative: base
Purpose: ALL MODE: Transit

DESTINATION

ORIGIN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	TOTAL
1 DC CR	49296	23341	9834	9658	4315	7033	2840	9742	22	62	0	0	142	87	2	0	1	0	0	0	0	0	0	116375
2 DC NC	127125	77494	17435	7001	4358	5935	3128	4170	39	55	0	0	276	217	4	0	9	0	0	0	0	0	0	247246
3 MTG	71515	12253	32123	3932	3584	8437	1547	5538	7	27	0	0	36	17	2	0	3	0	0	0	0	0	0	139021
4 PG	64541	10677	11582	11933	5203	4373	2065	3093	7	38	0	0	428	55	1	0	4	0	0	0	0	0	0	114000
5 ARLCR	6590	1419	567	474	912	1426	861	982	2	14	0	0	7	7	0	0	0	0	0	0	0	0	0	13261
6 ARNCR	43835	7745	3501	1494	4214	9224	4744	5852	27	79	0	0	22	34	0	0	0	0	0	0	0	0	0	80771
7 ALX	19882	4333	1826	829	5780	6057	7905	6162	10	67	0	0	17	7	0	0	0	0	0	0	0	0	0	52875
8 FFX	60965	4371	4682	1688	16050	26268	6768	25275	207	141	0	0	9	9	0	0	1	0	0	0	0	0	0	146434
9 LDN	3234	413	677	24	354	623	74	2226	2189	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9814
10 PW	10538	1373	1631	173	1337	2762	1055	5121	0	24505	0	0	0	0	0	0	0	0	0	0	0	0	0	48495
11 FRD	484	146	419	5	18	46	3	4	0	0	249	0	0	0	0	0	0	0	0	0	0	0	0	1374
12 CAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 HOW	4530	392	347	579	165	253	44	43	0	0	0	0	567	20	0	0	0	0	0	0	0	0	0	6940
14 AAR	5068	515	294	939	139	193	66	80	0	0	0	0	56	671	1	0	0	0	0	0	0	0	0	8022
15 CAL	761	89	41	23	47	106	16	11	0	0	0	0	0	0	31	0	0	0	0	0	0	0	0	1125
16 STM	132	21	8	5	9	23	3	3	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	218
17 CHS	3726	181	130	136	490	245	27	26	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	4968
18 FAU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19 STA	1070	250	162	11	337	544	343	186	0	11	0	0	0	0	0	0	0	0	3	0	2	0	0	2919
20 CL/JF	23	1	53	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80
21 SP/FB	199	43	23	4	51	88	101	89	0	8	0	0	0	0	0	0	0	0	9	0	9	0	0	624
22 KGEO	20	6	4	0	3	3	3	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	44
23 EXTL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	473534	145063	85339	38908	47367	73641	31593	68607	2510	25008	249	0	1560	1124	41	0	39	0	12	0	11	0	0	994606

Table 12
2005 Difference in Total transit
(Base/SIP_Rerun – Base/SIP)

MODE CHOICE COMPARISON   Difference (Test - Base)
Purpose: ALL   MODE: Transit

ORIGIN | DESTINATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	TOTAL
1 DC CR	-126	88	-109	170	50	-42	-72	-338	1	-6	0	0	-28	8	1	0	-2	0	0	0	0	0	0	405
2 DC NC	-898	-418	-136	33	-104	-54	-5	-71	-9	-8	-1	0	-33	-34	-1	0	1	0	0	0	0	0	0	1738
3 MTG	-1543	-143	-666	-46	-148	-178	-92	135	-3	-7	-2	0	-4	-18	1	0	2	0	0	0	0	0	0	2712
4 PG	-1924	-281	-428	-73	-185	-118	34	-21	1	-8	0	0	-86	-3	-1	0	0	0	0	0	0	0	0	3093
5 ARLCR	40	35	-45	51	8	0	-47	-33	0	-3	0	0	0	3	0	0	0	0	0	0	0	0	0	-9
6 ARNCR	19	83	-119	146	-35	-98	-82	-88	1	-8	0	0	-6	-1	0	0	-1	0	0	0	0	0	0	189
7 ALX	-105	-5	-92	60	-100	-99	-40	-220	3	-3	0	0	6	-5	-2	0	0	0	0	0	0	0	0	602
8 FFX	-1493	-229	-4	80	-786	-1420	-259	-1538	-25	0	0	0	-4	-3	0	0	-4	0	0	0	0	0	0	5685
9 LDN	155	-8	-66	-5	-19	-34	-9	-468	-231	0	0	0	0	0	0	0	0	0	0	0	0	0	0	685
10 PW	865	-3	223	3	-43	-43	-50	-327	0	160	0	0	0	0	0	0	0	0	0	0	0	0	0	-785
11 FRD	-60	-7	-98	-1	-4	-5	-5	1	0	0	-6	0	0	0	0	0	0	0	0	0	0	0	0	185
12 CAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 HOW	-521	-26	-43	-19	-14	0	5	-4	0	0	0	0	-144	-12	0	0	0	0	0	0	0	0	0	778
14 AAR	308	7	10	-48	2	8	0	7	0	0	0	0	-10	-70	-1	0	0	0	0	0	0	0	0	-213
15 CAL	-80	-12	-2	-5	-7	-13	-1	-3	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	119
16 STM	7	-2	-1	-1	0	3	-3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	-4
17 CHS	-106	-18	-14	-16	-10	-14	-2	-7	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	188
18 FAU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19 STA	207	27	35	-2	30	45	9	-5	0	-2	0	0	0	0	0	0	0	0	1	0	-1	0	0	-344
20 CL/JF	-1	-2	-14	-1	1	1	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17
21 SP/FB	61	8	11	4	7	9	9	-3	0	0	0	0	0	0	0	0	0	0	-1	0	-1	0	0	-104
22 KGEO	2	-1	4	-1	0	2	-1	1	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	-5
23 EXTL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	-5193	-907	-1554	329	-1357	-2050	-611	-2983	-262	114	-9	0	-309	-135	1	0	-4	0	0	0	-2	0	0	-14932

Table 13
2025 Base Total Transit

Simulation - Year: 2025 Alternative: base
Purpose: ALL MODE: Transit

DESTINATION

ORIGIN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	TOTAL
1 DC CR	51046	24773	9149	9971	5566	9373	2492	9923	27	79	0	0	96	38	0	0	2	0	0	0	0	0	0	122535
2 DC NC	151063	96121	18379	9202	5765	8511	3341	4257	53	80	0	0	210	166	0	0	1	0	0	0	0	0	0	297149
3 MTG	91854	17342	44495	5412	5445	11516	1498	7544	34	32	0	0	60	19	0	0	3	0	0	0	0	0	0	185254
4 PG	91822	18935	12612	19043	7586	7346	2851	3653	29	20	0	0	711	105	0	0	5	0	0	0	0	0	0	164718
5 ARLCR	7447	1751	535	436	1381	2676	1063	1398	8	25	0	0	4	3	0	0	0	0	0	0	0	0	0	16727
6 ARNCR	51350	9525	3283	1484	7511	18502	6475	9285	132	143	0	0	39	18	0	0	0	0	0	0	0	0	0	107747
7 ALX	25456	5812	1700	1134	8316	10762	11139	7800	22	105	0	0	20	12	0	0	1	0	0	0	0	0	0	72279
8 FFX	67090	6280	4040	1974	21620	51826	9533	49327	2646	284	0	0	23	13	0	0	4	0	0	0	0	0	0	214660
9 LDN	1848	436	1011	87	396	1271	156	18139	14026	0	0	0	2	0	0	0	0	0	0	0	0	0	0	37372
10 PW	6710	1428	462	182	1181	3998	1458	9244	19	26736	0	0	3	2	0	0	0	0	0	0	0	0	0	51423
11 FRD	72	54	918	7	9	14	1	7	0	0	689	0	0	0	0	0	0	0	0	0	0	0	0	1771
12 CAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 HOW	2265	448	516	673	141	180	25	40	0	0	0	0	1274	61	0	0	0	0	0	0	0	0	0	5623
14 AAR	6298	1062	384	1836	210	312	113	121	0	0	0	0	160	998	4	0	0	0	0	0	0	0	0	11498
15 CAL	1765	534	63	377	115	271	78	36	0	0	0	0	1	1	65	0	0	0	0	0	0	0	0	3306
16 STM	203	71	9	45	9	32	11	5	0	0	0	0	0	1	0	0	30	0	0	0	0	0	0	416
17 CHS	8755	915	159	762	868	654	155	84	0	0	0	0	4	2	0	0	65	0	0	0	0	0	0	12423
18 FAU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19 STA	207	79	39	6	87	230	217	288	0	65	0	0	0	0	0	0	0	0	3	0	1	0	0	1222
20 CL/JF	0	0	198	0	0	0	0	10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	209
21 SP/FB	28	14	12	2	10	23	20	43	0	13	0	0	0	0	0	0	0	0	8	0	14	0	0	187
22 KGEO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23 EXTL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	565279	185580	97964	52633	66216	127497	40626	121204	16996	27582	690	0	2607	1439	69	0	111	0	11	0	15	0	0	1306519

Table 14
2025 Base_Rerun Total Transit

Simulation - Year: 2025 Alternative: base
Purpose: ALL   MODE: Transit

ORIGIN \ DESTINATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	TOTAL
1 DC CR	49472	24621	9368	10244	5315	9234	2742	9355	41	59	0	0	96	69	0	0	2	0	0	0	0	0	0	120618
2 DC NC	143428	93595	18466	9234	5464	8621	3523	4352	116	51	0	0	270	229	0	0	4	0	0	0	0	0	0	287353
3 MTG	86802	16273	40704	5242	4836	12911	1662	7206	63	24	1	0	63	19	0	0	1	0	0	0	0	0	0	175807
4 PG	78249	15926	11870	17416	6670	6672	2638	3543	42	26	0	0	616	89	1	0	7	0	0	0	0	0	0	143765
5 ARLCR	7416	1867	599	499	1273	2544	1044	1261	11	16	0	0	8	3	0	0	0	0	0	0	0	0	0	16541
6 ARNCR	50368	9992	3646	1726	6981	17394	6409	8651	210	104	0	0	40	35	0	0	1	0	0	0	0	0	0	105557
7 ALX	23991	5901	1887	1212	7664	10037	11010	7393	39	69	0	0	29	18	0	0	0	0	0	0	0	0	0	69250
8 FFX	65026	6246	4812	2086	19694	45904	8795	41411	2422	309	0	0	47	25	1	0	2	0	0	0	0	0	0	196780
9 LDN	3282	800	1514	84	603	2142	258	19723	10599	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39005
10 PW	7865	1646	839	209	1225	3815	1158	7127	9	26560	0	0	1	2	0	0	0	0	0	0	0	0	0	50456
11 FRD	488	207	1264	21	20	46	5	23	0	0	505	0	0	0	0	0	0	0	0	0	0	0	0	2579
12 CAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 HOW	3756	438	370	587	168	266	37	49	1	0	0	0	723	40	0	0	0	0	0	0	0	0	0	6435
14 AAR	6397	885	364	1544	202	307	101	124	2	0	0	0	105	822	5	0	0	0	0	0	0	0	0	10858
15 CAL	1475	366	62	184	105	266	56	28	0	0	0	0	0	0	52	0	0	0	0	0	0	0	0	2594
16 STM	266	82	14	36	19	51	14	5	0	0	0	0	0	0	0	0	24	0	0	0	0	0	0	511
17 CHS	7740	674	199	517	1002	603	107	82	0	0	0	0	0	1	0	0	59	0	0	0	0	0	0	10984
18 FAU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19 STA	580	188	70	11	192	450	336	302	0	39	0	0	0	0	0	0	0	0	3	0	4	0	0	2175
20 CL/JF	88	15	188	4	4	10	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	312
21 SP/FB	52	19	14	2	21	43	43	70	0	14	0	0	0	0	0	0	0	0	8	0	13	0	0	299
22 KGEO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23 EXTL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	536741	179741	96250	50858	61458	121316	39938	110708	13555	27271	506	0	1998	1352	59	0	100	0	11	0	17	0	0	1241879

Table 15
2025 Difference in Total Transit
(Base_Rerun – Base)

MODE CHOICE COMPARISON   Difference (Test - Base)
Purpose: ALL   MODE: Transit

DESTINATION

ORIGIN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	TOTAL
1 DC CR	-1574	-152	219	273	-251	-139	250	-568	14	-20	0	0	0	31	0	0	0	0	0	0	0	0	0	1917
2 DC NC	-7635	-2526	87	32	-301	110	182	95	63	-29	0	0	60	63	0	0	3	0	0	0	0	0	0	9796
3 MTG	-5052	-1069	-3791	-170	-609	1395	164	-338	29	-8	1	0	3	0	0	0	-2	0	0	0	0	0	0	9447
4 PG	-13573	-3009	-742	-1627	-916	-674	-213	-110	13	6	0	0	-95	-16	1	0	2	0	0	0	0	0	0	20953
5 ARLCR	-31	116	64	63	-108	-132	-19	-137	3	-9	0	0	4	0	0	0	0	0	0	0	0	0	0	186
6 ARNCR	-982	467	363	242	-530	-1108	-66	-634	78	-39	0	0	1	17	0	0	1	0	0	0	0	0	0	2190
7 ALX	-1465	89	187	78	-652	-725	-129	-407	17	-36	0	0	9	6	0	0	-1	0	0	0	0	0	0	3029
8 FFX	-2064	-34	772	112	-1926	-5922	-738	-7916	-224	25	0	0	24	12	1	0	-2	0	0	0	0	0	0	17880
9 LDN	1434	364	503	-3	207	871	102	1584	-3427	0	0	0	-2	0	0	0	0	0	0	0	0	0	0	-1633
10 PW	1155	218	377	27	44	-183	-300	-2117	-10	-176	0	0	-2	0	0	0	0	0	0	0	0	0	0	967
11 FRD	416	153	346	14	11	32	4	16	0	0	-184	0	0	0	0	0	0	0	0	0	0	0	0	-808
12 CAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 HOW	1491	-10	-146	-86	27	86	12	9	1	0	0	0	-551	-21	0	0	0	0	0	0	0	0	0	-812
14 AAR	99	-177	-20	-292	-8	-5	-12	3	2	0	0	0	-55	-176	1	0	0	0	0	0	0	0	0	640
15 CAL	-290	-168	-1	-193	-10	-5	-22	-8	0	0	0	0	-1	-1	-13	0	0	0	0	0	0	0	0	712
16 STM	63	11	5	-9	10	19	3	0	0	0	0	0	0	-1	0	0	-6	0	0	0	0	0	0	-95
17 CHS	-1015	-241	40	-245	134	-51	-48	-2	0	0	0	0	-4	-1	0	0	-6	0	0	0	0	0	0	1439
18 FAU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19 STA	373	109	31	5	105	220	119	14	0	-26	0	0	0	0	0	0	0	0	0	0	3	0	0	-953
20 CL/JF	88	15	-10	4	4	10	0	-7	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	-103
21 SP/FB	24	5	2	0	11	20	23	27	0	1	0	0	0	0	0	0	0	0	0	0	-1	0	0	-112
22 KGEO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23 EXTL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	-28538	-5839	-1714	-1775	-4758	-6181	-688	-10496	-3441	-311	-184	0	-609	-87	-10	0	-11	0	0	0	2	0	0	-64640

Appendix F

Airport choice and ground access mode choice models:
A review of practice

A technical working paper

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Metropolitan Washington Council of Governments

June 30, 2003

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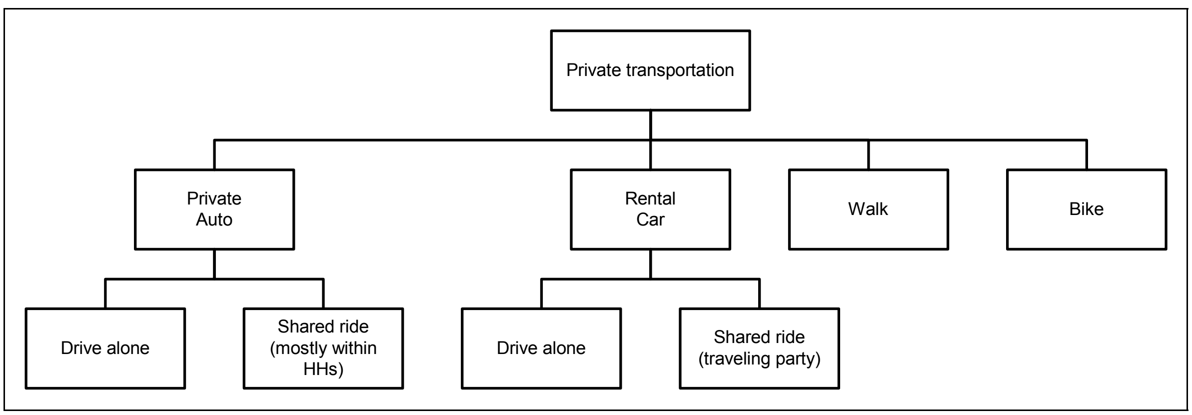
Introduction

One of the goals of the COG/TPB models development program has been to improve the representation of special traffic generators. A special generator is a site, facility, or area that has unique trip making characteristics that are different from those represented in the standard trip production and attraction models used in the trip generation step of the regional travel forecasting model. Examples of special generators include airports, military bases, universities, tourist attractions, and major shopping centers. The goal of this project was to begin development of a more formal airport access demand model, including potentially incorporating a mode choice component.[6] The focus of this report is a review of both airport choice models and airport ground access mode choice models in use in the U.S. The report concludes with a set of recommendations.

Airport ground access travel in the Washington area is very complex. The region is served by three commercial airports and there are many ground access modes of travel to each airport. The region's three commercial airports are Ronald Reagan Washington National Airport (DCA), Washington Dulles International Airport (IAD), and Baltimore/Washington International Airport (BWI). Travel modes can be divided into private modes (such as private auto, walk, bike) and public modes (such as mass transit and paratransit), as shown in Figure 1 and Figure 2.

Figure 1 Private transportation modes



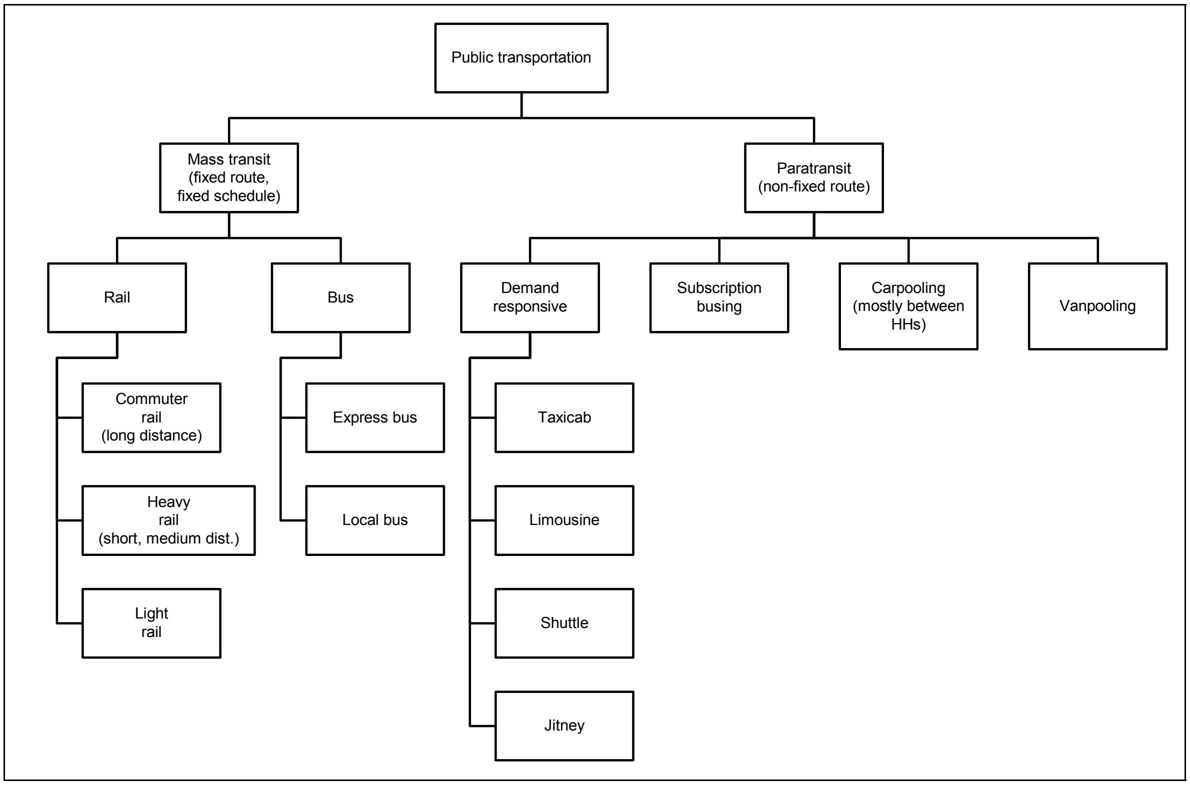
Ref: modes_private.vsd

Paratransit represents a middle ground between the flexibility of private transportation and the fixed-route, fixed-schedule nature of mass transit. Carpooling is sometimes considered part of private transportation and sometimes considered part of public transportation. In the Washington area, all of the modes shown in Figure 1 and Figure 2 are represented as airport access modes, with the exception of jitney and subscription busing. Two of the three airports are well served by rail transit (National and BWI) and there are plans to extend rail to Dulles. The transit networks developed to support the regional travel demand model usually include (fixed-route) mass transit, but not paratransit modes. Similarly, the walk and bicycle modes are usually only

[6] Unified Planning Work Program (UPWP) for Transportation Planning for the Metropolitan Washington Region, FY 2003, MWCOG, p. 2-35.

represented in a limited way (e.g. as access modes to transit) in the travel demand forecasting model.

Figure 2 Public transportation modes



Ref: modes_public.vsd

Local data about airport access trips

Airport access trips are defined to be trips to or from the airport that make use of the ground transportation system. Airport access trips can be classified into four groups: 1) air passenger trips, 2) employee trips, 3) airport visitor trips, and 4) air cargo trips (Shapiro 1996 p. 75). Air passenger ground access trips include only originating and terminating (destination) air passengers – also known as O&D air passengers – not connecting air passengers, who never leave the airport premises. Employee trips include airline employees, airport employees, and tenants at the airport, such as shops and restaurants. Airport visitor trips include trips made by "meeters and greeters," delivery trips (such as couriers), and service trips (such as maintenance and repair). Air cargo ground access trips include those made by trucks delivering or picking up cargo at the airport.

Airport access trips generated by airline passengers typically represent only about half of the trips to and from an airport (Shapiro 1996 p. 77). Ideally, an airport ground access model would include all four classes of users. In reality, it is hard to obtain observed data for all four user groups. Many cities conduct recurring air passenger surveys at their commercial airports, but few, if any, conduct surveys that cover all four of the airport user groups. For example, COG conducts an air passenger survey on a regular basis – what is now every two years – but COG does not have data on the other three user groups (airport employees, airport visitors, or air cargo).

The latest Washington-Baltimore air passenger survey was conducted in 2002, but it will not be available for use until the summer of 2003. However, the previous survey, conducted in 2000, is available for use now. Funded jointly by the Metropolitan Washington Airports Authority (MWAA) and the Maryland Aviation Administration (MAA), the 2000 survey was the fifth in a series of air passenger surveys at the three commercial airports. More than 19,000 departing passengers were surveyed, out of a possible 48,000 passengers on 688 flights, representing a 40 percent overall rate of return for the survey (MWCOG 2002, p. 1). Previous surveys were conducted in 1981/1982, 1987, 1992, and 1998. The 2000 survey was conducted concurrently at the three commercial airports over a two-week period, from October 15 to October 28. A sample of departing air travelers was obtained by surveying all passengers on selected flights scheduled during the survey period. The sample frame was developed using an electronic file of flights from the Official Airline Guide (OAG). The survey responses were factored to represent *annual* passenger trips. Trip origin addresses were geocoded to the transportation analysis zone (2,191 TAZs), as well as to the aviation analysis zone (AAZ). AAZs 1-83 are internal and AAZs 84-99 are external to the Washington-Baltimore region (e.g., 84 = Outer Maryland and 89 = New Jersey).

Treatment of airport access trips in the COG/TPB travel model

Travel forecasting models typically segment the estimated population into market segments. For example, one could segment the population in terms of resident travel vs. non-resident travel. Although the Version 2.1 travel forecasting model makes use of a resident/non-resident market segmentation, the major market segmentation in the Version 2.1 mode is “modeled” trips vs. “non-modeled” trips. “Modeled” trips are those that are estimated in trip generation and flow through the entire model chain, ending with traffic assignment. “Non-modeled” trips, also known as “residual” trips are exogenous trip tables that pass through only the last two model steps: the time-of-day model and the traffic assignment model. Estimates of modeled trips are based on regional household travel surveys, such as the COG 1994 Household Travel Survey. So modeled trips correspond roughly to resident trips, although it is possible that some non-resident trips could be recorded in a household travel survey (e.g. visitors staying at a private residence). Non-modeled or “residual” trips include the following groups:

- Through trips
- Taxi
- School
- Visitor
- Air passenger

Non-modeled trips are a mix of non-resident trips (e.g., visitor), resident trips (e.g., school), and categories that include both residents and non-residents (e.g., taxi, air passenger).

The weighted air passenger survey data represents *annual* air passenger enplanements, due to both residents and non-residents. Therefore, the survey contains both modeled and non-modeled motorized travel attracted to each of the three commercial airports from various TAZs (MWCOG

2001b, p. 6-2). Since the COG travel model estimates average *weekday* travel, the air passenger survey data was adjusted as follows:

1. Annual passenger enplanements were converted to average weekday enplanements.
2. Since every trip *to* the airport (originating air passenger trip) was presumed to have a corresponding trip *from* the airport (destination air passenger trip), the trip table with airport access trips was transposed, resulting in an airport egress trip table. The access and egress trip tables were added together to get total local origination and destination air passenger trips on an average weekday.

Modeled air passenger trips are subsumed in two existing trip purposes: home-based other (HBO) and non-home-based (NHB). Non-modeled air passenger trips exist in a separate daily trip table, that is then divided into the three time-of-day time periods using the following factors: AM peak period (10%), PM peak period (10%), and off peak (80%).

Logit models

Logit models, either multinomial logit (MNL) or nested logit (NL) are the most common model type for discrete choice models, such as airport choice models. Given the preponderance of these models, a brief description of logit models will follow.

Under the theory of utility maximization, a decision maker will generally choose the alternative that maximizes his or her utility. However, one cannot simply calculate the utilities for each alternative and for each decision maker, and then determine which one is the maximum. One must transform the utility values into probability values. The logit equation, Eq. 1, is used to transform utility values into probability values. Each utility function is assumed to have a random error term and the distribution of this random error term determines the functional form of the logit equation. In this case, the logit equation is derived from the fact that the error term is assumed to be logistically distributed. The logit equation gives the probability P that a decision maker i will choose alternative j, given a utility U for each alternative (where n is the set of available alternatives). It is basically a way to transform utility values into probabilities.

$$P[i,j] = \frac{e^{U[i,j]}}{\sum_{k=1}^{n} e^{U[i,j]}} \qquad \textbf{Eq. 1}$$

The utility U[i,j] is generally expressed as a linear function, as shown in Eq. 2.

$$U[i,j] = b_0 + b_1 * X_1[i,j] + \ldots + b_m * X_m[i,j] \qquad \textbf{Eq. 2}$$

where m is the number of variables in the utility equation, the X's are variables that capture relevant attributes of the decision maker and the alternative, and the b's are the coefficients to be estimated.

Case Studies

For this study, eight different planning agencies were contacted in seven different cities - two agencies were in New York City. Three of the cities have only one commercial airport apiece: Atlanta, Boston, and Portland, Oregon. One of the cities, Chicago, has two commercial airports. Two of the cities have three commercial airports: New York and San Francisco. And one city, Los Angeles, has six commercial airports (See Table 6). All the cities contacted have had air passenger surveys conducted within the last ten years. Of the eight planning agencies contacted for this study, two had no airport model as a part of their four-step travel model (CATS and NYMTC) and one could not be reached to obtain information about its airport model (Boston MPO). The remaining five agencies had one or more models used to estimate air passenger ground access trips (See Table 7). A list of contacts for each agency is found at the end of this report.

Table 6 Summary of commercial airports and air passenger surveys: Contacted cities vs. Washington, D.C.

City	Commercial Airports	Date of Most Recent Air Pax. Survey
Atlanta	Hartsfield (ATL)	2000
Boston	Logan (BOS)	1999
Chicago	O'Hare (ORD) Midway (MDW)	1997 (ORD)
Los Angeles	Los Angeles (LAX) Ontario (ONT) John Wayne (SNA) Burbank (BUR) Long Beach (LGB) Palm Springs (PSP)	2000/2001 (LAX and ONT) Also 1993
New York	John F. Kennedy (JFK) Newark (EWR) LaGuardia (LGA)	1992/1993
Portland, Oregon	Portland Int'l (PDX)	1996
San Francisco	San Francisco (SFO) Oakland (OAK) San José (SJC)	2001 Also 1975, 1980, 1985, 1990, 1995
Washington, D.C.	Baltimore-Washington (BWI) Dulles (IAD) National (DCA)	2002 Also 1981/1982, 1987, 1992, 1998, 2000

Table 7 Summary of airport models used by various planning agencies: Contacted cities vs. Washington, D.C.

City	Planning Agency	Airport Model(s)
Atlanta	ARC	1) Zonal allocation of O&Ds, 2) Ground access mode choice model
Boston	Boston MPO, CTPS	Airport ground access mode choice model*
Chicago	CATS	None
Los Angeles	SCAG	RADAM. MNL model that allocates current and forecast air passenger and cargo demand
New York	NYMTC	None
New York	PANYNJ	Econometric model for forecasting the number of passengers at the three airports
Portland, Oregon	Portland Metro	1) Zonal allocation of origins, 2) Ground access mode choice model
San Francisco	MTC	Airport choice model and airport ground access model
Washington, D.C.	MWCOG	No formal model. Resident air passenger trips are part of HBO and NHB. Non-resident air passenger trips are kept as separate trip table that is used in traffic assignment, but not in TG, TD, or MC.

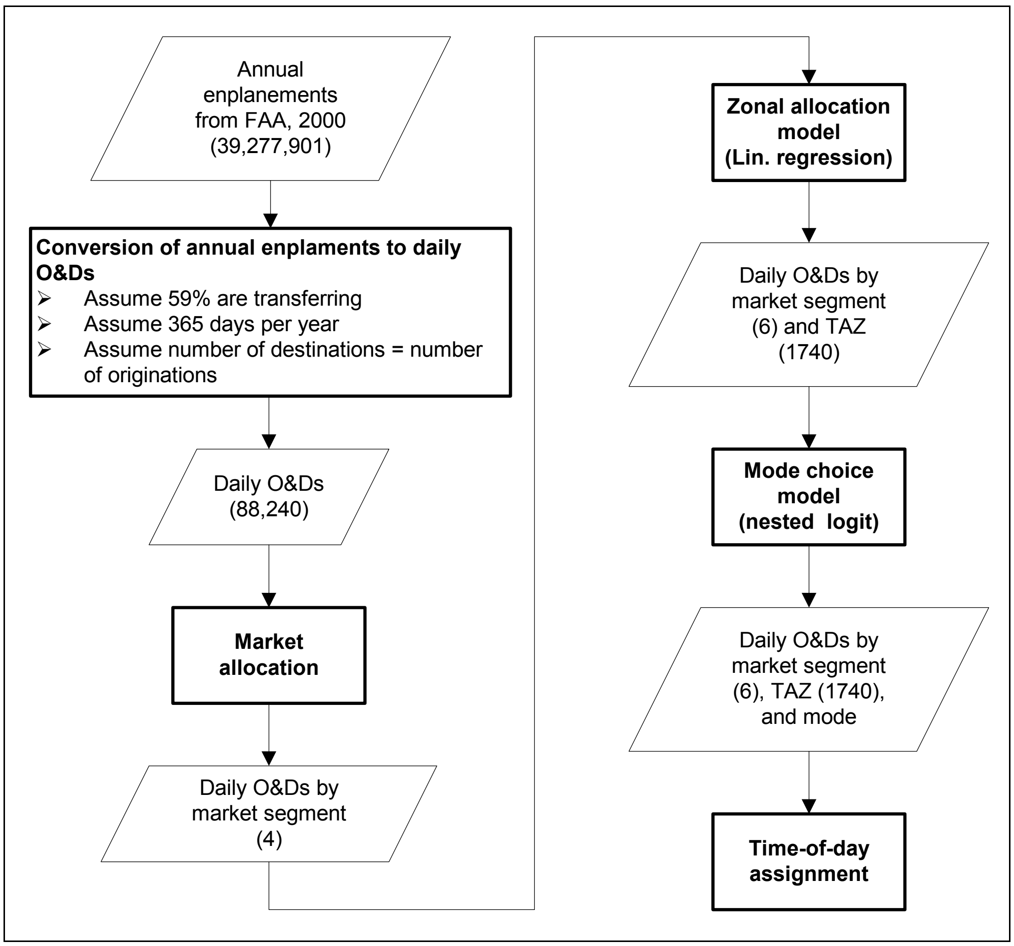
* Unable to obtain information on this model.

Case studies of each city contacted are presented below.

Atlanta: Atlanta Regional Commission (ARC)

The Atlanta Regional Commission (ARC) is the MPO for the Atlanta region. Atlanta has only one major commercial airport – Hartsfield Atlanta International Airport (ATL) - but it is one of the world's busiest passenger airports. An air passenger survey was conducted at Hartsfield in 2000 and was used for the development of their airport model. COG has received pre-release drafts of the model documentation (ARC 2003) and the user's guide (ARC 2003b). The basic structure of the Atlanta airport mode can be seen in Figure 3. The model has essentially four main sub-models: 1) conversion of annual enplanements to daily originations and destinations; 2) market allocation of O&Ds; 3) zonal allocation of O&Ds; and 4) mode choice of ground access trips.

Figure 3 Atlanta's airport model: Data flow



Ref: "atlanta airport model.vsd"

The initial input to the model is annual enplanements, which ARC gets from the FAA. In 2000, Hartsfield Airport had 39,277,901 annual enplanements. An enplanement is a passenger boarding an aircraft. Enplanements include both locally originating passengers (local originations) and "connecting" or "transferring" passengers. Since transferring passengers neither leave the terminal building nor make use of the ground transportation system, they need to be subtracted out. According to the Hartsfield Master Plan, 59% of these enplanements were transferring passengers. Consequently, about 41%, or 16,103,939, were originating enplanements. After factoring out the transferring enplanements, annual figures are converted to daily figures by dividing by 365, resulting in about 44,120 daily originating enplanements. Finally, it is assumed that for each locally originating air passenger enplanement, there is one locally destined air passenger deplanement. Thus, daily originations are multiplied by 2 to obtain daily originations and destinations, resulting in about 88,240 local O&Ds per day.

The second step in the modeling chain is the market allocation. The Atlanta airport model uses four primary market segments: resident business, resident non-business, non-resident business, and non-resident non-business. These four market segments are used in many of the airport models reviewed. Based on airport survey data, the share of air passengers in each market segment was determined (See Table 8).

Table 8 Atlanta's airport model: Share of air passenger trips by market segment

Market segment	Percentage
Resident business	22.49%
Resident non-business	31.30%
Non-resident business	24.44%
Non-resident non-business	21.77%
Total	100.00%

Source: (ARC 2003, p. 2)

The third step is the zonal allocation model, which allocates the non-airport end of air passenger ground access trips to ground-side locations (i.e., residences, offices, hotels, etc.). In addition to the four major market segments, two types of origin location are defined: private residence and business (which can include hotel/motel). The four market segments and two origin location types were combined to form seven market segment categories for use in the zonal allocation model, as shown in Table 9.

Table 9 Atlanta's airport model: Market segment categories used

	Resident status	Purpose of air trip	Percent of total	Daily origs	Origin location	Pct of market segmnt	Daily origs
1	Resident	Business	22.49%	9,923	Private residence	77.11%	7,651
2					Business	22.89%	2,271
3		Non-business	31.30%	13,810	Private residence	100.00%	13,810
4	Non-resident	Business	24.44%	10,783	Business	91.87%	9,907
5					Private residence	8.13%	877
6		Non-business	21.77%	9,605	Private residence	81.65%	7,843
7					Business	18.35%	1,763
			100.00%	44,121			44,121

The form of the zonal allocation model is a series of ordinary least squares (OLS) linear regression equations. The independent variables in the regression equations were chosen to be either households by income level or total employment. The set of equations making up the market allocation model is shown in Figure 4. For resident business travelers, it was found that 77% began their trip at a private residence and 23% began at a business. The two allocation models for resident business travelers are Eq. 3 and Eq. 4. The coefficients of these two equations have been adjusted so that they will estimate the total 2000 air passenger originations correctly. In developing these two equations, it was found that they underestimated the number of air passenger originations to Fulton County (primarily the city of Atlanta) and overestimated origins to some of the outer counties, such as Cherokee, Forsyth, Paulding, Douglas, Coweta, Fayette, Clayton, Henry, and Rockdale. A set of six K factors was developed to adjust the model for these errors (See Table 10). These K factors were used on the two equations for resident business travel and on the other equations that are shown in Figure 4.

Figure 4 Atlanta's airport model: Equations to allocate air passenger trip ends to the non-airport end of the ground access trip

Market segment	Equation	
Resident Business, from Private Residence	0.0006517 * Low Income HHs + 0.0032581 * Med. Low Income HHs + 0.0065163 * Med. High Income HHs + 0.0097031 * High Income HHs	**Eq. 3**
Resident Business, from Business	0.0018795 * Total Employment	**Eq. 4**
Resident Non-Business	0.0012032 * Low Income HHs + 0.0060157 * Med. Low Income HHs + 0.0200527 * Med. High Income HHs + 0.0245934 * High Income HHs	**Eq. 5**
Non-Resident Business	0.0084322 * Total Employment	**Eq. 6**
Non-Resident Non-Business, from Private Res.	0.0006354 * Low Income HHs + 0.0031770 * Med. Low Income HHs + 0.0105898 * Med. High Income HHs + 0.0132372 * High Income HHs	**Eq. 7**
Non-Resident Non-Business, from Business	0.0019881 * Total Employment	**Eq. 8**

Table 10 Atlanta's airport model: K factors used to adjust the zonal allocation models

Region	Factor on Employment	Factor on HHs
Middle Fulton	1.49	1.37
Cobb/Gwinett/DeKalb/NF/SF	0.55	0.95
Other areas	0.07	0.40

For resident non-business travelers, it was found that almost all trips originated at a private residence. Therefore, the equation for this category of travelers (Eq. 5) uses HHs by income level. For non-resident business travelers, 92% of the travelers began at a business (55% of these from a hotel or motel) and 8% began at a private residence. Since the land use forecasts for Atlanta did not include specific measures for hotels and motels, the non-resident business was developed in the same manner as the resident business model, namely, "total employment" was the independent variable in the regression allocation equation (Eq. 6). For non-resident non-business trips, 82% began at a private residence and 18% began at a business. Thus, the following two equations were Eq. 7 and Eq. 8.

The fourth step is the mode choice model. A nested logit model was used for the ground-access mode choice model. There were two separate model structures, shown in Figure 6 and Figure 5, but four separate logit models, shown in Figure 7, which spans two pages. Non-residents are assumed to have three primary choices: 1) being dropped off or picked up by someone in a private automobile, 2) using a rental car, or 3) using public transportation, which is referred to as "non-private-auto." Public transportation includes either regularly scheduled fixed route service (such as the MARTA heavy rail and bus) or taxi. The free hotel shuttles were considered for inclusion in the model, but, according to the report, "the survey data did not include enough observations of this mode to support it being used as a separate mode." (ARC 2003, p. 5) Residents are assumed to have the same travel modes available, except that the rental car mode is replaced with "drive self" and both "drive self" and "dropped off" are members of the "private auto" branch.

Figure 5 Atlanta's airport model: Mode choice model, non-residents

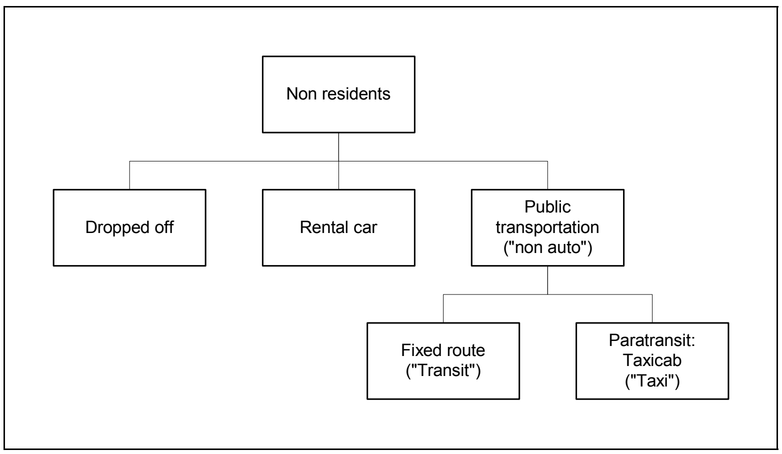
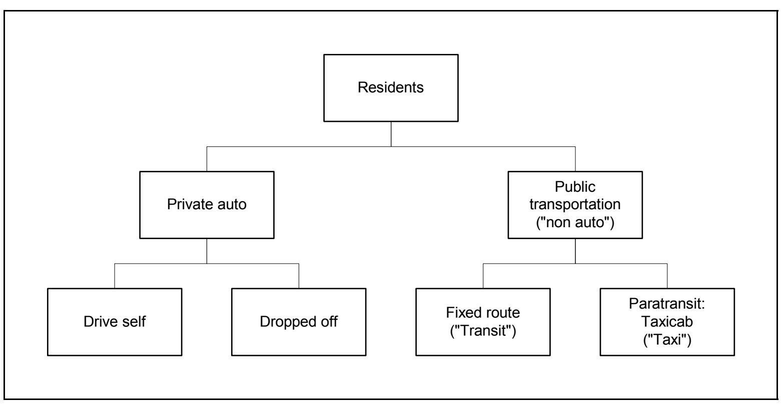


Figure 6 Atlanta's airport model: Mode choice model, residents



According to the documentation, the coefficients on time and cost in Figure 7 were obtained from other air passenger models, mainly those used in Washington[7] and San Francisco. However, the modal bias constants, at the bottom of Figure 7, were developed using the Atlanta air passenger survey. The resident mode choice model calculates the number of trips in the

[7] When the report refers to a "Washington" air passenger model, it is uncertain which model is being referenced. Perhaps an air passenger model developed by a consultant for a study in the Washington, D.C. area.

"drive self" and "dropped off" modes, but it does not do a separate calculation of auto occupancy. Instead, it uses user-entered values. For calibration, the following values were used: Drive Self = 1.0, Dropped Off = 1.1, Rental Car = 1.1, Taxi = 1.1. In the case of "drop off" trips, it is assumed that each air passenger being dropped off generates two vehicle trips – one coming and one going.

Observed and estimated daily O&D air passenger trips for 2000 are shown in Figure 8. The model appears to perform well at the regional level.

Figure 7 Atlanta's airport model: Ground-access mode choice model - Utility equations and bias coefficients

Part 1 of 2

<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

Figure 7 Atlanta's airport model: Ground-access mode choice model - Utility equations and bias coefficients

Part 2 of 2

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 lonF-term parking cost at MSY (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 not divided by average vehicle occupancy.

biasMM = bias coefficients by mode and purpose, as follows:

Mode (MM)	Bus., Res.	Bus., Non-Res.	Non-Bus. , Res.	Non-Bus. , Non-Res.
Transit (TR)	-9.544	-7.994	-2.605	-6.047
Rental Car (RC)	N/A	-3.735	N/A	-2.994
Drive Self (DS)	5.428	N/A	4.517	N/A
Non-Auto Nest (NA)	7.959	7.577	2.760	3.383

Figure 8 Atlanta's airport model: Observed and estimated O&D air passenger trips by mode, 2000

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	0	14,936	0	30,140
Rental Car	0	7,426	0	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	549	3,853	5,357	9,474	19,233
Drive Self	15,173	0	14,907	0	30,080
Rental Car	0	7,375	0	7,510	14,885
Taxi	3,075	5,868	796	1,230	10,969
Transit	1,049	4,471	6,559	996	13,075
Total	19,846	21,567	27,619	19,210	88,242

Percent Difference (Estimated less Observed / Observed)

Mode	Business, Residents	Business, Non-Residents	Non-business, Residents	Non-business, Non-Residents	Total
Dropped Off	-0.54%	-0.18%	-0.24%	0.00%	-0.12%
Drive Self	-0.20%	N / A	-0.19%	N / A	-0.20%
Rental Car	N / A	-0.69%	N / A	0.00%	-0.34%
Taxi	0.29%	0.03%	4.46%	0.00%	0.41%
Transit	2.44%	1.29%	0.11%	0.00%	0.69%
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.

Boston: Central Transportation Planning Staff (CTPS)

The Boston Metropolitan Planning Organization is composed of seven agencies, seven municipalities, and a public advisory committee that collectively carry out the federally mandated "continuing, comprehensive and cooperative" ("3C") transportation planning process for the Boston region. The Central Transportation Planning Staff (CTPS) provides technical and policy-analysis support to the Boston MPO and other members of the region's transportation community.

According to a recent newsletter from the Boston MPO (TRANSReport, April 2001), CTPS had $85,000 in FY-2001 to update the Logan Airport ground-access mode-choice model to reflect the results of a 1999 air passenger survey. Despite several attempts, COG staff has been unable to get further information on either the Boston airport model or their air passenger survey.

Chicago: Chicago Area Transportation Study (CATS)

The Chicago Area Transportation Study (CATS) is the designated MPO for the northeastern Illinois region. The Chicago area has two commercial airports - Chicago O'Hare Airport (ORD) and Chicago Midway Airport (MDW) – though O'Hare is by far the dominant airport; it is over three times as busy as Midway. According to staff at CATS, the agency has neither an airport choice model nor a ground access mode choice model. According to CATS staff, the big policy debate is where to build a new third commercial airport, with the most likely location being southeast of the city.

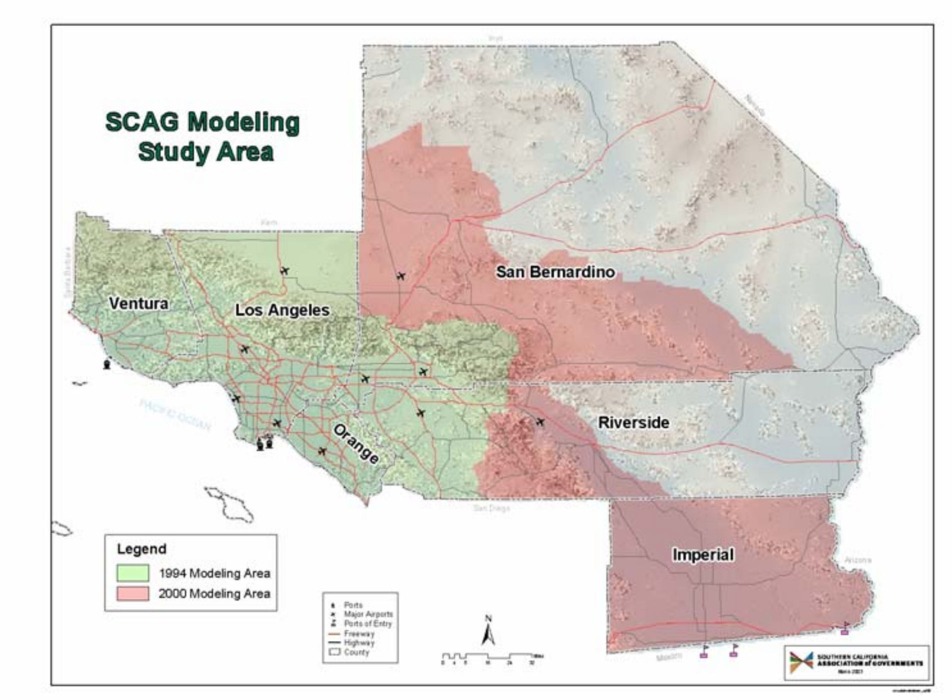
In the CATS four-step travel model, airport trips are treated in trip generation. CATS creates a fixed trip table and treats the airport (O'Hare) as an external station. Trips are HBO in terms of mode choice. The mode choice model is a binary logit model (highway or transit). CATS does not collect air passenger surveys, but the Chicago Department of Aviation does.[8] The last air passenger survey was conducted in 1997.

Los Angeles: Southern California Association of Governments (SCAG)

The Southern California Association of Governments, or SCAG, is the MPO for the six-county, 166-city Southern California region, the nation's largest metropolitan area. The six member counties are Imperial, Los Angeles, Orange, Riverside, San Bernardino, and Ventura. The region includes over 15 million people in an area of more than 38,000 square miles. The modeled area for travel demand forecasting work includes all of Ventura, Los Angeles, Orange, and Imperial counties and parts of San Bernardino and Riverside counties (See Figure 9). The modeled area includes 3,827 TAZs and 26 external stations.

[8] Phone conversation with Kermit Wies, CATS, April 23, 2003.

Figure 9 SCAG modeled area



SCAG Regional Model – Year 2000 Validations, PowerPoint presentation.

The region has 65 airports, including 6 commercial air carrier airports, 3 commuter airports, 45 general aviation airports, and 11 existing or recently closed military installations. The six commercial airports are Los Angeles International (LAX), Ontario International (ONT), John Wayne-Orange County (SNA), Burbank-Glendale-Pasadena (BUR), Long Beach (LGB), and Palm Springs (PSP).

SGAG uses an airport model called the Regional Airport Demand Allocation Model (RADAM). RADAM is a multinomial logit (MNL) model that generates and allocates current and forecast air passenger and cargo demand to airports. The model was originally developed by a consulting firm, Advanced Transportation Systems (ATS), for SCAG's 1994 Southern California Military Air Base Study to study the potential of closed or downsized military air bases for use as future commercial airports. SCAG's staff had supposedly had a disappointing experience with simple gravity models in previous system studies and this led the staff to seek a new approach – RADAM. Although the model was developed for SCAG, it is owned by Citigroup Technologies Corporation (CTC), is proprietary, and can only be run by CTC. The director of CTC is Andrew M. McKenzie, Ph.D. The current version of RADAM, which includes both an air passenger model and a cargo model, is version 9.11.

The modeled area for RADAM includes 100 RADAM zones (which are aggregations of SCAG TAZs) in the SCAG modeled area plus additional zones beyond the SCAG modeled area in Santa Barbara County (to the west of Ventura County) and San Diego County (south of Riverside County). The first step in the RADAM air passenger model methodology is demand generation, which is done for each RADAM zone in the modeled area. Current and forecast air passenger demand is developed for the RADAM modeled area. For current-year demand, available origination-and-destination passenger data is used. For future-year demand, correlated models are applied to SCAG's forecast socioeconomic data. Socioeconomic factors used in the correlation process include total population, total employment, retail employment, high-tech employment, median household income, disposable income, household size, number of HHs, and licensed drivers per household. The categories of passengers (not mutually exclusive) include short-, medium-, and lonF-haul passengers, international passengers, and business, pleasure, and exclusive tour passengers. The primary airport choice variables that are calibrated by the RADAM model for the various passenger groups noted include: total number of flights, frequency of flights, nonstop destinations served, number of discount airlines, travel time from home and work, travel time from hotel/convention center, ground access congestion, air fare, terminal congestion and convenience, parking costs, and convenience and airport mode choice options.

The second step of the RADAM air passenger model methodology is demand allocation. Demand allocation is based on a process of matching major airport attributes (such as available flights, air fares, ground travel time) with the primary airport choice factors identified and calibrated for the different passenger categories (business, non-business, and all-inclusive tours) in each RADAM zone. A series of MNL equations evaluate a set of airport attributes and airport choice factors to determine the degree of matching. The output of this step is the passengers in each passenger categories from each zone to each airport (existing or planned), which results in a total passenger allocation to each airport. Passengers from a given zone may be allocated to one or multiple airports. The modeling procedure involves an iteration process. After the first iteration, the model reads in typical fleet mixes and passenger load factors for each haul type, and flight frequencies are adjusted to be consistent with different combinations of demand, aircraft capacity, and load factors. During the last iteration, the number of flights is adjusted until load factors do not decrease below a set percentage that is considered to be consistent with what is economically acceptable. The iterations continue until only minor changes occur and a point of equilibrium is reached (TRB 2002, p. 18).

When COG staff requested a calibration report from SCAG staff, SCAG staff reported that "there is no such thing as a calibration report for the RADAM model since the model has thousands of variables, most of which are self-calibrating for each aviation system scenario that is run."[9] According to the minutes of a recent meeting of the SCAG Aviation Technical Advisory Committee (ATAC), SCAG staff is proposing to develop an in-house air passenger model. Although SCAG has been pleased with the current RADAM model, there are a number of issues that provide impetus for developing an in-house model:

[9] E-mail message from Mike Armstrong, SCAG, May 5, 2003.

1. *The model is owned and operated by a single consultant who must be paid every time there is a request for a new scenario. This takes considerable time and funding while limiting the number of new and different scenarios that can be run.*
2. *The model is proprietary. The consultant owns all of the inputs and the methodologies.*
3. *The model is a black box. Queries from the public or other professionals about how forecasts are developed are difficult to explain and justify since the modeling is not done in-house.*
4. *The current model is not integrated with the other forecasting models that SCAG uses which makes it difficult to calibrate scenarios based on model results.*

(Source: Minutes of the February 14, 2002 meeting of the SCAG Aviation Technical Advisory Committee)

New York City: Port Authority of New York and New Jersey (PANYNJ)

The Port Authority of New York and New Jersey (PANYNJ) operates four airports in the New York-New Jersey metropolitan region, three of which have commercial air service: LaGuardia (LGA), John F. Kennedy International (JFK), and Newark Liberty International (EWR). PANYNJ is not an MPO - the New York Metropolitan Transportation Council, or NYMTC, is the MPO for the New York City metropolitan area.

The PANYNJ air passenger forecast provides 10-year passenger estimates by market – domestic and international – and terminal building for the three airports with scheduled service. These forecasts are used for internal budgeting, financial projections, airport planning, and as input for other forecasts of airport activity (TRB 2002, p. 14). NYMTC does not use these air passenger forecasts in their 4-step model.[10] The forecast process involves three phases: data collection, model estimation, and a disaggregation process. In Phase I, the data collection phase, data comes from the Immigration and Naturalization Service (INS), the Official Airline Guide (OAG), the FAA, and DRI-WEFA.[11] In Phase II, the model specification and estimation phase, two to three types of models are developed and reconciled. Phase II makes use of time series techniques, such as single equation exponential smoothing models (TRB 2002, p. 15). The structure of the exponential model is

$$Pax_{t+1} = \beta Pax_t + (1-\beta)\, PPax_t$$

where

Pax_{t+1}	=	Forecast of next year's passengers
$PPax_t$	=	Actual value for current passengers
β	=	Smoothing constant
$PPax_t$	=	Forecast value of current period's passengers

[10] E-mail correspondence from Sangeeta Bhowmick, New York Metropolitan Transportation Council, May 7, 2003.
[11] DRI (formerly Data Resources Inc.) and WEFA (formerly Wharton Econometric Forecasting Associates) were merged in 2002 to form a new company: Global Insight, Inc.

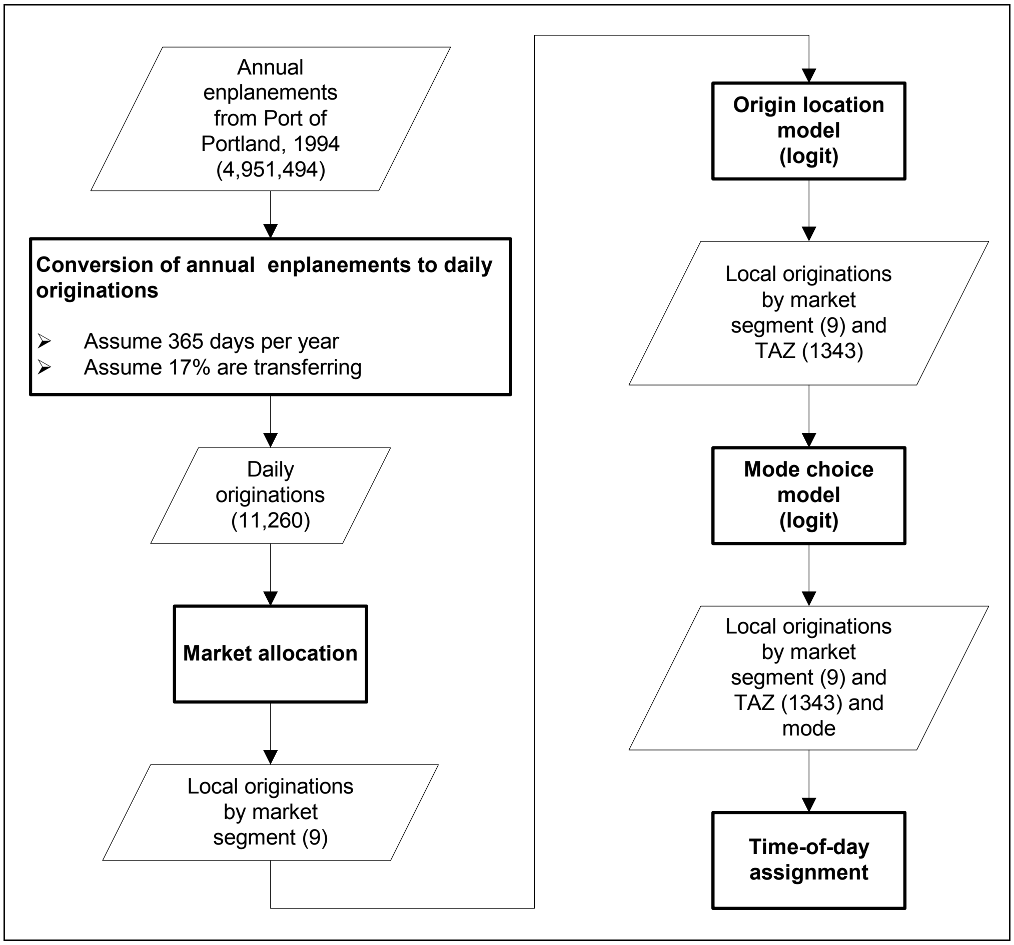
In Phase III, the disaggregation process, the regional passenger forecasts are disaggregated into airport-specific forecasts. Disaggregation factors are developed using variables such as airport-specific development, terminal expansion plans, new entrant plans, carrier plans, and schedule data. Finally, terminal-specific and carrier-specific information at each airport is used to divide each airport forecast into terminal forecasts. Seasonal factors ("Census X11 factors") are derived and used to disaggregate the annual forecasts into monthly forecasts (TRB 2002, p. 16).

Portland, Oregon: Portland Metro

The Portland Area Metropolitan Service District, or Metro, is the directly elected regional government that serves more than 1.3 million residents in Clackamas, Multnomah and Washington counties, and the 24 cities in the Portland, Oregon metropolitan area. It also serves as the MPO for the Portland area. Portland has only one commercial airport: the Portland International Airport (PDX), which is owned and maintained by the Port of Portland. Since there is only one commercial airport, there is no need for an airport choice model. The airport has historically been treated as a special generator in the Portland Metro model set. This means that the airport zone has its own trip generation rates. These special rates are based on enplanement data from the Port of Portland. Although the treatment of the airport zone as a special generator improved model performance, it was still felt that more could be done. Consequently, the Portland International Airport (PDX) model was developed. The airport model was estimated and calibrated using the 1996 air passenger survey, conducted by both the Port of Portland and Cambridge Systematics. The survey included a revealed preference (RP) portion (of about 4,000 passengers) and a stated preference (SP) portion.

Like the Atlanta airport model, the Portland International Airport model is essentially a ground-access mode choice model with a zonal allocation ("origin location") model preceding it. The modeling process is shown in Figure 10. The model has essentially four main sub-models: 1) conversion of annual enplanements to daily originations; 2) market allocation of originations; 3) origin location model; and 4) mode choice of ground access trips.

Figure 10 Portland's airport model: Data flow



Ref: portland airport model.vsd

The input to the modeling chain is the number of annual enplanements at PDX, which is supplied by the Port of Portland. In the first modeling step, annual enplanements are converted to daily enplanements by dividing by 365 days per year. The Port of Portland estimates that 17% of passengers are connecting passengers. Consequently, the daily enplanement total was multiplied by 0.83 (= 1.00 – 0.17) to obtain the daily local originations. In the Portland study, daily local originations are referred to as average daily number of "non-transferring passengers," or NTP. In theory, originating air passengers would account for only about half of the ground-access air passenger trips to and from the airport. One would probably need to multiply origins by a factor of 2 to get originating and departing air passenger trips to and from the airport. The Portland documentation furnished does not discuss this issue, but we assume that origins are multiplied by 2 at some point in the modeling chain before traffic assignment.

The second step of the modeling chain is market allocation or segmentation. There were four main market segments: resident business, resident non-business, non-resident business, and non-resident non-business. There were also origin types: private residence, place of business, hotel/motel, and other. These two sets of items were combined to form nine market segment categories (See Table 12).

Table 11 Portland's airport model: Annual enplanements and estimated daily local originations at Portland International Airport

Year	Annual Enplanements	Estimated Ave. Daily Local Originations ("Non-Transferring Passengers")
1994	4,951,494	11,260
2005	10,100,000	22,967
2010	11,460,000	26,060
2015	12,885,000	29,300

Source: Portland Area Metropolitan Service District (Portland Metro)

Table 12 Portland's airport model: Market segments used

Resident status	Purpose of air trip	Origin type of ground access trip	Percent of total air passengers
Resident	Business	Private residence	23.5%
		Place of business	5.1%
	Non-business	Private residence	31.2%
		Other	2.2%
Non-resident	Business	Place of business	4.7%
		Hotel/Motel	11.6%
		Other	2.8%
	Non-business	Hotel/Motel	5.7%
		Private residence	13.2%
			100.0%

The factors in Table 12 are applied to the daily local originations, creating nine market segments. The same factors are used for the base year and for forecast years.

The third modeling step is the origin location model. The origin location model is a multinomial logit (MNL) model that allocates locally originating air passenger trips to 1343 transportation analysis zones (TAZs).

Note that Portland Metro's normal travel forecasting runs use 1244 TAZs. For airport modeling work, however, there are an additional 99 TAZs which cover the remaining area of Oregon that is not part of the normally modeled area. These "external zones" were defined by the Oregon DOT and are used for statewide modeling work.

The variables used to determine origin location were:

- Number of HHs in each TAZ
- Average HH size in TAZ
- Household income
- Total employment in a TAZ

- Employment by Standard Industrial Classification (i.e., services, manufacturing, public utilities, etc.)
- HHs-to-jobs ratio dummy variable

The estimated origin location choice model can be seen in Table 13.

The forth modeling step is the (originating air passenger ground access) mode choice model. The ground access mode choice model takes the output of the origin location model and determines the mode of travel to the airport for each market segment. The mode choice model is also a multinomial logit (MNL). In the base year, the following modes are represented:

- Auto Drop Off
- Auto Park – for residents only
- Rental Car – for non-residents only
- Taxi/Limo
- Van/RAZ
- Hotel Shuttle

According to an e-mail from a Portland Metro staff member, the taxi and limo modes are demand-responsive (i.e., paratransit) and were not coded in the transit network. Hotel shuttle and RAZ have fixed routes, so they were coded in the transit network.[12]

In future-year scenarios (e.g., 2005 and beyond), the alternatives also include:

- Light Rail Drop Off
- Express Bus Drop Off

Mode choice is a function of travel time, travel cost, and average income of each zone. The market segments are further stratified into internal (Portland metropolitan area) and external (the rest of Oregon) trips. The chauffeur's value of time was assumed to be $20/hour for business travelers and $10/hour for non-business travelers. Two versions of each of the four models were estimated by Cambridge Systematics. The first version ("model 1") was based on data from the revealed preference survey. It assumed that the new modes of LRT and express bus had the same characteristics (e.g., sensitivities to time and cost) as the existing Van/RAZ mode. The second version ("model 2") was based on data from the RP and SP surveys. This model version was developed using "joint estimation procedures" with the stated preference survey data. This second model version contains unique bias constants for each of the new modes.

The four models (non-resident business, resident business, non-resident non-business, and resident non-business) in two versions ("model 1" and "model 2") are presented in Figure 11, which spans two pages.

In the two non-resident models, the "rental car" mode is arbitrarily taken as the base or referent, so its alternative-specific constant is equal to zero. Similarly, in the two resident models, the

[12] E-mail message from Jean Alleman, Portland Metro, June 13, 2003.

"auto park" mode is arbitrarily taken as the base or referent, so its alternative-specific constant is equal to zero. Each of the four models has two level-of-service variables – time and cost – and the drop-off alternatives also include a chauffeur's travel time variable. The coefficients on all three of these LOS variables are negative, which is expected, since more time and cost should reduce utility. Note of the coefficient values show the associated goodness-of-fit measure, the t-statistic.

Variable definitions were included in the provided report. For example, the travel time associated with the "auto, park" mode is defined with the following rules:

Travel Time = auto in vehicle time + on-airport time

In vehicle time	= p.m. 1 hour peak auto time (from path building) if internal
	= arcview free flow time if external
On-Airport time	= 15 minutes

and

Travel Cost = (cost/partycap)/ln(income)

Cost = $0.12 * distance + (parking cost * average duration of trip)/2

Where time is in minutes, distance is the over-the-network distance in miles, parking cost is in dollars per day, partycap is the average party size capped at 5 by zone and by market segment, the income is average household income by zone by market segment, and average trip duration is in days based on survey responses.

In the Portland documentation, they acknowledge that locally originating and departing air passengers are not the only users of the airport who would make use of the surrounding ground-access system (Portland Metro 1998, p. 11). According to the documentation, other users include:

- Trucks
- Parking shuttles - from economy, airport employee, and off-site parking facilities
- Shoppers/visitors
- Additional well-wishers/entourage
- Economy parkers dropping off other party members before parking
- Retail deliveries/service
- Port business
- Employee drop off/pick-up
- Rental Car Maintenance
- Rental Car Pick-up by non-airport passengers

To account for these additional airport trips, Portland Metro developed a factor, based on count data, whose value was 1.82. Trips made by airport terminal employees were modeled using Port of Portland employee control totals and the existing trip distribution and mode choice model that are already part of Metro's standard 4-step model. The time-of-day distribution of airport terminal employees was based on employee parking data supplied by the Port of Portland.

Table 13 Portland's airport model: Origin Location Choice Model, Estimation Results

Residency	Resident				Non-Resident				
Trip Purpose	Business		Non-Business		Business			Non-Business	
Origin Type Attribute/Code	Home rbh	Business brr	Home rnh	Other rno	Business nbb	Hotel nbm	Other nbo	Hotel nnm	OtherResid nnr
All Zones									
Households	0.1705E-03 (11.7)		0.1153E-03 (10.0)				0.1827E-03 (5.0		0.1430E-03 (9.3)
Household Size	-0.7149 (5.8)		-0.6843 (8.0)				-0.6229 (1.7)		-1.019 (7.9)
HH Income-Low (<=$35,000)							-01308E-03 (3.7)		
HH Income-High (>35,000)							-0.1035E-03 (3.5)		
Total Employment								0.4811E-04 (6.4)	
Lodging Employment						0.6108E-02 (15.0)		0.3160E-02 (9.6)	
All Services Employment		0.4309E-04 (4.0)		0.5614E-04 (4.1)					
FIRE, Services, Government					0.4989E-04 (3.6)	0.8029E-04 (5.0)			
Manufacturing Employment					0.1750E-03 (2.9)	0.1997E-03 (2.3)			
TCPU Employment						0.1480E-03 (1.7)			
Dummy =1 if (Hhlds/TotEmp) <=2					2.833 (4.0)				

Source: Cambridge Systematics, Inc. (1998) Portland International Airport Alternative Mode Study, Final Report and Appendices. Prepared for the Port of Portland. Portland, Oregon. October 1998, p. B-24.

Figure 11 Portland's airport model: Ground access mode choice models

Page 1 of 2

Non-Resident Business

		Model 1	Model 2
Internal (rental car base), Alt-specific constants			
	Auto Drop Off	-0.50	-0.50
	Taxi and Limousine	-0.9135	-1.2335
	Hotel Shuttle	-0.8865	-0.9965
	Van and RAZ	-0.9365	-1.3965
	Light Rail Drop Off	-0.9365	-0.8009
	Express Bus Drop Off	-0.9365	-0.9960
External (rental car base) , Alt-specific constants			
	Auto Drop Off	-0.30	-0.30
	Taxi and Limousine	-1.0635	-2.2135
	Van and RAZ	N/A	N/A
	Light Rail Drop Off	-1.287	-1.4665
	Express Bus Drop Off	-1.287	-2.4165
Level of Service Variables			
	Drop Alternatives: chauffeur's time and cost in $, with $20/hr. value of time	-0.0082	-0.0082
	Travel time, in minutes	-0.0073	-0.0073
	Cost/ln(income), in $/ln($K)	-0.0913	-0.0913

Resident Business

		Model 1	Model 2
Internal (auto park base) , Alt-specific constants			
	Auto Drop Off	0.85	0.85
	Taxi and Limousine	-1.162	-1.272
	Van, RAZ, Hotel Shuttle	-0.988	-1.258
	Light Rail Drop Off	-0.988	-1.258
	Express Bus Drop Off	-0.988	-1.258
External (auto park base) , Alt-specific constants			
	Auto Drop Off	-0.85	-0.85
	Taxi and Limousine	N/A	N/A
	Van, RAZ, Hotel Shuttle	2.312	0.742
	Light Rail Drop Off	2.312	0.742
	Express Bus Drop Off	2.312	0.742
Level of Service Variables			
	Drop Alternatives: chauffeur's time and cost in $, with $20/hr. value of time	-0.0195	-0.0195
	Travel time, in minutes	-0.0176	-0.0176
	Cost/ln(income), in $/ln($K)	-0.2185	-0.2185

Figure 11 Portland's airport model: Ground access mode choice models

Page 2 of 2

Non-Resident Non-Business

		Model 1	Model 2
Internal (rental car base) , Alt-specific constants			
	Auto Drop Off	0.10	0.10
	Taxi and Limousine	-1.754	-1.574
	Hotel Shuttle	-0.246	-0.046
	Van and RAZ	-0.596	-0.956
	Light Rail Drop Off	-0.596	-0.914
	Express Bus Drop Off	-0.596	-0.935
External (rental car base) , Alt-specific constants			
	Auto Drop Off	-0.50	-0.50
	Taxi and Limousine	-1.304	-2.054
	Van and RAZ	-0.346	-1.206
	Light Rail Drop Off	-0.346	-1.206
	Express Bus Drop Off	-0.346	-0.6862
Level of Service Variables			
	Drop Alternatives: chauffeur's time and cost in $, with $20/hr. value of time	-0.0082	-0.0082
	Travel time, in minutes	-0.0092	-0.0092
	Cost/ln(income), in $/ln($K)	-0.0716	-0.0716

Resident Non-Business

		Model 1	Model 2
Internal (auto park base) , Alt-specific constants			
	Auto Drop Off	-0.30	-0.30
	Taxi and Limousine	-2.068	-1.538
	Van, RAZ, Hotel Shuttle	-1.632	-1.362
	Light Rail Drop Off	-1.632	-0.3654
	Express Bus Drop Off	-1.632	-1.5281
External (auto park base) , Alt-specific constants			
	Auto Drop Off	-0.80	-0.80
	Taxi and Limousine	-2.188	-2.188
	Van, RAZ, Hotel Shuttle	2.368	-0.652
	Light Rail Drop Off	2.368	-2.3447
	Express Bus Drop Off	2.368	-3.8869
Level of Service Variables			
	Drop Alternatives: chauffeur's time and cost in $, with $20/hr. value of time	-0.0235	-0.0235
	Travel time, in minutes	-0.0264	-0.0264
	Cost/ln(income), in $/ln($K)	-0.2170	-0.2170

San Francisco: Metropolitan Transportation Commission (MTC)

The Metropolitan Transportation Commission (MTC) is the transportation planning, coordinating and financing agency for the nine-county San Francisco Bay Area. The Bay Area has three commercial airports: San Francisco International Airport (SFO), Oakland International Airport (OAK), and Norman Y. Mineta San José International Airport (SJC).

MTC's airport model consists of an airport choice model and a ground access mode choice model. The two models are applied with a program named ACCESS and were developed in the 1980s and early 1990s by the late Greig Harvey, using data from MTC's 1985 and 1990 airline passenger surveys. The models are disaggregate, nested logit models, and are applied in a "sample enumeration" framework, meaning that disaggregate samples from the base year survey are growth-factored and aged to represent current and forecast-year airport users.[13] There are four separate models:

- Resident business travelers
- Resident non-business travelers
- Non-resident business travelers
- Non-resident non-business travelers

In 1995, MTC conducted a new airline passenger survey. Due to resource constraints, this survey has never been used for model estimation work, but, as described below, this data has been used as a data input for applying the current (i.e., 1985/90) airport model.[14] In 1996, with the death of Greig Harvey, MTC lost all the computer source code to run ACCESS and all the input data files, other than the airline passenger survey data. MTC was left with only the documentation to the ACCESS (version 1.2) model. In the summer of 2001, staff was working on redeveloping the application software (in SAS) from scratch, using the documentation as a guide. Staff was also using SAS to apply the airport mode choice models by aging the 1995 Airline Passenger Survey to a 1998 base year.[15] Also in 2001, MTC was collecting its 2001 Airline Passenger Survey. Currently, MTC staff is busy cleaning the 2001/2002 Air Passenger Survey, cleaning the 2000 Household Travel Survey, and preparing for the 2004/2005 Regional Transportation Plan. Consequently, there are no current plans to re-estimate the two airport models with more current (than 1985/90) data. Staff felt that, at some point in the future, if resources are available, they would probably hire a consultant to re-estimate a full set of airport choice and airport ground access choice models. Below is a more detailed description of the two airport models.

In the late 1980s, Greig Harvey, developed both an airport choice model and a ground-access mode choice model for MTC. Both models were applied with a software program called ACCESS. According to the documentation, ACCESS is suitable for airport-by-airport studies of ground access and for regional airport system planning (Harvey 1988). The models in ACCESS were calibrated using a survey of air travelers and a detailed representation of ground access modes and airline service at each airport. In forecasting, the models make use of a database of

[13] E-mail from Chuck Purvis, Metropolitan Transportation Commission, Oakland, California, June 9, 2003.
[14] E-mail from Chuck Purvis, Metropolitan Transportation Commission, Oakland, California, August 2, 2001.
[15] Ibid footnote 14.

information, including information from the most recent MTC Air Passenger Survey. The unit of analysis is the air passenger, or, more specifically, the air travel *party*. The models in ACCESS are of the multinomial logit form and rely on variables such as access time, access cost, household income, party size, and frequency of airline service. Version 1.2 of ACCESS was developed in 1988. The prototype version of ACCESS, Version 1.0, was developed in 1986. Note that, in the documentation we have in house, the models are referred to as both "multinomial logit" (Harvey 1988 p. 3) and as "nested logit" (Harvey 1988 p. 11). By contrast, in *A Manual of Regional Transportation Modeling Practice for Air Quality Analysis*, Harvey refers to the models as "nested logit" (Harvey 1993 p. 3-54; See also Harvey 1989).

Logit models are designed to represent the behavior of a homogeneous group of decision makers. Air travelers are divided by whether they are a resident of the region and whether they are traveling for business or pleasure. Consequently, ACCESS includes four multinomial logit (MNL) models for the groups mentioned earlier:

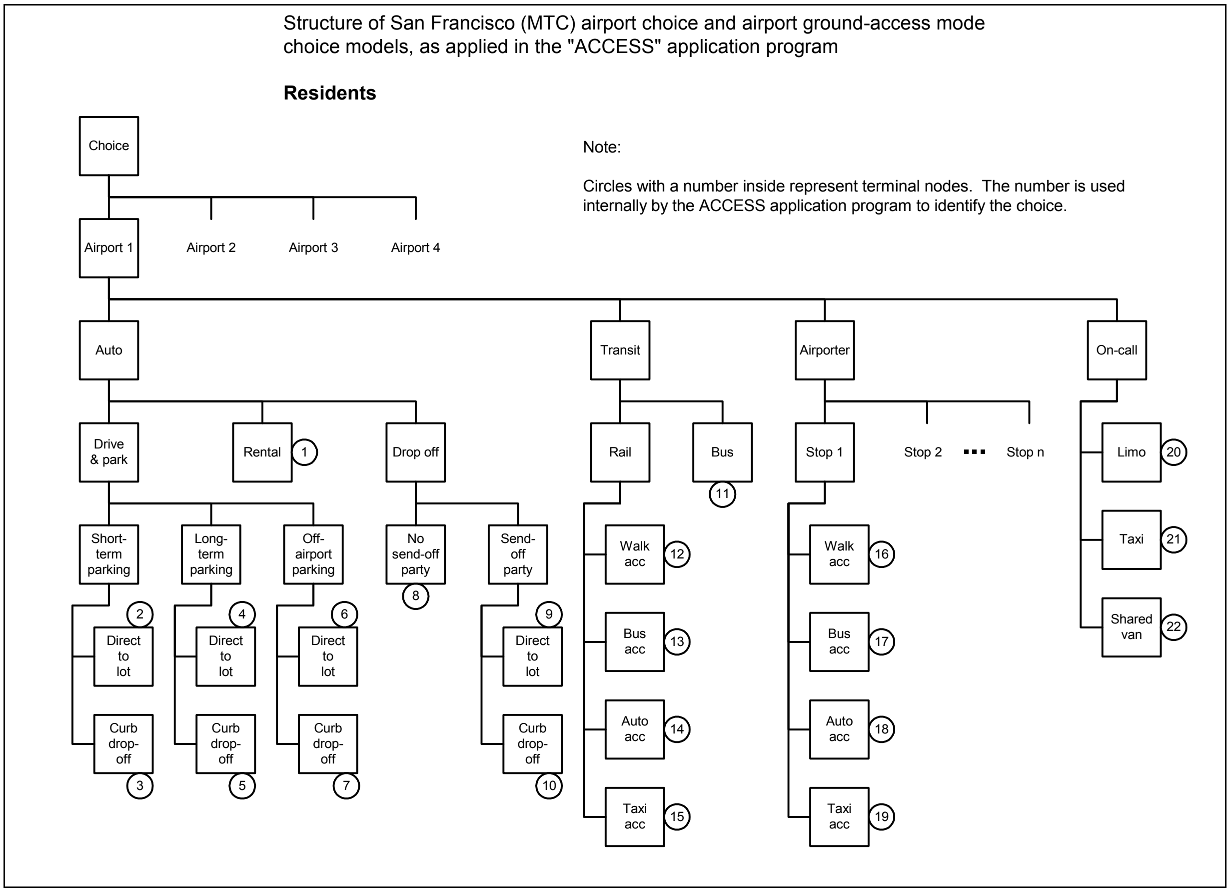
- Resident business travelers;
- Resident non-business travelers;
- Non-resident business travelers;
- Non-resident non-business travelers;

Each of the four models was estimated separately and has its own set of coefficients, but there are only two model structures: one for residents and one for non-residents (See Figure 12 and Figure 13).

Airport choice model

The airport choice model assumes there are three airports available: SFO, OAK, and SJC. The base year for model estimation was 1985. MTC has collected air passenger data, generally in August, for the three Bay Area airports at five-year intervals since 1975. The estimated coefficient values for the four airport choice models are shown in Table 14. The models include two alternative-specific constants: Dum(SFO) and Dum(OAK), SJC is the referent. Other than the alternative-specific constants, there are only three level-of-service variables in each model. The first variable, RF, is the relative flight frequency. RF is used to capture the information-related effects of flight concentration at one airport, due, perhaps, to increased advertising. RF was defined to be the number of direct flights at a given airport that are destined to the traveling party's final destination divided by the sum of flights at all three airports (Connecting and commuter flights are omitted). RF was developed by extracting the number of direct flights listed in the Official Airline Guide (OAG), including multi-stop flights that did not require a change of plane.

Figure 12 San Francisco's airport model: Residents

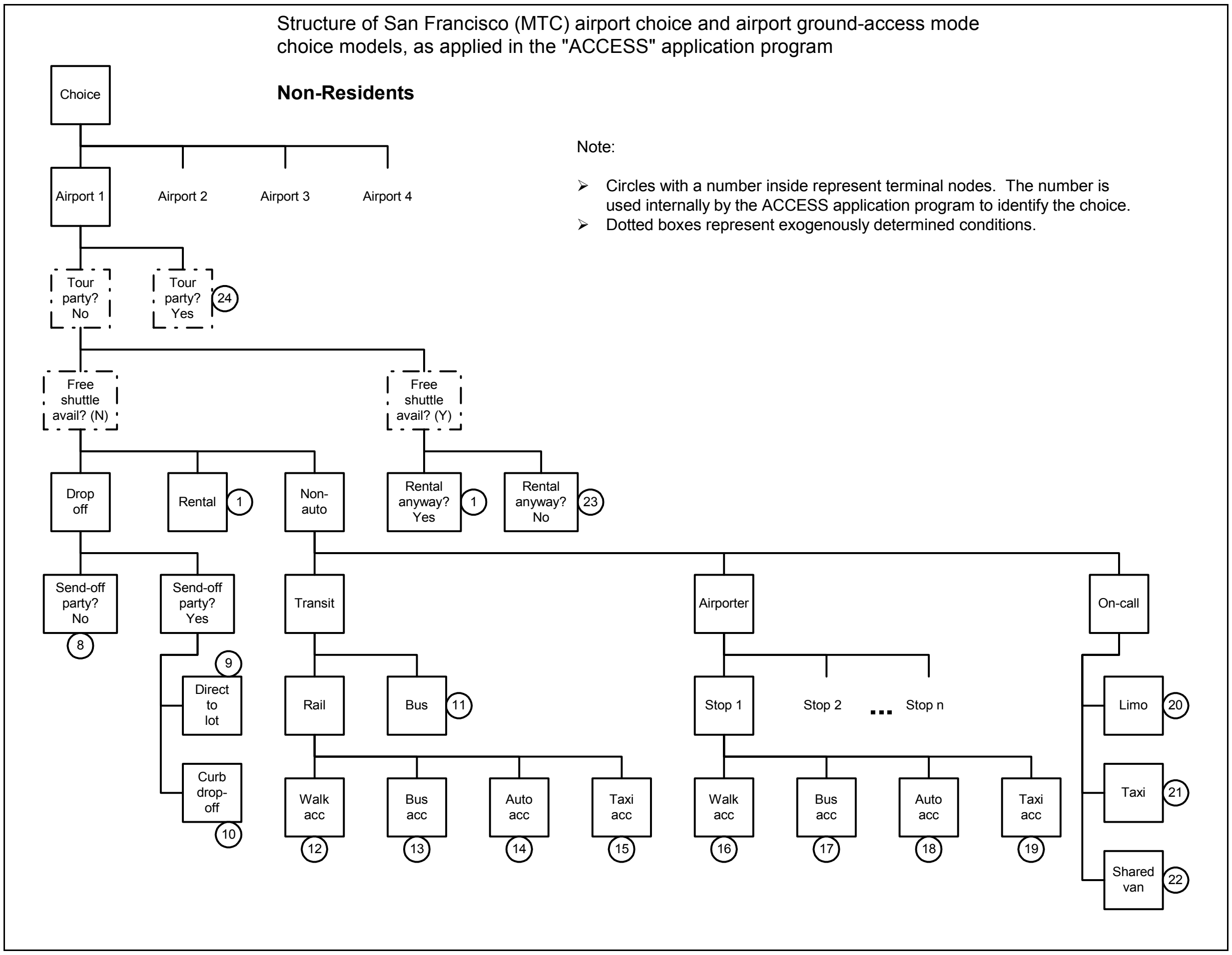


The second variable is DF or daily frequency of flights, also known as the absolute flight frequency. DF is the daily frequency of flights at each airport to the traveling party's destination. It is used as an explicit indicator of schedule convenience – more flights to a given destination imply more convenience, since as the number of flights goes up, there is a greater likelihood that flight times will match with a traveler's desired departure time. Based on earlier research, Harvey decided not to used DF directly, but a parabolic function of DF, named f(DF), which was constrained to have its maximum at the cutoff point of DF:

$$f(DF) = 2*9*DF - DF^2 \qquad \textbf{Eq. 9}$$

Harvey also found that the effect of flight frequency diminishes sharply as frequency rises. A parabolic form of the direct frequency was found to fit the data best, with the maximum frequency set at 9 flights per day. Thus, in calculating DF, connecting flights are omitted, as are more than 9 daily flights at a given airport.

Figure 13 San Francisco's airport model: Non-residents



The third variable, ln({mode}), represents the expected utility from the mode choice model and is a comprehensive measure of the quality of the ground access at each airport. In an MNL model, the "expected utility" is simply the natural log of the denominator of the logit formula (Eq. 1). The logit denominator incorporates all information contained in the model. The "expected utility" is also called the "logsum" or "inclusive price." In this version of ACCESS, the coefficient of ln({mode}) was constrained to 1.0. This effectively imposes the assumption that airport and mode choices are made simultaneously.

Table 14 San Francisco's airport model: Airport choice model

	Resident Business		Resident Non-Business		Non-Resident Business		Non-Resident Non-Business	
	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat
Dum(SFO)	-0.054	(-0.31)	-0.259	(-1.01)	0.203	(0.96)	0.811	(3.51)
Dum(OAK)	1.12	(6.04)	1.03	(9.89)	-0.451	(-3.42)	-0.502	(-5.02)
RF	3.34	(5.41)	3.09	(7.82)	3.21	(5.79)	2.99	(8.74)
f(DF)	0.0408	(7.16)	0.0205	(5.09)	0.0469	(6.23)	0.0231	(6.62)
ln({mode})	1.0	n/a	1.0	n/a	1.0	n/a	1.0	n/a
Overall statistics								
Obs, SFO	238		431		625		949	
Obs, OAK	134		294		153		343	
Obs, SJC	575		920		618		919	
Obs, total	947		1,645		1,396		2,211	
Rho bar squared	0.789		0.644		0.701		0.595	

Ref: sanfran_airpch_gamc.xls

Definitions and notes:

- SFO, OAK, and SJC indicate San Francisco International, Oakland International, and San Jose International airports.
- Dum(i) – A constant term in the utility equation for alternative i. The alternative-specific constant.
- RF – The relative frequency of flights to the traveling party's destination at each airport. Connecting and commuter flights are omitted. RF is the number of flights at a given airport divided by the sum of flights at all three airports.
- DF – The daily frequency of flights at each airport to the traveling party's destination. Connecting flights are omitted, as are more than 9 daily flights at a given airport (a cutoff determined empirically, as discussed in Harvey 1987, Airport Choice in Multiple Airport Region)
- f(DF) – A parabolic function of DF, constrained to have its maximum at the cutoff point of DF: f(DF) = 2*9*DF – DF^2.
- ln({mode}) – The expected utility from the highest level of the mode choice model. In this version of ACCESS, the coefficient of ln({mode}) is constrained to 1.0. This effectively imposes the assumption that airport and mode choices are made simultaneously.
- N(i) – Number of travelers in the sample choosing alternative i.
- Rho bar squared – The adjusted likelihood ratio index.

Source: Harvey 1988, p. 11.

The information in Table 14 can be used to construct a utility equation for each alternative (airport choice). For example, the equation for resident business travelers for SFO is

$$U[sfo] = -0.054 + 3.34 * RF[sfo] + 0.0408 * f(DF) + 1.0 * \ln(\{mode[sfo]\}) \quad \textbf{Eq. 10}$$

Harvey (1988, p. 12) makes several points regarding his airport model:

- The expected mode choice utility explains a large fraction of the variation in airport choice, which suggests that airport choice depends greatly on access characteristics. It appears that the general decision about access mode may be made jointly with airport choice. In Harvey's 1988 airport model, this simultaneity was imposed, by setting the coefficient on the expected utility to 1.0. But, according to Harvey, estimations performed without this constraint indicate that the true value of the coefficient is close to one and highly significant.
- Flight frequency also has a strong influence on airport choice. Together with the access time effect, this means that the pattern of airport use within a multi-airport region may be quite sensitive to: 1) changes in relative access time; 2) differential changes in the quality of ground access alternatives to the car; 3) arge changes in flight frequency; 4) development of additional reliever airports; 5) demographic changes that shift the spatial distribution of airport users.
- The supply of airline service is treated as an exogenous variable. In other words, the model does not predict what the airlines will do in response to a particular pattern of demand.
- The model omits an airline fare variable, because the Bay Area survey did not ask that question.[16]

Ground access mode choice

The ground access mode choice model includes five main modes for airport access:

- Drive – The resident traveling party drives an auto to the airport and leaves it parked in a lot (on or off the airport) for the duration of the trip. The non-resident traveling party drives a rental car and returns it at or near the airport.
- Drop off – A family member, friend, or associate drives the passenger to the airport and removes the vehicle from the airport vicinity.
- Transit – The passenger rides conventional fixed route public transit to the airport. In the Bay Area, this could be either BART (heavy rail), bus, or a combination of the two.
- Airporter – The passenger rides a scheduled, dedicated access service to the airport. These are not viewed as part of conventional transit, even though they would have a fixed route and schedule, like conventional transit. These services are not typically coded in regional transit networks used to support MPO-related travel demand forecasting activities (though they could be).
- On call – The passenger rides a personalized door-to-door service to the airport. This type of service, sometimes called paratransit, would include taxi, limo, and, potentially, shared van and shared limo services.

[16] The latest COG air passenger surveys, 1998 and 2001, also lack a question about what air fare was paid.

Each of these broad mode designations can then be further disaggregated into submodes. The complete set of submodes can be seen as the end nodes in Figure 12 and Figure 13. The key variables used in the ground access mode choice model include:

- Auto in-vehicle travel time
- Bus in-vehicle travel time
- Rail in-vehicle travel time
- Walk distance – The distance walked during the course of the access trip
- Moving walkway distance – The distance traveled on moving walkways during the course of the access trip
- Wait time – The time spent waiting for a transit or on-call vehicle
- Travel cost – Includes tolls, published fares, parking costs and/or auto operating costs. For drive, drop off, limo, and taxi, total costs were divided by the number of air travelers in the party to obtain a cost per person. For non-business travelers, cost was divided by a function of income.
- Schedule mismatch time – The "extra" time required when airporter shuttle schedules do not match flight schedules, forcing air travelers to spend additional time in terminal waiting areas.
- Drop off passenger time – The round trip in-vehicle time of one non-air traveler
- Luggage – Luggage is considered a deterrent to the use of transit. This variable is a dummy variable included in the transit utility equation, equal to 1 when the number of pieces of luggage per party member is greater than 1.0.
- Household size – For local residents, the composition of a traveler's household can have a strong effect on airport access, with increased likelihood of drop off if there is another person in the household to perform the task. Defined as a dummy variable (placed in the drop off utility equation) equal to 1 when the household size is two or more.
- Departure from home – A dummy variable equal to 1 if the traveler left from either their own home or that of a friend or relative.
- Sex of traveler – Women may be attracted to drop off and on-call modes, seeing it as more secure than waiting at transit stops or parking structures. Defined as a dummy variable in the drop off and on-call utility equations, set equal to 1 if the traveler is a women and to 0 otherwise.

Each sub-model also includes a full complement of alternative-specific constants. The estimated model coefficients can be seen in Table 15 (Harvey 1988, p. 21). The table does not show any t-statistics, but Harvey includes a note about the table stating that "more detailed model descriptions will be published in the literature." Harvey states that "Time is relatively more important for business travel, while cost is more important for non-business travel." Although the first part of that statement seems to be borne out by the coefficient values in Table 15, the second part of the statement is harder to verify, since there doesn't appear to be one cost variable that is the same across both business and non-business travelers. Harvey goes on to say that "distinctions between residents and non-residents are less obvious" (1988, p. 20).

Table 15 San Francisco's airport model: Ground access mode choice model

Variable	Resident Business Coeff.	Resident Non-Bus. Coeff.	Non-Res. Business Coeff.	Non-Res. Non-Bus. Coeff.
tt(auto)	-0.071	-0.044	-0.068	-0.039
tt(bus)	-0.093	-0.051	-0.089	-0.045
tt(rail)	-0.053	-0.031	-0.05	-0.029
walk	-5.17	-3.28	-4.69	-2.94
mwalk	-2.59	-1.68	-2.53	-1.62
wait	-0.107	-0.077	-0.096	-0.071
cost	-0.00277		-0.00256	
cost/f(inc)		-1.04		-0.973
delay	-0.107	-0.077	-0.096	-0.071
tdrop	-0.024	-0.011	-0.031	-0.018
luggage	-0.414	-1.22	-0.524	-1.17
hhsize	0.501	1.43		
home	0.816			1.51
sex	0.322	0.787	0.476	0.911
Overall statistics				
Observations	947	1,645	1,396	2,211
Rho squ, primary	0.542	0.595	0.491	0.466
Rho squ, overall	0.223	0.261	0.184	0.212

Ref: sanfran_airpch_gamc.xls

Definitions and notes:

- tt(auto) – Access travel time in an automobile, taxi, or limousine (minutes).
- tt(bus) – Access travel time in a bus or van (minutes).
- tt(rail) – Access travel time on rail transit (minutes).
- walk – Access distance (miles).
- mwalk – Access distance on moving walkways (miles).
- wait – Access wait time for transit and on-call (minutes).
- cost – Access cost (cents), including auto operation, parking, and fares. For lonF-term parking, only half of the total cost is used (the other half is attributed to the trip home). Cost elements are divided by party size when appropriate.
- f(inc) – A simple transformation of the survey respondent's household income (in thousands of dollars): $f(inc) = (inc)^{1.5}$.
- delay – Extra airport waiting time due to airporter schedule mismatch (minutes). "Wait" and "delay" are constrained to have the same coefficient in the current version of ACCESS.
- tdrop – Drop off time required for one accompanying non-air traveler (minutes).
- luggage – A dummy variable in transit to indicate whether the party has more than one piece of luggage per person (1 if yes; 0 if no).
- hhsize – A dummy variable in the "drop off" mode to indicate whether the respondent's household is larger than 1 person (1 if yes; 0 if no).
- home – A dummy variable in the "drop off" mode to indicate whether the access trip begins at either the respondent's home or that of a friend or relative (1 if yes; 0 if no).
- sex – A dummy variable in the "drop off" and "on-call" mode to indicate whether the respondent is female (1 if yes; 0 if no).
- Rho squared primary – The adjusted likelihood ratio index for the primary mode choice model.
- Rho squared overall – The adjusted likelihood ratio index for the full model structure.

Conclusion and Recommendations

This report has presented a number of different ways to model airport access trips, especially those made by locally originating or terminating air passengers. ARC in Atlanta and Metro in Portland use very similar techniques: First, annual enplanements are converted to daily originations (in the case of Metro) or originations and destinations (in the case of ARC). Next, market segments are defined and airport access trips are assigned to those market segments. Next, the non-airport end of airport access trips in each market segment is allocated to one of the zones in the modeled area (ARC's zonal allocation model is a linear regression type; Metro's is a logit type model). Last, a ground access mode choice model is applied to estimate the share of airport access trips by each ground access mode (both ARC and Metro use logit models for this). SCAG in Los Angeles uses a proprietary model, called RADAM, that generates and allocates current and forecast air passenger and cargo demand to the airports. RADAM uses a multinomial logit model structure, but, due to its proprietary nature, it has the drawback of being a "black box." Even though SCAG has been satisfied with the performance of RADAM, SCAG has plans to develop its own airport access model that can be run in-house. Some of the internal models in RADAM are probably quite similar to those used in MTC's ACCESS model, although ACCESS does not include a cargo component. PANYNJ uses a time-series econometric model, that is unlike any of the others reviewed in this study. PANYNJ is an airport operator, not an MPO, so it has a different set of needs when generating forecasts of air passenger ground access travel. MTC's ACCESS model uses a multinomial or nested logit model of airport choice and ground access mode choice. One of the advantages of the models developed by ARC, Metro (with the Port of Portland), and MTC is that the models are very well documented, making it easier for others to understand how they were developed.

At this time, it would seem the most useful models for COG/TPB to emulate would be those of ARC, Metro/Port of Portland, and MTC. All three of these model relied on having an air passenger survey as one of the primary data inputs for the calibration file. MTC's model was built without having information about airfare ticket prices (since it was not asked in their 1985 and 1990 surveys). Similarly, TPB's latest air passenger surveys also lack a question about ticket prices. In order to develop the necessary calibration file, TPB will probably need to purchase flight frequency data for the three commercial airports from a vendor such as OAG. It should be noted that airport choice and ground access models are quite complex. Many times, the most complex task in model estimation is not the estimation at all, but rather the development of the calibration/estimation data set. Nonetheless, model estimation can be more involved than that typically needed for regular mode choice models. For example, for Portland's ground access mode choice model, relied on a combination of both revealed preference data and stated preference data, and needed special estimation procedures that may not be part of the tool kit of many MPO modelers. It is recommended that TPB staff begin development of a calibration file that makes provision for the features of the model structures in Atlanta, San Francisco, and Portland.

Glossary

Airport access model: Used in a region with one or more major commercial airports, this model predicts the ground access travel mode of locally originating air passengers.

Airport access trips: Ground access trips (i.e., not access via the air).

Airport choice and access mode model: Predicts both airport choice and ground access.

Airport choice model: Used in a region with more than one major commercial airport, this model predicts which of these airports will be used by a locally originating air passenger.

Airport operations − Landings (arrivals) and takeoffs (departures) from an airport.

Commuter Aircraft – Commuters are commercial operators that provide regularly scheduled passenger or cargo service with aircraft seating less than 60 passengers. A typical commuter flight operates over a trip distance of less than 300 miles.

Connecting Passenger – An airline passenger who transfers from an arriving aircraft to a departing aircraft in order to reach his or her ultimate destination.

Deplanement: A passenger alighting an aircraft. See Enplanement.

Enplanement: A passenger boarding an aircraft. More formally a Revenue Passenger Enplanement.
(Enplaning passengers) = (originating enplanements) + (connecting enplanements)

Local Passenger − A passenger who either enters or exits a metropolitan area on flights serviced by the area's airport. A local passenger is the opposite of a connecting passenger.

Revenue Passenger Enplanement: A revenue passenger boarding an aircraft in scheduled service, including origination, stopover, and any connections. Generally corresponds to a flight coupon. Does not include through passengers.

Through Passenger − An airline passenger who arrives at an airport and departs without deplaning the aircraft.

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Worldwide Web Links

Washington, D.C.
Ronald Reagan Washington National Airport (DCA) [www.mwaa.com/national/]
Washington Dulles International Airport (IAD) [www.mwaa.com/dulles/]
Baltimore/Washington International Airport (BWI) [www.bwiairport.com/]

Atlanta, Georgia
Atlanta Regional Commission (ARC) [http://www.atlantaregional.com/]
Hartsfield Atlanta International Airport (ATL) [http://www.atlanta-airport.com/]

Boston, Massachusetts
Boston MPO, Central Transportation Planning Staff (CTPS) [http://www.ctps.org/bostonmpo/]

Chicago, Illinois
Chicago Area Transportation Study (CATS) [http://www.catsmpo.com/]
Chicago O'Hare Airport (ORD) [http://www.ohare.com/ohare/]
Chicago Midway Airport (MDW) [http://www.ohare.com/midway/]
Chicago Department of Aviation [http://www.ohare.com/]

Los Angeles, California
Southern California Association of Governments, or SCAG [http://www.scag.ca.gov/]
Los Angeles International Airport (LAX) [www.lawa.org]
Ontario International Airport (ONT) [www.lawa.org]
John Wayne-Orange County Airport (SNA) [http://www.ocair.com/]
Burbank-Glendale-Pasadena Airport (BUR) [http://www.burbankairport.com/]
Long Beach Airport (LGB) [http://www.lgb.org/]
Palm Springs Airport (PSP) [http://www.palmspringsairport.com/]

New York, New York
Port Authority of New York and New Jersey (PANYNJ) [http://www.panynj.gov/]
LaGuardia Airport (LGA) [http://www.panynj.gov/aviation/lgaframe.HTM]
John F. Kennedy International Airport (JFK) [http://www.panynj.gov/aviation/jfkframe.HTM]
Newark Liberty International Airport (EWR) [http://www.panynj.gov/aviation/ewrframe.HTM]
New York Metropolitan Transportation Council (NYMTC) [http://www.nymtc.org/]

Portland, Oregon
Portland Area Metropolitan Service District (Metro) [http://www.metro-region.org/]
Portland International Airport (PDX) [http://www.portlandairportpdx.com/]
Port of Portland [http://www.portofportland.com/]

San Francisco, California
Metropolitan Transportation Commission (MTC) [http://www.mtc.ca.gov/]
San Francisco International Airport (SFO) [http://www.flysfo.com/]
Oakland International Airport (OAK) [http://www.flyoakland.com/]
Norman Y. Mineta San José International Airport (SJC) [http://www.sjc.org/]

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Appendix G

Questions on Planned New Regional Household Travel Survey for TRB Committee

Sample Size Needed for Future Models Development – A new regional household travel survey similar to that conducted in 1994 could be designed to fit within expected UPWP budget levels. Estimated survey contractor costs for 5,000 household samples are $750,000 to $1,000,000 spread over two fiscal years. Expected budget constraints will require termination of the Continuing Longitudinal Panel Household Travel Survey to permit the planned new cross-sectional regional household travel survey.

TPB models development staff would like to have a new regional household travel survey with a completed sample size of 10,000 to 15,000 households. This would represent a one quarter to one half percent sample of all households in the modeled region and be more than twice the sample size of the 1994 Household Travel Survey. The main reason for preferring a larger new regional cross-sectional travel survey as opposed to a continuing longitudinal panel survey is that the size of our current panel travel survey is too small (approximately 2,400 households) and lacks sufficient geographic detail at the sub-regional level.

TPB staff notes with interest that the Puget Sound Regional Council, which has had an on-going continuing panel travel survey for more than a decade, conducted a new 6,000 household cross-sectional travel survey in 1999, in addition to their continuing panel survey, and currently plans to conduct another 6,000 household cross-sectional survey around the middle of this decade. TPB staff also notes that the New York metropolitan region conducted an 11,000 household travel survey in 1997, the San Francisco region conducted a 15,000 household travel survey in 2000, and the metro Atlanta region conducted an 8,000 household travel survey in 2001.

To achieve the desired household sample size will require a travel survey budget in the 2 to 3 million dollar range, a figure two to three times more than TPB staff currently expects to have available from existing budget resources. (The 2001 8,000 household sample regional household travel survey for Atlanta was budgeted at 2.7 million dollars.)

TPB staff would like the TRB Committee to comment on the cost/benefit trade-offs in increasing the TPB's planned new regional cross-sectional survey from 5,000 households to a sample size of 10,000 to 15,000 households. Is there a compelling need for future models development in our region to increase regional household travel survey sample size to a minimum of 10,000 households? Also, the geographic area of the TPB's modeled region extends beyond the TPB planning region. Currently, the TPB staff plans to collect new household travel survey data only for jurisdictions within the TPB's planning region and "borrow" any available data from other "similar" areas to develop household trip generation rates and other parameters for areas outside of the TPB's planning region, but within the modeled region. Is there a compelling need for TPB's models development to collect some minimum number of household samples for jurisdictions beyond the TPB planning area, but included in the TPB modeled area?

Activity-Based v. Trip-Based Travel Survey Diaries – While most other major metropolitan regions that conduct their own travel surveys have moved to some type of activity-based diaries in their regional household travel surveys, TPB has continued to use traditional trip-based travel survey diaries in its household travel surveys. The issue of changing to an activity-based diary was discussed with the TPB Travel Forecasting Subcommittee in planning the 1994 Household Travel Survey and rejected. The rationale for this decision was that activity diaries were too complicated and burdensome for most survey respondents and would likely negatively impact survey response rates and overall survey data quality. Further, it was noted that detailed activity-based information was not necessary for the enhanced trip-based four-step model that was planned for development using the household survey data.

Since 1994, activity-based travel survey diaries have been greatly simplified and used successfully in a number of regional household travel surveys, although diary retrieval response rates for some activity-based travel surveys have been somewhat lower than for traditional trip-based travel diaries, even with the inclusion of some small incentive with the activity diary. One of the questions TPB staff would like the TRB Committee to comment on is whether or not there is a compelling reason to move to activity-based travel diaries in future TPB surveys and the likely trade-offs in terms of survey response rates and overall survey data quality. This issue will also require some coordination with the metropolitan Baltimore region because they also chose to go with a trip-based travel diary in deciding to purchase a metro region add-on sample as part of the 2001 NHTS.

One Day v. Multi-day Travel Survey Diaries – Another conscious decision made in planning the 1994 Household Travel Survey was to maintain a one-day travel survey as opposed to a multi-day survey where each respondent would report on their daily travel or activities for two or more days. Again the concern was that going to a multi-day survey would negatively impact survey response rates and overall survey data quality because of greater respondent burden and greater respondent fatigue in reporting second day travel and other activities. Another question TPB staff would like the Committee to comment on is whether or not there is a compelling reason from a models development perspective to move to a multi-day survey and what are the likely trade-offs in terms of survey response rates and overall survey data quality.

Declining Telephone Survey Response Rates – TPB staff has observed in the RDD panel replacement component of the TPB Continuing Longitudinal Panel Household Travel Survey that initial CATI survey recruitment response rates drop from about 45% in 1999 to 37% percent of potentially eligible households in 2003. (RDD component diary retrieval response rates have remained constant at 70-71% in the same period.) Lower initial CATI household recruitment response rates have also been reported for households in travel surveys recently conducted in other metropolitan areas. This decline in CATI survey response rates ajppears to be because of increased use of caller ID, answering machines, voice mail and other call screening technology by households residing in large metropolitan areas like Washington. A further concern is the exclusive use of mobile wireless telephones as a replacement for traditional land line telephone services by some households, especially those households composed primarily of young males and females aged 18 to 24 who make many daily trips throughout the day. A further concern is the recently initiated and highly popular “DO NOT CALL” database registry. Even though survey research firms are exempted from these recently enacted “DO NOT CALL” regulations, individual households (especially those with unpublished numbers) may not make this distinction between these survey firms and telemarketers who are prohibited from calling them.

TPB staff seeks the TRB Committee’s comments on the advisability of continuing to use RDD sample frames for future household travel surveys and on other sampling and survey methods that might be considered in selecting travel survey sample households.

Survey Respondent Trip Underreporting – One of the perennial issues in the use of household travel survey data for models development is travel underreporting by respondents in these surveys. Research has shown that even in the best household travel surveys there is some level of underreporting or misreporting of daily travel, especially for short non-commuting trips. Modelers have generally found that they have to adjust upward non-work trip generation rates to match observed vehicle volumes from traffic counts. Some of this upward adjustment is because of household survey respondent trip underreporting, but some of it is also likely due to an under-accounting of commercial light vehicles that are currently not well measured or captured in travel surveys. Without additional data and analysis it is not possible to determine how much of the needed upward adjustment is because of survey respondent underreporting and how much is because of under-measurement of daily commercial vehicle travel.

To obtain more information on this problem TPB staff is currently considering a GPS household vehicle tracking add-on sub-sample to the planned new household travel survey. This add-on sub-sample would recruit approximately 200 households who had agreed to participate in CATI to also agree to carry GPS tracking devices in their household vehicles on their travel survey day. Household respondent vehicle trip reports recorded in the CATI would then be compared with the vehicle tracking records recorded using the GPS device. In this manner the GPS add-on sub-sample would provide a direct measure of survey respondent vehicle-trip underreporting and misreporting of vehicle trip details because the GPS tracking would also provide direct measures of trip starting and ending times as well as very accurate measures of trip distances. Preliminary results from such a GPS tracking add-on sub-sample in a California household travel survey showed an estimated CATI survey vehicle trip-underreporting rate of approximately 27%.
It is estimated that such a 200 household GPS tracking add-on sample would increase travel survey costs by about $100,000. Results from such an add-on sample could be used to develop more precise vehicle trip adjustment factors to account for survey respondent trip underreporting.

TPB staff seeks the TRB Committee's comments on the cost/benefits of a GPS household vehicle tracking add-on sub-sample to the regional household survey in terms of future model development activities.

"Typical Season" Data Collection v. Year-Round Survey Data Collection – Historically, most travel survey and travel monitoring data in the Washington region has been collected in the late spring or mid-fall seasons which are considered representative of "typical" daily travel conditions in the region (i.e. children in school, not a large number of tourists, fewer workers on vacations, etc.) and are fairly uniform throughout the 6-9 week survey period, with no major snow storms, heat waves or other weather-related events that might disrupt daily travel patterns. Some other metropolitan areas with large sample household travel surveys collect their travel data throughout a 12-month period. TPB staff is interested in the Committee's comments on the advantages and disadvantages from a models development perspective of moving from a "typical season" to a year-round data collection strategy for future household travel surveys.