Metropolitan Washington Council of Governments
National Capital Region Transportation Planning Board

FY-2003 Models Development Program for COG/TPB Travel Models

June 30, 2003

Item III C
From the FY-2003 Unified Planning Work Program
For Transportation Planning for
the Metropolitan Washington Region

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The Metropolitan Washington Council of Governments (COG) and the National Capital Region Transportation Planning Board (TPB).

COG serves as the regional planning organization for the Washington metropolitan area. COG works toward solutions to regional problems, especially those related to regional growth, transportation, housing, human services, and the environment. The TPB is the designated Metropolitan Planning Organization (MPO) for transportation for the Washington region. Members of the TPB include representatives of local governments; state transportation agencies; the Maryland and Virginia General Assemblies; the Washington Metropolitan Area Transit Authority; and non-voting members from the Metropolitan Washington Airports Authority and federal agencies.

Credits

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Abstract:

The objective of this report is to document the work activities undertaken to fulfill the FY-2003 COG/TPB work program in the area of models development. This work represents a continuation of a multi-year models development plan that was formulated in FY-93 under the direction of the Travel Forecasting Subcommittee, a subcommittee of the Transportation Planning Board's Technical Committee. The plan strives to establish improved travel demand forecasting procedures at MWCOG, especially in the areas of accuracy, internal consistency, and policy sensitivity, in accordance with recent federally mandated requirements.

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Table of Contents

List of Figures

List of Tables

1 Introduction

This report documents work activities that have been undertaken to fulfill the FY-2003 COG/TPB work program in the area of travel models development. The work program represents a continuation of a multi-year development program that was formulated in FY-1993 in response to requirements established by the Clean Air Act Amendments of 1990 and the Intermodal Surface Transportation Efficiency Act of 1991. The requirements are aimed at improving the accuracy, temporal sensitivity, and policy sensitivity of travel models used by MPOs. Models development activities at COG/TPB are overseen by the Travel Forecasting Subcommittee (TFS). The TFS is a subcommittee of the Transportation Planning Board's Technical Committee, and is comprised of representatives from both state and local transportation agencies in the Washington, D.C. region, as well as from local transportation consulting firms. It operates by consensus in providing guidance to COG/TPB staff in the conduct of the models development work program.

During FY-2003, staff has moved as expeditiously as possible to bring the new Version 2.1 travel demand model into production mode operating on the TP+ software platform. The immediate need was to apply the model set in conjunction with the MOBILE6 emissions model to help establish an updated SIP. Plans call for the application of this model in the next round of air quality conformity of the FY2004-2009 transportation improvement program (TIP) and the 2003 constrained long range plan (CLRP), replacing the Version 1 travel demand model used previously.

There has been extensive debate and comment about the capabilities of the new travel demand model in meeting the requirements for updating the plan and program. The TPB therefore requested an independent assessment from the Transportation Research Board of the National Academies (TRB) of whether its new travel demand modeling process is "state of the practice" and has asked for technical assistance to guide future improvements. The TPB approved an amendment to the FY-2003 unified planning work program (TPB R6-2003) on November 20, 2002 to include a peer review of the TPB travel demand modeling process by the TRB. The scope of services is described in Chapter 2 of this report. The TRB peer review will continue into the first half of FY-2004.

The remaining elements in the FY-2003 work program involved the development of training for application of the Version 2.1 travel demand model on the TP+ software platform, an investigation of airport access demand models, and an exploration of future travel survey designs that could be less intrusive and yield better response. These are described in Chapters 3, 4, and 5, respectively. Finally, COG/TPB staff presents its thoughts on future direction in the models development work program in Chapter 6.

2 TRB Travel Model Peer Review

During FY-2003, staff has moved as expeditiously as possible to bring the new Version 2.1 travel demand model into production mode operating on the TP+ software platform. The immediate need was to apply the model set in conjunction with the MOBILE6 emissions model to help establish an updated SIP. Plans call for the application of this model in the next round of air quality conformity of the FY-2004-2009 transportation improvement program (TIP) and the 2003 constrained long range plan (CLRP), replacing the Version 1 travel demand model used previously.

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The TPB approved an amendment to the FY-2003 unified planning work program (TPB R6-2003) on November 20, 2002 to include a peer review of the TPB travel demand modeling process. The statement of task is to review the state of the practice of travel demand modeling by the TPB and to provide guidance in the following areas:

1) The performance of the TPB's latest travel demand model (Version 2.1) in forecasting regional travel;

2) The proposed process for merging the latest travel demand model outputs to produce mobile source emissions (i.e., the post-processor);

3) The TPB's proposed direction of future travel demand model upgrades;

4) Travel survey and other data needed to accomplish future model upgrades; and

5) The detail (grain) of travel analysis zones that should be developed for future upgrades.

An ad hoc peer review committee has been formed by the TRB comprised of individuals familiar with MPO travel demand modeling, consultants with expertise in developing and applying travel demand models, and scholars in the field. Persons involved in transportation issues in the

Washington region are not to be included on this panel. The committee is charged with producing the following deliverables:

1) a brief letter report assessing whether TPB's modeling is "state of the practice" (items one and two in the statement of task) by June 30, 2003; and

2) a second letter report providing guidance on future topics (items three, four, and five in the statement of task), to be delivered by December 31, 2003.

Funding for this project is $130,000, and is being split 50/50 between the FY-2003 and FY-2004 work programs in models development at TPB.

It is envisioned that the second letter report will be used to fashion the future direction of COG/TPB's models development program, both in the short- and long-terms, subject to the approval of the Travel Forecasting Subcommittee.

3 Status of Travel Model Training Activity

The Version 2.1/TP+ model is considerably more complicated in structure and operation compared to previous model sets used at MWCOG. The complexity is a direct result of more stringent requirements placed on forecasting practice at MPOs across the country in order to improve the robustness of the simulation. The Version 2.1 model now includes greater temporal, advanced speed feedback, and a more complete depiction of modal travel. At the same time, the added complexity also raises the potential for several problems. The model requires longer preparation times since highway and transit networks are needed by time of day. The added complexity also translates into increased turn-around times for modeling executions. Finally, the potential for errors caused unintentionally by the end-user is a concern that accompanies complex model sets. COG recognizes that formal training in the use of the model is a way to minimize the potential for such error.

With the release of the model in December 2002, there has been a strong desire to begin using it to support immediate air quality work as well as other planning activities. Furthermore, there has been a growing demand by local agencies and consultants to obtain it for various project-planning studies around the region. In response, COG has produced a standard transmittal package of files and programs supporting the modeling process, as well as a user's guide. A model training element was put into the FY-2003 COG work program to facilitate the application of the model for interested analysts. This element will remain as an on-going work activity in coming years.

During FY-2003, training activities were confined to individual COG staff members responsible for executing the Version 2.1 model to serve immediate planning needs. The training was not conducted in a classroom setting, but instead, was done on an individualized basis. COG has, however, had the opportunity to consider what a more comprehensive and structured training program would entail. The training program would be arranged into three sections, the first aimed at a review of the software, the second aimed at the application process of the model, and the third section involving a practice application. Table 3-1 below shows a more detailed outline of the proposed training.

Table 3-1 Version 2.1/TP+ Training Outline

Primary Training Section	Subsections
1. Background on Software	a. Overview of TP+/Viper
	b. Basics of TP+ Script Language
	c. TP+ Module Description
	d. Review of Sample Scripts
	e. Viper
2. Software Application Process	a. Input file Requirements
	b. Input file Checking
	b. Application Subdirectory Structure
	c. Review of the Application Stream
	d. Reviewing results
3. Practice Application(s)	

During FY-2004, COG will compile training materials based on the outline shown on Table 3-1, and will begin conducting training for COG staff members and other interested analysts. It is expected that training in this regard will be an on-going activity over the next few years.

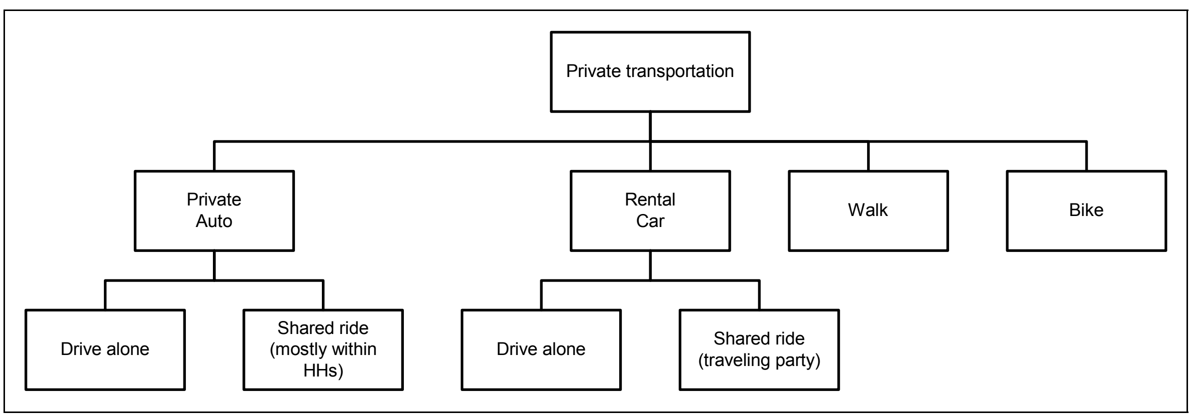
4 Investigation of Airport Access Demand Models

4.1 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.[1] The focus of this chapter is a review of both airport choice models and airport ground access mode choice models in use in the U.S. The chapter 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 4-1 and Figure 4-2.

Figure 4-1 Private transportation modes



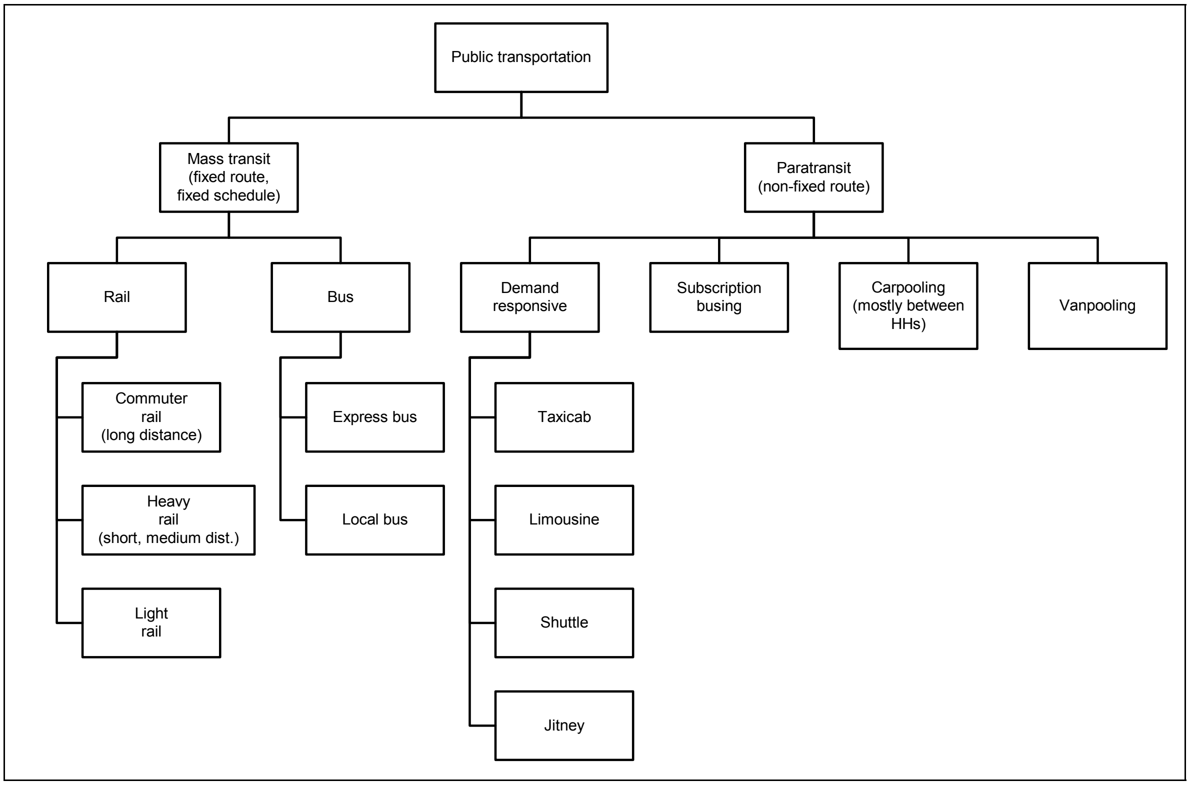
Ref: modes_private.vsd

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 4-1 and Figure 4-2 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)

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

mass transit, but not paratransit modes. Similarly, the walk and bicycle modes are usually only represented in a limited way (e.g. as access modes to transit) in the travel demand forecasting model.

Figure 4-2 Public transportation modes



Ref: modes_public.vsd

4.1.1 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).

4.1.2 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%).

4.1.3 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.

4.2 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 4-1). 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 4-2). A list of contacts for each agency is found at the end of this chapter.

Table 4-1 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) Burbank (BUR) Ontario (ONT) Long Beach (LGB) John Wayne (SNA) 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 4-2 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.

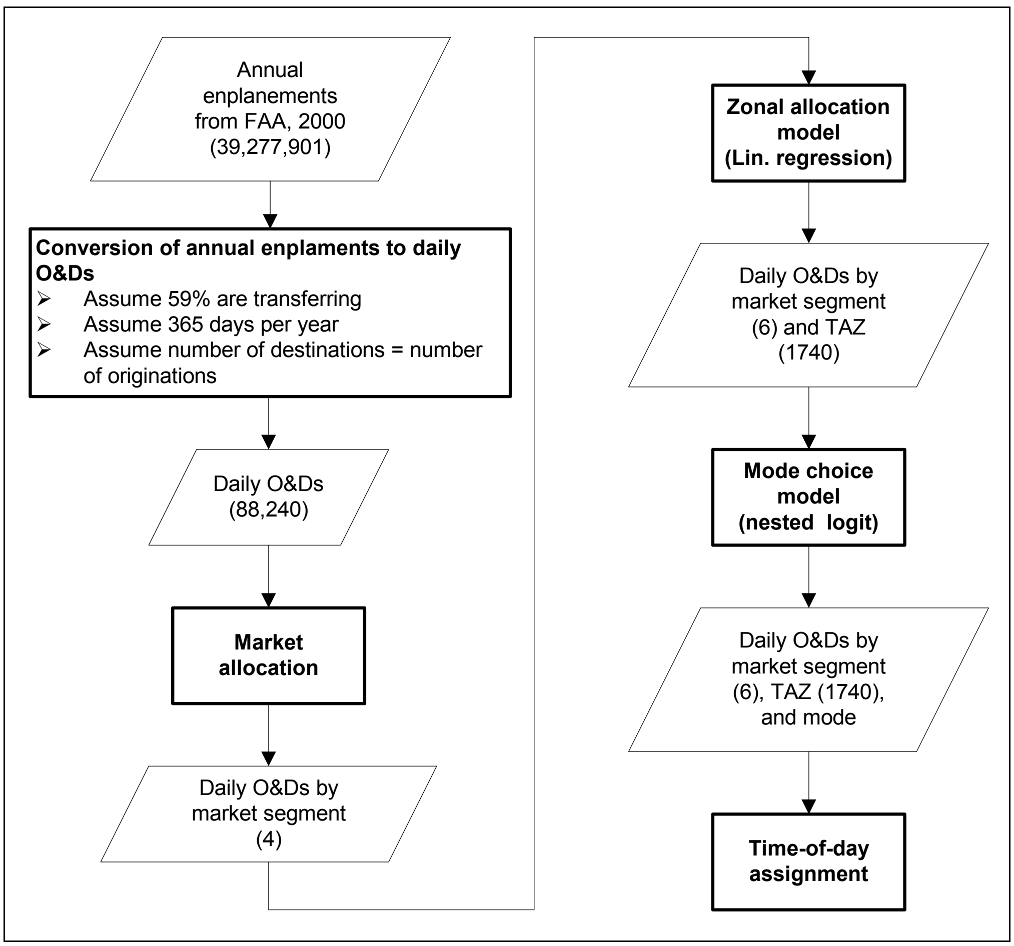
* Unable to obtain information on this model.

Case studies of each city contacted are presented below.

4.2.1 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 4-3. 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 4-3 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 4-3).

Table 4-3 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 4-4.

Table 4-4 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 4-4. 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 4-5). These K factors were used on the two equations for resident business travel and on the other equations that are shown in Figure 4-4.

Figure 4-4 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 4-5 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 4-6 and Figure

4-5, but four separate logit models, shown in Figure 4-7, 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 4-5 Atlanta's airport model: Mode choice model, non-residents

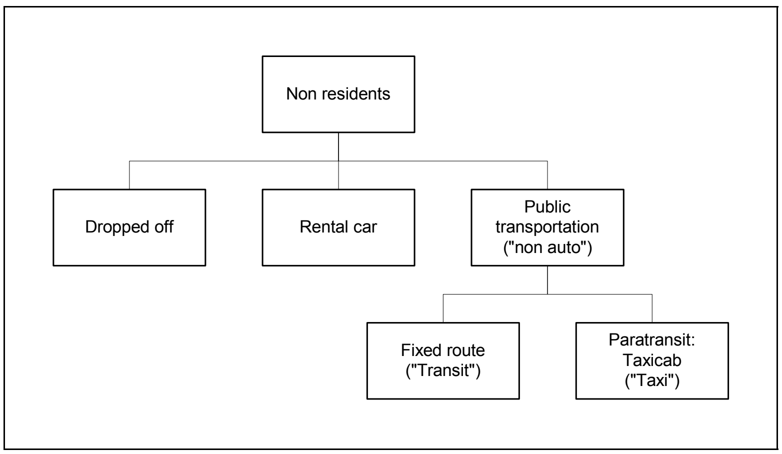
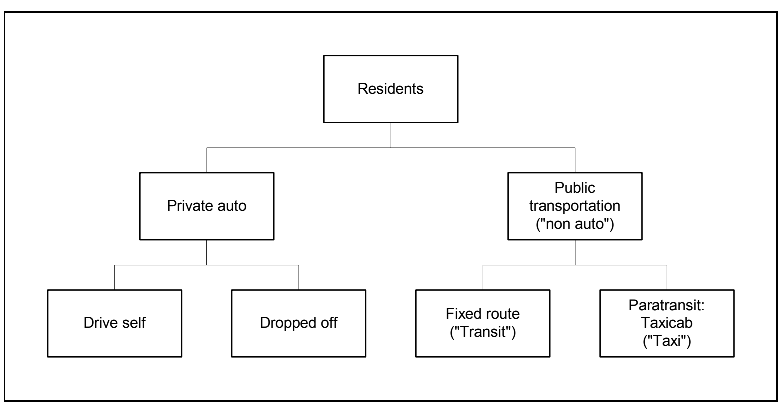


Figure 4-6 Atlanta's airport model: Mode choice model, residents



According to the documentation, the coefficients on time and cost in Figure 4-7 were obtained from other air passenger models, mainly those used in Washington[2] and San Francisco. However, the modal bias constants, at the bottom of Figure 4-7, were developed using the Atlanta air passenger survey. The resident mode choice model calculates the number of trips in

[2] 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.

the "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 4-8. The model appears to perform well at the regional level.

Figure 4-7 Atlanta's airport model: Ground-access mode choice model - Utility equations and bias coefficients

Part 1 of 2

Business, Residents

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

Business, Non-residents

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

Non-Business Residents

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

Non-business, Non-residents

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 4-7 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 long-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 <u>not</u> 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 4-8 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.

4.2.2 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.

4.2.3 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.

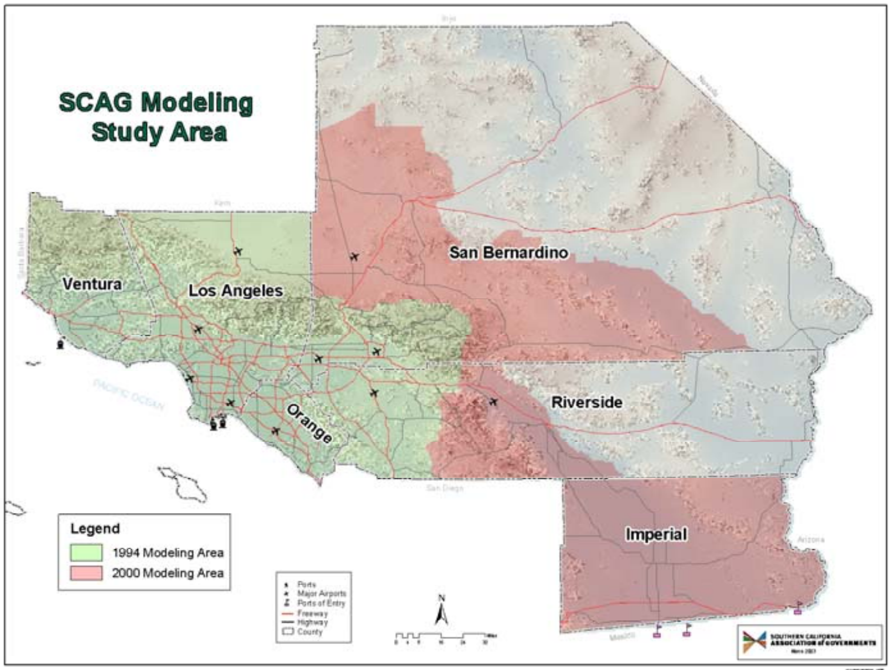
In the CATS four-step travel model, airport trips are treated in trip generation. CATS creates a fixed trip table and treats the airport (O'Hare) as an external station. Trips are HBO in terms of mode choice. The mode choice model is a binary logit model (highway or transit). CATS does not collect air passenger surveys, but the Chicago Department of Aviation does.[3] The last air passenger survey was conducted in 1997.

4.2.4 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 4-9). The modeled area includes 3,827 TAZs and 26 external stations.

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

Figure 4-9 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 long-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."[4] 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:

[4] 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)

4.2.5 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.[5] 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.[6] 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

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

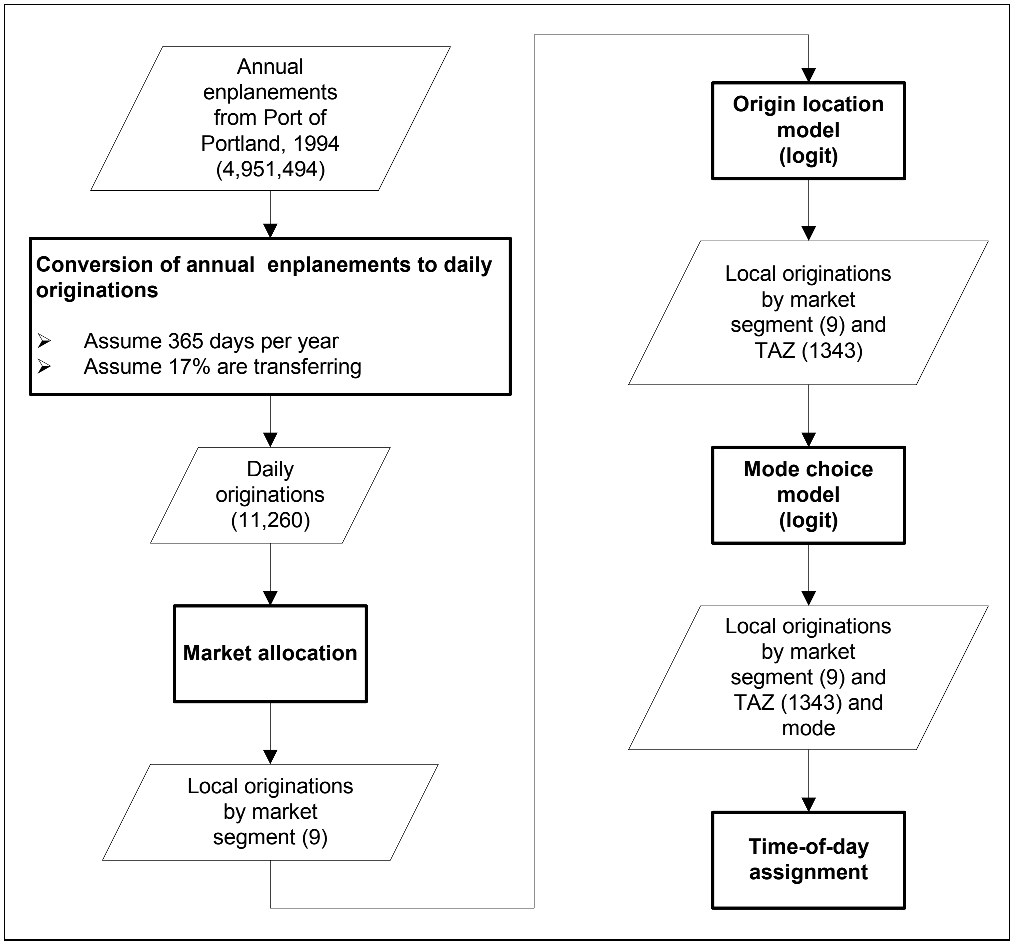
In Phase III, the disaggregation process, the regional passenger forecasts are disaggregated into airport-specific forecasts. Disaggregation factors are developed using variables such as airport-specific development, terminal expansion plans, new entrant plans, carrier plans, and schedule data. Finally, 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).

4.2.6 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 4-10. 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 4-10 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 4-7).

Table 4-6 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 4-7 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 4-7 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 4-8.

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.[7]

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 4-11, 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

[7] 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 4-8 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 4-11 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 4-11 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

4.2.7 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.[8] 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.[9] 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.[10] 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 information, including information from the most recent MTC Air Passenger Survey. The unit

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

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:

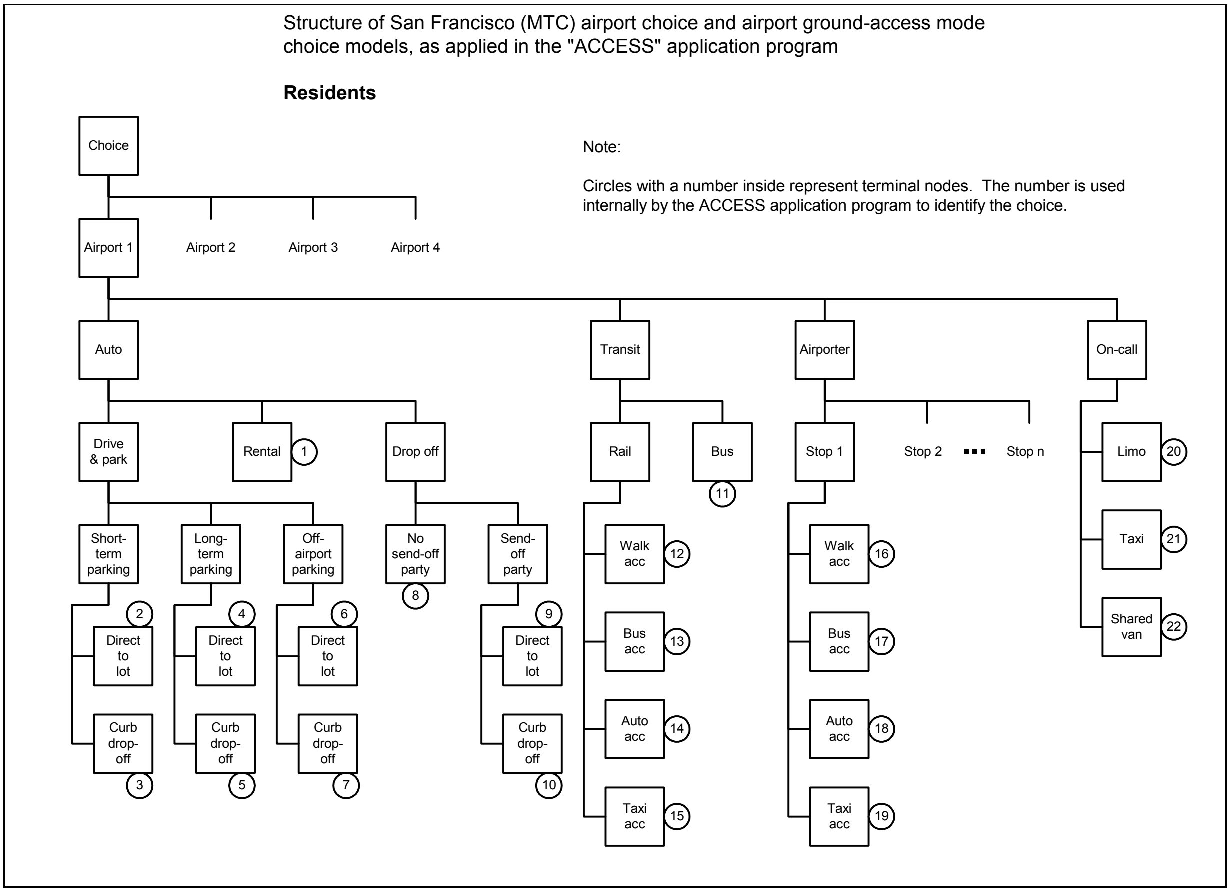
- Resident business travelers;
- Resident non-business travelers;
- Non-resident business travelers;
- Non-resident non-business travelers;

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 4-12 and Figure 4-13).

4.2.7.1 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 4-9. 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 4-12 San Francisco's airport model: Residents

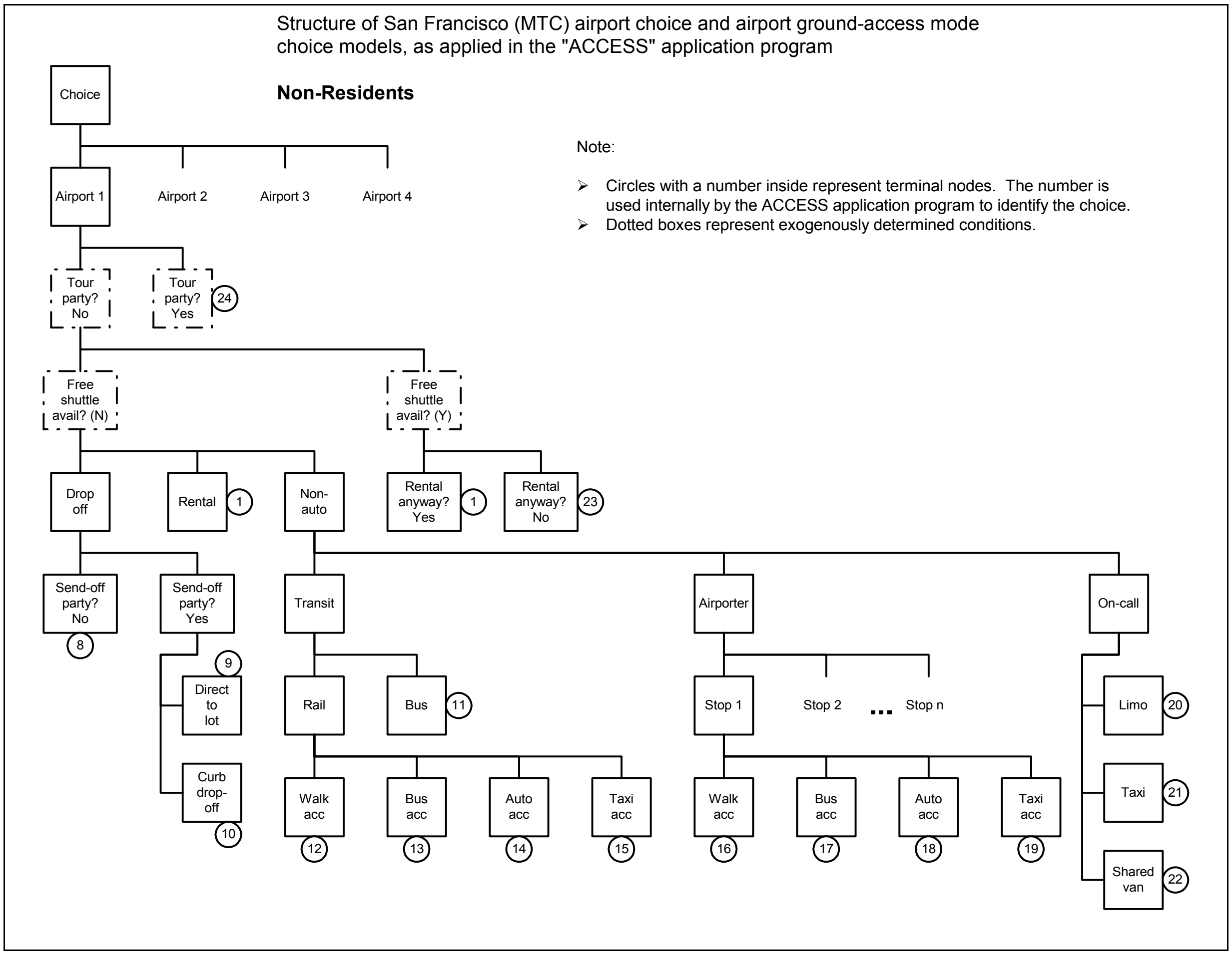


The second variable is DF or daily frequency of flights, also known as the absolute flight frequency. DF is the daily frequency of flights at each airport to the traveling party's destination. It is used as an explicit indicator of schedule convenience – more flights to a given destination imply more 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 4-13 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 4-9 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 4-9 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]}) **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.[11]

4.2.7.2 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.

[11] 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 4-12 and Figure 4-13. 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 4-10 (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 4-10, 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 4-10 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 long-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.

4.3 Conclusion and Recommendations

This chapter 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.

4.4 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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Chicago	CATS	Kermit Wies (312) 793-0438, kwies@catsmpo.com
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New York	NYMTC	Kuo-Ann Chiao Director of Technical Services 45-46 21st Street Long Island City, NY 11101 New York Metropolitan Transportation Council Sangeeta Bhowmick New York Metropolitan Transportation Council 45-46 21st Street, LIC, NY 11101-5407 Telephone - 718-472-3177 Fax - Fax - 718-472-3338
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Portland, OR	Port of Portland	Jane McFarland McFarland, JK (Jane) [mcfarj@portptld.com]
San Francisco	MTC	Charles L. Purvis, AICP Principal Transportation Planner/Analyst Metropolitan Transportation Commission 101 Eighth Street Oakland, CA 94607-4700 (510) 464-7731 (office), (510) 464-7848 (fax) www: http://www.mtc.ca.gov/ Census WWW: http://www.bayareacensus.ca.gov/

5 Exploration of Less Intrusive Travel Survey Designs

MWCOG is currently reviewing travel survey design options to support future travel demand model development work. With the completion of the Version 2.1 model set, COG staff is looking toward the next generation of forecasting models to be implemented. As explained in Chapter 2, the Version 2.1 model is undergoing an evaluation by a TRB peer review panel. In addition to the evaluation, the review panel will be offering recommendations to COG staff about the future directions for the model development program and about related data needs. As future data collection needs are now being formulated, this chapter examines the relationship between alternative survey designs and a critical problem that is facing the transportation modeling profession: increasing nonresponse rates. Less intrusive travel survey design considerations are examined as a means of addressing the nonresponse problem.

The increasing complexity of current travel demand models require data that is detailed and accurate. At the same time, travel surveys are becoming increasingly expensive to conduct while response rates are declining. Consequently, survey design issues have been the focus of many recent travel survey conferences. The following is a list of key factors associated with survey designs:

1. Survey type
   - trip-based, activity-based, or tour-based
   - revealed response or stated preference response

2. Survey time frame
   - length of the survey period
   - frequency of conducting the survey (cross-sectional or longitudinal)
   - one-day versus multi-day
   - weekday versus weekend

3. Survey method
   - self-administered or interviewer administered

4. Data collection mode
   - telephone
   - computer
   - mail
   - face-to-face
   - multi-instrument

5. Sampling
   - selection of sample frame
   - sample size
   - sample stratification

6. Other issues
   - cost
   - reliability (i.e., required level of precision)
   - data quality (i.e., degree of survey bias and problem of non-response)

Thus, survey design factors cover a large array of concerns that are interrelated to be sure. Trade-offs must be made in the formulizing of travel survey designs.[12] For example, an optimal survey design is weighed by the survey cost. Reducing one type of survey error might lead to an increase of another error. The use of new methods and technologies might increase response rates but introduce new cost items and new types of technical problems and bias.

The first section of this chapter introduces the concept of nonresponse, its causes and impacts on travel surveys. The second section includes a brief review of MWCOG's recent home interview surveys in terms of their design, response rates and lessons learned about nonresponse. The third section is a literature review of alternative survey designs used to address the problem of non-response including improvements in standard survey methods and modes of data collection, the use of multi-method / multi-instrument survey designs and the use of new technologies. Conclusions and recommendations for further work are presented at the end of the chapter.

5.1 Non-Response: Definition, Causes & Impacts on Travel Surveys

Recently, much attention has been devoted to the problem of nonresponse in travel surveys, as well as, in other types of surveys. The federally sponsored Travel Modeling Improvement Program (TMIP) dedicated a research project to the study of this problem (1). The Transportation Research Board organized special conferences on household travel surveys (1995, 1999, 2001), with great emphasis on the problem of nonresponse. The Federal Committee on Statistical Methodology (36) produced a comprehensive study on nonresponse with emphasis on statistical concepts. Information from these sources was used in this section to provide a general understanding of the nonresponse problem and its impacts on travel surveys.

5.1.1 Definitions of Nonresponse and Other Types of Travel Survey Errors

Travel surveys are subject to a wide variety of sampling error and/or survey bias. The following is a brief review of survey errors/bias: [13]

[12] For an excellent discussion of trade-offs in transport survey design see A.J. Richardson, E.S. Ampt, & A.H. Meyburg, "Non-Response Issues in Household Travel Surveys", a resource paper for a conference on Household Travel Surveys: New Concepts and Research Needs, Beckman Center, Irvine, California, March 1995.

[13] Two references were found useful:
- A comprehensive discussion of these errors is in the report " Measuring and reporting sources of errors in surveys", Statistical policy working paper # 31, prepared by the Subcommittee on Measuring and Reporting the Quality of Survey Data, Federal Committee on Statistical Methodology, Statistical Policy Office, Washington, D.C. June 2001.
- Groves, R. (1987) reviewed the elements of survey quality and errors in his article, "Research on Survey Data Quality", Public Opinion Quarterly 51: pp S-158 - S-172.

1. Sampling Error is the variability that occurs because a sample, rather than the entire population, is surveyed. This type of error is a function of the sample size and the inherent variability of the attributes being studied. For example, sampling errors in a telephone survey may result, if a large number of households have multiple telephone lines or if multiple households share a single telephone. In these cases, the household unit will not have an equal opportunity of being selected.

2. Nonresponse bias is considered as an indicator of potential bias in a survey [14] and an overall indicator of the quality of survey data. In household travel surveys, there are two types of nonresponse: unit nonresponse, which occurs when a sampled household declines to participate in the survey, and item nonresponse, which occurs when a household agrees to participate but does not respond to some questions of the survey. Many household travel surveys are hierarchical with a screening phase to recruit households and to collect general demographic information and a retrieval-interviewing phase where every household member is requested to provide information about his/her trips/activities. Nonresponse could potentially occur in both of these phases. The final response rate reflects the cumulative effect of the two levels. More detailed discussion of this error will follow.

3. Coverage bias occurs because of differences between a population target and the sample frame population, from which a sample is drawn. For example, a telephone list might be used as a sample frame that is assumed to represent the target population. This type of bias could lead to undercoverage of certain population subgroups (such as households without telephones). It could also lead to overcoverage of population units (such as respondents that are not part of the target population, but are nonetheless surveyed because they happen to live in grouped quarter locations within the surveyed area). Coverage bias is different from nonresponse bias in that the latter is totally unobservable.

4. Measurement error (or response bias) could occur during the data collection steps or at the data processing step. This type of error is attributed to potential problems associated with the questionnaire design, the data collection method, the interviewer, and/or the respondent. Specifically, the measurement error is defined as the difference between the observed value of a variable and the true, but unobserved, value of that variable. It could include both types of error, random and non-random (bias).

5. Processing error occurs after the data were collected and could be attributed to any of the data processing steps including data entry, transmission, poorly specified editing or imputation, and geocoding.

The total survey error is defined as the accumulation of the above separate sources of error, which could be grouped into sampling and non-sampling errors associated with survey biases. Sampling error affects the precision of a parameter while sample bias impacts its accuracy. It is

[14] Bias is defined as a systematic deviation of the estimated statistics from the population value. Bias usually impacts the data validity while the random sampling error impacts the data reliability.

possible to get a precise but not accurate estimate, and vice versa.[15] The impact of sample error is seen in the variability around the estimated mean of a parameter while the bias error might change the very value of the mean. Because the total survey error consists of bias (systematic error) and a variable random error, there is a "substantial technical and practical problem in the measurement of total survey error" (36). No satisfactory method exists to measure the total error. One method suggested for measuring total error is to compare estimates from the survey to values from independent data sources, such as the Census data.

5.1.2 Trends & Impacts of Nonresponse

The general public attitude towards travel surveys has been increasingly negative in recent years. Though it is difficult to reach a generalization about the trend of nonresponse from different travel studies, "it is generally accepted that nonresponse rates are increasing" (17). Many studies are not comparable in terms of methods, design, survey environment, and the way nonresponse is defined and reported. To mention one example of consistent measure of trend in response rate, Moritz and Brog found that total response rate for the national Dutch travel survey declined from 50.7% in 1985 to 34.7% in 1998 (18). It is important to mention here that the nonresponse bias could happen irrespective of the level of response rate. In one of their conclusions, Heer & Mortz stated, "Only improving response might not pay off, because it does not necessarily reduce nonresponse bias"(17).

The impacts of nonresponse are seen in two ways. First, it reduces the sample size, which increases the sampling error, and consequently reduces the degree of survey precision. Second, it may introduce bias to the survey results. While the first problem could be resolved by increasing the sample size, the systematic survey bias is non-random and difficult to detect and quantify. The problem of nonresponse arises once we establish that there is a difference in the demographic characteristics or travel behavior of respondents and nonrespondents. If, for instance, the characteristics of nonrespondents are similar to those of respondents, then the bias impact of nonresponse will be reduced to a sampling error. However, research indicates that there are distinct population subgroups that are disinclined to respond to surveys. The subgroups include those with language barriers, non-mobile and less-mobile people (e.g., the elderly), high mobility people (the young and those with multiple jobs), people less educated or with limited literacy skills. Analysis of the 1995 NPTS revealed that people who live in densely populated areas have lower response rates than those in rural or less populated areas (1). Richardson (38) indicated that a series of adjustment factors should be applied to compensate for information lost through nonresponse. However, significant survey research is required to identify the characteristics of nonrespondents, and estimation of these factors.

FHWA funded a special study for Denver Regional COG (39) to study nonrespondents. The study was conducted in 1998 after the DRCOG 1997 HTS. Three special surveys of nonrespondents were addressed, including households without a telephone, quick-refusal and no-contact households, and partially completed households. The following are selected findings of these three surveys:

[15] Richardson, Ampt & Meyburg (1995), Survey Methods for Transport Planning, made an illustrating example of trade-offs between precision (sampling error) and accuracy (bias).

- The non-telephone households had different demographic characteristics compared to other respondents. They were found to be low in income, vehicle ownership and employment. No statistically significant difference was found in trip rates between non-telephone households and other households, with similar demographic characteristics, in the random-based survey households.

- The survey of quick-refusal households found that the reasons for not participating were "get too many calls" (52%), "don't like surveys (16%), and "don't travel much" (12%). The quick-refusal households group had a higher proportion of elderly households, with the implication that trip purpose of quick-refusal households might be different. Trip rates were found to be not statistically different for households with similar income and household size. The result refuted the hypothesis that quick refusal results in a widespread underreporting of trips. Finally, offering the quick-refusal household a $2 incentive doubled the survey response rate.

- Households who partially completed the questionnaire were more likely to be of large size or of non-English speaking families. Households with 3 or more members and income levels $35,000-$49,000 and $50,000-$75,000 were found to have significantly different trip rates from those who completed the survey.

Since there is no objective way to quantify the nonresponse bias, Reinke (19) suggested that it is essential for every survey design to consider a high response rate as the ultimate goal. As a rule of thumb, he suggested three indicators to evaluate the magnitude of nonresponse. First, the nonresponse rate is likely to be low if the response rate is above 70%. Second, nonresponse presents a problem if the response rate is 50% to 70%, especially for nonwork trips and for households with few trips (the elderly and low income). Third, nonresponse will present a serious problem if the response rate is below 50%. Trip rates could be overestimated. Most recent surveys would probably fall in the third category, since average response rates are currently below 40%, as will be shown later.

5.1.3 Causes of Nonresponse

Knowing the causes of nonresponse is the basis for assessing the level of bias in a survey and how to address it. It is also important for the purpose of assessing "the potential payoff of re-tailoring the survey to specific groups" (1). According to Grove (21), nonresponse errors could be attributed to four design features: the behavior of interviewers, the characteristics of the respondents, the survey questionnaire, and mode of data collection. A. J. Richardson (38) counted three major sources of systematic error (bias): a) inaccurate reporting: when responses are found to be incorrect, inaccurate, or incomplete; b) non-reporting: when certain or all questions of a survey have not been answered; and c) non-response: when a household or individual refuses to respond. The following are highlights of some causes of nonresponse:

- Factors related to the survey environment, defined here as a gauge for the willingness of respondents of a specific geographic location to participate in surveys. The perception of survey burden could reach a point of saturation where respondents become extremely reluctant to respond, or find ways to shield themselves from interviews. In some countries, like Ireland, where generally few surveys are conducted, the survey environment was found to be positive with a low rate of nonresponse (17). Other factors that shape the survey environment are related to the growing concerns about personal privacy and confidentiality, even for mandated surveys such as the Census. The new technological advances, e.g., the Internet, have created higher levels of concern about privacy and confidentiality to the extent that people are becoming more and more sensitive about cooperating with any kind of survey effort. Consequently, more attention has to be given in survey design to establishing legitimacy for the survey and to convincing respondents that there is some kind of personal benefit for giving up some of their scarce time. Recent surveys, e.g. the MTC 2000 HTS, utilized different media outlets to create a more favorable public awareness of the survey. This problem has been exacerbated by the proliferation of telephone screening devices such as Caller ID and answering machines.

- Factors related to the respondent including comprehension of the questions asked, memory lapse, perceived or real burden as seen in lengthy questionnaires, intrusion on what respondents perceive as personal privacy and security (e.g., questions about income). Respondents might sometimes deliberately misreport facts. Zmud, et al explained that respondents might do this as a burden-avoiding tactic or as a way of polite avoidance (22). Respondents might also have different interests on the subject of travel and transportation. For instance, elders who make no trips might not have any interest to respond to travel surveys. As mentioned before, the DRCOG study found that 12% attributed their quick-refusal to a low level of travel. Nonrespondents may also include individuals who are mentally or physically handicapped, who have language barriers, who have limited literacy skills, and urban dwellers (1).

- Factors related to survey design when the target population and the sample frame are defined. For instance in selecting a sample frame for the survey, the sample frame might not cover the whole population. As discussed above (under survey errors), coverage error occurs if the characteristics of the omitted part of the population are different from the covered part.

- Factors related to the interviewer and fieldwork errors. Response rate could differ according to the characteristics of the interviewer (training, gender, vocal, etc.). This difference might introduce a non-random error into the survey results.

- Factors related to the field approach and survey instrument such as confusing questions (discussed above under measurement errors).

5.2 MWCOG Home Travel Surveys: Design & Nonresponse

MWCOG conducted three home travel surveys in 1968, 1987 and 1994. Detailed documentation about survey design and sampling issues are available only for the last, 1994, survey. The following brief review of these three surveys is meant to help in drawing some conclusions about nonresponse from MWCOG survey design experience.

5.2.1 1968 Home Interview Survey

In1968, MWCOG completed its first and largest home interview survey of 26,000 households. Personal interviews of all persons, age 5 and older, were conducted in the home. Wickstrom reported that the sample covered one of every 20 households in the region (5%) (3). Collected data included information about the household, and the trips made by each member during specified weekdays. The data was used to develop travel demand models throughout the 1970's and 1980's. No information is available about survey response rate and nonresponse.

5.2.2 1987/88 Household Travel Survey

MWCOG conducted its second household travel survey in two waves: one during the spring of 1987 and the second in the spring of 1988. As the cost of in-home interviews became more expensive, the survey method was changed to a combined telephone/mail back interviewing approach. The overall sampling rate was about one half percent of total households in the region, with over sampling for D.C. Alexandria, Montgomery and Loudoun counties. The distribution of the completed sample is shown in Exhibit 5-1.

Table 5-1: 1987/88 Home Interview Survey Sampling Distribution

Jurisdiction	No of Households	Completed Sample
D.C.	*259,000*	1,952
Montgomery Co.	258,000	1,827
Prince George's Co	252,000	992
Arlington Co.	79,000	266
Alexandria	55,000	378
Fairfax Co.	275,000	1059
Loudoun Co.	27,000	258
Price William Co.	77,000	288
Charles Co.	N/A	446
Frederick Co.	N/A	481
Total Sample		**7,947**

* Source: George V. Wickstrom, "Preliminary Comparisons of 1987/1988 Home Interview Data with Past Data, November 16, 1988.

It was reported that the 1987/88 survey achieved a 70% response rate in the household telephone screening and a 55% response rate for the mail-back travel diaries (24). This amounts to a 38.5% overall response rate. There is no documentation about the disposition of the survey results.

5.2.3 1994 Home Interview Survey

The 1994 Household Survey was conducted in two waves, during May to June and September to October of 1994. The sample frame was comprised of residential telephone exchange numbers. After initial screening for nonworking numbers, the final telephone list consisted of 16,112 telephone numbers. The sampling procedure utilized Random Digital Dialing to cover both listed and unlisted numbers. The CATI administration method was used for quality control. Pre-survey letters, signed by high-ranking officials to secure legitimacy for the survey, were sent to all households in the selected sample. The survey field approach consisted of a screening phase and an extended telephone-interviewing phase to collect trip and person information (15, 16).

The disposition of the household screening phase is shown in Exhibit 5.2. Approximately 16,000 calls were made during the two waves of the survey. 25% of these calls (3,986) were non-eligible units, which include non-residential numbers, unassigned/nonworking numbers, disconnected and changed numbers. Other non-eligible numbers include numbers of fax machines, households who live outside the region, and telephone numbers of unoccupied units. This high percentage of non-eligible units represents a considerable reduction of the sample despite the fact that a prescreening for non-residential numbers was performed within the frame design. The Random Digital Dialing (RDD) protocol was effectively used to address the survey bias that could occur if unlisted telephone numbers were neglected by design. However, the RDD could also generate a high percentage of non-eligible units. Non-eligible units could also be attributed to either the quality of the sample frame or the efficiency of the contacting procedures. Suggested remedies for the non-contact problem include increasing the limits for maximum callback and increasing the field period. The 1994 HTS procedure included a maximum of nine attempts to complete an interview, special procedures for refusal conversion, and reminder cards and calls (15, 16).

More than half of the total (12,126) eligible units completed the screening survey. The 1994 HTS field procedures allowed for a “proxy”, who was 18 years or older, to provide the required information about other household members. If most of the critical information was collected, the unit was classified as complete. The TMIP document on nonresponse suggested procedures to define the survey codes of eligibility and non-eligibility to facilitate a standard way of calculating the survey response rate. Following that standard and the disposition provided by WESTAT, the response rate is shown in column 6 of Exhibit 5.2. The overall response rate for the first screening phase of the survey was 50.2% (i.e. 49.8% nonresponse). The nonresponse consisted mainly of refusal (24% of eligible) and non-contact telephones (17% of eligible) which represent households that did not respond after nine trials of contact. The highest nonresponse rates of eligible households were in the core jurisdictions: DC (55.8%), followed by Arlington (51.7%) and Alexandria (51.1%). A break down of nonresponse factors indicates that these three jurisdictions had the highest rate of unanswered calls (19-24% of eligible) and the highest level of language problems (2-3% of eligible). The refusal rate is higher in outer jurisdictions (Frederick, Stafford, Charles and Loudoun counties).

Table 5-2: 1994 Home Travel Survey: Disposition of Screener Cases by Jurisdiction

Jurisdiction	Total Calls Attempted No	Total Calls Attempted Pct of Tot Calls	Eligible Cases: Total Eligible (ELG)	Completed	**Response Rate**	Refusal	Language Problem	Max Call Attempts	No Answer	Non Eligible Cases: Total Non Eligible	Non-resid Non-Working	Other Non-Eig
D.C.	4,341	26.9%	2,913	1,287	**44.2%**	884	58	255	429	1,428	1,408	20
Calvert	416	2.6%	349	201	**57.6%**	112	0	11	25	67	53	14
Charles	883	5.5%	683	350	**51.2%**	238	5	43	47	200	185	15
Frederick	801	5.0%	644	336	**52.2%**	233	3	20	52	157	148	9
Montgomery	1,616	10.0%	1,266	670	**52.9%**	383	23	78	112	350	341	9
P.G.	1,775	11.0%	1,350	687	**50.9%**	436	22	91	114	425	392	33
Arlington	1,013	6.3%	735	355	**48.3%**	220	22	43	95	278	272	6
Alexandria	910	5.6%	699	342	**48.9%**	181	14	57	105	211	201	10
Fairfax City	279	1.7%	220	146	**66.4%**	52	4	6	12	59	56	3
Faifax County	1,571	9.8%	1,239	640	**51.7%**	377	28	69	125	332	312	20
Fauquier	431	2.7%	343	171	**49.9%**	116	4	15	37	88	79	9
Loudoun	815	5.1%	665	350	**52.6%**	226	6	33	50	150	137	13
PW	853	5.3%	689	372	**54.0%**	227	3	35	52	164	151	13
Stafford	408	2.5%	331	183	**55.3%**	117	0	15	16	77	61	16
Total	**16,112**	100.0%	**12,126**	**6,090**	**50.2%**	3,802	192	771	1,271	3,986	3,796	190
Pct of Tot Calls	100.0%	0.0%	75.3%	37.8%		23.6%	1.2%	4.8%	7.9%	24.7%	23.6%	1.2%

Source: Compiled from Westat survey reports (15, 16) of the fall and spring waves of the 1994 HTS.
* Response Rate = Percent Completed Eligible Cases / Total Eligible Cases.

In the second phase of the 1994 HTS, trip information was retrieved from each person of the household who agreed to participate in the first phase. As shown in Exhibit 5.3, 11,216 out of 14,851 eligible persons provided complete information resulting in a 75.5% response rate. The highest nonresponse was found in D.C., Prince George's County, and Arlington County. The major reasons for nonresponse were non-contact and language barriers in Arlington.

Table 5-3: 1994 Home Travel Survey: Disposition of Extended Cases by Jurisdiction

Jurisdiction	Total Calls Attempted No	Total Calls Attempted Pct of Tot Calls	Eligible Cases: Total Eligible	Completed	**Response Rate**	Refusal (	Language Problem	Max Call Attempts	OTHER NONRESP	Total Non Eligible
D.C.	2,811	18.7%	2,740	1,936	**70.7%**	325	49	414	16	71
Calvert	558	3.7%	548	428	**78.1%**	61	5	54	0	10
Charles	998	6.6%	993	746	**75.1%**	126	0	119	2	5
Frederick	873	5.8%	870	701	**80.6%**	73	1	95	0	3
Montgomery	1,721	11.4%	1,705	1,286	**75.4%**	173	31	210	5	16
P.G.	1,759	11.7%	1,721	1,230	**71.5%**	182	16	278	15	38
Arlington	707	4.7%	697	502	**72.0%**	68	28	98	1	10
Alexandria	669	4.4%	654	508	**77.7%**	50	21	67	8	15
Fairfax City	340	2.3%	327	257	**78.6%**	26	7	37	0	13
Faifax County	1,661	11.0%	1,645	1,337	**81.3%**	151	15	141	1	16
Fauquier	471	3.1%	463	361	**78.0%**	47	3	48	4	8
Loudoun	922	6.1%	920	714	**77.6%**	105	0	93	8	2
PW	1,044	6.9%	1,037	799	**77.0%**	112	1	118	7	7
Stafford	535	3.6%	531	411	**77.4%**	59	0	61	0	4
Total	**15,069**	100.0%	**14,851**	**11,216**	**75.5%**	1,558	177	1,833	67	218
Pct of Tot Calls	100.0%		98.6%	74.4%		10.3%	1.2%	12.2%	0.4%	1.4%

Source: Compiled from Westat survey reports (15, 16) of the fall and spring waves of the 1994 HTS.

A summary of the final results of the two survey phases is shown in Exhibit 5.4. The number of completed households dropped from 6,090 in the first phase to a final number of 4,864 households. The final response rate, 37.9%, is the multiplication of the response rates of the recruitment phase (50.2) and the retrieval phase (75.5%). A final editing of the 1994 HTS survey file reduced the number of households to 4,864, which has been used in the models development work. Assuming the same survey performance, the original goal of collecting

8,750 completed households would have been accomplished only if the survey resource were essentially doubled. (i.e., by increasing the number of calls from 16,112 to 28,886).

Table 5-4: 1994 Home Travel Survey: Final Response

	Attempted Calls		Completed Households			Response Rate (Pre-Editing)		
Jurisdiction	Tot Calls	Eligible Households	Screen	Pre-Editing	Final Used for Models	Screen HHS	Extended Psn/trips	Final
D.C.	4,341	2,913	1,287	1,001	993	44.2%	70.7%	31.2%
Calvert	416	349	201	165	161	57.6%	78.1%	45.0%
Charles	883	683	350	272	271	51.2%	75.1%	38.5%
Frederick	801	644	336	281	280	52.2%	80.6%	42.0%
Montgomery	1,616	1,266	670	534	537	52.9%	75.4%	39.9%
P.G.	1,775	1,350	687	533	530	50.9%	71.5%	36.4%
Arlington	1,013	735	355	278	281	48.3%	72.0%	34.8%
Alexandria	910	699	342	282	276	48.9%	77.7%	38.0%
Fairfax City	279	220	146	121	120	66.4%	78.6%	52.2%
Faifax County	1,571	1,239	640	549	554	51.7%	81.3%	42.0%
Fauquier	431	343	171	139	139	49.9%	78.0%	38.9%
Loudoun	815	665	350	283	279	52.6%	77.6%	40.8%
PW	853	689	372	300	296	54.0%	77.0%	41.6%
Stafford	408	331	183	146	147	55.3%	77.4%	42.8%
Total	**16,112**	**12,126**	**6,090**	**4,884**	**4,864**	50.2%	75.5%	37.9%

Source: Compiled from Exhibit 4, 5 and SAS tabulation of 1994 Linked trip survey file.

As shown in Exhibit 5.5, the 1987 HTS has a lower retrieval rate as compared to the 1994 HTS. That probably reflects the merits of the CATI method over the call-mail back method used in the 1987 survey. In general, the table indicates that the response rate of recent surveys, with one exception, has fallen to a range of 26-32%, which is the real reason why there is so much concern about the problem of nonresponse. It is noticeable from this small sample that the drop of the overall response rate is attributed, to a great extent, to the drop in the recruiting phase rather than the retrieval phase of the survey. Therefore, it is more effective to allocate more resource to the recruiting phase of the survey. Within that phase, those who opt not to answer averaged 20% to 33% of the eligible sample (about 17% for MWCOGs' 94 HTS)[16]. Those who opt not to answer were either out of home, such as high mobility groups, or the respondents were using telephone screening devices (answer machines or caller ID) and do not want to answer. As mentioned earlier, the important question here is whether these non-respondents have different characteristics from the rest of the sample. Ashish Sen et al (37) constructed a Logit regression model with demographic data (from the Census) as independent variables and response rate (using CATS HTS) as the dependent variable. They concluded that the lower-income, less-educated households are usually underrepresented. Mere factoring of the survey will maintain the same sample bias and will be reflected in all models based on that survey. Though most models are usually built on un-factored records, the only solution is a careful sampling scheme which under- and over-samples by subareas or groups. Surveying of nonrespondents is another avenue, as was the case of DRCOG.

[16] Computed from the detailed disposition of the listed surveys, referenced in the last column of Table 5.5.

Table 5-5: Comparison of Response Rates

Survey	Rate	Notes	Reference
1987 MWCOG HTS	38.5%	70% Screening & 55% Retrieval	(24)
1994 MWCOG HTS	38%	50.2% Screening & 75.5% Retrieval	Exhibit 5.4
1994 Portland Metro HTS	33%	53.2% Screening & 63% Retrieval	(34)
2000 MTC	7.6%	15.6% Screening & 48.2 Retrieval.	(2 p. 3)
2000 Philadelphia/South Jersey	33%		(35)
2000 Maricopa Association of Governments	31%	42.0% Screening & 73.0% Retrieval	(35)
1997/98 NY/NJ/CT	26%	33.6% Screening & 78.2% Retrieval	(33 p. 19)
1997 Seattle	32%		(35)

5.3 Alternative Methods to Reduce the Impacts of Nonresponse

This section starts with a brief note on survey methods and then reviews alternative methods that could be used to reduce the impacts of nonresponse. These include improvements in standard survey procedures, the use of statistical methods to impute missing values, and the use of less intrusive technologies and multi-methods / multi-instruments designs to improve data quality and target nonresponse groups.

5.3.1 Note on Survey Methods

Data collection methods can be classified in different ways. Ettema et al[17] (40) used a three-dimensional classification of survey methods, stratified by survey administration (survey administered by respondent or interviewer), type of data collected (travel or activity diary), the use of computer (paper and pencil versus computer assisted methods). Ettema et al summarized the characteristics of home interview, telephone interview and mail interview as shown in Exhibit 5.6:

Table 5-6: Comparison of Response Rates

	Home Interview	Telephone Interview	Mail Questionnaire
Non-coverage	+ + +	+	+ +
Nonresponse	+ + +	+ +	+
Complexity of Questions	+ + +	+	+
Cost	+	+ +	+ +

+, ++, +++ represent an ordinal scale with +++ as the best score.
Source: Ettema et al (40) page 24.

The face-to-face home interview method was found to have the best coverage, least nonresponse but most expense. It has the advantage of not requiring a detailed sampling frame. In this case area probability sampling can be used, whereby certain geographical units (streets and households within these streets) could be targeted. Stopher, 2002 (6) described the evolution of household travel surveys and their methods. He reported that earlier face-to-face home

[17] Ettema Dick, Harry Timmermans and Leo van Veg (40) prepared a comprehensive literature review and a manual to evaluate the different effects of survey methods.

interview surveys achieved a 90-95% response rate. They were eventually suspended because of increasing cost and concerns about interviewers' safety. Telephone and mail methods are not the best in reaching all members of the population because the sample frame (telephone or address list) does not cover every one. For instance, the telephone interviews fail to reach mobile groups, groups without telephones, and groups who use telephone-screening devices. The Computer-Assisted-Telephone Interview (CATI) method was used in the 1990's to counter the drop in response rate of mail-back surveys. Stopher and Metcalf, 1996 (7) reviewed 55 surveys and found that the mean rate of completion for telephone interviews was 73% compared to 61% for mail-back. Different results were obtained in other countries. In the Netherlands and Germany, a mail-back survey design coupled with telephone call motivation achieved a 74% response rate compared to 45% for the CATI administration method.

Following are examples of survey methods with different modes of data collection.
When respondents complete forms on their own (self-administered), one or more of the following methods could be used:

- Self Administered Questionnaires SAQ, using paper and pencil.
- Computer-Assisted Self-Administered interviewing CASI. (e.g. using of Electronic Travel Diary - ETD).
- Audio Computer-Assisted Self-Administered Interviewing (ACASI).
- Computer-Assisted Web Interview (CAWI).

When an interviewer administers the questionnaire, one or more of the following methods could be used:

- Paper and Pencil Interviewer administered (PAPI).
- Computer-Assisted-Personal Interview (CAPI).
- Computer-Assisted-Telephone Interview (CATI).

Self-completed methods are generally known for lower reporting errors but higher nonresponse. These methods are not mutually exclusive, since a combination of them could be used in one survey, as will be explained later under a multi-method multi-mode approach.

5.3.2 Standard Methods to Reduce Nonresponse

Many improvements have been added to the standard survey procedures to increase response rate and to address the bias problems introduced by nonresponse. The cumulative experience of travel surveys, with respect to nonresponse, was summarized in a special TMIP report (1). The report provided a set of recommendations on how to reduce both unit and item nonresponse. These recommendations have now become part of the standard procedures in conducting household travel surveys. A short list of selected recommendations to reduce nonresponse is compiled in Exhibit 5.7. The listed procedures cover both mail and telephone survey methods.

Table 5-7 Standard & Statistical Procedures For Reducing Nonresponse

Interviewer Characteristics
1. To the extent possible, use experienced interviewers with strong track records in recruiting sample members and in converting reluctant participants. 2. Use bilingual interviewers when the sample includes a substantial portion of non-English speakers. (The disposition of the 1994 HTS revealed that language barrier was present in DC, Montgomery, Arlington and Alexandria.) 3. Consider the vocal characteristics of the candidate when recruiting interviewers for a telephone survey.
Questionnaire Design & Survey Administration
4. Postpone the rostering of individual household members until the end of the screening interview. Respondents might be reluctant to give detailed information about family members. 5. Allow for at least 8 callbacks per sample telephone number when conducting a telephone survey. (Though Westat made up to 9 callbacks, non-contact was a major contributor to nonresponse in the 1994 HTS.) 6. Pre-contacts and reminder letters decrease unit nonresponse. Send out advanced letters to sample members. 7. Extend field period long enough to permit multiple contact attempts. 8. Establish a telephone hot line to answer respondent's questions. 9. Use methods of optimizing the timing of contact calls. 10. Questionnaire appeal decreases item nonresponse. 11. Conduct pretest to test survey instruments and field procedure. 12. Provide prepaid money incentives of $2 or less. (1997 price). 13. Allow for proxy reporting during the screening interview. 14. Use special methods for hard-core nonrespondents by tailoring the survey to address their special needs, concerns and objections. 15. When all fails, select a sub-sample and use special methods to achieve a high response rate among the subgroup. 16. Place sensitive items towards the end of the questionnaire.
Statistical Methods for Reducing Nonresponse 17. Deductive imputation by conducting logic and consistency editing. 18. Nonresponse re-weighting. 19. Compensate for nonresponse by adjusting weights (post stratification to align with values from an independent source – such as the Census). 20. Statistical Imputation for missing values. (deductive imputation, overall mean imputation, class mean imputation, hot-cold deck imputation, regression imputation and multiple imputations).
Source: Compiled from the TMIP Report (1997), "Nonresponse in Household Travel Surveys", prepared by NARC, Michele Zimowski, Roger Tourangeau, Rashna Ghadialy, and Steven Pedlow.

5.3.3 Use of Multi-Method / Multi-Instrument to Reduce Nonresponse

Recently, a combination of survey methods and modes of data collection have been used in what is known as mixed mode, or Multi-Method Multi-Instrument (MMMI). One important motivation for using this method is the observed drop in response rates. Werner Brog (7) provided the rationale for using MMMI in travel surveys in a two-part design:

1. Increase response by changing our perception of the respondent. “Take respondents as customers.” This concept was explained by Griffiths et al (8) as giving respondents “greater choices over how, where, and when to be interviewed”.
2. Idea of satellite surveys: i.e., having core data (base survey) that is asked of everyone, and then a series of nested surveys for specific topics. (using sub-samples).

In his article on MMMI Goulias (4) defined three settings for the use of (MMMI) in travel surveys:

1. Use different instruments to reach different segments of the population, as a means to reduce respondent burden and nonresponse;
2. Use different methods to study a complex problem from different perspectives (triangulation approach); and
3. combine different existing data sources to answer one or more policy questions (data fusion).

Goulias cautioned that, while the Multi-Method approach can reach some groups by using different methods or instruments, the lack of knowledge about sample composition might lead to introducing survey bias by a systematic self-selecting sample. When different data sources are combined, it is important to identify and quantify the variations that occur because of respondents and trip characteristics, variations due to survey methods and instrument, and variations due to the time period of the survey.

In summary, one way to address the nonresponse problem was to target subgroups of non-respondents by using different survey methods or instruments that satisfy the requirements of those subgroups. The Computer Assisted Self Interviewing method (CASI), allows for different options to reach households with high mobility. New technologies such as GPS, Web-based questionnaire submission, recruitment by e-mail, TV-based multimedia are some examples used to overcome the intrusion of personal contact. Pilot and pre-test surveys provide the vehicle to evaluate the need for MMMI. At the pre-test stage it is possible to detect which subgroups are underrepresented and which special methods could be more effective in reaching these population segments. Sample disposition of previous surveys could also provide useful information about non-respondents and which groups are typically under-represented. However, information from previous surveys might be outdated because large surveys are not frequently conducted. Another expensive alternative is to conduct special surveys of nonrespondents. The Census data could also provide valuable information about the distribution of households by some critical variables used in different models (e.g. household size, vehicles ownership, income). In some recent surveys target sample sizes were set according to cross-classification of these critical variables to insure sufficient observations for estimation of valid and reliable models.

The idea of satellite surveys (base survey that is asked of everyone, and then a series of nested surveys for specific topics) is a useful concept with several applications. Recently, some travel surveys combined trip diaries with stated preference surveys to study respondents' choices under certain hypothetical situations, such as introducing highway value pricing (fixed and variable tolls). In this kind of survey different methods and instruments are usually used to study a complex problem or to reach different groups. The next section will provide more detail about the use of different technologies within the multi-method multi-instrument surveys.

5.3.4 Use of New Technologies as a Means to Reduce Nonresponse

Automation of data collection has received much thought in many areas in transportation. Recently, the CASI administration method has brought many technological advances to travel surveys. This section provides a brief literature review of recent advances in survey data automation, capitalizing on new technologies including: Global Positioning Systems (GPS), handheld Electronic Travel Diaries (ETD), Geographical Information Systems (GIS), the Internet, and Interactive Video/Audio Interfaces (IVIS). The review will concentrate on how these new technologies were used as a means to reduce respondents' burden and to adjust for under-reporting of trips in travel surveys (missing items).

5.3.4.1 GPS / GIS Technology

The application of GPS technology to track travelers started in the U.S. during the mid-90's. Stopher (9) defines two forms of GPS applications:

1. Passive GPS device with an antenna. The device is connected to a data storage unit (logger), with no capability of interaction with the respondent. In some applications the respondent is asked to turn on the unit when he begins a trip and to turn it off at the end of the trip. In other applications, the unit is kept permanently on, or is automatically activated/deactivated by the car ignition.

2. Active GPS device with an antenna connected to a handheld Electronic Travel Diary (ETD). The ETD is used to store the GPS data and as a Computer-Assisted Self-Administered Interviewing (CASI) device. Similar to the conventional survey, the respondent is asked to answer questions about each trip or activity. Most of the reviewed applications collected activity information with the GPS data.

Other applications, such as in Atlanta, added an engine computer monitor to collect data related to emissions such as vehicle speed, acceleration, engine revolutions etc. (10). Atlanta is also planning to extend the application to other modes by using portable and user-friendly GPS designs that can be "employed for walking, cycling, and other trips" (10). One pilot survey conducted in the Netherlands tried to apply the GPS technology for all modes, including walk, cycle, and transit. The project reported two problems: privacy aspects limiting the willingness to participate and shielding of antennas from signals (for walk and transit) resulting in missing trips (13). In general, most of the GPS applications are vehicle-based and most of them use GIS to provide the route matching routines that link the GPS origin/destination points with the road network.

Besides being a less intrusive method of data collection, other advantages of using the GPS technology are seen in reducing respondent burden, capturing many unreported trips, and providing accurate spatial and temporal information about trip origin, destination and route. The disadvantages of the technology, as cited in different applications, include:

- The passive GPS does not provide information about the trip purpose of the driver and passengers, the car occupancy and parking/toll cost. Respondent interviewing, by ETD or other methods, is used to collect this kind of missing information.

- The use of the ETD is a burden for the respondent. It is also subject to the same problems facing the conventional HTS; the respondent might fail, or forget to enter all required information. As Stopher describes it:

  > "This defeats the purpose of the GPS device, which is not only to gain more precise geographic and temporal data than people are capable of providing, but is also to record travel that they frequently forget to enter into a trip, activity, or time-use diary" Stopher, (10).

- The case studies reported several operational problems such as equipment failures, stability of power supply, data storage limits, ETD screen contrast, and other computer problems. The high cost of equipment is another concern. The FHWA and the Lexington, Kentucky MPO conducted one of the early pilot studies in the fall of 1996. The reported cost was $1,400 per unit (8). However, the cost and operational efficiency of the GPS units are expected to improve with time.

- Many GPS projects reported difficulties in transferring the recorded GPS track points into coherent (GIS-aided) trips. First, the GPS produces extremely huge volumes of data, depending on the frequency of data recording and the duration of the monitoring period. Second, it is sometimes difficult to distinguish short stops from traffic congestion. Since the accuracy of GPS coordinates are within 100 meters, a correction algorithm might be required to align the GPS locations with those of the GIS, especially at intersections. Finally, the GPS might not record the trip starting point because of the time lag in picking up the satellite transmission.

Most GPS applications in U.S. (about 15 of them) are labeled as "proof of concept". With the fast pace of technology development, the GPS could very soon provide a tool to enhance, rather than, replace the conventional HTS. In particular, the GPS/GIS technology could help in assessing the quality of the HTS in adjusting household trip rates, analysis of trip chaining, improving the accuracy of trip times and distance, and allowing more understanding of trips variability, since passive GPS could be used for a long monitoring period.

The Atlanta ARC is in the process of completing a multi-instrument survey covering an activity survey of 8,000 households, of which 1,100 will be sub-sampled for both activity and automated

(GPS) vehicle surveys.[18] The rationale for the automated vehicle sub-sample was to "compare between what was traveled and what was reported, helping to overcome any bias in the way the data is collected." (11).

The Austin (Texas) Regional Household Survey utilized GPS technology by selecting a sub-sample of 161 households, of whom only 28% agreed to participate. The reason of high refusal was either "too busy to commit to a set of appointments" or "do not want anyone tinkering with their car" (32). The results indicated that travel diaries recorded an average of 4.87 trips compared to 4.9 trips recorded by GPS. However, because of the small sample size, the standard error is +/- 15 trips.

Stopher (9) reported that a vehicle-automated sub-sample of 100 households would be part of the Sydney Regional Travel Survey (2,000-3,000 households). After processing the GPS data, each respondent would receive maps and summary tables of his trips in preparation for an in-depth interview. The vehicle-based automated sample will be used to study the extent of under-reporting (12). In this case the GPS is utilized as a memory jogger.

Use of incentives was suggested by many applications of GPS surveys. A recent (2001) case study in Ohio paid $10 for each vehicle equipped with GPS (14). Finally, Doherty (26) acknowledged the role of GPS and GIS technologies to replicate observed travel patterns, but the target, as he stated it, "is not only observed patterns, but underlying decision process". For that reason, he suggested that the accurate product of these technologies is best used as a "memory jogger" for more in-depth exploration of travel behavior in home travel surveys.

5.3.4.2 Internet Technology

Computer Assisted Web Interview (CAWI), a recent addition to the CASI administration method, has been gaining ground with the steady proliferation of computers and Internet connections in households.[19] Multi-instrument surveys could use the Internet as a viable option to reach selected segments of the population, such as mobile professionals who usually have high refusal rates in telephone-only surveys. The Internet technology became more attractive, since it is now possible to attach rich graphical interfaces, which enhances the efficiency and appeal of the electronic questionnaire. It is also possible to incorporate interactive geocoding at the time when the respondent is completing the survey. As software development becomes more ubiquitous, the Internet option will also become a cost effective one. Currently, there are ongoing efforts to develop a client-friendly GIS-Internet software, "WWW-GIS". (27). The

[18] The survey was conducted during spring of 2001& 2002 as part of SMARTRAQ program. The Web site www.smartraq.net/survey.htm reported that: " The project was initiated by Georgia Department of Transportation and is supported through a partnership between: **transportation** interests (Georgia Department of Transportation, Federal Highway Administration, Georgia Regional Transportation Authority, Atlanta Regional Commission); **environmental** interests (U.S. Environmental Protection Agency, Turner Foundation); public **health** interests (U.S. Centers for Disease Control and Prevention, Georgia Division of Public Health); and **land** and economic development interests (Metro Atlanta Chamber of Commerce and Urban Land Institute - Atlanta District Office)."

[19] Adler et al (28) reported that in the U.S., almost 60% of all households have direct access either at home or at work. He believes that the effective rate could be greater than that, given the internet penetration into schools, libraries and other public places.

Internet software could also incorporate intelligent features such as " error-trapping" to detect logical / procedural errors and prompts respondents to fill missing information.

A full field application of the CAWI was conducted by a small size MPO at Las Cruces, New Mexico. The survey purpose was "to update trip generation information and to provide data on how the Internet response differs from response to a more conventional instrument." (28). The application used secured servers, standard browser interface, a geocoding and mapping module and a set of pre-programmed validation checks to ensure internal consistency. With a sample frame consisting of 3,000 address records, the study split-sample design allowed for a variety of administration methods including CATI/Internet, CATI/Mail, Internet only, mail only, and internet/mail. While two thirds of the sample were given the Internet option, only 23% actually used the Internet. The authors estimated that half of those with Internet access chose to complete the survey using the Internet option (28). The overall response rate for the survey was 31%. A detailed analysis of the survey disposition revealed that "providing an Internet option had a small positive effect" with respect to response rate. The small impact was attributed to an unexpected Internet service disruption during the survey period. Another finding was that those who used the Internet reported higher trip rates than the rest of the sample.

A study prepared by Resource Systems Group, Inc. for the FHWA, developed a" proof-of-concept" prototype consisting of two modules: an Internet travel dairy software and an interactive geocoding module. The Baltimore Metropolitan Council (BMC) applied the interactive geocoding module in a mode choice survey (29, 30).[20] In this survey a few questions were added to evaluate the potentials for an Internet-based survey. It was found that 21% had never used computers, while 50% used a computer frequently. The use of a computer was found strongly related to income, 50% of low income never used a computer, while 70% of high-income respondents used a computer frequently. As for Internet usage, 14% of respondents who use computers do not have access to the Internet.

To conclude, the CAWI has great potential as an option for conducting travel surveys. However, this option should be considered as part of a multi-method multi-instrument survey, because the Internet population is not representative of the full population. As a new technology, the CAWI is going through a process of refinement including Internet software, questionnaire design, and enhancement of interactive geocoding. Accessibility to the Internet is not yet universal. It is also not clear how to define the sample frame for Internet users. The Las Cruces experiment indicates that the Internet option could be attractive to high-mobility professionals.

[20] The Baltimore 1993 HTS was found insufficient for analysis of demand management policies. Because of its broad regional coverage, the 1993 BMC survey did not provide a large sample for transit riders. To compensate for this shortage, the BMC conducted the mode choice survey covering both revealed and stated preferences. The stated preference survey was used to evaluate a set of 10 choices including current and future transit modes with different pricing schemes by time-of-day. The survey covered 600 residents intercepted at shopping malls, office parks, welfare centers and other locations.

5.3.4.3 Mobile Communication System: Personal Handy-Phone System (PHS) Technology

Mobile communication systems, like the GPS, present another technological opportunity to trace travelers. In an urban environment where roads and intersections are multilevel, the GPS measurements are difficult to interpret. Moreover, the GPS transmission usually fails if the device is used in closed areas. That is why GPS has not been successfully used in tracing users of non-vehicular modes. An experiment in Japan used Personal Handy-Phone System (PHS) Technology to measure travel path, for all modes, in a multilevel city. The results indicate that the PHS could collect spatial/temporal data similar to that of the GPS (31).

5.4 Conclusions & Recommendations for Further Work

The ultimate goal for travel surveys is to provide reliable (in precision) and valid (unbiased) information for modeling with minimum cost. This is a challenging proposition since modeling is becoming more complex and surveys are getting more expensive and difficult to collect. The drop in response rates, underreporting of trips and inaccurate reporting are three proven difficulties facing survey data collection. The search for less intrusive survey designs is the direct reaction to these problems. This chapter defined the problem of nonresponse, its causes and alternative solutions to address it. Other survey design issues, which are not covered in this chapter, need as much consideration and planning before conducting the next generation of MWCOG travel surveys.

The first step in survey design is to prepare background information, including a review of recent surveys and other conceptual design issues. It is recommended that time and resources should be allocated for planning and documentation of all stages of future surveys. The survey documentation should include detailed information about sample disposition and response rates. This kind of information will help in evaluating the problem of nonresponse and the degree of reliability/validity of survey variables, especially those used in modeling. A few MPO's, with sufficient resources, produced excellent examples of working papers, and reports document all stages of survey design and statistical confidence of survey results. Unfortunately, documentation, supporting products, and data editing have always been the first victims of limited survey resources. As one expressed it, "A cheap survey is always the most expensive one", in terms of making use of the final product.

Many of the models' problems could be traced back to the quality of survey data. The problem of survey bias has been difficult to detect and fix as recent surveys showed declining response rates from above 90 % in the mid 60's to below 30% by the late 90's. The major issues here are under-representation of subgroups (unit nonresponse), the inaccurate reporting, and under/over-reporting of trips (item-nonresponse).

The concern about under-reporting has provided an impetus for improvements in survey procedures, the use of less intrusive survey designs and new technologies which are thought to reduce respondents burden. One reason for replacing trip diaries with activity diaries is that the latter is assumed to capture many of the underreported trips. However, the use of activity diaries is more related to shifts to behavioral models that view travel as a derived demand and give more consideration to sensitivity to changing policy contexts.

Based on the cumulative experience of recent household travel surveys, which added several improvements to the standard survey methods and procedures, the following are some specific recommendations that should be considered to improve our next generation of HTS:

- It is important to create a favorable environment and publicity for the survey by utilizing different media outlets and creative advertising, and involvement of local leaders. Innovative methods for survey recruiting should be considered, such as involving community organizations and institutions.

- A common theme in survey literature is that respondents should be treated as "customers" by reducing their burden and providing them with incentives. The use of incentives has become a common feature of recent surveys, and it should be tested in our next survey. The effectiveness of different incentive schemes could be examined at the pre-test stage of the survey. Several recent surveys used different incentive schemes to target special groups with low response rates.

- Experience from MWCOG's 1994 HTS proved that spending some resources in editing and "cleaning" of the survey files have considerable pay-off in terms of improving the data quality. The 1994 HTS utilized most of the procedures recommended for reducing nonresponse. A clear testimony to the quality of the 1994 HTS is that it has been intensively utilized in modeling activities with relatively consistent results. However, the small sampling rate (0.31 or 4,864 households) is best suited to support regional grain models. Modelers have faced many limitations to use the survey data to estimate models requiring finer grain level. Because of the nonresponse problem, the 1994 sample goal of 8,000 households would have been accomplished only by doubling the survey resources. Considering the persistent problem of nonresponse, it is a recommended that a larger sample size (0.5% -0.6% sample rate) should be considered besides other measures to lower nonresponse.

- Special efforts need to be directed towards acquiring a complete and accurate sample frame, since it is considered the source of the non-coverage problem. If a multi method is used to target special groups, the sample frame could be derived from a multitude of sources covering both addresses and residential telephone numbers.

- Mail-back (improved by telephone motivation) or in-home interviewing should not be completely discarded if no effective options are found to deal with the nonresponse problem. These methods could be used as part of a multi-layer design. The face-to-face method has the advantage of not requiring a detailed sampling frame. For instance, area probability sampling can be used, whereby certain geographical units (streets and households within these streets) could be targeted.

- Pre-test, pilot surveys and focus groups should be used to improve the survey design in general and, in particular, to detect the problem of nonresponse and to find the most effective methods to address it. The importance of a survey pre-test should not be undermined or sacrificed to preserve survey resources, as is usually the case.

- Available data from the 2000 Census and the latest NPTS should be analyzed with respect to background information required for the next HTS survey. An example of background data is cross-classification of households by household size, vehicle ownership, age, and income. This kind of information is important for setting the sample goals, detecting nonresponse problems and forming a strategy to address it. The information will be useful for both the pilot test and the main survey.

- It is recommended that a small sub-sample be selected to participate in both a passive GPS tracking survey and the main survey. The results could be used to evaluate the extent of underreporting, and computing adjustment factors for vehicle-based trip rates.

- The use of Internet technology has not yet reached the state of wide practice. However, the fast pace of this technology could make it feasible for use in a few years. The next survey could use a sub-sample to pre-test the Internet option for delivery and retrieval of survey information. A caution in using the Internet is that survey bias might be incurred because of differences in survey methods, rather than respondents.

- Recently, value pricing has been gaining momentum in the Washington region. Future surveys should help in building models to evaluate the impacts of different pricing options, such as fixed and variable tolls. It is recommended that the next surveys should include a multi-method feature where a sub-sample is selected for both revealed and stated response surveys to provide the necessary information for modeling of value pricing alternatives. The stated response surveys could also be used to evaluate the impacts of new modes and modes with insufficient data. One should caution that combining stated and revealed response data is not a straightforward exercise.

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6 Looking Ahead

During FY-2003, estimation of the Version 2.1 travel demand model operating on the new TP+ software platform was completed. In conjunction with the model estimation, updated documentation was prepared detailing 1) the recalibration of entire Version 2.1 modeling process to fit the new software and 2) a model validation for the year 2000 using available data from the U.S. Census, WMATA, and other sources. This updated model set incrementally advances the practice of travel demand modeling in the Washington region with added policy sensitivity, operation entirely at zone level during all model steps, and the addition of non-work transit and non-motorized travel estimation. The Travel Forecasting Subcommittee adopted a policy of incremental improvements to the travel demand modeling procedures five years ago, adding new features that enhance the policy relevance of these methods as these can be empirically determined.

Also during FY-2003, the new EPA-promulgated MOBILE6 emissions model was installed, and computer program code was written to link the Version 2.1 model with MOBILE6. These two models, Version 2.1 and MOBILE6, operate in tandem to produce air quality emissions of future updates to the Constrained Long Range Plan (CLRP) and the Transportation Improvement Program (TIP). A revision to the State Implementation Plans (SIP) was performed using these new tools.

There has been extensive debate and comment about the capabilities of the new travel demand model in meeting the requirements for updating the plan and program. The TPB therefore requested an independent assessment from the Transportation Research Board of the National Academies (TRB) of whether its new travel demand modeling process is "state of the practice" and has asked for technical assistance to guide future improvements. The TPB approved an amendment to the FY-2003 unified planning work program on November 20, 2002 to include a peer review of the TPB travel demand modeling process by the TRB. The statement of task is to review the state of the practice of travel demand modeling by the TPB and to provide guidance in the following areas:

1) The performance of the TPB's latest travel demand model (Version 2.1) in forecasting regional travel;

2) The proposed process for merging the latest travel demand model outputs to produce mobile source emissions (i.e., the post-processor);

3) The TPB's proposed direction of future travel demand model upgrades;

4) Travel survey and other data needed to accomplish future model upgrades; and

5) The detail (grain) of travel analysis zones that should be developed for future upgrades.

An ad hoc peer review committee has been formed by the TRB comprised of individuals familiar with MPO travel demand modeling, consultants with expertise in developing and applying travel demand models, and scholars in the field. The committee is charged with producing the following deliverables:

1) a brief letter report assessing whether TPB's modeling is "state of the practice" (items one and two in the statement of task) by June 30, 2003; and

2) a second letter report providing guidance on future topics (items three, four, and five in the statement of task), to be delivered by December 31, 2003.

These reports will help shape the scope of activities in the models development work program during FY-2004 and beyond. FY-2004 effort in models development will focus on the following tasks:

- Providing continued training in the use of the new Version 2.1 travel demand model;

- Continuing the development of a more formal airport access demand model, incorporating mode choice;

- Completing the second phase of the peer review of the TPB modeling procedures conducted by the TRB;

- Beginning implementation of the recommendations of the TRB peer review; and

- Continued participation on a national MPO panel established to recommend practices in travel demand modeling.

Staff will keep abreast of developments in the implementation of TRANSIMS, while keeping posted on other emerging methods in travel demand forecasting, through participation in Transportation Research Board meetings and reviews of the literature.