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16. Abstract
The Texas Department of Transportation (TxDOT), in conjunction with the metropolitan planning organizations (MPOs) under its purview, oversees the travel demand model development and implementation for most of the urban areas in Texas. In these urban areas, a package of computer programs labeled as the "Texas Travel Demand Package" or the "Texas Package" is used as the decision making tool to forecast travel demand and support regional planning, project evaluation, and policy analysis efforts. The Texas Package currently adopts the widely used four-step trip-based urban travel demand modeling process, which was developed in the 1960s when the focus of transportation planning was to meet long-term mobility needs through the provision of additional transportation infrastructure supply. The trip-based model was intended to provide basic, aggregate-level, long-term travel demand forecasts for long-range regional transportation plans and evaluation of major infrastructure investments. Over the past three decades, however, the supply-oriented focus of transportation planning has expanded to include the objective of evaluating a range of travel demand management strategies and policy measures to address rapidly growing transportation problems, including traffic congestion and air quality concerns. The travel demand management emphasis, combined with federal regulations, has placed additional information demands on the capabilities of travel demand models. As a result, new approaches have been developed to model and forecast travel demand. The new approaches include the tour-based modeling approach, which employs tours instead of trips as the unit of analysis. The tour-based approach enhances the behavioral realism in modeling travel demand and the abilities of travel forecasting models in assessing transportation policies and evaluating alternative transportation investments. Hence, TxDOT is considering the implementation of tour-based modeling procedures. As a first step of a potential advanced model implementation, this proposed project evaluates the feasibility of, and documents the potential benefits from, a tour-based modeling process. It documents the steps to transition toward a tour-based framework, including an evaluation of data needs, software requirements, and software enhancements, ease of implementation and application, and staffing and related resource needs.

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Tour-Based Model Development for TxDOT: Evaluation and Transition Steps

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Chapter 1. A Review of Current Tour-based Travel Demand Models

1.1 Travel Demand Models

Since the beginning of civilization, the viability and economic success of communities have been, to a major extent, determined by the efficiency of the transportation infrastructure. To make informed transportation infrastructure planning decisions, planners and engineers have to be able to forecast the response of transportation demand to changes in the attributes of the transportation system and changes in the attributes of the people using the transportation system. Travel demand models are used for this purpose; specifically, travel demand models are used to predict travel characteristics and usage of transport services under alternative socio-economic scenarios, and for alternative transport service and land-use configurations.

Within the context of travel demand modeling, the "trip-based" travel demand models used in most of the metropolitan areas of Texas and other states were developed in the 1960s when the focus of transportation planning was to meet long-term mobility needs through the provision of additional transportation infrastructure supply. Given such a supply-oriented focus of transportation planning, the primary role of travel demand models was to predict aggregate-level, long-term, travel demand for evaluating major transportation infrastructure investments.

Over the past three decades, however, there has been an increasing realization that simply increasing the capacity (or supply) of transportation facilities is not a sustainable solution to meet the growing levels of travel demand. This is primarily due to the decreasing amount of available space for, and the escalating costs of, building additional transportation infrastructure. In addition, due to increasing auto dependency, symptoms of non-sustainable development and other adverse impacts (such as the increased reliance on fossil fuel resources and the sharp rise in traffic congestion levels) have become increasingly evident. Consequently, the supply-oriented focus of transportation planning has expanded to include a range of travel demand management strategies and policy measures to address transportation problems and promote sustainable growth. These include (but are not limited to) (1) congestion mitigation measures such as peak-period pricing, high occupancy preference lane provision, and congested area-specific tolling, (2) multimodal transportation planning strategies such as park and ride facilities, (3) transit promotion policies such transit oriented development, (3) employer-based travel demand management schemes such as compressed work weeks and flexible work timings, (4) land-use policies such as mixed-use development and better non-motorized mode facilities in neighborhoods, and (5) parking disincentives such as downtown parking taxes.

The increased interest in the policies listed above stems from a desire to control aggregate-level travel demand and enhance the efficiency of transport infrastructure usage through strategies that fundamentally influence disaggregate-level (i.e., individual-level) travel behavior. Accordingly, there has been a shift in travel demand modeling from the statistical prediction of aggregate-level, long-term, travel demand to understanding disaggregate-level behavioral responses to short-term demand management policies (Bhat and Koppelman, 1999). Also, the socioeconomic composition of the population in many metropolitan areas is changing quite rapidly over time, which implies that aggregate-level models (and disaggregate-level models that do not consider the range of relevant demographic variables affecting travel behavior) are not likely to provide accurate long term travel demand forecasts.

The need to examine individual-level behavioral responses, and accurately forecast long-term travel demand in a rapidly changing demographic context, has led to a more behaviorally oriented tour-based approach to travel demand modeling. In the following section, we briefly describe and contrast the traditional trip-based and tour-based approaches to model travel demand.

1.2 Trip-based versus Tour-based Travel Demand Models

The traditional trip-based approach to travel demand modeling uses individual trips as the unit of analysis and usually comprises four sequential steps in travel dimensions as shown in Figure 1.1. The first, trip generation, step involves the estimation of the number of home-based and non-home based person-trips produced from, and attracted to, each zone in the study area. The second, *trip distribution*, step determines the trip-interchanges (i.e., number of trips from each zone to each other zone). The third, mode choice, step splits the person-trips between each pair of zones by travel mode obtaining both the number of personal and commercial vehicle trips and number of transit trips between zones. The fourth, *traffic assignment*, step assigns the vehicle trips to the roadway network to obtain link-level vehicle volumes and travel times, and assigns the person trips to the transit network for coarsely aggregated time periods in the day.

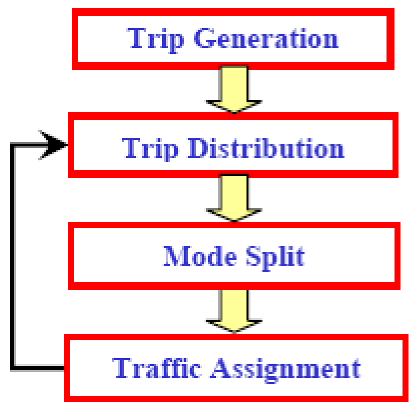

Figure 1.1: Four-step trip-based approach

In a tour-based structure to travel demand modeling, on the other hand, the *tour* is used as the base unit of analysis. A tour is a closed chain of trips beginning and ending at same location, such as home or work. A tour is generally characterized through its primary destination, defined as the destination in which the most important activity is made, such as a person's workplace. Travel to activities served at other locations during the tour is modeled as secondary stops. The parts of travel made on each segment between origin, stops, and the primary destination on a tour represent trips. For example, consider an individual who drives a child to school on the way to work in the morning and comes home straight from work in the evening (see Figure 1.2). This is a home-based tour with work as the primary destination (home-based work tour), and child's school as the secondary destination. The tour comprises three trips: (a) home to child's school, (b) child's school to work, and (c) work to home.

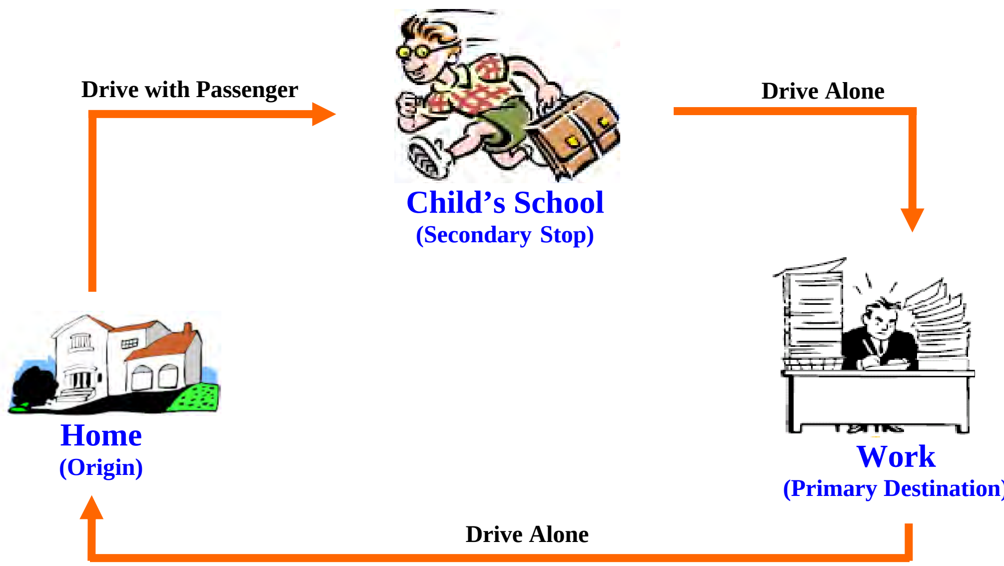

Figure 1.2: Trip sequencing and inter-relationship in attributes of tour-based approach

Using tours instead of trip as the base unit of modeling overcomes several limitations of the trip-based approach. First, a fundamental shortcoming of the trip-based approach is the representation of travel as a mere collection of “trips,” ignoring linkages across trips within the same tour. Each trip is considered as independent of other trips, without considering the inter-relationship in the choice attributes (such as mode, destination, and time) of different trips. In particular, trips are simply classified as home-based or non home-based trips, and separate models are estimated for these aggregate groups of trips, ignoring the temporal and spatial linkages between the trips. This can lead to illogical trip chain predictions, inaccurate estimates of the overall travel demand forecasts, and distorted evaluations of the impact of policy actions. Consider the previous example of the individual who drives a child to school on his/her commute to work (Figure 1.2). The three trips in this scenario—home to child’s school, child’s school to work, and work to home—are likely to be inter-related in several ways. For instance, the travel mode for the individual’s trip from home to school is likely to be the same as that of the school to work and work to home. However, a trip-based approach can assign the auto mode for the home to school trip, and the transit mode for the school to work and work to home trips. The tour-based approach precludes such illogical mode choice by using a “tour” as the basic element to represent and model travel patterns. The tour-based approach to travel demand modeling takes account of the time and space constraints among the trips of the same tour and preserves consistency along various choice dimensions characterizing each tour (mode, time of day, destination). Thus the travel attributes related to non-home-based trips can be properly linked to the corresponding home-based trips.

A second shortcoming of the trip-based approach is that time-of-day choice is either ignored, or is modeled after one of the first three steps (trip generation, trip distribution, and model choice) in a relatively straightforward manner through the application of fixed time-of-day factors. Typically, only two or three periods of the day are considered (*e.g.* AM peak hour, PM peak hour, off-peak), and the proportion of trips made in each period is treated as being fixed. For the assessment of time-of-day specific policy measures such as peak period pricing, high occupancy vehicle lane designation during peak periods, and flexible work schedules, such limited and fixed representation of time of day in the modeling process can lead to unrealistic evaluations of policy measures. In contrast, the tour-based approach employs advanced duration/scheduling models with a high level of temporal resolution (such as 30 minute or 1 hour time periods, with explicit temporal modeling of tours and trips within tours).

The third shortcoming of the trip-based approach relates to the level of aggregation used in model application. Although some of the current trip-based models undertake disaggregate-level estimation (for example, the use of disaggregate destination choice models instead of an aggregate-level gravity model), these models are typically applied at the aggregate level of traffic analysis zones (or TAZs). The tour-based model, however, is used to predict travel patterns at the individual and household levels at which decisions are actually made. Thus, the impact of policies can be assessed by predicting individual-level behavioral responses instead of employing trip-based statistical averages that are aggregated over coarsely defined demographic segments. Further, even from a long-term forecasting point of view, the cross-classification techniques that are at the core of the application of trip-based methods employ statistical averages over highly aggregated socio-demographic segments. The tour-based model, on the other hand, has the ability to relatively easily accommodate virtually any number of decision factors related to the socio-demographic characteristics of the individuals, and the travel service characteristics of the surrounding environment. Thus, the tour-based models are better equipped to forecast the longer-term changes in travel demand in response to the changes in the sociodemographic composition and the travel environment of urban areas.

In summary, the tour-based modeling paradigm is a closer representation of how individuals think and make decisions regarding their daily travel choices. This makes tour-based models of travel demand model prediction and policy analysis intuitively appealing, better understandable, and potentially more accurate. Also, the immediate outputs from tour-based models are entire individual daily travel patterns that resemble the data from a household travel diary (as opposed to the unintuitive zonal-level aggregate measures output from trip-based models). Such individual-level outputs from the tour-based models can be used for a wide variety of contemporary planning and policy analysis purposes, including for evacuation and homeland security planning (see Bhat and Pinjari, 2008). Finally, the features of tour-based models identified above represent modeling and prediction standards that are consistent with or beyond the modeling standards set by federal mandates. This makes the tour-based models attractive for transportation air quality conformity planning, FTA funding proposals for transit investments, and corridor expansion-related plans (see Davidson et al., 2007).

1.3 The Transition toward Tour-based Frameworks

The preceding discussion indicates that the behavioral realism implicit in the tour-based representation and modeling of travel patterns, and the usage of appropriate techniques to forecast individual-level travel patterns, enables the evaluation of a wide range of travel demand management policies that cannot be analyzed, or can be analyzed only partially, using a traditional trip-based framework (Vovsha and Bradley, 2006).

The potential benefits of the tour-based approach, combined with the increasing demands placed by federal legislations on the evaluation capabilities of travel demand models, has led several planning agencies, within and outside the United States, to shift (or consider the shift) to tour-based approach. Within the United States, five agencies—Portland METRO, New York NYMTC, Columbus MORPC, Sacramento SACOG, and the San Francisco SFCTA—have developed tour-based travel models, while several other agencies such as ARC of Atlanta GA, NCTCOG of Dallas-Fort Worth TX, DRCOG of Denver CO, PSRC of Seattle WA, MAG of Phoenix AZ, El Paso MPO, and SBCAG of Santa Barbara CA are in the process of either moving toward or considering a move toward an tour-based (or activity-based) travel model.

The experience of the agencies that currently use a tour-based travel model, and other agencies that are moving toward a tour-based model, indicate that the new approach can require significant resources in terms of skilled personnel. Further, the tour-based models appear to be relatively exacting in the quality and the quantity of the data required[1]. There is also the initial overhead of data preparation, model estimation and calibration, and the process of "*putting it all together*" to develop and implement tour-based modeling software.

As several agencies are considering the move toward tour-based modeling approach, it has become important for the agencies to clearly identify and understand the steps required, including the data collection, data preparation, model design, estimation, calibration, and software implementation, to develop operational tour-based models. Further, since most agencies currently use trip-based modeling tools, it would be useful to layout the development and implementation path from the currently used trip-based modeling tools to the advanced tour-based procedures. It is also important to assess the ease of such implementation, and the extent of resource requirements (i.e., the staff and budget estimates).

1.4 The Case of Texas

The Transportation Planning and Programming (TP&P) Division of the Texas Department of Transportation (TxDOT), in conjunction with metropolitan planning organizations (MPOs) around the state, oversees the travel demand model development and implementation for most of the urban areas in the state. Exceptions include such metropolitan areas as Dallas Fort-Worth, Houston, and El Paso, where the regional MPOs oversee the travel demand modeling operations. In all the urban areas where TP&P is directly responsible for travel demand modeling, a package of computer programs labeled as the "Texas Travel Demand Package" or the "Texas Package" is used to forecast travel demand and support regional planning, project evaluation, and policy analysis efforts.

The Texas Package has been developed and updated since the 1960s by TxDOT and the Texas Transportation Institute. However, the range and complexity of policy questions for which the model is being used, as well as the stakes for accurate policy evaluations and long-term projections, has been increasing. As a result, TP&P is considering the implementation of advanced modeling procedures such as tour-based modeling procedures. The end goal is to enhance the ability of the TP&P to assess proposed transportation policies, evaluating infrastructure improvement benefits, and forecasting long-term travel demand in the context of a rapidly changing demographic profile in many urban areas of the state. However, prior to the implementation of such an advanced modeling procedure, and as part of a cautious, systematic, and step-by-step approach, the first step is to evaluate the practicality and feasibility of implementing tour-based modeling procedures. Further, TP&P has to assess the potential benefits (for transportation project evaluation, policy analysis, and travel demand forecasting) of

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[1] We have used the term "appear" here to indicate a general misperception in the field that tour-based analysis necessarily means more data requirements; that is, that tour-based models are, by nature, data hungry. This need not be the case. Tour-based models can be estimated using the same data currently available from travel surveys, though they require careful and extensive data preparation procedures to construct entire "sequences" of activities and "tours" of travel. We will discuss the data sources used by various tour-based models in subsequent sections of this report.

implementing tour-based travel demand models relative to the costs of implementation. This discussion leads us to the purpose and objectives of this research report, which are identified below.

1.5 Research Objectives, Purpose, and Outline of the Report

The primary objectives of the TxDOT-sponsored project are (1) to identify the practical benefits and advantages of implementing a tour-based modeling framework from the standpoint of behavioral realism, model accuracy, and ease of implementation, and (2) if it is demonstrated that there are distinct advantages in implementing a tour-based model, then clearly lay out (and evaluate the feasibility of) the steps required to implement a tour-based modeling process. Toward this end, this report documents the research performed, findings, and recommendations to achieve the research objectives identified above. Specifically, Chapter 2 synthesizes information on the Texas Package and travel demand modeling resources in Texas, and assesses the future modeling needs in Texas. Chapter 3 discusses the available literature on, and the experience with, tour-based models. Chapter 4 provides tour-based modeling design recommendations for Texas MPOs, and identifies data needs. Chapter 5 provides a compilation of data sources that are readily available for transportation model development. Finally, Chapter 6 presents the details of implementing a tour-based travel demand model system.

Chapter 2. Current TxDOT Travel Demand Modeling Practice and Future Modeling Needs in Texas

2.1 Introduction

2.1.1 Background

For policy planners ample information is fundamental to informed decisions. Deciding where and how to improve a regional transportation system is a complex process involving a variety of options and trade-offs. Travel demand models (TDMs) inform and support this process by quantifying and predicting the results of proposed enhancement alternatives. Indeed, for the past 40+ years travel models have been the basis within Texas for assessing regional highway system performance and improvement options as well as development of long-range plans.

The confidence placed in travel models as an important aid in the decision-making process resides in the model's ability to produce rational and defensible results. Though traditional four-step travel models adequately fulfill these expectations, there is also an increasing interest to utilize travel models to support the analysis of complex policy issues. This is a role that traditional travel demand models were never intended to fulfill. The potential inadequacies of traditional four-step model's capacity to support policy related decision-making were recently documented in Transportation Research Board (TRB) Special Report 288. The report notes that while "there is no single approach to travel forecasting or set of procedures that is "correct" for all applications or all MPOs;" nevertheless, "more advanced models can provide a better representation of actual travel behavior and are more appropriate for modeling policy alternatives and traffic operations." Consequently, a number of academics and practitioners now advocate a more realistic modeling of travel behavior through the use of activity-based models and/or tour-based models. In part, this can be attributed to the increased use of traditional TDMs to provide information that pushes the limits of reasonable model application.

Currently all Texas TDMs, as well as the vast majority of urban TDMs throughout the United States (U.S.), are still based on the traditional four-step modeling process. While still considered state of the practice, several large urban areas in the U.S. have transitioned, or are considering a transition to, activity-based and/or tour-based models. The U.S. Department of Transportation (DOT) sponsored Travel Model Improvement Program (TMIP), which has become a de facto barometer for gauging the future direction of TDM progress, points to further implementation of activity-based models, and/or a merging of traffic simulation methods with advanced travel model structures. These trends in model development suggest that now is an opportune time to assess the future direction of modeling within Texas.

In response, the Texas Department of Transportation (TxDOT) has chosen to identify and evaluate the steps required to implement a tour-based modeling process and determine whether derived benefits warrant the implementation of a tour-based model. Ideally, the decision to implement a new generation of travel models should be based on determining the extent of practical benefits and advantages that will be derived from the implementation. These would be advantages regarding model accuracy, behavioral realism and ease of application that indicate improved model effectiveness while retaining the ability to produce rational and defensible results. An equally important consideration is that an enhanced model structure may mean additional complexity. The extent to which new features are incorporated should acknowledge that new demands and challenges might be placed on TxDOT and MPO modelers as well as MPO planners in their role as providers of socio-economic data. Thus, there is also the need to identify whether additional data is required to support the implementation and defining the impact and resources required for actual implementation.

This chapter is a first step in that direction. The chapter's intent is focused on understanding TxDOT's modeling responsibilities and summarizing current travel demand modeling practice in Texas. Through understanding current practice in relation to future modeling needs within Texas the chapter will provide an assessment of the need for implementing more advanced modeling practices.

2.1.2 TxDOT's Current Travel Demand Modeling Responsibilities

Historically, TxDOT has been one of the leading travel model practitioners as evidenced by their record of continual TDM enhancements during the previous three decades. Major model improvement milestones include:

- During the early 1970s, TxDOT supported the development of the Texas Package instead of waiting for the federal government to complete its equivalent Urban Transportation Planning System (UTPS) mainframe based travel demand model software
- During the 1980s TxDOT supported research and continued enhancements of the Texas Package while also disseminating TRANPLAN to Texas metropolitan planning organizations (MPOs) to improve the availability technical tools to support local urban area long-range planning efforts. As part of the TRANPLAN deployment, TxDOT-TPP integrated numerous Texas Package mainframe capabilities with personal computer platforms and provided model application training to MPOs and TxDOT Districts throughout the state on the use of the Texas Package within the TRANPLAN environment
- During the 1990s, aware that urban travel patterns had changed significantly since the 1960s and new data was critically needed to support TDM development, TxDOT embarked on an extensive travel survey effort which is still on-going
- During the late 1990s TxDOT recognized the benefits of integrating transportation planning and the model development process with geographic information system (GIS) technology. TxDOT became one of the first states to adopt TransCAD, which is a fully integrated GIS/modeling platform, as the primary TDM software for in-house use as well as disseminating it to Texas MPOs. As a part of this effort, TxDOT-TPP completely migrated from the mainframe Texas Package and fully integrated all modeling capabilities to operate on personal computers. Similar to the TRANPLAN implementation, TransCAD was deployed to MPOs and TxDOT Districts throughout the state. Since that time TxDOT-TPP has continued to provide TransCAD training and modeling technical support to the MPOs and TxDOT District offices.

Currently, TxDOT's Transportation Planning and Programming (TPP) Division is responsible for developing travel demand models to support the regional long-range plan update and associated long-range planning activities within 22 of the 25 Texas urban areas. Table 2.1, Texas Metropolitan Planning Organizations (MPOs), lists the MPOs for which TxDOT-TPP currently develops models and provides model application assistance. The MPOs are listed by population in descending order based on U.S. Census Bureau 2007 population estimates. The three Texas MPOs that TxDOT-TPP does not assist with model development are the Dallas-Ft. Worth, El Paso, and Houston-Galveston MPOs; however, TxDOT-TPP does have a technical advisory or oversight role with the El Paso MPO.

Table 2.1: Texas Metropolitan Planning Organizations

MPOs Assisted by TxDOT-TPP	2007 Population
San Antonio	1,328,985
Austin	743,074
Hidalgo County	710,514
Jefferson-Orange-Hardin Counties	376,241
Corpus Christi	285,507
Midland-Odessa	255,978
Laredo	217,506
Lubbock	217,326
Tyler	198,705
Killeen-Temple-Belton	188,094
Amarillo	186,106
Brownsville	172,806
Bryan-College Station	152,330
Waco	122,222
Sherman-Denison	118,675
Abilene	116,219
Wichita Falls	101,590
San Angelo	90,483
Harlingen-San Benito	88,936
Longview	76,816
Texarkana	65,755
Victoria	62,246

Source for Population Figures: US Census Bureau

TxDOT-TPP's model development responsibilities for the 22 MPOs include:

- *Development of the base year model*. TxDOT-TPP develops, calibrates, and validates the 22 MPO's base year models on a recurring five year cycle that coincides with the collection of saturation counts for each of the MPOs. The initiation of an MPO's model development process typically begins one to two years after the saturation counts have been collected, analyzed, and published. The base year network and zonal demographics are provided by the MPO, though the MPO coordinates the base year network inventory with the local TxDOT District Planning office. Once the model is completed and validated, the base year model validation results are presented to the MPO technical advisory and/or policy board for their concurrence that the model is validated and that TxDOT-TPP can proceed with a future year model application.

- *Forecast year model application*. TxDOT-TPP applies the validated model for at least one forecast year. The forecast year is typically 30 years beyond the base year condition to ensure that the model can be used as a technical tool for the life of the Metropolitan Transportation Plan (MTP), which has a 20-year planning horizon during the five year plan cycle. As with the base year model development process, the MPO provides the forecast year network and required demographics. Upon completion of the forecast year application the base and future year models are provided to the MPO to conduct alternatives analyses and to support their local long-range planning efforts.

- *Interim year(s) model application*: TxDOT-TPP, in conjunction with the MPO, will develop interim year model forecast applications for study areas that are required to demonstrate air quality conformity in accordance with the requirements outlined in the Clean Air Act Amendments (CAAAs). Interim years are determined as a part of the consultative process associated with conformity determination. Similar to the forecast application, the MPO is responsible for the socio-economic database and the network is a product of the collaborative effort between the MPO and the TxDOT District Planning Office. Once the interim year forecasts are complete, TxDOT-TPP provides conformity determination support via an inter-governmental contract (IAC) with the Texas Transportation Institute (TTI). Example study areas include Beaumont-Port Arthur, Tyler, and Longview.

- *Alternative forecast year model application*: As a matter of policy and depending on existing workloads and commitments, TxDOT-TPP may also provide one to two forecast year model applications using alternative networks to assist with MTP development.

- *Model application training*. If requested by an MPO, TxDOT-TPP will also provide the MPO training support in model application for alternatives analysis. Depending on the MPO staff's training needs, the training provided can comprise one-on-one assistance, an informal two-day training class or a formal full week class for several individuals. The training has been provided by TxDOT-TPP since the 1990s, when TRANPLAN was first distributed to Texas MPOs.

2.1.2.1 Intergovernmental Relationships

The framework and success of the travel demand model development process in Texas resides in the collaborative relationship that exists between TxDOT-TPP, TxDOT Districts, and the MPOs that TxDOT-TPP assists with their model development. The development of urban travel demand models is a cooperative process between the MPO, the local TxDOT District Office, and TxDOT-TPP. Though TxDOT-TPP is responsible for developing and validating an MPO's travel model, the MPO and District also play an important role in model development by providing base year and future year demographic data and the regional roadway information required for model development and forecast applications. Once TxDOT-TPP completes the base year travel model and considers the model validated; nevertheless, the process still requires the MPO's concurrence that the model is validated and functioning properly. After the forecast year model application is completed, TxDOT-TPP offers MPOs additional on-site assistance for loading software/files, displaying networks, developing alternatives and performing various system performance analyses. This collaborative relationship thus affords local planners the opportunity to fully utilize the regional travel demand model set in support of long-range planning efforts, metropolitan transportation plan development, and assessment of proposed transportation system improvements.

2.1.3 Current Travel Demand Modeling Practice in Texas

Within Texas, as for most urban areas throughout the U.S., the common practice of using a three or four-step travel demand model continues to be the norm; those four steps are:

- Trip generation
- Trip distribution
- Mode choice
- Trip assignment

Within the context of comparing modeling practice throughout the U.S., TRB Special Report 288 noted that "although the four-step process is nearly ubiquitous, there are considerable variations in the completeness and complexity of the models and data employed." In essence all travel models, no matter how simple or complex, attempt to describe human travel behavior using mathematical models. Traditional four-step models predict travel demand based on several simplifying assumptions regarding household travel propensity, trip types, trip destination, and route choice. Some of the simplifying assumptions are holdovers from mainframe computer days when computing time was expensive and computer memory size restricted the extent of data disaggregation.

In many ways the advantages and disadvantages of traditional four-step models are one and the same. Following is a brief overview of the methodology and assumptions made in development of a traditional TxDOT model:

- Trips are produced by households and attracted by employment location
- Trip destination is based on a gravity model formulation and average trip lengths
- Route choice is based on perceived minimum travel time paths in relation to congestion levels

For TxDOT travel demand models, the number and type of trips produced by a household are a function of two variables: household size and household income. Trips however, are not calculated for each individual household based on each household's unique income and household size. Instead, for any given traffic analysis zone (TAZ) the number of households within the TAZ are allocated among five income ranges and five household size ranges based on recent census data and the TAZ's median income and mean household size. The advantages in such a trip production model structure are that it simplifies demographic data collection and forecasting; MPOs need only provide the number of persons, households, and zonal median income for each TAZ for each model year. (The reader should keep in mind however that oftentimes merely that amount of data can be a challenge for some MPOs to forecast and provide in a timely and accurate fashion). The disadvantage is that all household travel behavior is only based on two variables, whereas, in actuality the decision of when, where and why to make a trip involves many more factors.

Total TAZ trip attractions are a function of the total number of households in a zone, the total number of employees in four pre-determined employment categories (i.e. basic, retail, service, or education) and the density of zone, as expressed in terms of area types (e.g. urban, suburban and rural). As with trip productions, trip attractions are calculated at the TAZ level and similarly ease the amount of required data collection and forecasting. Thus the advantage is that MPOs merely have to provide the total number of households in the zone and the total number of employees by type for each TAZ for each model year. The disadvantage is that trip attractions are calculated using an average trip rate applied at an aggregate level.

Trip destination choice is mathematically modeled as a gravity model analogy; the choice of where to go becomes a function of the total number of trips at a potential TAZ destination in relation to all other TAZ total trips and the distance between origin and destination end points. Essentially, trips from one TAZ are allocated among competing TAZs based on distance (expressed in time) between TAZs, the attractiveness (number of trip attractions) of competing TAZs and a desired average trip length frequency for each individual trip purpose. The primary advantage is that the formulation is based on a logical premise that is easily solved mathematically while acknowledging trip pattern differences by trip purpose. Other advantages include the ability to account for changes in land use and transportation system improvements. A singular disadvantage is the loss of the home-to-work connection when modeling an entire home to work and return commute. In other words, intermediate stops that are made as part of the entire home to work and return commute are classified as home-based non-work trips and non-home based trips in traditional models and consequently may inadequately model locational decisions made as part of the entire round-trip commute.

Route choice is modeled by taking into account the effect that varying levels of congestion have on roadway speeds and travel times. The equilibrium assignment process is an iterative process that attempts to ensure that travel times are equal on all competing routes for any given zone pair. Advantages of the equilibrium assignment process include being the current state of the practice as well as being available on all commercial TDM software packages.

2.1.4 Texas Travel Demand Package

In all 22 Texas urban areas for which TxDOT-TPP is responsible for model development (ref. Table 2.1) the Texas Package is used in conjunction with TransCAD as the primary software for model development and application. The Texas Travel Demand Package (Texas

Package) was originally a set of mainframe computer programs that TxDOT used to forecast urban travel. The mainframe version consisted of programs that addressed trip generation, trip distribution, and traffic assignment. Since TxDOT's adoption of TransCAD, the Texas Package's primary uses are for trip generation and trip distribution and for converting input and output files required to interface with TransCAD. Several additional utilities have been added to the Texas Package to take advantage of the geo-spatial database system in TransCAD to further aid in the analysis of data received by TxDOT-TPP from the MPOs. Table 2.2, Model Steps and Software Application, lists key steps in the travel demand modeling process and indicates whether the step is performed using the Texas Package or TransCAD.

Table 2.2: Model Steps and Software Application

Model Step or Component	Software Application
Trip generation	Texas Package – TRIPCAL5
Network definition	TransCAD
Travel time matrix (Skims)	TransCAD
Trip distribution	Texas Package – ATOM2
External-through trip matrix	TransCAD
Summing trip matrices	TransCAD
PA to OD conversion	TransCAD
Traffic assignment	TransCAD
Traffic assignment reporting	Texas Package

TRIPCAL5 is the trip generation software used in the Texas Package. The most notable characteristic of TRIPCAL5 is its flexibility in terms of model specification and data inputs. For example, TRIPCAL5 offers the use of two-way or three-way cross-classification models or linear regression models for estimating trip productions and attractions. It also includes features permitting the input of user-specified data or use of default models for the disaggregation of data at the traffic analysis zone level. Program options include trip production models, trip attraction models, disaggregation models, multiple trip purposes, and user-selected data inputs. With relatively few exceptions, TxDOT-TPP models 24-hour vehicle trips.

The Texas Package trip distribution model is ATOM2. The program is comparable to other trip distribution models in that it uses a gravity analogy formulation. The difference and primary advantage of ATOM2 is the ability to account for zone size as part of the distribution process. In essence, zones are treated as smaller spatial units (atoms) during the distribution process and travel, or trip interchanges, is modeled between those smaller units. The trip interchanges between atoms are subsequently summed to compute the actual zone-to-zone trip movements. This provides additional accuracy in the estimation of inter-zonal and intra-zonal trip movements.

Mode choice is not included in the Texas Package because of the lack of interest (and need) to implement such a model. Only two of the 22 urban areas have expressed an interest in modeling mode choice and those two areas (Austin and San Antonio) have contracted with private firms to develop a mode choice model. As a part of this process, TxDOT requests that the models be structured in such a manner as to be compatible with the Texas Package. The Texas Package does include a mezzo-level HOV carpool model which converts person trips to vehicle trips based on auto-occupancy values at the sector level. However, it is rarely used in TxDOT model applications. The mezzo-level HOV model has been used for the development of the 1997 El Paso and 1997 Beaumont MPO regional model.

Trip assignment, as noted previously, is performed using TransCAD software. Trip assignment is the final step in the model development process designed to replicate base year regional travel patterns and system demand. Using the final 24-hour trip matrix from trip distribution and the base year regional network, the trip assignment program assigns (i.e. loads) trips onto the network's zone-to-zone minimum travel time paths for a specified number of iterations. After an initial iteration, revised travel times are derived for all non-centroid network links for a prescribed number of subsequent iterations. The iteratively estimated revised travel times for all links are based on the ratio of the current iteration assigned volume to the link capacity. The trip assignment program then re-assigns the trips to the network based on the updated minimum time paths. TransCAD's equilibrium traffic assignment procedure is used for the trip assignment step. Ideally, the assignment model will achieve an equilibrium solution within a reasonable number of iterations or network loadings. Equilibrium is reached when no travelers can improve their travel times by shifting to an alternative route. The standard criteria applied during TxDOT-TPP equilibrium traffic assignments are as follows:

- A maximum of 24 iterations
- A convergence criteria of 0.001

Thus, when the equilibrium assignment is applied, either 24 iterations are completed or the convergence value will be achieved in less than 24 iterations.

The remainder of this chapter documents the use of the Texas Package focusing on required inputs and available model outputs. Section 2.2 of the report addresses Texas Package model inputs while Section 2.3 details Texas Package outputs. Section 2.4 provides a brief overview of Texas Package routines required to interface with TransCAD. Section 2.5 provides a summary of Texas modeling needs in conjunction with an assessment of modeling resource availability. It concludes the report with an assessment of the need and benefit for implementing a tour-based model.

2.2 Texas Package Model Inputs

Travel models require a variety of input data. The development and collection of necessary data and information is a time consuming process as well as a cooperative process between TxDOT-TPP, TxDOT Districts and the individual MPOs (see section 1.2.1 of Chapter 1).

Typically the primary input datasets are:

- A description of the transportation system (networks)
- An inventory of demographic data
- Relevant travel characteristics (e.g. trip rates and trip lengths)

Apart from those three input datasets this section also discusses the inputs specifically required for trip generation (TRIPCAL5) and trip distribution (ATOM2).

2.2.1 Transportation System Description

At the inception of a model update the MPO and TxDOT District begin the initial step in defining the base year network by identifying all transportation system facilities that will comprise the base year roadway network. Generally, all facilities functionally classified as a collector, or higher functional classification, are included in the roadway description provided by both agencies. Primary network attributes are then inventoried by the MPO to be included in the network database; these attributes include facility type, number of lanes, and whether the roadway is a divided or undivided facility. Physical and operating characteristics including roadway length, number of lanes, and median access type (divided or undivided) as well as operational characteristics such as daily speed, daily capacity, average weekday traffic count and direction (one-way/two-way) are also collected or developed for the network database. Apart from link distance, which is automatically calculated by the TransCAD software, physical characteristics are primarily provided by the MPO and operational characteristics are developed by TPP.

Based on a roadway inventory for the base year network, the MPO provides the following network attributes:

- *Number of lanes*—the total number of lanes in both directions; however, the total does not include continuous left turn lanes.
- *Posted speed limit*—the facility's posted speed limit for every network link
- *Direction*—the specification of whether a facility is a one-way or two-way facility
- *Median Access Type*—Divided, undivided or continuous left turn facility
- *Functional classification and facility types*—each network link is identified by a functional classification and facility type. Functional classification is a grouping of streets and highways into a set of classes or systems based on the type of highway service they provide. Generally streets and highways provide two types of services: traffic mobility or land access. Every class of roadway serves as a collecting or distributing facility for the next higher class of roadway. Freeways and arterials primarily facilitate traffic movement and mobility whereas collectors and local streets primarily provide access to adjacent property and are associated with lower speeds. Local roads are generally not included in the network. Typical functional classifications include: interstate highway, freeway, expressway, major and minor arterial, collector, local, ramp, and frontage road. Facility types are more precise classifications to properly code representative operational characteristics; for example, divided and undivided principal arterials. TxDOT-TPP has 22 standard facilities that can be annotated to the network geography.

For future year network enhancements the MPO will provide all of the data listed above with the exception of posted speed limit data.

TxDOT-TPP then develops additional roadway descriptive characteristics for each network link; these include the following:

- *Distance*—the length of each network link is required in determining link travel time. TxDOT-TPP uses the conflated distance (as opposed to straight line distance) automatically calculated by the modeling software (TransCAD).

- *Area types*—Area types designate physical boundaries where operational characteristics (e.g. network speeds and capacities) are assumed to change due to adjacent land use densities and the resulting impact on travel propensities.
- *Capacity*—the traffic assignment process uses roadway link speeds and capacity. TxDOT-TPP develops capacity look-up tables for network roadways based on area type and facility type. The capacity assigned to each network link is cross-classified by facility type and area type and represents a daily capacity value. The capacities typically used represent a service volume at level of service (LOS) E and are based on Transportation Research Board *Highway Capacity Manual* (HCM) guidelines.
- *Speed*—TxDOT-TPP develops speed look-up tables for network roadways based on area type and facility type. The input speed that is coded on each network link is a function of the posted speed limit that was inventoried and provided by the MPO. The trip distribution and assignment process uses network link distance and the coded speed to produce an estimate of link travel time, from which minimum path routes between all traffic analysis zones are developed.

Apart from the base year network, forecast year networks are required for each year that the MPO wishes to analyze. The base year network includes roadways and conditions as they exist at the time the urban saturation counts were collected. The forecast year network will include the existing base year network plus modifications to the network that reflect the planned regional network enhancements that will be included in the long-range plan or MTP. For both base and forecast year networks, TxDOT-TPP will develop the computerized network using the previous travel demand model network geography for the corresponding study area. A corresponding STRATMAP geography for each study area is used for alignment purposes to conflate the travel demand model networks and post street names on the base and forecast year networks.

2.2.1.1 Saturation Counts

Each year, TxDOT TPP's Traffic Section (TPP-T) collects (through contractors) thousands of traffic counts on numerous road segments in four to six urbanized areas. These "saturation" counts are 24-hour tube counts performed on both on and off-system roadways. The counts are collected on Mondays through Thursdays (excluding holidays) and are used to obtain data to support the travel model validation process and for the Highway Performance Monitoring System (HPMS) database. These counts are in addition to annual counts performed on state highways.

Traffic counts are additional network attributes that are collected and annotated in base year networks to support the traffic assignment validation process. The traffic assignment model's validity will be determined primarily by comparing modeled traffic volumes to actual counts (i.e. the saturation counts) on each facility comprising the network. Typically, 50 to 60 percent of non-centroid connector links will have a saturation count annotation. Saturation counts are collected on a five-year cycle for a given urban area. The counts simply represent total axles divided by two and are commonly referred to as average daily traffic (ADT) counts by TxDOT-TPP. The saturation counts are collected primarily for the purpose of travel demand model validation efforts. In contrast, the annually collected on-system counts are annual average daily traffic (AADT) counts that have been adjusted for seasonal and monthly variations and have also been adjusted to account for vehicle mix (e.g. commercial vehicles). Annual District counts are not used or coded in the travel demand model networks.

2.2.2 Demographic Data

Trip generation primarily requires two types of data: socioeconomic data and travel behavior data. The MPO, in cooperation with TPP, develops the following socioeconomic data for each traffic analysis zone in the urban area for the base and forecast year:

- *Total Population*—The total population for each traffic analysis zone in the urban area. TxDOT-TPP recommends that each MPO reference the Texas State Data Center (TSDC) data in developing base and forecast year(s) population control totals. The MPO is responsible for allocating the region's control totals to the zones.
- *Number of Households*—The total number of households for each traffic analysis zone in the urban area. A household is defined as an occupied dwelling unit. Since dwelling units may be vacant, households and not dwelling units are provided by the MPO.
- *Average Household Size*—The average household size for each traffic analysis zone in the urban area.
- *Total Employment*—The total employment for each traffic analysis zone in the urban area. The total employment should represent the summation of basic, retail, service, education, and special generator employment. As a part of the model development process, TxDOT-TPP provides the MPO third-quarter Texas Workforce Commission (TWC) employment data. TxDOT-TPP obtains this data through a cooperative agreement between TxDOT and the TWC. The TWC data provides a list of employment sites by four major employment categories: basic, retail, service and education. The TWC uses the *North American Industry Classification System* (NAICS) employment categories to aggregate the data into the four employment categories required by TxDOT-TPP for modeling purposes.
- *Basic Employment*—The total basic employment for each traffic analysis zone in the urban area. Basic employment is defined as the NAICS employment categories of mining, construction, manufacturing, wholesale trade, transportation, communication, and public utility groups.
- *Retail Employment*—The total retail employment for each traffic analysis zone in the urban area. This is the employment in NAICS retail industry groups.
- *Service Employment*—The total service employment for each traffic analysis zone in the urban area. Service employment is defined as NAICS financial, insurance, real estate, education, government, and service industry groups.
- *Education Employment*—The total education employment for each traffic analysis zone in the urban area. The MPO is required to note whether the site is an elementary, middle school, high school, university, or vocational school. Education employment consists of employment in NAICS education groups. Public education

employment is segregated because school districts typically report the headquarters office only in conjunction with the total school district employment. A school district's distinct school locations are not individually reported in the TWC database; therefore, these locations need to be identified by the MPO when developing the demographic database.

- *Median Household Income*—Median household zonal income, expressed in dollars, should correspond to the year that the urban traffic (saturation) counts were collected (e.g. if the counts were made in 2008, income should be in 2008 dollars) for each TAZ in the study area. For the forecast demographic data, the median household zonal income should be specified in constant dollars (i.e. same as the base year) and not adjusted for inflation. Zonal median household income is collected rather than average income to avoid outlier's unduly influencing the income characteristics of individual zones.
- *Special Generators*—Special generators are locations or employment sites whose trips ends are different than those derived from the surveyed trip rates. Specification of special generators by zone and the specific information needed for identified special generators are required data from the MPO. Examples of special generators include but are not limited to regional malls, airports, colleges, and hospitals. To properly estimate the total number of trips by trip purpose generated by a special generator, it is necessary to have additional information regarding the special generator so an appropriate trip rate can be used. For example, trips to a university will often be estimated based on a combination of student enrollment, the number of students residing on and off campus, and the total employment on campus.

2.2.3 Travel Characteristics

Travel surveys are the primary source of travel characteristics or travel behavior data. Travel surveys provide the following information necessary to develop:

- Trip production rates (person and vehicle) by trip purpose
- Trip attraction rates (person and vehicle) by trip purpose
- Trip length frequency distributions by trip purpose
- Average trip lengths by trip purpose
- External station apportionments (i.e. the percent mix of external through and external local travel associated with each external station)

Additional information derived from travel surveys includes:

- Auto occupancy factors
- Mode of travel
- Special generator trip rates

The survey information listed above is input to one of three model steps: trip generation, trip distribution, or mode choice. The specific inputs to the Texas Package trip generation and trip distribution models are further discussed in sections 2.4 and 2.5.

Texas urban area comprehensive travel surveys may include any or all of the following surveys:

- Household survey
- Workplace survey
- External station survey
- Commercial vehicle survey
- Special generator survey
- On-board public transit survey

Data from these surveys serve as inputs to the travel demand models to ensure that the travel models adequately reflect regional travel behavior.

2.2.3.1 Household Survey

In this type of survey, households are randomly selected to participate in the household travel survey program. As a part of the process, interviewers ask people who agree to participate to record in a travel diary the activities and travel by each person over the age of five years during a 24-hour period. For each trip, interviewers ask participants to record the time, activity, place the trip began and ended, mode of travel, number of passengers, purpose of the trip, and other descriptive information. In addition to the data on travel, participants record characteristics of the household such as number and age of persons in the household, number of household members employed, household income, and number of vehicles available. TxDOT-TPP will use data from the household survey to develop urban area trip production rates that are a required input to the trip generation model. The trip rates represent "typical" weekday travel (e.g. Monday through Thursday). The household survey data also provides an estimate of average trip lengths by trip purpose which will be used in the trip distribution model.

2.2.3.2 Workplace Survey

A workplace survey collects information on travel at the destination end of trips. This type of survey consists of two primary components: one part designed to collect travel information and household characteristics (such as income, vehicle availability by type/make of vehicle, household size, etc.) of employees at the work sites, and one designed to collect travel data on visitors (non-employees) traveling to and from the workplace during the day. For the workplace survey, TxDOT-TPP cross-classifies employment establishments by employment type (basic, service, retail or education), area type, and freestanding or non-freestanding business. Interviewers provide employees at participating workplaces with a survey and ask them to record all of their trips on a specified day. Collected data include the origin and destination for each trip, trip arrival and departure times, travel mode, reason for trip (trip purpose), vehicle occupancy, vehicle make/model/year, and parking costs. Interviews are also conducted with randomly selected non-employees arriving at the workplace during the survey day. The data collected from non-employees includes trip origin, trip purpose, mode of travel, vehicle occupancy and arrival/departure times. TxDOT-TPP uses the data collected from the workplace surveys in conjunction with traffic or person counts at the specific workplace to develop attraction rates for basic, service, retail, and educational employment for each area type. The resulting attraction rates are another primary trip generation model input data requirement.

2.2.3.3 External Station Survey

At each external survey station location (e.g. a major roadway facility at the model area boundary), surveyors randomly select out-bound vehicles and interview the drivers to determine information on the trip purpose, the trip origin and destination, and the vehicle occupancy. TxDOT-TPP uses this information to estimate the number of trips originating outside the study area and traveling to a point inside the area, the number of trips beginning and ending at a point outside the study area (through trips), and trips originating inside the study area and destined to a point outside the study area. This data will be required for the trip distribution process.

2.2.3.4 Commercial Vehicle Survey

In some areas, TxDOT conducts a separate commercial truck survey to develop a more comprehensive database of travel patterns, vehicle weights, and fuel types for commercial trucks operating in the urban area. TxDOT-TPP uses information collected from this survey to develop truck trip rates for trip production and in modeling associated with air quality conformity analysis. Participating firms provide data for each trip taken during one day's travel. Information collected includes departure and arrival times, an address for each destination, truck types, truck weight, fuel type, and truck routes traveled. The commercial vehicle survey data provides an estimated truck trip control total for the truck trip purpose in the trip generation model.

2.2.3.5 Special Generator Survey

Special generator surveys collect information on travel patterns for employees and visitors at sites that exhibit special trip generating characteristics. Special generators are unique employment sites that generate or attract lesser or greater amounts of traffic than employment sites within the same employment category (i.e. basic, retail, service or education).

Special generator surveys provide information on those unique land uses having special trip generating characteristics which normal trip attraction rates do not adequately reflect. The special generator survey emphasizes the generating establishment's noteworthy and distinguishing characteristics. The information developed from a special generator survey enables TxDOT-TPP to determine trip attraction rates, both person and vehicular, for internal person, auto-driver, and truck-taxi rates for each surveyed special generator. This data will be applied in the trip generation model. Typically, special generators are counted at each entrance/exit and the total number of trip ends estimated for a special generator conforms to the count for that particular location.

2.2.3.6 On-Board Public Transit Survey

An on-board survey of bus passengers collects information on current bus rider characteristics and to provide data to develop a representative origin-destination trip table for use in the travel demand models. Survey data collected includes trip origins and destinations, mode of travel to/from transit stop, trip purpose, transit routes taken during trip, ridership frequency, transit fare paid and method of payment, and the traveler's household characteristics, such as household vehicle availability, household size, and household income. On-board transit survey data in conjunction with household survey data will be used to estimate and calibrate a mode choice model.

2.2.4 Trip Generation Model (TRIPCAL5) Inputs

Trip generation models are used to determine the number of person or vehicle trips that occur at all traffic analysis zones (TAZ) comprising an urban area. The estimation of person or vehicle trips primarily requires demographic data (ref. Section 2.2.2) for each TAZ as well production and attraction rates that are derived from the on-going TxDOT funded Texas travel survey program (ref. Section 2.2.3).

2.2.4.1 TRIPCAL5

The trip generation module used in the Texas Package is TRIPCAL5. TRIPCAL5 is a multifunctional program that estimates trip productions and attractions for up to ten trip purposes and 9,999 traffic analysis zones. This program includes features that allow input of user-specified data or use of default models for the disaggregation of data at the traffic analysis zone level. Program options include trip production models, trip attraction models, disaggregation models, multiple trip purposes, and user-selected data inputs.

The sub-programs within TRIPCAL5 are designed to use the socio-economic data normally used in trip generation. The trip production models use estimates of the number of households stratified by household size and household income or auto ownership for each zone. Trip attraction models employ estimates of each zone’s employment stratified by employment type and area type. The specific data elements recommended for running TRIPCAL5 include population, number of households, median household income, and number of employees by employment category for each traffic analysis zone.

2.2.4.1.1 Trip Purposes

Up to 10 trip purposes may be used in TRIPCAL5 with specific trip rates for each. Typical trip purposes include:

- Home-Based Work
- Home-Based School
- Home-Based Shopping
- Home-Based Other
- Non-Home-Based Work
- Non-Home-Based Other
- Truck and Taxi
- External-Local Auto
- External-Local Truck

For most urban areas in Texas the following trip purposes have been traditionally used:

- Home-Based Work
- Home-Based Non-Work
- Non-Home-Based
- Truck -Taxi
- External Local

2.2.4.1.2 Trip Production Models

Three trip production model structures are available for use in TRIPCAL5; these are as follows:

- *Two-Way Cross-Classification Model Structure*. The two-way cross-classification model offers the ability to use production trip rates stratified by two independent variables and each variable can have up to six categories
- *Three-Way Cross-Classification Model Structure.* The three-way structure allows trip production rates to be stratified for up to six categories for two independent variables and up to four categories for a third independent variable
- *Linear Regression Model.* The linear regression model can include a maximum of six independent variables

The TxDOT-TPP recommended trip production model structure is a two-way cross-classification model with person trips (or auto-driver trips) per household cross-classified by up to six row categories and up to six column categories. Although TRIPCAL5 has been developed to allow the user to input any independent variables for the cross-classification model, the TxDOT-TPP standard independent variables are median household income and household size in five categories each.

2.2.4.1.3 Trip Attraction Models

TRIPCAL5 offers five trip attraction model structures to estimate trip attractions; these are:

- *Two-Way Cross-Classification Model.* The two-way cross-classification model offers the ability to use attraction trip rates stratified by two independent variables and each variable having up to six categories
- *Three-Way Cross-Classification Model.* The three-way cross-classification model allows trip attraction rates to be stratified for up to six categories for two independent variables and up to four categories for a third independent variable
- *Cross-Classification/Regression Model.* This model structure allows trip rates stratified for up to 24 generation areas by households and employment type
- *Linear Regression Model.* The linear regression can include a maximum of six independent variables
- *Two-Tier Regression Model.* This structure also offers the use of six independent variables

The recommended trip attraction model is a regression type cross-classification model for each trip purpose stratified by four generation areas. The recommended independent variables are employment and households.

2.2.4.1.4 Disaggregation Models

Disaggregation models in TRIPCAL5 produce planning year estimates of the number of households classified by household size, household income, or auto ownership for each traffic analysis zone. These estimates required in trip production are independently estimated from the MPO provided demographic data using U.S. Census data for the study area. For any of these three variables (household size, household income, or auto ownership), the base year marginal distribution of each zone, a disaggregation curve for the urban area, or defaults built into the model may be used to estimate the regional distribution of households.

2.2.4.2 TRIPCAL5 INPUTS

Figure 2.1, TRIPCAL5 Example Input File, provides an abbreviated example of a standard input file for applying TRIPCAL5. The following items are the required primary inputs:

- Consumer price index
- Trip production rates
- Trip attraction rates
- Regional distribution of households
- Demographic data
- Special generators

```
PS URBAN AREA NAME  1517  4  4 2004 1 0 1     24570  5.66 1
TP 1 NON HOME BASED WORK A D P N
TP 2 NON HOME BASED OTHER A D P N
TP 3   HOME BASED WORK A D P
TP 4 HOME NON WORK RETAIL A D P
TP 5 HOME NON WORK OTHER A D P
TP 6 HOME NON WORK SCHOOL A D P
TP 7      TRUCK TAXI  D P T     154017
TP 8      NHB EXLO  A D P N     132284
TP 9 EXTERNAL LOCAL AUTO A D P
TP 10 EXTERNAL LOCAL TRUCK A D P
NAM 7  BASIC EMP
NAM 8  RETAIL EMP
NAM 9  SERVICE EMP
NAM 10  EDUCATION EMP
SEL  1477 1478
TBL   6  10  23 -24
PCI HH SIZE  H 5 HH SIZE 1 HH SIZE 2 HH SIZE 3 HH SIZE 4 HH SIZE5+
PRI MED INCOME I 5 0 - 10K  10K-20K  20K-35K  35K-50K  50K PLUS
AMC 1 1 5    3  0.080 7  0.230 8  1.200 9  0.45010  0.250
AMC 1 2 5    3  0.070 7  0.180 8  1.100 9  0.41010  0.240
AMC 1 3 5    3  0.060 7  0.100 8  0.500 9  0.29010  0.210
AMC 1 4 5    3  0.050 7  0.070 8  0.400 9  0.26010  0.200
PT 1   1   0.050   0.070   0.200   0.190   0.100
PT 1   2   0.190   0.160   0.410   0.330   0.290
PT 1   3   0.270   0.240   0.660   0.470   0.520
PT 1   4   0.420   0.370   0.920   0.650   0.730
PT 1   5   0.640   0.610   1.200   0.930   1.000
PCR  1 6.50 4.10 3.20 2.80 3.90
PCR  2 3.00 5.20 3.70 3.70 5.10
PCR  3 2.10 5.00 3.80 4.40 6.10
PCR  4 1.40 3.30 2.40 2.60 3.60
PCR  5 1.60 6.80 4.40 4.80 6.50
IR    9999   19999   34999   49999  199999
HS   1  2  3  4  5
ES 1  1 -977
EA 1 116 117 136 -138 141 337
DA1  1 3000.5  124   33 3.758  9638  286   83   11  192
```

Figure 2.1: TRIPCAL5 Example Input File

Table 2.3, TRIPCAL5 Inputs, lists the required TRIPCAL5 inputs and the standard sources for deriving the data.

Table 2.3: TRIPCAL5 Inputs

Data Item	Data Source
Consumer price index	Bureau of Labor Statistics
Trip production rates	Household travel survey
Trip attraction rates	Workplace survey
Regional distribution of households	Census data
Demographic data	Provided by MPO
Population	Census data and Texas State Data Center
Households	Census data
Median income	Census data
Employment by category	Texas Workforce Commission
Special Generators	Provided by MPO

2.2.4.2.1 Consumer Price Index

The 1967 consumer prices index (CPI) value is supplied for the year corresponding to the median income used in the base year application. The Bureau of Labor Statistics (BLS) is the recommended source for CPI values. Table 2.4 provides the CPI values used for base year models developed since year 2000. The CPI value is entered on the program specification (PS) record.

Table 2.4: Consumer Price Index Values for Years 2000 to 2007

Median Income Year	1967 CPI Value
2000	5.16
2001	5.30
2002	5.39
2003	5.51
2004	5.66
2005	5.85
2006	6.04
2007	6.21
2008	6.36

Source: Bureau of Labor Statistics

2.2.4.2.2 Trip Production Rates

Trip production rates are data entered based on the stratification of rates by household median income and household size. Typically, there are five income ranges and five household sizes. The production rates can be either person or vehicle trip production rates. The rates are provided for each trip purpose via the production trip rate (PT) record (ref. Figure 2.1). Establishing what the row and column variables on the PT record represent can be determined via the PRI and PCI records respectively.

2.2.4.2.3 Trip Attraction Rates

Trip attraction rates are primarily stratified by employment category and area type though household attraction rates are also provided by area type. In previous years there were three employment categories (basic, retail and service) that were used though recently a fourth category (education) has been included. Four area types are usually employed: CBD (central business district), urban, suburban and rural. Attraction rates which can also be either person or auto-driver trip rates are provided for each trip purpose via the attraction cross-classification model (AMC) record (ref. Figure 2.1).

2.2.4.2.4 Regional Distribution of Households

The regional household distribution is typically stratified by median household income and household size. The distribution of households is provided via the PCR records. The values designated on the PCR records represent percentage values (e.g. six and a half percent is data entered as 6.50), and the values on all PCR records should sum to 100.

2.2.4.2.5 Demographic Data

Please refer to the discussion in section 2.2.2 Demographic Data.

2.2.4.2.6 TRIPCAL5 Record Formats and Descriptions

Table 2.5, TRIPCAL5 Records, provides a brief description of each of the records shown in Figure 2.1, TRIPCAL5 Example Input file. It should be noted that Table 2.5 is not a comprehensive list of all the records available for use in TRIPCAL5 but rather summarizes the standard set-up used by TxDOT-TPP for the 22 urban areas for which they develop travel demand models. For descriptions of additional records that can be used in TRIPCAL5, the TRIPCAL5 Users Manual should be referenced. Following are designated formats and descriptions for each of the TRIPCAL5 records listed in Table 2.5.

Table 2.5: TRIPCAL5 Records

Record	Record Description	Data Source
PS	Program Control/Specification Record	Combination of model developer specified data and locally provided data
TBL	Table command	Determines which output tables to place in output or listing file
SEL	Select command	Determines which zones to print in Table 2.6 of the output or listing file
TP	Trip Purpose	Model developer specified
PCI	Production Column Information	Typical practice is to have 1, 2, 3, 4 and 5+ household size categories
PRI	Production Row Information	Model developer specified
PCR	Regional Distribution for Production Cross-Classification	Census data
PT	Production Trip Rate	Household survey data
AMC	Attraction Trip Rate	Workplace survey data
ES	Sector Table of Equals	Zonal-to-sector geography
EA	Area Type Table of Equals	Activity density ranges developed from demographic data
IR	Income Ranges	Household survey data
HS	Household Size Ranges	Household survey data
DA1	Demographic Data Input	MPO provided demographic data
AOP	Add-on Trip Production	External survey
SGP	Special Generator Productions	ITE Trip Generation Manual
SGA	Special Generator Attractions	ITE Trip Generation Manual
SGZ	Special Generator Zones	Demographic data from local area
CMT	Zonal Comment Card	Model developer specified

Source: *TRIPCAL5 User's Manual*, November 1990

- *PS, Program Control/Specification Record*. The PS record lists the name of the urban area, the number of zones, sectors, and generation areas. The study year for which the trip generation model is being developed is input. A trip type code designates whether the model uses person trips (code = 0) or auto driver trips (code = 1). The purpose code specifies whether a distinct trip model for each purpose exists (code = 0). An add-on records code (0 = no add-on records, 1 = special generator or add-on records) designates the use of special generator add-on records. The regional median income value and the consumer price index value need to be consistent with the designated study year. The default truck-taxi model code specifies whether the TRIPCAL5 default model is applied or not (0 = yes, 1= no). The format of the PS record is provided in Table 2.6, PS Record.

Table 2.6: PS Record

Columns	Format	Contents
1-2	A2	PS
4-18	A15	Name of urban area
19-25	I7	Number of zones
26-29	I4	Number of sectors
30-33	I4	Number of generation areas
34-38	I5	Study year
39-40	I2	Trip type code
41-42	I2	Purpose code
43-44	I2	Add-on records code
47-56	F10.0	Regional median household income
57-64	F8.3	1967 based consumer price index
65-66	I2	Default truck-taxi model code

Source: *TRIPCAL5 User's Manual*, November 1990;
A = Alphanumeric, I = Integer, F = Fixed Format

- *TBL, Output Reports Record*. The TBL record specifies which of the available TRIPCAL5 output tables will be included in the output report. A consecutive range of report numbers can be specified on one TBL record by using a dash before the report number of the final number comprising end of the range. The format of the TBL record is provided in Table 2.7, TBL Record.

Table 2.7: TBL Record

Columns	Format	Contents
1-3	A3	SEL
6-10	I5	Report number
11-15	I5	Report number
16-20	I5	Report number
21-25	I5	Report number
26-30	I5	Report number
31-35	I5	Report number
36-40	I5	Report number
41-45	I5	Report number
46-50	I5	Report number
51-55	I5	Report number
56-60	I5	Report number
61-65	I5	Report number
66-70	I5	Report number
71-75	I5	Report number
76-80	I5	Report number

Source: *TRIPCAL5 User's Manual*, November 1990;
A = Alphanumeric, I = Integer, F = Fixed Format

- *SEL, Select Zones Record*. The SEL record designates which zones will summarized in the TRIPCAL5 Table 2.6 portion of the output report. The format of the SEL record is provided in Table 2.8, SEL Record.

Table 2.8: SEL Record

Columns	**Format**	**Contents**
1-3	A3	SEL
6-10	I5	Zone number
11-15	I5	Zone number
16-20	I5	Zone number
21-25	I5	Zone number
26-30	I5	Zone number
31-35	I5	Zone number
36-40	I5	Zone number
41-45	I5	Zone number
46-50	I5	Zone number
51-55	I5	Zone number
56-60	I5	Zone number
61-65	I5	Zone number
66-70	I5	Zone number
71-75	I5	Zone number
76-80	I5	Zone number

Source: *TRIPCAL5 User's Manual*, November 1990;
A = Alphanumeric, I = Integer, F = Fixed Format

- *TP, Trip Purpose Record*. The TP record specifies the trip purpose code and name for each trip purpose used in the trip generation model. It also designates which of the available TRIPCAL5 production and attraction models will be employed; the choices for the production model are as follows listed by code:
    - A = two-way cross-classification table
    - B = three-way cross-classification table
    - C = simple regression model

The attraction model option codes are as follows:

- A = two-way cross-classification table
- B = three-way cross-classification table
- C = simple regression model
- D = regression type cross-classification
- E = two-tier regression model

In addition the TP record calls for a flag variable to specify the use of a non-home-based trip purpose or a truck-taxi trip purpose. Finally, if the default truck-taxi model is not used, a trip production control total can also be included on the TP record. The format of the TP record is shown in Table 2.9, TP Record.

Table 2.9: TP Record

Columns	Format	Contents
1-3	A3	TP
4-5	I2	Trip purpose code
7-26	A20	Trip purpose name
28	A1	Production model option
30	A1	Attraction model option
32	A1	Trip balancing code
34	A1	Non-home-based or truck-taxi flag
41-50	F10.0	Trip control total

Source: *TRIPCAL5 User's Manual*, November 1990;
A = Alphanumeric, I = Integer, F = Fixed Format

- *PCI, Production Column Information Record*. The PCI record designates which primary variable is assigned to the columns in a two or three-way cross-classification model. The available choices are: "N" = none, "I" = Income, "H" = Household size, and "A" = Auto ownership. As shown in the Figure 2.1 example, the description for each column is also included in the PCI record. The format of the PCI record is shown in Table 2.10, PCI Record.

Table 2.10: PCI Record

Columns	Format	Contents
1-3	A3	PCI
5-14	A10	Column variable name
16	A1	Default marginal code
18	I1	Number of columns
20-29	A10	Column one data description
30-39	A10	Column two data description
40-49	A10	Column three data description
50-59	A10	Column four data description
60-69	A10	Column five data description
70-79	A10	Column six data description

Source: *TRIPCAL5 User's Manual*, November 1990;
A = Alphanumeric, I = Integer, F = Fixed Format

- *PRI, Production Row Information Record*. Similar to the PCI record, the PRI record designates which primary variable is assigned to the rows in a two or three-way cross-classification model. The available choices are: "N" = none, "I" = Income, "H" = Household size, and "A" = Auto ownership. As shown in the Figure 2.1

example, the description for each row is also included in the PRI record. The format of the PRI record is shown in Table 2.11, PRI Record.

- *PCR, Production Cross-classification Model Record*. The PCR record specifies the regional household distribution. As shown in Figure 2.1, one PCR record is included for each row variable listed on the PRI record. The regional household distribution numbers listed on the PCR record are assumed to be percentage values. As noted previously, the summation of all the numbers on all the PCR records should equal 100. The format of the PRI record is shown in Table 2.12, PRI Record.

Table 2.11: PRI Record

Columns	Format	Contents
1-3	A3	PRI
5-14	A10	Row variable name
16	A1	Default marginal code
18	I1	Number of rows
20-29	A10	Row one data description
30-39	A10	Row two data description
40-49	A10	Row three data description
50-59	A10	Row four data description
60-69	A10	Row five data description
70-79	A10	Row six data description

Source: *TRIPCAL5 User's Manual*, November 1990;
A = Alphanumeric, I = Integer, F = Fixed Format

Table 2.12: PCR Record

Columns	Format	Contents
1-3	A3	PCR
4-5	I2	Depth "i" category number (for three-way cross-classification models only)
6-7	I2	Row "j" category
8-12	F5.0	Regional percentage for depth "i", row "j" column 1
13-17	F5.0	Regional percentage for depth "i", row "j" column 2
18-22	F5.0	Regional percentage for depth "i", row "j" column 3
23-27	F5.0	Regional percentage for depth "i", row "j" column 4
28-32	F5.0	Regional percentage for depth "i", row "j" column 5
33-37	F5.0	Regional percentage for depth "i", row "j" column 6

Source: *TRIPCAL5 User's Manual*, November 1990;
A = Alphanumeric, I = Integer, F = Fixed Format

- *PT, Production Trip Rate Record*. The PT record provides the trip generation model the production trip rates. A PT record must be provided for each row variable listed on the PRI record and a set (for all row variables) of PT records is provided for each trip purpose. The format of the PT record is shown in Table 2.13, PT Record.

- *AMC, Attraction Cross-classification Model Record*. The AMC record specifies the attraction rates for each trip purpose by area type for each employment category as well as households. The format of the AMC record is shown in Table 2.14, AMC Record.

Table 2.13: PT Record

Columns	Format	Contents
1-2	A2	PT
3-5	I3	Trip purpose code
6-8	I3	Depth “i” category number
9-11	I3	Row “j” category
13-22	F10.0	Trip rate for depth “i”, row “j” column 1
23-32	F10.0	Trip rate for depth “i”, row “j” column 2
33-42	F10.0	Trip rate for depth “i”, row “j” column 3
43-52	F10.0	Trip rate for depth “i”, row “j” column 4
53-62	F10.0	Trip rate for depth “i”, row “j” column 5
63-72	F10.0	Trip rate for depth “i”, row “j” column 6

Source: *TRIPCAL5 User’s Manual*, November 1990;
A = Alphanumeric, I = Integer, F = Fixed Format

Table 2.14: AMC Record

Columns	Format	Contents
1-3	A3	SEL
4-5	I2	Trip purpose code
6-8	I3	Area type
9-11	I3	Number of independent variables
19-20	I2	First independent variable number
21-28	F8.0	Attraction rate
29-30	I2	Second independent variable number
31-38	F8.0	Attraction rate
39-40	I2	Third independent variable number
41-48	F8.0	Attraction rate
49-50	I2	Fourth independent variable number
51-58	F8.0	Attraction rate
59-60	I2	Fifth independent variable number
61-68	F8.0	Attraction rate
69-70	I2	Sixth independent variable number
71-78	F8.0	Attraction rate

Source: *TRIPCAL5 User’s Manual*, November 1990;
A = Alphanumeric, I = Integer, F = Fixed Format

- *ES, Sector Table of Equals Record*. The ES record lists each of the zones that comprise an individual sector. One or more ES records are provided for each sector depending on the number of zones comprising an individual sector. The format of the ES record is shown in Table 2.15, ES Record.

Table 2.15: ES Record

Columns	Format	Contents
1-2	A2	ES
3-5	I3	Sector number
6-10	I5	Zone number within sector
11-15	I5	Zone number within sector
16-20	I5	Zone number within sector
21-25	I5	Zone number within sector
26-30	I5	Zone number within sector
31-35	I5	Zone number within sector
36-40	I5	Zone number within sector
41-45	I5	Zone number within sector
46-50	I5	Zone number within sector
51-55	I5	Zone number within sector
56-60	I5	Zone number within sector
61-65	I5	Zone number within sector
66-70	I5	Zone number within sector
71-75	I5	Zone number within sector
76-80	I5	Zone number within sector

Source: *TRIPCAL5 User's Manual*, November 1990;
A = Alphanumeric, I = Integer, F = Fixed Format

- *EA, Area Type Table of Equals Record*. The EA record lists all of the zones that reside within each area type. One or more EA records are provided for each area type depending on the number of zones comprising an individual area type. The format of the EA record is shown in Table 2.16, EA Record.

- *IR, Income Ranges Record*. The IR record is a descriptive listing of the median household income ranges used as one of the primary production rate variables. The IR record is a single record describing the income ranges by specifying the upper end of each income range in a sequential format. Figure 2.1 provides an example of the IR record. The format of the IR record is shown in Table 2.17, IR Record.

- *HS, Household Size Ranges Record*. As with the IR record, the HS record is a descriptive listing of the household size ranges used as one of the primary production rate variables. The HS record is a single record describing the household size ranges by specifying each household size in a sequential format. Figure 2.1 provides an example of the HS record. The format of the HS record is shown in Table 2.18, HS Record.

Table 2.16: EA Record

Columns	Format	Contents
1-2	A2	EA
3-5	I3	Area type number
6-10	I5	Zone number within area type
11-15	I5	Zone number within area type
16-20	I5	Zone number within area type
21-25	I5	Zone number within area type
26-30	I5	Zone number within area type
31-35	I5	Zone number within area type
36-40	I5	Zone number within area type
41-45	I5	Zone number within area type
46-50	I5	Zone number within area type
51-55	I5	Zone number within area type
56-60	I5	Zone number within area type
61-65	I5	Zone number within area type
66-70	I5	Zone number within area type
71-75	I5	Zone number within area type
76-80	I5	Zone number within area type

Source: *TRIPCAL5 User's Manual*, November 1990;
A = Alphanumeric, I = Integer, F = Fixed Format

Table 2.17: IR Record

Columns	Format	Contents
1-2	A2	IR
5-14	F10.0	Ending value of income range for category one
15-24	F10.0	Ending value of income range for category two
25-34	F10.0	Ending value of income range for category three
35-44	F10.0	Ending value of income range for category four
45-54	F10.0	Ending value of income range for category five
55-64	F10.0	Ending value of income range for category six

Source: *TRIPCAL5 User's Manual*, November 1990;
A = Alphanumeric, I = Integer, F = Fixed Format

- *DA1, Data One Input Record*. The DA1 record specifies the primary socio-economic data for each zone in the study area. This includes population, households, median household income, and employment by category. The format of the DA1 record is shown in Table 2.19, DA1 Record.

Table 2.18: HS Record

Columns	Format	Contents
1-2	A2	HS
4-8	F5.0	Ending value of household size range for category one
9-13	F5.0	Ending value of household size range for category two
14-18	F5.0	Ending value of household size range for category three
19-23	F5.0	Ending value of household size range for category four
24-28	F5.0	Ending value of household size range for category five
29-33	F5.0	Ending value of household size range for category six

Source: *TRIPCAL5 User's Manual*, November 1990;
A = Alphanumeric, I = Integer, F = Fixed Format

Table 2.19: DA1 Record

Columns	Format	Contents
1-3	A3	DA1
4-8	I5	Zone number
9-15	F7.0	Zone size in acres
16-22	F7.0	Total zonal population
23-29	F7.0	Total zonal households
30-36	F7.0	Average zonal household size
37-43	F7.0	Zonal median household income
44-50	F7.0	Zonal total employment
51-57	F7.0	Zonal total basic employment
58-64	F7.0	Zonal total retail employment
65-71	F7.0	Zonal total service employment

Source: *TRIPCAL5 User's Manual*, November 1990;
A = Alphanumeric, I = Integer, F = Fixed Format

- *AOP, Add-on Production Record*. The AOP record provides an opportunity for specifying additional add-on productions by zone that have not been accounted for elsewhere in the input data. An example of add-on production data is the need to account for non-home-based productions made by university on-campus households. The format of the AOP record is shown in Table 2.20, AOP Record.

Table 2.20: AOP Record

Columns	Format	Contents
1-3	A3	AOP
4-8	I5	Zone number
9-10	I2	Trip purpose number for added trips
11-15	I5	Number of added trips
16-17	I2	Trip purpose number for added trips
18-22	I5	Number of added trips
23-24	I2	Trip purpose number for added trips
25-29	I5	Number of added trips
30-31	I2	Trip purpose number for added trips
32-36	I5	Number of added trips
37-38	I2	Trip purpose number for added trips
39-43	I5	Number of added trips
44-45	I2	Trip purpose number for added trips
46-50	I5	Number of added trips
51-52	I2	Trip purpose number for added trips
53-57	I5	Number of added trips
58-69	I2	Trip purpose number for added trips
60-64	I5	Number of added trips
65-66	I2	Trip purpose number for added trips
67-71	I5	Number of added trips
72-73	I2	Trip purpose number for added trips
74-78	I5	Number of added trips

Source: *TRIPCAL5 User's Manual*, November 1990;
A = Alphanumeric, I = Integer, F = Fixed Format

- *SGP, Special Generator Production Record.* The SGP record specifies the number of trip productions by trip purpose estimated for a given special generator. The format of the SGP record is shown in Table 2.21, SGP Record.

Table 2.21: SGP Record

Columns	Format	Contents
1-3	A3	SGP
4-8	I5	Zone number
9-10	I2	Trip purpose number for added trips
11-15	I5	Number of added trips
16-17	I2	Trip purpose number for added trips
18-22	I5	Number of added trips
23-24	I2	Trip purpose number for added trips
25-29	I5	Number of added trips
30-31	I2	Trip purpose number for added trips
32-36	I5	Number of added trips
37-38	I2	Trip purpose number for added trips
39-43	I5	Number of added trips
44-45	I2	Trip purpose number for added trips
46-50	I5	Number of added trips
51-52	I2	Trip purpose number for added trips
53-57	I5	Number of added trips
58-69	I2	Trip purpose number for added trips
60-64	I5	Number of added trips
65-66	I2	Trip purpose number for added trips
67-71	I5	Number of added trips
72-73	I2	Trip purpose number for added trips
74-78	I5	Number of added trips

Source: *TRIPCAL5 User's Manual*, November 1990;
A = Alphanumeric, I = Integer, F = Fixed Format

- *SGA, Special Generator Attraction Record*. The SGA record specifies the number of trip attractions by trip purpose estimated for a given special generator. The format of the SGA record is shown in Table 2.22, SGA Record.

Table 2.22: SGA Record

Columns	Format	Contents
1-3	A3	SGA
4-8	I5	Zone number
9-10	I2	Trip purpose number for added trips
11-15	I5	Number of added trips
16-17	I2	Trip purpose number for added trips
18-22	I5	Number of added trips
23-24	I2	Trip purpose number for added trips
25-29	I5	Number of added trips
30-31	I2	Trip purpose number for added trips
32-36	I5	Number of added trips
37-38	I2	Trip purpose number for added trips
39-43	I5	Number of added trips
44-45	I2	Trip purpose number for added trips
46-50	I5	Number of added trips
51-52	I2	Trip purpose number for added trips
53-57	I5	Number of added trips
58-69	I2	Trip purpose number for added trips
60-64	I5	Number of added trips
65-66	I2	Trip purpose number for added trips
67-71	I5	Number of added trips
72-73	I2	Trip purpose number for added trips
74-78	I5	Number of added trips

Source: *TRIPCAL5 User's Manual*, November 1990;
A = Alphanumeric, I = Integer, F = Fixed Format

- *SGZ, Special Generator Data Record*. The SGZ record is comparable to the DA1 record in that it lists the socio-economic data by zone associated with each special generator. This includes the relevant population, households, median household income, and employment by category associated with the special generator. The format of the SGZ record is shown in Table 2.23, SGZ Record.
- *CMT, Zone Comment Record*. The CMT record allows for documenting unique conditions or observations regarding an individual zone or a special generator within a zone. The format of the CMT record is shown in Table 2.24, CMT Record.

Table 2.23: SGZ Record

Columns	Format	Contents
1-3	A3	SGZ
4-8	I5	Zone number
9-15	F7.0	Special generator size in acres
16-22	F7.0	Special generator population
23-29	F7.0	Special generator households
30-36	F7.0	Average household size
37-43	F7.0	Median household income
44-50	F7.0	Special generator employment
51-57	F7.0	Special generator basic employment
58-64	F7.0	Special generator retail employment
65-71	F7.0	Special generator service employment

Source: *TRIPCAL5 User's Manual*, November 1990;
A = Alphanumeric, I = Integer, F = Fixed Format

Table 2.24: CMT Record

Columns	Format	Contents
1-3	A3	CMT
4-8	I5	Zone number
10-80	F7.0	Comments describing special generator

Source: *TRIPCAL5 User's Manual*, November 1990;
A = Alphanumeric, I = Integer, F = Fixed Format

2.2.5 Trip Distribution Model (ATOM2) Inputs

The trip distribution step determines the interchange volume between all zones by trip purpose. The result of the trip distribution process is a description of the travel patterns for each trip purpose in the form of a person or vehicle trip matrix. The Texas Package trip distribution model is ATOM2 and comparable to other distribution models uses a gravity analogy formulation. The difference and primary advantage of ATOM 2 is the ability to account for zone size as part of the distribution process.

The original mainframe version of ATOM was converted in 1996 to operate in a micro-computer environment and was designed to interface with a travel demand model software package named TRANPLAN. Consequently, the current control files for ATOM2 are similar in appearance and form to those used by the TRANPLAN software. Figure 2.2 offers an example of an ATOM2 control file.

```
$ATOM2 MODEL
$FILE
   INPUT FILE = SEPTP, USERID = $C:\tdm_wrk\T08skim.bin$
   INPUT FILE = RADII, USER ID = $C:\tdm_wrk\t08rad.asc$
   INPUT FILE = GENE, USER ID = $C:\tdm_wrk\t08p_a.asc$
   INPUT FILE = EQUATE, USER ID = $C:\tdm_wrk\t08equ.asc$
   OUTPUT FILE = TRIP-TP, USER ID = $C:\tdm_wrk\TY08HBW.BIN$
   OUTPUT FILE = LISTING, USER ID = $C:\tdm_wrk\TY08HBW.OUT$
$HEADERS
   STUDY AREA NAME 2008 HBW Trip Distribution
$PARAMETERS
 &VALUES M= 319, N=346, TABLE= 1, LIMIT=5 &END
 REPORT  = A1(5),Z1,R1,A2(5),A3(5),L1(5),S1(1-5),GET2
$DATA
FORMAT(A4,T11,I5,T26,F5.0,F5.0)     HBW      GENERATION
FORMAT(A4,T11,I5,F15.4,T50,A4)             LENGTH
LENGTH    1    1.1145    1167.73
LENGTH    2    3.1339    3283.48
LENGTH    3    5.0844    5327.18
LENGTH    4    6.5860    6900.47
LENGTH    5    7.5410    7900.97

LENGTH    55     0.0004      0.37
LENGTH    56     0.0003      0.28
LENGTH    57     0.0002      0.22
LENGTH    58     0.0002      0.17
LENGTH    59     0.0001      0.13
LENGTH    60     0.0001      0.10
FORMAT(A4,6X,2I5,F10.3)                 BIAS
FORMAT(A4,T11,I5,F15.4)               F-FACTOR
F-FACTOR   1    225.6918
F-FACTOR   2    184.1352
F-FACTOR   3    150.2304
F-FACTOR   4    122.5685
F-FACTOR   5    100.0000

F-FACTOR   55    0.0038
F-FACTOR   56    0.0031
F-FACTOR   57    0.0025
F-FACTOR   58    0.0021
F-FACTOR   59    0.0017
F-FACTOR   60    0.0014
END
```

Figure 2.2: ATOM2 Control File

2.2.5.1 Travel Time Matrix

The travel time matrix used in ATOM2 represents the daily travel times between all zone pairs derived from the minimum network travel time path for each zone pair. The travel time matrix, or skim matrix, is produced using TransCAD software and then exported as a binary file using a Texas Package utility (ref. Section 4). The travel time matrix can be input to ATOM2 as either a TRANPLAN binary file or in an ASCII 3I8 format (as exported by TransCAD). To run ATOM2, the user must provide a separation matrix data set as an input file.

2.2.5.2 Internal Productions and Attractions by Trip Purpose

A file containing the internal productions and attractions by trip purpose is automatically created by TRIPCAL5. This file is known as the generation file. Normally the generation file will contain up to five trip purposes with the production value listed prior to the attraction value by zone for each trip purpose. Additional trip purposes will automatically be included in additional generation files. A maximum of three generation files is produced by TRIPCAL5. ATOM2 uses a format record to specify which columns of the generation file to read for a specific trip purpose. An example format record structure is provided in Table 2.25, Generation Format Record.

Table 2.25: Generation Format Record

Columns	Format	Contents
1-10	A10	GENERATION
11-15	I5	Zone number
26-30*	I5	Production or origin volume
31-35*	I5	Attraction or destination volume

*The columns specified will be dependent on the trip purpose

Source: *ATOM2 User Manual*, February 2001; A = Alphanumeric, I = Integer, F = Fixed Format

2.2.5.3 External Local Productions and Attractions by Trip Purpose

The external local productions and attractions are included in one of the generation files produced by TRIPCAL5. The only difference between the external and internal productions and attractions included in a generation file is that the production values for all internal zones will be zero and the only non-zero production values will be for external zones. Likewise, the attraction values for internal zones will be positive, however, the external zonal attraction values will be zero. This is in keeping with the framework that external productions originate at external station zones and are destined to internal zones.

2.2.5.4 Friction Factors

Friction factors describe the impedance to travel based on spatial separation. ATOM2 uses a format record to specify which columns of the friction factor records to read for the appropriate values. An example format record structure is provided in Table 2.26, Friction Factor Format Record.

Table 2.26: Friction Factor Format Record

Columns	Format	Contents
1-4	A4	F-FA
11-15	I5	Separation value or time in minutes
16-25	F10.5	Desired F-factor

Source: *ATOM2 User Manual*, February 2001;
A = Alphanumeric, I = Integer, F = Fixed Format

2.2.5.5 Trip length Frequency Distribution (Length Records)

A trip length frequency distribution curve describes the number of trips or percent of trips occurring at each minute of separation for a given trip purpose. A trip length frequency distribution (TLFD) model is available as a part of the Texas Package to automatically develop a TLFD for each trip purpose. Input needed for the ITLFDM (Improved Trip Length Frequency Distribution Model) includes an estimate of the mean trip length and the maximum trip length. The output of the ITLFDM routine will be a trip length frequency distribution with the desired mean trip length in the form of length records formatted according to ATOM2 requirements. An example format record structure is provided in Table 2.27, Length Format Record.

Table 2.27: Length Format Record

Columns	Format	Contents
1-6	A6	LENGTH
11-15	I5	Length or separation value (usually minutes)
16-30	F15.4	Percent of trips occurring at separation value

Source: *ATOM2 User Manual*, February 2001; A = Alphanumeric, I = Integer, F = Fixed Format

2.2.5.6 Radii Values

Zonal radii values are required for every zone. Radii value is the average distance in minutes of travel time for all centroid connectors from the center point of the zone centroid to the perimeter of the zone. The zonal radii value is the centroid distance parameter that ATOM2 uses to account for zone size in the trip distribution process. An example format record structure is provided in Table 2.28, Radii Format Record.

Table 2.28: Radii Format Record

Columns	Format	Contents
1-7	A7	RADIUS or R-VALUE
9-12	I4	Zone number
15-20	F6.1	Radius or R-value for the zone in minutes (maximum radius = 10.0)

Source: *ATOM2 User Manual*, February 2001; A = Alphanumeric, I = Integer, F = Fixed Format

2.2.5.7 Equals Values

Equals records are an aggregate list of zones grouped into larger geographic areas commonly referred to as sectors. An example format record structure is provided in Table 2.29, Equals Format Record.

Table 2.29: Equals Format Record

Columns	Format	Contents
1-3	I3	Sector number
5-10	A5	Equals
11-15 16-20 21-25 . . . 76-80	14I5	Zone number or ranges of zone numbers

Source: *ATOM2 User Manual*, February

2.2.5.8 Bias Records

Bias records are factors that can be used to address social and economic conditions or topographic barriers that have not been appropriately accounted for in the trip distribution process. A bias factor with a value greater than one increases the opportunity for trip interchanges between specified sectors and values less than one deter sector interchanges. Typically bias records are used sparingly, if at all, to improve modeled regional trip patterns by trip purpose. An example format record structure is provided in Table 2.30, Bias Format Record.

Table 2.30: BIAS Format Record

Columns	Format	Contents
1-4	A4	GENE
11-15	I5	Zone number
26-30*	F5.0	Production or origin volume
31-35*	F5.0	Attraction or destination volume

Source: *ATOM2 User Manual*, February 2001; A = Alphanumeric, I = Integer, F = Fixed Format

2.3 Texas Package Model Outputs

The summary output reports provided by TRIPCAL5 and ATOM2 are undoubtedly one of the most important features of the Texas Package. The reports are extensive and offer a wealth of data for assessing the performance of the model. Following is a description of various outputs provided by the Texas Package.

2.3.1 Trip Generation Model (TRIPCAL5) Outputs

As mentioned previously, TRIPCAL5 is responsible for estimating the total number of productions and attractions by trip purpose for each urban area zone. TRIPCAL5 produces two output files, a generation file (or files) and a report file.

2.3.1.1 Generation File(s)

Depending on the number of trip purposes more than one generation file will be output since a maximum of five trip purposes are included in the first generation file. Three generation files will be output if the maximum of ten trip purposes are specified in the input file. The ten trip purposes can be output in any order; however, the output order will coincide with the order that the trip purposes were specified in the input file. Tables 2.31 through 2.33 indicate the content and format of the three generation files. Generation file one will contain the first four trip purposes listed in the input file in addition to external local productions and attractions. The second generation file will contain trip purposes five through eight and the third generation file will contain trip purposes nine and ten.

Table 2.31: First Generation File

Columns	Format	Contents
1-10	A10	GENERATION
11-15	I5	Zone number
16-20	I5	Trip purpose 1 productions
21-25	I5	Trip purpose 1 attractions
26-30	I5	Trip purpose 2 productions
31-35	I5	Trip purpose 2 attractions
36-40	I5	Trip purpose 3 productions
41-45	I5	Trip purpose 3 attractions
46-50	I5	External local productions
51-55	I5	External local attractions
56-60	I5	Trip purpose 4 productions
61-65	I5	Trip purpose 4 attractions
66-75	A10	Urban area name
76	I1	0=Person trips, 1=Auto Driver trips
77-80	I4	Year

A = Alphanumeric, I = Integer

Table 2.32: Second Generation File

Columns	Format	Contents
1-10	A10	GENERATION
11-15	I5	Zone number
16-20	I5	Trip purpose 5 productions
21-25	I5	Trip purpose 5 attractions
26-30	I5	Trip purpose 6 productions
31-35	I5	Trip purpose 6 attractions
36-40	I5	Trip purpose 7 productions
41-45	I5	Trip purpose 7 attractions
56-60	I5	Trip purpose 8 productions
61-65	I5	Trip purpose 8 attractions
66-75	A10	Urban area name
76	I1	0=Person trips, 1=Auto Driver trips
77-80	I4	Year

Table 2.33: Second Generation File

Columns	Format	Contents
1-10	A10	GENERATION
11-15	I5	Zone number
16-20	I5	Trip purpose 9 productions
21-25	I5	Trip purpose 9 attractions
26-30	I5	Trip purpose 10 productions
31-35	I5	Trip purpose 10 attractions
66-75	A10	Urban area name
76	I1	0=Person trips, 1=Auto Driver trips
77-80	I4	Year

2.3.1.2 TRIPCAL5 Report File

TRIPCAL5's reporting function is a flexible structure that offers the user the ability to specify which of 24 available tables are printed for a given application. The user specifies which report tables are printed by specifying the desired Table numbers on the TBL record in the TRIPCAL5 input file. A listing of the report tables and their respective numbers is shown in Table 2.34. In addition to the 24 designated report tables, TRIPCAL5 always prints a complete record of the input file at the beginning of the TRIPCAL5 report file and provides the generation file content and format at the end of the report. These two additional report tables are shown as unnumbered report tables in Table 2.34. Following is a description of each report table listed in Table 2.34.

- Report Table 1 provides the production and attraction models for each trip purpose. The production models by trip purpose are listed first followed by the attraction models for each trip purpose.

Table 2.34: TRIPCAL5 Report File Structure

Table No.	Table Contents
-	Input file is always listed at the beginning of the report
1	Production model trip rates for each trip purpose
2	Zone to sector table of equivalencies
3	Zone to district table of equivalencies
4	Zone to area type table of equivalencies
5	Regional household distribution
6	Disaggregate zonal results (for specified zones)
7	Disaggregate results by sector
8	Disaggregate results by area type
9	Unscaled productions and attractions by zone and by trip purpose
10	Scaling factor computations for each trip purpose
11	Aggregate productions and attractions by sector
12	Aggregate productions and attractions by zone within each sector
13	Aggregate productions and attractions by area type
14	Aggregate productions and attractions by zone within each area type
15	Study area characteristics summary by sector
16	Study area characteristics summary by zone within each sector
17	Study area characteristics summary by area type
18	Study area characteristics summary by zone within each area type
19	Study area characteristics summary by zone
20	Final productions and attractions by zone and by trip purpose
21	Special generator data comments
22	Zonal characteristics and final productions and attractions for zones specified on the Select record
23	Characteristics and final productions and attractions by sector
24	Characteristics and final productions and attractions by area type
-	Generation file(s) contents is provided at end of report

- Report Tables 2, 3, and 4 essentially list the zonal equivalency tables for sector equivalencies, district equivalencies, and area type equivalencies respectively.
- Report Table 5 provides the regional household distribution as a percentage of the total households for each variable. For example, if the production model is a two-way cross-classification using household size and household income, then the percentages will be listed by household size for each category of household income.
- Report Table 6 lists the zonal disaggregate results of the trip generation process for each zone specified on the SEL (Select) record in the input file. Depending upon the number of zones specified this report can be rather extensive. If no zones are specified on the SEL record, Table 6 will not be printed; consequently, if Table 6 output is required a SEL record must be input.
- Report Tables 7 and 8 output the trip generation disaggregate results by sector and area type respectively.

- Report Table 9 provides the unscaled productions and attractions by trip purpose for each zone.
- Report Table 10 summarizes the scaling factor computations by trip purpose.
- Report Tables 11, 12, 13, and 14 contain the final scaled productions and attractions that have been estimated for each trip purpose. Report Table 11 presents the estimates by sector, Report Table 12 lists the estimates by zone within each sector, Report Table 13 presents the estimates by area type, and Report Table 14 presents the estimates by zone within each area type.
- Report Tables 15, 16, 17, 18, and 19 summarizes both study area data and trip data. Each report table presents the data in different summary formats. The study area data presented includes population, households, average household size, employment, employment by type, autos per household, autos per person and household income. The trip data provided is trips per person and trips per household by trip purpose. Thus, depending on the report table, the summary information can be printed by sector, by zone within each sector, by area type, by zone within each area type, and merely by zone.
- Report Table 20 lists the final productions and attractions by trip purpose for each zone. These are the scaled productions and attractions that will be input to the trip distribution process.
- Report Table 21 lists as a reference, the relevant special generator information for each zone that was input via the CMT records.
- Report Table 22 provides the zonal characteristics and final productions and attractions for zones that were specified on the SEL (Select) record in the input file. If no zones were specified on the SEL record, Report Table 22 is not generated.
- Report Tables 23 and 24 present the study area characteristics and final productions and attractions by sector and by area type respectively.

2.3.2 Trip Distribution Model (ATOM2) Outputs

ATOM2 produces two types of output files, trip matrices and report files. For each trip purpose ATOM2 produces a single trip matrix and an individual report; both are described in the next two report sections.

2.3.2.1 ATOM2 Output Files

The ATOM2 output file is a trip table file containing the zone-to-zone distributed trips. ATOM2 provides the option to produce a trip matrix in either TRANPLAN format (a binary file format) or in an ASCII 3I8 format (for importing to TransCAD). If the ATOM2 output trip table is created in binary format then the trip table will need to subsequently be converted to a format that can be used in TransCAD.

2.3.2.2 ATOM2 Report Files

Table 2.35 lists the individual report tables that are available as part of the ATOM2 report file. ATOM2 report files provide an extensive amount of data including summaries of input data to the trip distribution process, summaries of model performance and summations of the resulting trip tables. As can be seen in Table 2.35, the available reports offer the ability to summarize various input data such as productions and attractions by zone, zonal radii values, and desired trip length frequency distributions. Other reports summarize model results such as resulting zonal attractions and trip interchange movements. Some of the reports are also controlled by iteration number which means that a report table is provided for each iteration.

Table 2.35: ATOM2 Report File Structure

Table No.	**By Iteration**	**Table Contents**
R1	No	Zonal radii
Z1	No	Summary of input productions and attractions by zone
A1	Yes	Attraction volume balance
A2	Yes	Attraction volume balance summary
A3	Yes	Total intra-zonal trips
F1	No	Centroid to sector equivalencies
G1	No	Zonal trip generation summary
G2	No	Trip length frequency table
G3	No	Number of zone pairs within and between sectors
G4	No	Number of interactions (zone pairs with nonzero interchange volumes) within and between sectors
G5	No	Trip volumes within and between sectors
G6	No	Sector interchange
G7	No	Sector production summary
G8	No	Sector attraction summary
G9	No	Summary of average trip length by sector
L1	Yes	Trip length balance
S1	Yes	Attraction volume balance by sector
X1	No	Summary comparison of estimated vs. modeled trip length frequency

Source: *ATOM2 User Manual*, February 2001

- Report Table R1 provides a listing of the zonal radii values that were input to the trip distribution model. The radii values are listed in tabular format with 20 zonal values listed in each row of the output table.
- Report Table Z1 summarizes the input trip productions and attractions by zone. In addition it lists terminal times at the production and attraction end of the trip along with a listing of the zonal radii value and a listing of whether any trip prohibits were input for specific zones.
- Report Table A1 provides a comparative listing of the desired and resulting attractions by zone. The difference between desired and resulting and the percent error are also provided for each zone.

- Report Table A2 presents an overall graphical summary of the attraction volume balance. Using ranges of desired attractions in conjunction with percent error ranges, a graph is displayed of the cross classification of attraction zones by desired attraction volume and percent error of resulting attraction volume.
- Report Table A3 lists the total intra-zonal trips that resulted during the trip distribution process. The number of intra-zonal trips that occurred at each separation value listed in addition to the total number of intra-zonal trips.
- Report Table F1 provides a listing of all zones that comprise an individual sector. The centroid to sector equivalencies are output for all sectors.
- Report Table G1 presents a summary of the final production volume, attraction volume and intra-zonal volume for every zone.
- Report Table G2 is titled trip length frequency table. The table provides for each separation interval the total number of zone pairs, the number of interactions that occurred at each separation value, the actual interchange volume for each separation and the highest trip volume interchange at each separation value.
- Report Table G3 summarizes the number of zone pairs within each sector and between all sectors.
- Report Table G4 presents the number of interactions within each sector and between all sectors. Interactions are defined as nonzero interchange volumes.
- Report Table G5 summarizes the resulting trip volumes within each sector and between all sectors.
- Report Table G6 lists the number of interchanges within each sector and between all sectors.
- Report Table G7 provides a summary of the trip productions by sector and also lists the destination of the trip productions by sector.
- Report Table G8 provides a summary comparable to report table G7. Report table G8 however summarizes trip attractions by sector and also lists the origin sector from which the trip attractions originated.
- Report Table G9 summarizes the average trip length for each sector. The total number of productions and the corresponding average trip length is listed for each sector followed by the total number of attractions and the corresponding average trip length for the sector.
- Report Table L1 provides a comparison of the desired and resulting average trip length by iteration. For each model iteration except the last, the comparative listing is merely a summary comparison of the desired and resulting average. For the final iteration a comprehensive summary of the differences between desired and resulting trips for each separation value is also listed.
- Report Table S1 summarizes the desired and resulting attractions by sector for each model iteration.

- Report Table X1 provides a summary comparison of estimated versus modeled trip length frequency by ranges of separation values. The ranges are listed in ten unit increments.

2.4 Texas Package Utilities

There are two Texas Package utilities that are required in order for trip matrix files to be properly used as input and output files between ATOM2 and TransCAD. The two utilities are:

- Export matrix
- Import matrix

2.4.1 Export Matrix

For ATOM2 applications a separation matrix or travel time matrix is a required input file. The separation matrix that is created in TransCAD can be exported using the Export Matrix utility program. The Export Matrix utility is designed to allow the user to export either a separation matrix or trip table. When separation matrices are exported, the travel times are rounded to integer hundredths of a minute (e.g., a travel time of 11.45 minutes would be exported as 1145). When trip tables are exported the trips are rounded to integer trips (e.g., 34.2 trips are exported as 34 trips). The Export Matrix utility also provides the user with the option of exporting the matrix as either a binary file or an ASCII file. The binary file format is the standard format used in TxDOT-TPP models since the file sizes are much smaller than the ASCII files.

2.4.2 Import Matrix

Standard TxDOT-TPP practice is to create binary trip tables when applying the ATOM2 trip distribution model. Consequently, the binary trip tables must be converted prior to further use within a TransCAD environment. The Import Matrix utility offers the ability to import into TransCAD from one to 14 trip table files that are in binary format. The Import Matrix utility can also import from one to 14 trip table files in ASCII 3I8 format into TransCAD.

2.5 Texas Modeling Resources

Building on the prior discussion regarding current TxDOT modeling practice and the Texas Package synthesis, this final section of the report considers future Texas modeling needs. This is accomplished by taking into account the available TxDOT-TPP and MPO staff resources in conjunction with Texas MPO’s expectations for future model capabilities to support local planning efforts.

2.5.1 TxDOT Modeling Resources

TxDOT-TPP has 12 staff members that are assigned travel demand modeling responsibilities. Two of the 12 staff positions are supervisory team leader positions and are not directly involved in model development and application (one of the two team leader positions is currently vacant). These 12 individuals are also responsible for all of the corridor analysis work performed by TxDOT-TPP in addition to dedicated responsibilities in other related activities such as oversight of research projects and coordinating other model activities in the state, such as the Statewide Analysis Model (SAM) and working cooperatively with the El Paso MPO to update the El Paso TDM. Given the amount of additional commitments for which the 12 TxDOT-TPP staff members are responsible, only six full-time staff may be available to attend to one of the 22 urban area models at any one time.

This ratio of six staff for 22 models stands in stark contrast to the resources that a few of the larger Texas MPOs have dedicated to model development (ref. Table 2.36). The number of North Central Texas Council of Government (NCTCOG, the Dallas-Ft. Worth MPO) staff dedicated to modeling was not publicly available (and are thus not included in Table 2.36) but is considered to be comparable to or exceeding the number of modeling staff at Houston-Galveston Area Council (HGAC, The Houston region MPO). Though only a few Texas MPOs have staff responsible for model development or application, those that are involved in modeling activities have several staff members available for such work. In comparison, TxDOT-TPP's ratio equates to each staff person being responsible for a minimum of three models. TxDOT-TPP's staffing may initially appear to be untenable given the amount of study areas in the states; however, given the staggered count collection cycle and the fact that some MPOs periodically decide to opt out of model updates during each update cycle, the staff equity issue has not been of any historical consequence.

Table 2.36: Comparison of Modeling Staff Resources

Agency	**Modeling Staff**	**Staff/Model Ratio**
HGAC – Houston Galveston MPO	8	8.0
CAMPO – Austin MPO	3	3.0
San Antonio MPO	3	3.0
TxDOT-TPP	6	0.27

The amount of formal modeling experience among TxDOT-TPP staff ranges from one year to nearly 20 years with more than half the staff having 10 years or less of relevant experience. With regard to educational background, two of the 12 staff, or 17 percent of staff, have an advanced degree. Forty-two percent (5 of the 12) have an undergraduate degree and the remaining staff have completed some amount of undergraduate coursework or have a high school degree.

2.5.2 Texas Model Users Survey

The Center for Transportation Research (CTR) and the Texas Transportation Institute (TTI) conducted a survey of the 22 MPOs on behalf of TxDOT-TPP for which TxDOT-TPP provides model development assistance. The survey was aimed at determining how the travel demand models provided by TxDOT-TPP are currently utilized by Texas MPOs. In addition the survey attempted to elicit the MPO's current analytical requirements and agency expectations of the model to support local planning efforts. The survey was divided into three sections with questions addressing the following topics:

- *Current MPO model use*. The first section queried the MPOs to determine what planning activities are currently supported by the use of the model and how often the MPO uses the model to support those activities

- *Impediments to model usage*. The second set of questions focused on the extent to which various issues potentially hinder or prevent the MPO from using the model in support of local planning activities
- *Future MPO requirements or expectations*. The third set of questions was structured to elicit what expectations or requirements the MPOs have with regard to future model application.

It should be noted that the survey findings summarized below are based on a limited number of responses since only eight of the 22 MPOs surveyed responded and returned a completed questionnaire. This represents a response rate of only 36 percent. Based on such a limited response rate it is difficult to fully characterize the summary observations as completely indicative of all 22 MPO’s model uses or future expectations.

Figure 2.3, MPO Model Uses provides a summary of the responses to the first set of survey questions. Based on the survey responses it appears that there are approximately ten planning activities for which the MPOs use their model on a frequent basis; not surprisingly these ten activities can be characterized as the primary activities that are undertaken in support of regional long-range plan development. These activities include Transportation Improvement Plan (TIP) prioritization, evaluation of system enhancements, identification of system deficiencies, evaluation of transportation system levels of service, public involvement meetings, and actual long-range plan development.

It is interesting to note that a few activities that might be classified as supportive of assessing operational aspects of the transportation system tended to be grouped in the medium usage range. Those would include activities such as VMT and VHT analysis and travel time studies. Of further interest was the small percentage of respondents that reported a rather frequent use of the models to support traffic operations analysis.

With the exception of studying development impact fees, all of the model uses listed were identified as at least being intermittently undertaken by all the respondents. The five planning activities that garnered a high response of never being used (or minimally used by a few respondents) are undoubtedly a function of the urban area size, unavailability of alternate modes of travel and attainment status. The activities least used included air quality analysis, public transportation improvements, toll road and pricing studies, facility specific market analysis and high-occupancy vehicle (HOV) analyses.

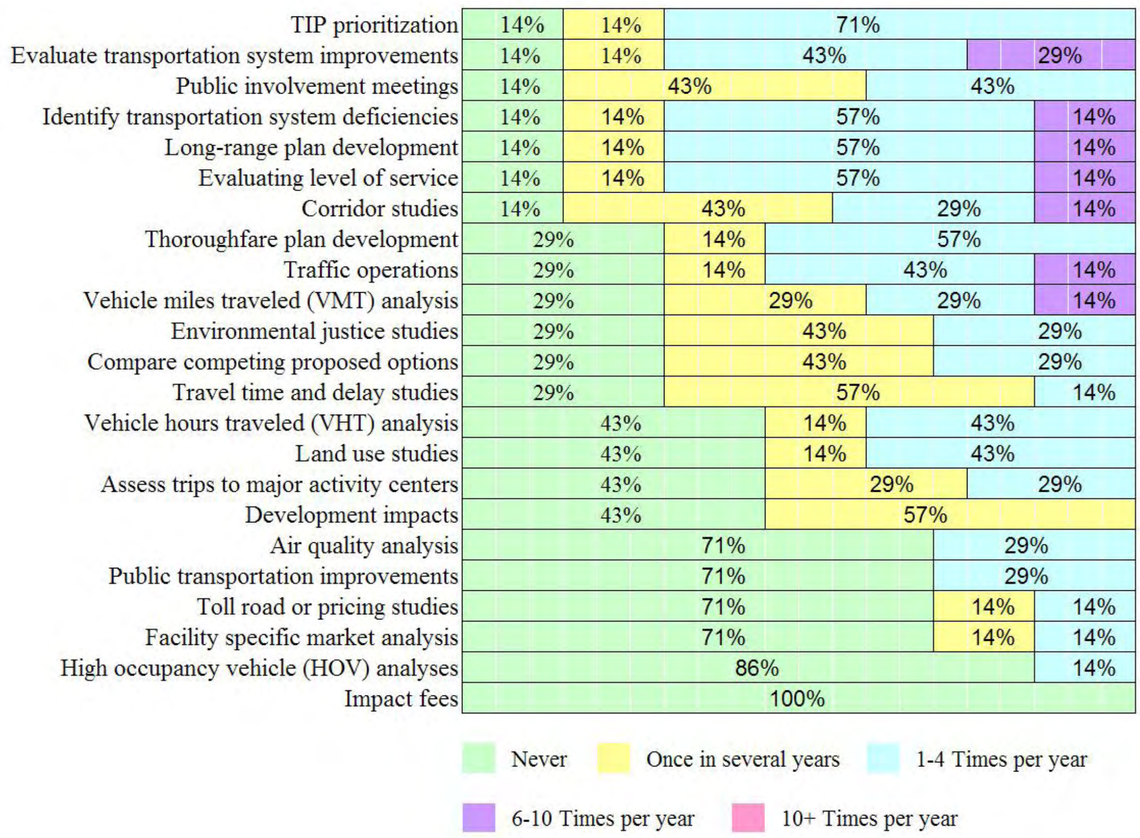

Figure 2.3: MPO Model Uses

The second section of the survey addressed impediments to model usage. As can be seen in Figure 2.4, the standout issue was the need for more training on the part of MPO staff. The need for additional training will not be a surprise to TxDOT-TPP staff as MPOs repeatedly request that TxDOT-TPP provide formal and informal training opportunities either before, during and after the models have been developed. As noted in section one of the report, TxDOT-TPP regularly provides on-site or regional training for MPOs. Alternatives analysis training tends to become more critical once the model has been delivered by TxDOT-TPP and the MPO is ready to utilize the tool to support the development of the long-range plan.

The continued need for travel demand model application training can be attributed to MPO staff turnover rates, lack of staff resources and lack of familiarity with the modeling process. Though TxDOT-TPP is continually aware of the need for additional training on the part of MPOs this issue and the others that are listed in Figure 2.4 as primary hindrances to using the model in support of local planning activities raise a cautionary flag regarding the implementation of more advanced models and whether many of the 22 MPOs will have the wherewithal to apply such a model. Of note are the staff skills and knowledge and model complexity categories that were viewed by many respondents as somewhat or a substantial hindrance. Moreover, the responses for model complexity and lack of model complexity tend to underscore that observation since 57 percent found that lack of model complexity was not a hindrance at all and only 43 percent thought it was somewhat of an impediment. However, 86 percent of the responses indicated that model complexity was somewhat of a hindrance and 14 percent indicated that it was a substantial impediment.

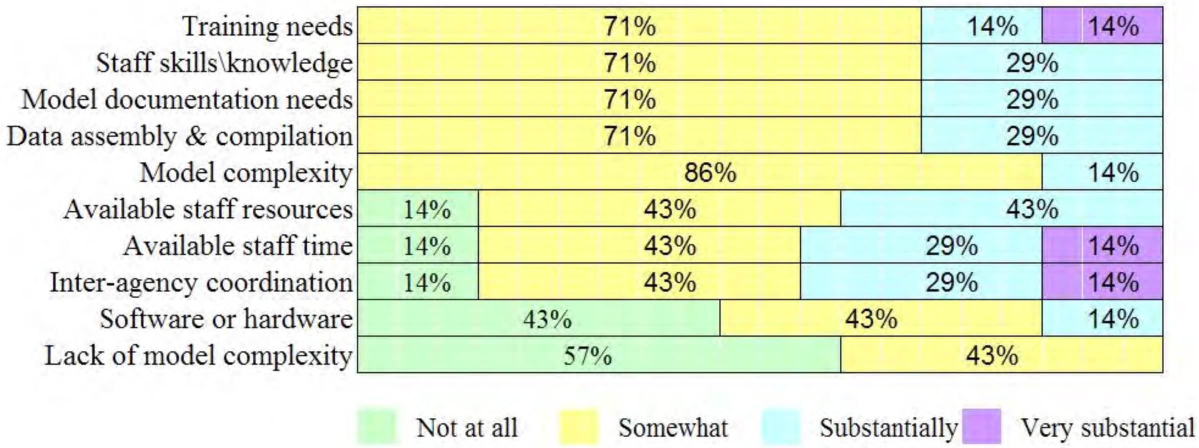

Figure 2.4: Impediments to Model Usage

The third survey section addressed MPO's expectations towards future model applications. Following are summary observations based on the survey results provided in Figure 2.5, Model Expectations.

- *Training needs*. The issue that elicited the highest amount of agreement was that additional training classes would assist MPO staff in using the model more frequently. A comparable issue that scored a significant amount of agreement is that the model is not used often enough for MPO staff to become proficient at using the model. There is obviously some correlation between those two issues.
- *Advanced model needs*. The second and third highest scoring issues in amount of agreement were that current models do not provide adequate information to support local policy issues and the need to explore advanced modeling methods. Taken together these two issues point to an MPO expectation of requiring more advanced models to support local planning efforts. One caveat to this observation is that there was also much agreement with the statement that if the model were easier to use or less complex then MPOs would use the model more often to support planning activities.
- *MPO resource needs*. With regard to MPOs not having the resources to apply their model on a regular basis, the responses were evenly split with 50 percent agreeing and 50 percent not agreeing.
- *MPO model uses*. Seventy-five percent of the respondents indicated that their model provides the necessary information to support local planning needs. In one sense this could be seen as contradicting the need for more advanced models; however, it more likely seems to echo the primary uses of the model indicated in section one of the survey.

2.5.3 Findings and Recommendations

The survey findings suggest that there is a keen interest on the part of Texas MPOs to explore the use of more advanced models. Based on survey responses it is apparent that a number of MPOs use their existing model to support local long-range planning activities. Thus, it can only be assumed that many of those same MPOs would take advantage of having a model that also supports the analysis of local policy issues.

That assessment though must also be tempered with the acknowledgement that many of the MPOs do not have the resources or experience to fully utilize the existing model as evidenced by the extent of survey responses suggesting that additional training was a much needed requirement. An additional constraint that should be kept in mind is TxDOT-TPP's lack of staff resources in relation to the number of models (22) and their overall workload. Though a more advanced model will not add to the overall modeling workload it more than likely will necessitate that TxDOT-TPP provide additional training and technical assistance to many Texas MPOs. That in turn may increase TxDOT-TPP's workload and further skew the already imbalanced ratio of staff to responsibilities. These cautionary observations imply that a lack of MPO and TxDOT-TPP resources may be an obstacle to wide-spread application of a tour-based model but should not however, impede the implementation of such a model framework.

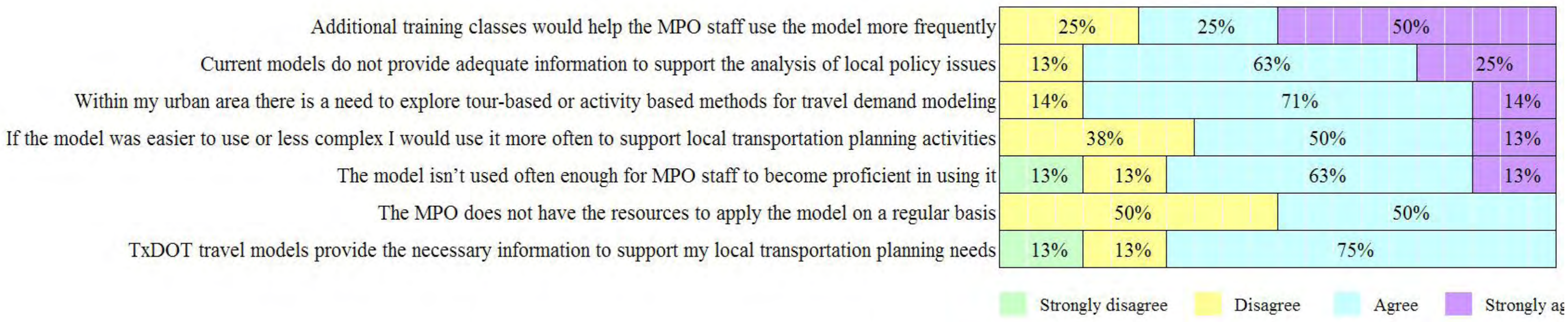

Figure 2.5: Model Expectations

The preceding review of the Texas Package and the current state of the modeling practice within Texas suggest that a more advanced model will better serve the future travel demand modeling needs of Texas MPOs and TxDOT-TPP. Moreover, it is recommended that the research into a practical implementation of a tour-based model proceed accordingly. The recommendation to further investigate the means for implementing a tour-based model is based on several reasons, all of which emanate from prior discussion:

- *The collaborative process*. The cooperative relationship between TxDOT-TPP and the MPOs that it assists necessitates that TxDOT-TPP be receptive to MPO's technical needs and requirements in order for the relationship to remain successful and viable. The preliminary survey findings suggest that Texas MPOs are indeed interested in having a model that can support that assessment of various proposed policies. If TxDOT-TPP does not acknowledge and respond to those technical needs then it will potentially begin to erode a collaborative process that has been rather successful for nearly forty years.

- *TxDOT's leadership role*. As noted previously, TxDOT has been one of the leading travel model practitioners as evidenced by their record of continual TDM enhancements during the previous three decades. Given that history, it is apparent that TxDOT-TPP has understood the importance and the benefits that are derived from continually improving their modeling procedures. Implementation of an advanced model structure does not imply that all 22 MPO models will be required to adhere to such a structure; however, it would provide TxDOT-TPP the ability and flexibility to model policy issues when needed. Consequently, implementation of a tour-based model can be viewed as a logical progression of TxDOT-TPP's record of TDM enhancements.

- *The future role of travel models*. Given current trends, it appears reasonable to assume that the future emphasis in transportation systems will be focused less on growth and improvements and more on managing and maintaining the existing system. In such an environment travel models will increasingly be called upon to assess complex policy issues instead of the traditional "predict and provide" role of previous eras. Thus, it will be to TxDOT-TPP's benefit and interest to have a model structure that can accommodate such an environment.

Chapter 3. A Review of Current Tour-based Travel Demand Models

3.1 Introduction

This chapter provides a brief review of the tour-based models in practice and under development in general, and then examines four of these models in particular.[2] These four tour-based models are:

(1) The SF-CHAMP Model (developed for SFCTA),

(2) The MORPC Model (developed for MORPC),

(3) The SACSIM Model (developed for SACOG), and

(4) The NYBPM Model (developed for NYMTC).

The chapter examines the above four models in terms of their alternative conceptual structures, decision sequencing processes, inputs and outputs, model components, and the calibration and validation process. The report also includes information on the software platform used, practical applications, and lessons learned for each of the four models. Unfortunately, the research team is unable to find information on development/implementation costs for the models. However, informal investigations reveal that, depending on study area and complexity of the model, budget resources required for a tour-based model development could range from $1 million to $1.4 million (Transportation Research Board of the National Academies (2007) Special Report 288). But, in the case of TP&P, there can be considerable economies of scale since the tour-based modeling approach can be applied to multiple urban areas under TP&Ps modeling jurisdiction with relatively little overhead to populate the model with local data and parameters.

The rest of this chapter is structured as follows. Section 3.2 presents a review of the tour-based models in general. Sections 3.3, 3.4, 3.5, and 3.6 are devoted to a thorough overview of the SF-CHAMP, MORPC, SACSIM, and NYBPM systems, respectively. Section 3.7 concludes the report with a summary and discussion.

3.2 A Review of Tour-based Models in Practice

Before proceeding to a detailed overview of the four tour-based models, this section provides a general overview of tour-based models. In this regard, Table 3.1 provides a summary of the tour-based models developed in the U.S. [3]

Most of the tour-based models can be classified into two categories, based on their representation frameworks: (1) Tour-based representation with no recognition of the interactions among tours, and (2) Tour-based representation with explicit recognition of the interactions among tours. In both the approaches, the linkages among the trips within a tour are recognized. However, in the former approach, different tours of a person on a day are treated independently

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[2] The report does not consider activity-based efforts such as CEMDAP (developed for the Dallas Fort-Worth area) and FAMOS (developed for the Tampa Bay area) that (a) focus on activities as the fundamental driving force for travel, (b) consider extensive space-time interactions over the entire day (or other time units), and (c) use a continuous time-scale for analysis.

[3] Table 2.1 is, in part, borrowed from Bradley and Bowman (2006).

of each other, and in the latter approach the linkages among the tours and trips made by a person on a day are recognized in some fashion. Only the New Hampshire model, which is the only statewide model, falls under the first category. All the other models in Table 3.1 fall under the second category.

The Portland Metro model (listed first in Table 3.1) is the first model to be implemented and used for policy analysis. The model follows the full-day activity schedule approach developed by Bowman and Ben-Akiva (1996) and provides as output a one-day activity and travel schedule for each person in the population. However, the model was never fully calibrated and was used only once before being discontinued. The San Francisco model (SF-CHAMP) was developed following the same design framework as in the Portland model. This model is the first to be calibrated and has been in use since its development. The Sacramento model (SACSIM) also employs the Bowman and Ben-Akiva approach. SACSIM is the first model to introduce parcel level spatial resolution in the modeling framework. In the New York model (NYBPM), a different approach was used for integrating the tour models. The tour purpose for each individual in a household was simulated first, making tour choice explicitly dependent on tour purpose and other individuals in the household. The time of day model in NYBPM has a simple framework, based on a set of predetermined time-of-day distribution. The Ohio model (MORPC) first adopted the NYBPM framework, but then enhanced it substantially with a strong emphasis on implementation of joint activities linked explicitly across household members as well as modeling time of day at a high temporal resolution. The remaining models in Table 3.1 are in various stages of development. The design of Atlanta model is based on the MORPC model with a flexible population synthesizer and other innovations. The DRCOG, MTC, and Lake Tahoe models are also based on the MORPC framework.

Table 3.1: Summary Information on Tour-Based Travel Demand Model Systems (in use and under development in USA)

	MODEL									
ASPECT	**Portland Metro – Tour-Based Model (third version)**	**SF-CHAMP**	**SACSIM**	**New York Best Practices Model (NYBPM)**	**MORPC**	**The New Hampshire Statewide Travel Model System (NHSTMS)**	**Atlanta Regional Commission (ARC) Travel Demand Model**	**DRCOG**	**Bay Area MTC**	**Tahoe Model**
MPO	Portland Metro	San Francisco County Transportation Authority	Sacramento Area Council of Governments	New York Metropolitan Transportation Council (NYMTC)	Mid-Ohio Regional Planning Commission		Atlanta Regional Commission (ARC)	Denver Regional Council of Governments (DRCOG)	Metropolitan Transportation Commission (MTC) (San Francisco Bay Area)	Tahoe Regional Planning Agency
Region	Portland, Oregon	San Francisco County, CA	Sacramento, CA	New York	Columbus, Ohio	New Hampshire	Atlanta, Georgia	Denver, Colorado	San Francisco County, CA	California and Nevada
Base year	1994	1998	2000	1996, updated in 2002	2000	1990	2000	1997	2000	2004
Population in base year		0.3 Million Households	0.7 Million Households	9 Million Households	0.6 Million Households					
		0.8 Million Individuals	1.8 Million Individuals	20 Million Individuals	1.4 Million Individuals					55,000 individuals

	MODEL									
ASPECT	**Portland Metro – Tour-Based Model (third version)**	**SF-CHAMP**	**SACSIM**	**New York Best Practices Model (NYBPM)**	**MORPC**	**The New Hampshire Statewide Travel Model System (NHSTMS)**	**Atlanta Regional Commission (ARC) Travel Demand Model**	**DRCOG**	**Bay Area MTC**	**Tahoe Model**
Model estimation data	In 1994 roughly 5,000 HHs (giving more than 10,000 persons) were surveyed in Portland and surrounding counties. A number of stated preference experiments were also carried out.	1990 SF Bay Area Household Travel Survey Data of 1,100 HHs on SF County, stated preference survey of 609Hs for transit related preferences.	Household activity diary survey	1997/98 Household travel survey data of 11,263 HHs located in 28 counties in New York, New Jersey, and Connecticut.	1999 Household travel survey data of 5,500 HHs in the Columbus region, on-board transit survey data.	New Hampshire Activities and Travel Survey of 2,844 HHs in New Hampshire conducted between August 1994 and June 1995, and onboard transit survey.	2001 Atlanta Regional Commission's (ARC) household travel survey data of 8,069 HHs.	1997 Denver home-interview survey of 4,196 households, the onboard transit survey of 677 households, a commercial vehicle survey, and an external station survey.	Bay Area Travel Survey 2000 (BATS2000)	2004 Lake Tahoe Origin Destination Survey
Network zones (TAZs)	approximately 10,000 zones	1,900	1,300	3,586	2,000	Zones followed municipal boundaries, each city and town represented by 1 to 21 zones	2,500	2,800	1,600	282
Use of time window duration in scheduling	No	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes

ASPECT	MODEL: Portland Metro – Tour-Based Model (third version)	SF-CHAMP	SACSIM	New York Best Practices Model (NYBPM)	MORPC	The New Hampshire Statewide Travel Model System (NHSTMS)	Atlanta Regional Commission (ARC) Travel Demand Model	DRCOG	Bay Area MTC	Tahoe Model
Explicit modeling of interactions between activity patterns of household members?	No	No	No	No	Yes	No	Yes	Yes	Yes	Yes
Network time periods	5 time periods	5 per day	4 per day	4 time periods	5 per day	4 time periods	4 time periods	8 time periods	5 time periods	5 per day
Predicted time periods	5 time periods	5 per day	30 min	4 time periods	1 hour	4 time periods	1 hour periods	most likely 30 min	most likely 30 min	1 hour
Status of the model	Not in use (the model was never calibrated or validated)	In use	In use	In use	In use	In use	Expected to be completed in 2009	Under development	Expected to be completed in 2009	In use
References	Bowman *et al*. (1998), Bradley *et al.* (1998), Bradley *et al.* (1999)	Cambridge Systematics (2002)	Bowman and Bradley (2005-2006), Bowman and Bradley (2005), Bowman *et. al*. (2006), Bradley *et al*. (2007)	PB Consult (2005)	PB Consult (2005)	Hampshire Department of Transportation, and Cambridge Systematics	PB Consult (2004)	In-house and Cambridge Systematics (prime consultant)	PB Consult (prime consultant)	PB Consult

3.3 The SF-CHAMP Model

3.3.1 General Background and Overview

The SF-CHAMP (San Francisco County Chained Activity Modeling Process) is a tour-based travel demand model system that was developed for the San Francisco County Transportation Authority (SFCTA) for regional travel demand modeling purposes in the County. The model development and calibration was carried out for the base year 1998 using household travel data from San Francisco area households collected as part of the 1990 MTC (Metropolitan Transportation Commission) Bay Area Travel Survey (BATS).

The SF-CHAMP model system starts with a population synthesizer which takes the U.S. Census Public Use Microdata Sample (PUMS), the population and employment data developed for San Francisco County, and other socioeconomic data developed for the MTC as inputs, and creates a synthetic population of households drawn from the PUMS and allocated to the Traffic Analysis Zones (TAZs).[4] The control variables used to create the synthetic population include: household size, number of workers, household income, and age of the household head. The output from the population synthesizer comprises a list of synthetic households (and individuals) in each TAZ with information on all the control variables. Information on other sociodemographics is obtained by matching each of the synthetic households to similar households from the PUMS. The synthetic households and individuals are then ready to be input to the subsequent models.

The synthesized population of San Francisco residents is input to estimate choices for work location, vehicle availability, and tours and trips by time-of-day, destination, and mode of travel. The predicted trips are aggregated into Origin-Destination (OD) trip tables by time-of-day and mode to represent flows between each pair of traffic analysis zones in the San Francisco (SF) County. These OD tables are combined with a visitor trip OD table obtained from a set of visitor models to SF County, and the OD tables of the rest of the population of the Bay Area (obtained from MTC's BAYCAST trip tables)[5]. These trip tables are loaded into network traffic assignment (for highway and transit) procedures that load the trips onto the network to provide traffic link volumes by mode and time-of-day.

3.3.2 Structure of the Travel Model System

Figure 3.1 depicts the sequence in which travel decisions are modeled in the SF-CHAMP model system. After the generation of synthetic population and other sociodemographics, long-term choices are simulated for all households and individuals in the population. The long-term choices for each household include the workplace location choices of all individuals in the household and the household-level auto ownership choice, applied in that order. Details of the work location model and the auto ownership model, including the model structure, choice alternatives, and the policy sensitivity variables in the specification, are provided in Table 3.2 (see rows labeled 1.2 and 1.3). Subsequent to the determination of work place location and auto ownership, each synthetic household (and individual) is passed through a number of tour-travel

[4] There are 1,739 zones in the full spatial system of the San Francisco Bay Area, of which 766 zones belong to SF County.
[5] The BAYCAST model is used to predict travel by residents from the eight counties other than the SF County in the Bay Area.

choice models, whose details are provided in rows 2.1 through 4.2 of Table 3.2. These models follow the full-day activity schedule approach developed by Bowman ad Ben-Akiva (2001) and provide as output a one-day activity and travel schedule for each person in the population, including a list of tours, and the trips on each tour.

The overall tour-travel modeling system of SF-CHAMP model can be broken down into 3 levels of hierarchy:

(1) Full-day tour pattern generation and time-of-day choice models,

(2) Tour-level destination and mode choice models, and

(3) Trip-level destination and mode choice models.

First, the full-day tour pattern *generation* and *time-of-day* choice models are used to predict the main dimensions of a person's travel across the day. These include the frequency of five tour types (home-based work primary tours, home-based education primary tours, home-based other primary tours, home-based secondary tours, and work-based tours), number of trip segments within each tour, and the timing decisions of all tours and trips. The corresponding model components from rows 2.1 through 2.8 in Table 3.2 provide further details, and the order in which these attributes are generated. Second, the tour-level destination and mode choice models (see rows 3.1 and 3.2 of Table 3.2) are used to determine the primary destinations of all non-work tours, and the primary modes used to travel for all work and non-work tours. Third, the trip-level destination and mode choice models (see rows 4.1 and 4.2 of Table 3.2) are used to determine the locations and modes of intermediate stops in all the tours, conditional upon the tour-level origin and destination, and mode choice. At the end of the tour-travel model system, the outputs include a full-day travel agenda, with a list of all tours and trips, and their schedule attributes (timings, destinations, and modes), for all individuals in a household. The tour-travel model system is applied, in succession, to each (and every) synthetic household to obtain the full-day travel information for all individuals in the population. The final output is essentially a simulated trip diary, which can be aggregated into trip tables for highway and transit assignment, and can also be used for several policy analyses.

An important aspect of this model system is the use of log-sums from tour-level mode choice models (i.e., the sum of the exponents of the individual modal utilities) to inform work location choice and non-work tour destination choices. The use of log-sum variables enhances the sensitivity of location choices to level-of-service attributes. Another salient feature of the model system is the incorporation of a visitor modeling system (see rows 5.1 through 5.4 of Table 3.2).

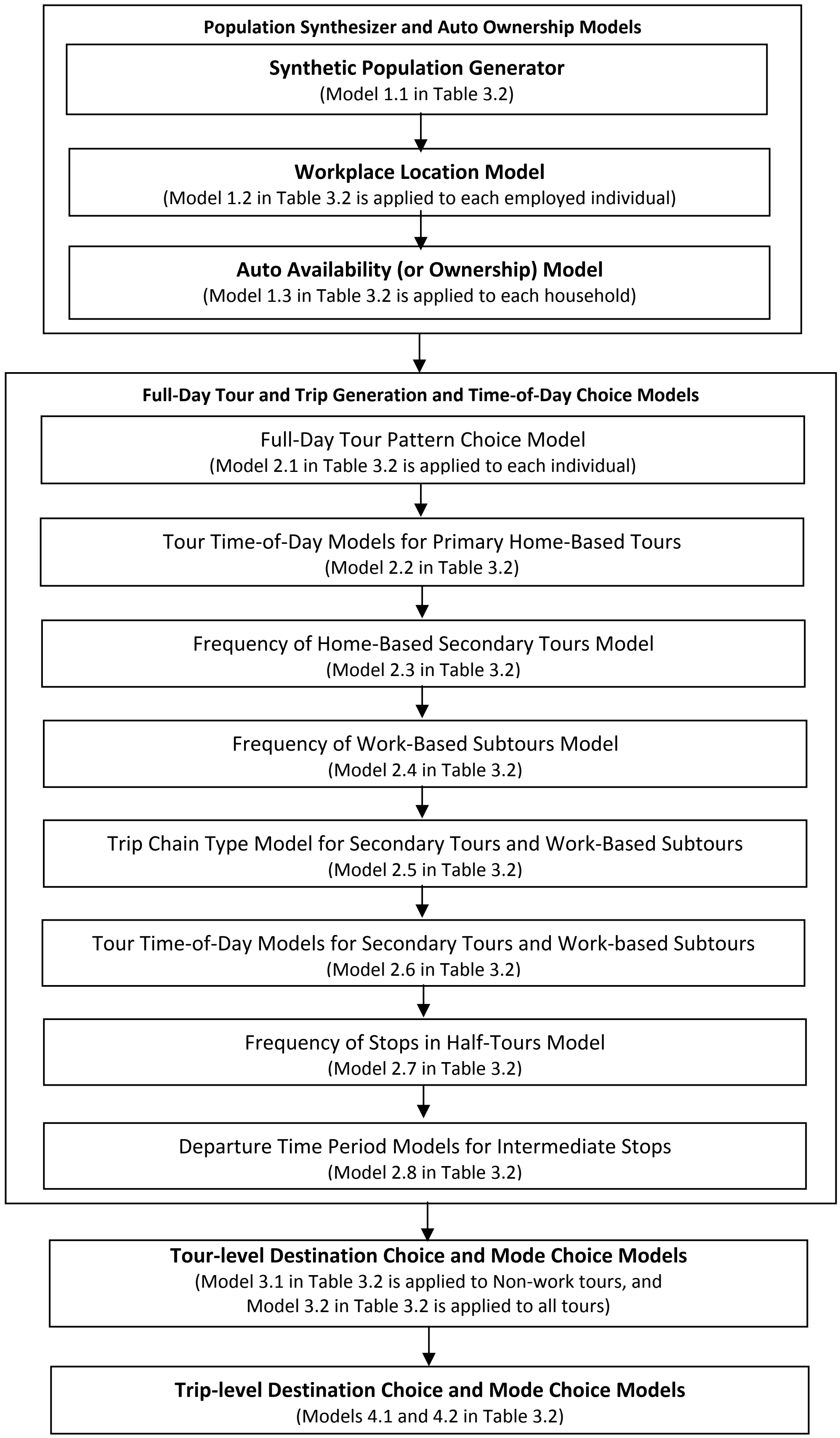

Figure 3.1: Structure of the SF-CHAMP Model System

Table 3.2: List and Sequence of Activity-Travel Choices Modeled in the SF-CHAMP Model

Model ID	Model Name and Outcome	Model Structure	Choice Alternatives	Comments/Policy Sensitive Variables
Population synthesizer and auto ownership models: Generate the disaggregate-level socio-demographic inputs consisting of individual and household records with residential locations, other socio demographics, and auto ownership levels.				
1.1	Synthetic population generator: Predicts household size, age of household head, number of workers, and income, along with the zonal-level location of the household	Iterative proportion fitting (IPF)	N/A	Household size, age of household head, number of workers, and income are used as control variables in the IPF procedure.
1.2	Workplace location model: Predicts the work location zone	MNL	Residence zone, and a stratified importance sample of 40 TAZs from the 1,739 TAZs in the San Francisco Bay Area	Area type, level-of-service, employment by type (cultural/institutional/educational, medical/health, management/professional, retail/entertainment, service, production/distribution/repair), Pre-calculated mode choice log-sums for an AM-PM peak work tour with no stops.
1.3	Auto availability (or ownership) model: Predicts the number of vehicles available to household drivers	MNL	0, 1, 2, 3+	Maximum travel time to work in the household, transit/auto accessibility ratio, work zone parking costs
Full-day tour and trip generation and time-of-day choice models: Predicts, for each person, the number of tours of different types on a day, number of trip segments within each tour, and the time period in which each trip segment stats. (Tour types are: home-based work, home-based education, home-based other, home-based secondary, and work-based). Models estimated and applied separately for 4 person types: Children, Working adults, Student adults, and Other adults.				
2.1	Full-day tour pattern choice model (segmented by person type: working adults, students/children, and other adults): Jointly predicts several dimensions, including the purpose of primary tour, trip chain type of the primary tour, frequency of home-based secondary tours, and frequency of work-based sub tours	Multidimensional MNL or NL with utility components for each dimension being modeled	Feasible combinations of work/education/other/no primary tour type, and its trip chain type (stops before/after primary destination, neither, both), 0,1, 2+ home-based secondary tours, 0 or 1+ work-based tours. Base alt is “Stay at home”	(1) Accessibility to retail and service locations (within 15 minutes, and half mile) from home and work
2.2	Tour time-of-day models for primary home-based tours: Jointly predicts the departure time from home and the departure time from the primary destination to return home.	MNL	Combinations of start time from home and start time from main destination with the following 5 time periods: Early(3-6am), AM peak(6-9am), Midday(9am-3:30pm), PM peak(3:30-6:30pm), Late (6:30-3am)	(1) Network accessibility to employment by auto and transit in work tours, (2) network accessibility to service employment in education tours, (3) network accessibility to retail and service employment in other tours
2.3	Frequency of home-based secondary tours	Probability model based on observed distributions	2, 3, or 4+	Probability model is a function of the primary tour pattern type predicted from model 2.1. Applied for those patterns with 2+ secondary tours
2.4	Frequency of work-based subtours	Probability model based on observed distributions	1, 2, 3, or 4	Probability model is a function of tour trip chain type, and no of secondary tours. Applied for patterns with 1+ work-based subtours

Model ID	Model Name and Outcome	Model Structure	Choice Alternatives	Comments/Policy Sensitive Variables
2.5	Trip chain type model for secondary tours and work-based subtours	Probability model based on observed distributions	intermediate stops: 1+ stops before/after primary destination, 1+ stops both before and after primary destination, no stops	Probability model is a function of primary tour purpose and trip chain type. Applied for each home-based secondary tour and work-based tour
2.6	Tour time-of-day models for secondary tours and work-based subtours: Jointly predicts the departure time from home and the return home departure time from primary destination.	Probability model based on observed distributions	Combinations of 5 Time periods as in model 2.2, but within available time windows based on primary tour timings	Probability model is a function of tour purpose and primary tour time period combination. Applied for each secondary tour and work-based subtour
2.7	Frequency of stops in Half-tours	Probability model based on observed distributions	1, 2, 3, or 4+ stops	Probability model is a function of tour purpose, and trip chain type. Applied for any half-tour with 1+ intermediate stops
2.8	Departure time period models for intermediate stops (in half-tours segmented by tour types: home-based work, school and other tours, and in work-based subtours): Predicts departure time period to and from that stop	Probability model based on observed distributions	Combinations of 5 Time periods as in model 2.2, but within available time windows based on tour timings	Probability model is a function of tour purpose, tour time period combination, and stop sequence number. Applied for each intermediate stop in all half-tours
Tour-level destination choice and mode choice models (Models estimated and applied separately for each tour type)				
3.1	Non-work tour-level primary destination choice models (all tour types except home-based work primary tours) Note: Home-based work primary tour destination choice model is used to determine work location in row 1.2. Home-based education, home-based other primary, home-based secondary, and work-based sub tour location choice models are used to determine non-work tour primary destinations	MNL	Stratified importance sample of 40 TAZs from the 1,739 TAZs in the San Francisco Bay Area	Area type, level-of-service, and zonal employment by type specific to tour purpose (cultural/institutional/educational, medical/health, management /professional, retail/entertainment, service, production/distribution/repair), and school/college enrollment of potential destination zones, area size, tour mode choice log-sums to potential destinations
3.2	Tour-level mode choice models (for all tours): Predict the primary mode for the tour, conditional upon the tours and trips generated along with the timing and tour destination choices determined using the models above (except the trip-based destination choice model 3.2)	NL with auto, non-motorized, and transit nests	Drive Alone, Shared-Ride 2, Shared-Ride 3+, Walk, Bike, Walk-Local-Walk, Walk-MUNI Metro-Walk, Walk-Premium-Walk, Walk-Premium-Auto, Auto-Premium-Walk, Walk-BART-Walk, Walk-BART-Auto, Auto-BART-Walk (total 13 alts)	Level-of-service and built environment factors (network connectivity, safety, vitality, topology, walking ease) of tour origin and primary destination. number of transfers, number of stops, constrained negative coefficients on parking cost and transit cost (= out of pocket cost coefficient)
Trip-level destination choice and mode choice models (Models estimated and applied separately for each tour type)				
4.1	Trip-level destination choice models (for all tours): Predict the intermediate stop location conditional on the origin and tour primary destination	MNL	Stratified importance sample of 40 TAZs from the 1,739 TAZs in the San Francisco Bay Area	Employment by type (note: trip purpose is unknown here), level-of-service by auto mode, and indicators for the TAZs belonging to Origin/Destination zones, and San Francisco and other counties

Model ID	Model Name and Outcome	Model Structure	Choice Alternatives	Comments/Policy Sensitive Variables
4.2	Trip-level mode choice models (for all tours) : Predict the mode for each individual trip made on the tour, based on the primary mode chosen for the tour	NL with auto, non-motorized, walk-transit, bike-transit nests	Selected trip mode alternatives based on the tour mode. *e.g.*, trips in a bike tour, has only bike or walk as available modal alternatives	Level-of-service (linear and non-linear specifications) and built environment factors same as above, but of trip origin and destination.
Visitor models				
5.1	Trip generation model: predicts trip generations and origins	--	--	Uses the number of hotel rooms in each TAZ, and an estimate of visitor party size per room to predict visitor trip generations and origins.
5.2	Destination choice model: Predicts the number of visitor trips to each destination (hence it can be viewed as a combined trip generation and distribution model)	MNL	29 tourist attraction regions	Predicts the number of visitor trips to each destination by multiplying the number of hotel rooms by the utility equation for each destination. Variables in the model include region specific alternative specific constants and mode choice log-sums of the Honolulu mode choice model calibrated to meet the San Francisco visitor mode shares.
5.3	Mode choice model	MNL	Auto, Transit, Walk	Due to the lack of data, the Honolulu mode choice model was used. The tourist markets in San Francisco and Honolulu are assumed to be similar.
5.4	Time-of-day model	Simple time-of-day factors	Early AM, AM Peak, Midday, PM peak, Evening	The time-of-day factors (by mode) were available from traffic count data at tourist destinations in San Francisco

3.3.3 Data

The SF-CHAMP model development and calibration was carried out for the base year 1998 using travel data from San Francisco households surveyed as part of the 1990 MTC (Metropolitan Transportation Commission) Bay Area Travel Survey (BATS).[6] In addition, a stated preference survey was conducted (for 609 households in June 1999) to augment the BATS data for mode choice model estimation. Specifically, the stated preference survey data provided travelers' preferences pertaining to transit reliability, crowding and personal security, and auto availability, and cost. The visitor models were developed using the San Francisco Hotel Guest Survey conducted in 1998 and San Francisco Visitor Demographics Survey conducted in 1995, in both of which the respondents identified all tourist attractions visited during their stay in the city.

Other data sources used in model development and application included the (1) zonal-level socioeconomic and land-use data and (2) transportation network level-of-service data. The zonal-level socioeconomic data included employment by six types (cultural / institutional / educational services, medical/health services, management/information/professional services, production/distribution/repair, retail/entertainment, and visitor), and were developed from parcel-level data, aggregated to TAZs and adjusted to match control totals.[7] The land-use data included pedestrian environment factors (such as network connectivity, ease of street crossing, perception of safety, urban vitality, and topology), parking data (parking availability index, and average parking cost for work and other trips), hotel and school data (number of hotel rooms, school enrollment, college enrollment, number of school buildings, and school area), and area type (CBD, UBD, urban, suburban, and rural). In addition to the socioeconomic and land-use data, the zonal data included zonal-level accessibility variables such as accessibility to different types of employment within specific time intervals and log-sum accessibility variables calculated from mode choice model estimates. The transportation network level-of-service variables included auto and transit times during AM, midday, PM, and evening time periods.

In addition to the zonal-level land-use, socioeconomic and accessibility data and transportation level-of-service data, the SF-CHAMP model requires disaggregate-level sociodemographic inputs with detailed sociodemographic information on each and every individual and household in the SF County. Hence, as described in Section 3.3.1, persons and households were generated for San Francisco County using a population synthesis procedure.

3.3.4 Calibration and Validation

The SF-CHAMP model calibration and validation was carried out at two levels: travel behavior validation and trip assignment validation.

Travel behavior validation was carried out by comparing travel data in the household travel survey to the predicted travel patterns of the surveyed respondents using the SF-CHAMP model. Further, the models were calibrated using various other observed data sources, including the decennial census, observed traffic counts and transit ridership, and vehicle registrations. This

[6] A 1996 MTC Survey data was eventually used for calibration to adjust for the under-reporting of trips that occurred in the 1990 survey.

[7] The San Francisco Planning Department provided a parcel database (with 152,535 parcels in San Francisco) and a business and employment database reflecting conditions in San Francisco as of April - June 1998. The Association of Bay Area Governments' *Projections '98* was used as a control total for countywide forecasts of population and employment.

effort involved calibrating each model separately, then reviewing highway and transit assignment results for each of the five time periods to make additional adjustments in the model components. The adjustments were all made to constants within the models; there were no adjustments to model coefficients.

The work location model was evaluated by comparing the employment estimates from the work location model to actual employment by TAZ. The vehicle availability (or ownership) model was calibrated using the 1990 census (as a primary reference) and the Department of Motor Vehicle (DMV) estimates of auto registrations. The full-day pattern tour models (estimated using the 1990 BATS data) were adjusted to account for the under-reporting of trips in the 1990 BATS data with the help of a 1996 MTC survey data of San Francisco Bay Area residents (expanded to match the 1998 population). The tour-level destination choice models were calibrated against the 1990 MTC survey data for primary destinations by purpose and trip length frequency distributions. Intermediate stop choice models were validated by reviewing the total tour length by tour purpose compared to the observed values in the 1990 MTC survey data. The mode choice models (for tours and trips) for each tour purpose were calibrated by adjusting the alternative specific constants to match observed modal shares from the 1990 MTC Household Survey. Tour mode choice models were first calibrated to match tours by mode and market segment, and then trip models were calibrated to match trips by trip mode and tour mode. Subsequently, the traffic assignment results were compared to observed traffic counts and transit boardings. Census journey-to-work data was also used as a reference for comparing transit share of work tours.

Traffic assignment validation was carried out separately for highway and transit modes using observed traffic counts and transit boardings, respectively. Assignment validation at the county level was completed using aggregated volumes by corridor (identified by screenlines), type of service (facility type, mode or operator), size (volume group), and time period.

3.3.5 Software

The tour-based models were incorporated into the SF-CHAMP model system as a series of C^{++} programs, while the visitor models and the highway/transit assignments were implemented with a pre-existing software package (TP+).

The initial implementation of the SF-CHAMP model took 36 hours to run. But, with parallel processing, it is possible to reduce the run time to just under 12 hours.

3.3.6 Application Experience and Sensitivity Tests

The SF-CHAMP model was developed in the period 2000-2001. Since its development, the model has been used to assess and evaluate a number of projects, including:

- New Central Subway light rail transit project (used to calculate user benefits for an FTA New Starts application) and an alternative analysis for the Geary Study.
- County long range transportation plan (used in an equity analysis where the model was used to estimate benefits and impacts to different communities of concern at a disaggregate level (i.e. person level)).
- Corridor and neighborhood level analysis, with detailed transit assignment and traffic simulation. For example, in a recent study, disaggregate model outputs were

used to explore the differences between travel patterns of Tenderloin residents (predominantly low-income) and other neighborhoods.

- Environmental Justice (EJ) analysis.
- Downtown cordon/area time-of-day pricing analysis (in progress).
- Comparison of the base year model with the trip based model.
- Comparison of the 2030 forecast year model with the trip based forecast year model.

3.3.7 Challenges/Lessons Learned

Some of the challenges/lessons learned in the process of the development and implementation of the SF-CHAMP model include:

- Provide firm commitment, in terms of resources, to develop the model properly.
- It would be useful to have specific milestones in the workplan.
- Having a schedule for completion is important (but be aware/prepared that it is probably going to take twice as long as initially envisioned).
- Establish a system of "point releases" of code that is workable and testable. It should be separate from regular development updates.

3.4 The MORPC Model

3.4.1 General Background and Overview

The MORPC tour-based model system was developed for the Mid Ohio Regional Planning Commission, the MPO for Columbus, Ohio. The model development and calibration was carried out for the year 2000, using household travel data from 5555 households in a Household Interview Survey (HIS) in 1999.

Figure 3.2 outlines the MORPC model system. The system comprises of a population synthesizer, a core set of activity-travel choice models (labeled as the core demand models), and the following auxiliary models and procedures to serve the core models, providing inputs to them or transforming their outputs:

1. Pre-calculated location attractors that represent size variables (functions of employment, school enrollment, and population) for destination choice models.
2. Accessibility measures calculated (based on land-use attributes and travel times) at each iteration after network processing and skimming.
3. Free-parking eligibility model that "tags" each person as either eligible for free parking in the CBD area or not.
4. Parking location choice model that chooses the actual parking location of each auto trip to the CBD area.

5. External (to and from external zones) traffic trip tables, and heavy and light truck trip tables for each time-of- day period that are modeled outside the core demand model, and added (before traffic assignment) to the trip tables from core demand model.
6. The highway and transit network assignment and skimming procedures which take the trip tables as inputs and provide the traffic volumes and level-of-service skims as outputs ready to be input to the core demand model for next iteration.

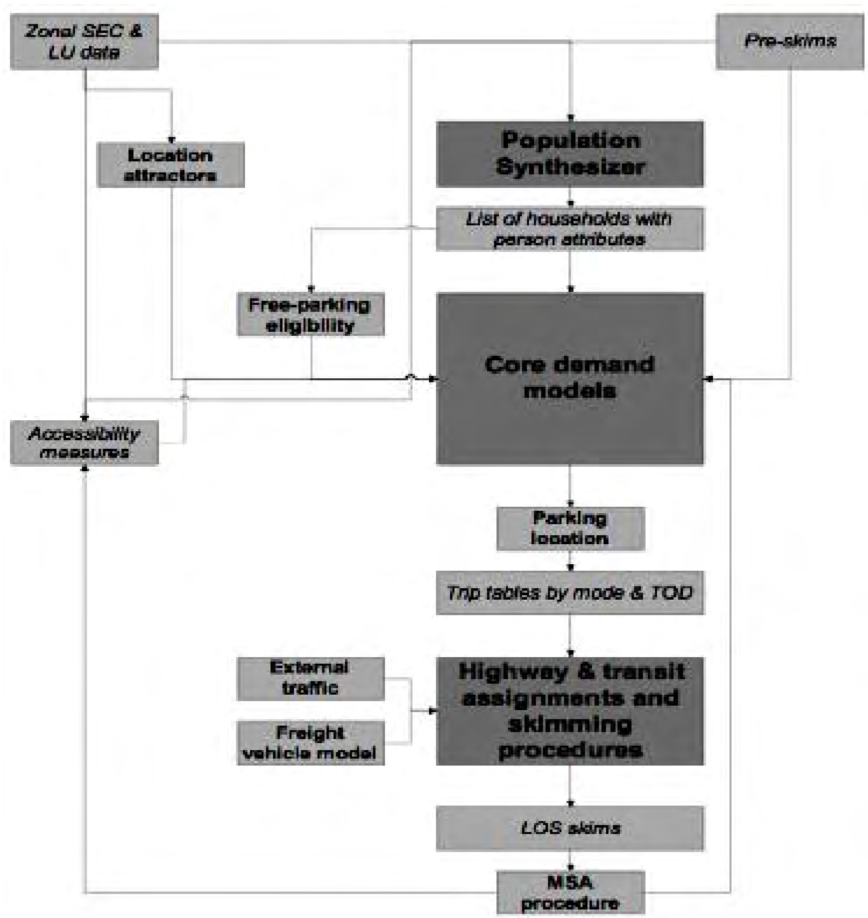

Figure 3.2: The MORPC Model System (from PB Consult, 2005)

The MORPC model system starts with a population synthesizer (labeled as PopSyn) which takes the zonal-level socioeconomic and land-use data (total population, number of households, labor force participation, and average household income) as inputs, and creates a synthetic population of households drawn from PUMS allocated to TAZs. The control variables used to create the synthetic population included: household size, number of workers, and income. The PopSyn outcome consists of a list of synthetic households (and individuals) in each TAZ with information on the control variables. Information on other sociodemographics, such as full-time and part-time workers, and students, is obtained by matching each of the synthetic households to similar households from PUMS.

The population of synthetic households and individuals is now ready for input to the core demand models. Other inputs to the core demand models are the TAZ level socioeconomic and land-use data, the network level-of-service data (pre-skim LOS data for the first iteration, and network assignment output LOS skims in the subsequent iterations), and other auxiliary data such as the location attractor variables, and the accessibility variables. The core demand models provide as outputs all the torus and trips undertaken by each (and every) individual in the synthetic population on the travel day, along with the information on the mode and timing, and the accompanying persons (if, any) for each trip. This information is aggregated into origin-destination trip tables for four time periods. These trip tables are augmented with external traffic trip tables and heavy and light truck trip tables, and passed as inputs to the highway and transit assignment modules. The assignment modules provide the traffic volumes and level-of-service skims as outputs ready to be input to the core demand model for next iteration.

3.4.2 Core Demand Models in MORPC

The structure of the core demand model system in MORPC follows the framework in Figures 3.3a and 3.3b. The framework comprises of eight sets of main choice models (see also the accompanying Table 3.3. For the convenience of the reader, each step in Figures 3.3a and 3.3b cross-refers to the models identified in Table 3.3):

(1) Household car ownership model

(2) Linked daily activity pattern type choice model,

(3) Joint household-level tour generation and person participation choice models,

(4) Individual non-mandatory travel generation models,

(5) Primary destination choice models,

(6) Tour time-of-day choice models,

(7) Tour mode combination choice models, and

(8) Stop frequency, location, and mode choice models

Among the above choice models, the activity-travel related models can be classified into six modules with the following hierarchy:

(1) Individual daily activity pattern type and tour generation

(2) Mandatory tour scheduling (mandatory tour destination, time-of-day, and mode)

(3) Joint household-level tour generation and person participation

(4) Individual non-mandatory travel generation

(5) Joint and non-mandatory tour scheduling (destination, time-of-day, and mode)

(6) Stop frequency, location, and mode choice models

This hierarchy is represented in Figures 3.3 and 3.4. Further, as can be observed from the figures, each module of the hierarchy involves several modeling components, each representing a specific decision. Table 3.3 provides further details on each of modeling components. The details include the model name and output of the model, model structure, choice alternatives, and any other useful information including the policy sensitive variables in the model.

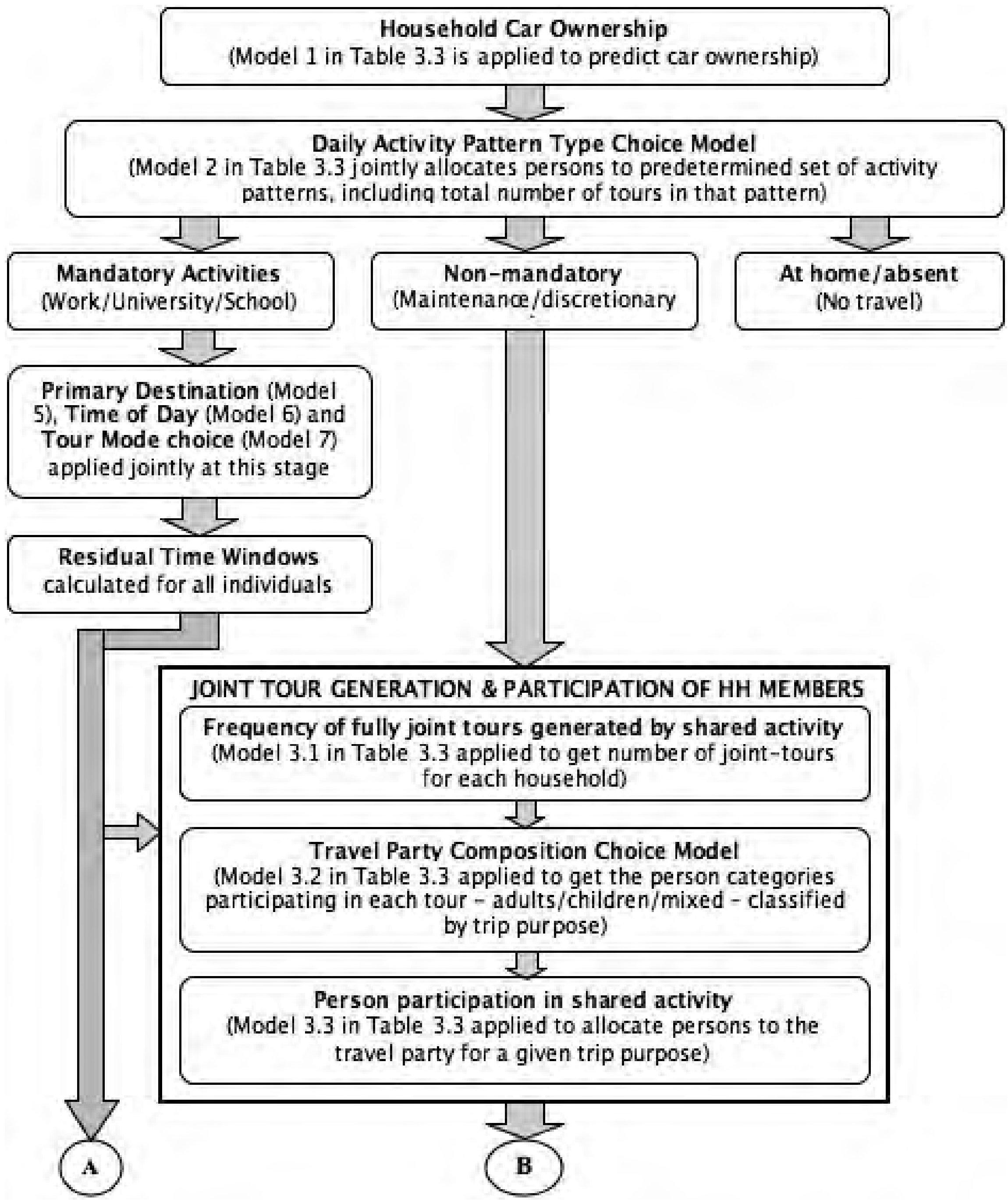

Figure 3.3: Outline of MORPC Modeling System (Part 1)

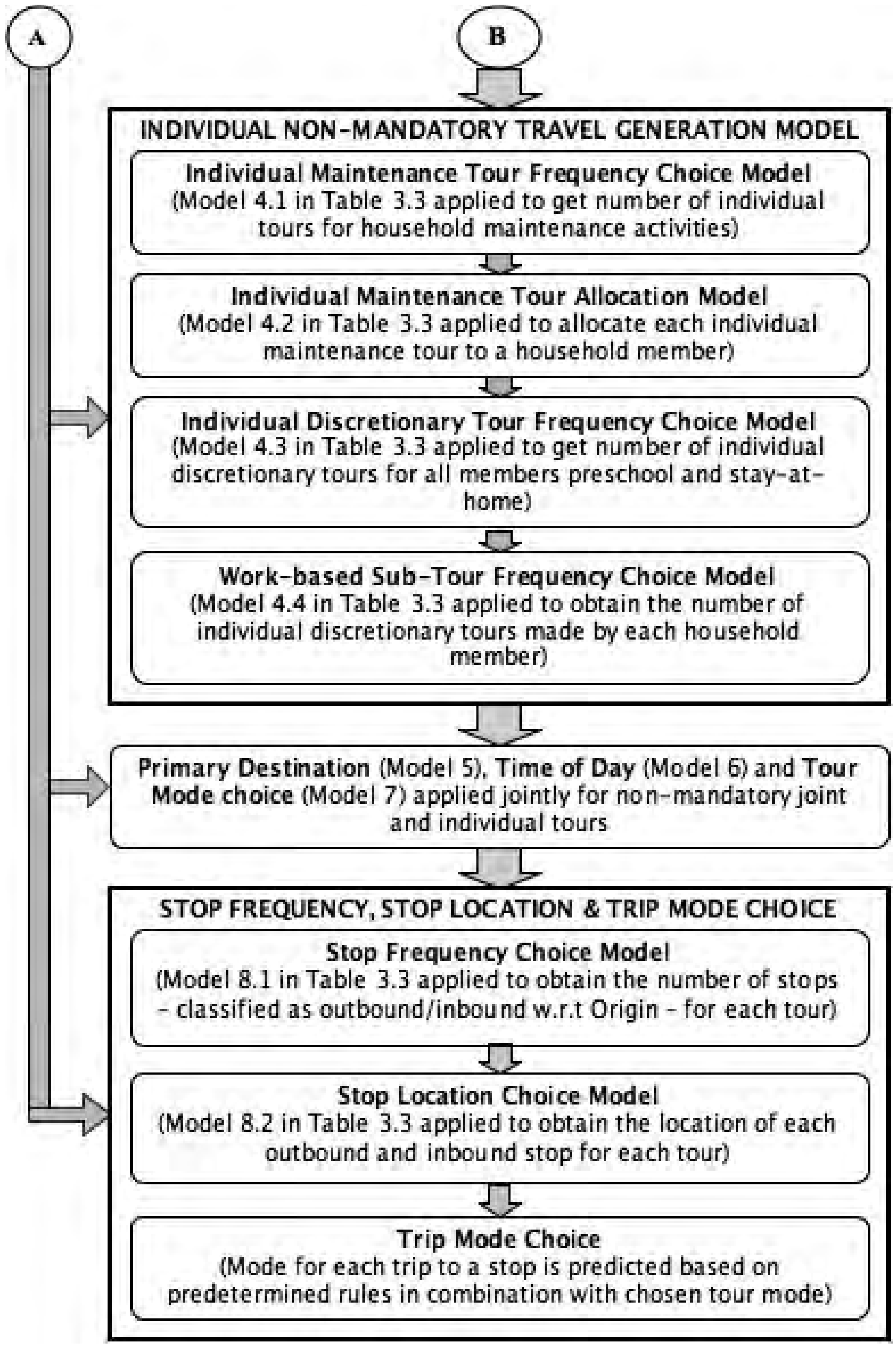

Figure 3.4: Outline of MORPC Modeling System (Part 2)

Table 3.3: List of Models in the MORPC Model System

Model ID	Model Name	Model Structure	Choice Alternatives	Comments
0	Synthetic population generator	Iterative proportion fitting	N/A	The control variables include: household size, number of workers, and income.
		CORE TRAVEL DEMAND MODELS		
1.	**Auto availability (or ownership) model**: Predicts number of vehicles available to household drivers	MNL	0, 1, 2, 3, and 4+	Area type, Transit, and Walk accessibility.
2.	**Individual Daily activity pattern (DAP) type choice model:** Allocates each individual to an activity pattern (DAP) for the day	MNL or NL	11 Daily Activity Patterns (DAPs): Work day (1 work tour, 2 work tours, Work + secondary University tours), University Day (1 university tour, 2 university tours, University + secondary work tours), School day (1 school tour, 2 school tours, school + secondary work tours) Non Mandatory out-of-home, stay at home	Car Sufficiency (#cars—#adults), accessibility (auto-job, walk-job, walk-retail)
Joint travel generation models				
3.1	Joint tour frequency model (Household level): Generates the number of joint tours undertaken at the household level (classified by trip purpose)	MNL or NL	No fully joint tours, 1 fully joint tours (shopping, discretionary, other maintenance, eating out tours); 2 fully joint tours (10 feasible pair-wise combinations of the 4 trip purposes listed above)	Car sufficiency, area type, logged size variable (max pair-wise overlaps of residual windows) for combinations of Adult-Adult + Adult-Child
3.2	Travel party composition choice model (Fully joint tour for non-mandatory purpose): Identifies the feasible subset of the members in the household relevant for each joint travel category	NL	Adults only, Children only, Mixed (at least 1 adult and at least 1 child). Suitable availability considerations implemented.	Car Sufficiency, area type, logged size variable (max pair-wise time window overlaps) for combinations of Adult-Adult, Child-Child and Adult-Child
3.3	Person participation in joint tour choice model: Maps every individual to a feasible (as determined in model 3.2) travel party for an activity type.	Binary logit for each activity, party composition, & person type.	Participate in joint tour (unavailable for people with stay-at-home pattern type and for persons infeasible for the travel party), Not to participate in joint tour (unavailable for persons whose presence is mandatory in the travel group)	Car sufficiency, area type, logged size variable (max pair-wise overlaps of residual time windows)—*e.g.* Adult with other adult for Adult party *etc*.
Individual non-mandatory travel generation models				
4.1	Individual maintenance tour frequency model: Predicts number of individual tours carried out for household maintenance activities	MNL or NL	36 combinations of (0,1,2) escorting tours, (0,1,2) shopping tours and (0,1,2,3) other maintenance tours	Accessibility Indices (to retail), car sufficiency, logged size variable (max pair-wise overlap of residual time windows)
4.2	Individual maintenance tour allocation model: Allocates HH members to each individual maintenance tour	MNL	All household members of 6 person types, excluding individuals with preschool or stay-at-home-pattern	Logged size variable (max pair-wise overlap of residual time windows), Car sufficiency, area type, accessibility to retail by transit

Model ID	Model Name	Model Structure	Choice Alternatives	Comments
4.3	Individual discretionary tour frequency model: Predicts the number of individual discretionary tours for each HH member excluding preschool children and members with stay-at-home activity pattern for the day	MNL or NL	No individual discretionary or eating out tours, 1 individual discretionary tour, 1 eating out tour, 2 individual discretionary tours, 1 individual discretionary + 1 eating out tour	Logged size variable (max pair-wise overlap of residual time windows), car sufficiency, area type, accessibility indices
4.4	Work-based sub-tour frequency model: Predicts the number of work-based sub-tours undertaken for each work tour	MNL or NL	No at-work-sub-tours, 1 sub-tour for eating out, 1 sub-tour for business, 1 sub-tour for other maintenance, 2 sub-tours for business, 1 eating out + 1 business related combination sub-tour.	Zero car ownership (dummy), work area, accessibility from work to retail (auto + walk)
Tour-level Models				
5.	Primary destination choice model: Predicts the destination zone for each tour/sub-tour.	MNL	5415 alternatives (1805 Traffic Analysis Zones (TAZs) with subdivision by 3 transit access zones (sub zones with 0 size variable are not available)	Logged sub-zonal size variable, travel impedance components, transit accessibility in the case of no car ownership, car sufficiency in the case of low car ownership.
6.	Tour time-of-day model (Applied sequentially for all tours in individual DAP according to predetermined priority of each activity type): Predicts the arrival and departure times for the tours	MNL	190 combinations of arrival times and departure times	Travel time variables, period-specific departure/arrival time constraints, bi-directional mode choice logsums for all combinations of outbound/inbound time periods.
7.	Tour mode choice model: Predicts the tour-level mode for each home-based tour (individual or fully joint) and for each work-based sub-tour	MNL or NL	6 alternatives (SOV, HOV, Transit with Walk, Transit with Drive, NM, School Bus). Appropriate availability considerations implemented.	Bi-directional (sum) travel time and cost O-D components for corresponding time-of-day combination, in-vehicle time, walk time, highway toll, operating cost for SOV/HOV as a function of distance and vehicle occupancy, transit fares
Stop-level models				
8.1	Stop frequency choice model: Predicts the number of intermediate (outbound or inbound) stops for every motorized home-based tour, motorized work based sub-tour	MNL or NL	4 alternatives (No stop, Outbound stop, Inbound stop, Outbound + inbound)	Stop-location density logsums (outbound and inbound logsums), early and late departure time dummy variables
8.2	Stop location choice model: Predicts the location zone for each intermediate stop in every half-tour (outbound/inbound) of either motorized home-based tour or motorized work-based sub-tour.	MNL	5415 alternatives (1805 TAZs with subdivision by 3 transit-access zones. Sub-zones with “0” size variable are not available)	Logged sub-zonal (stop attraction) size variable, transit access dummy variables

The salient feature of the core demand models in the MORPC model system is the explicit incorporation of intra-household interactions and the resulting joint activity engagement and travel patterns. To accommodate the intra-household interactions, the full-day activity schedule approach developed by Bowman and Ben-Akiva (2001) was enhanced to explicitly link the activity travel patterns of household members. For this purpose, a two dimensional typology was used to classify activities and tours, and an innovative overlapping time window concept was utilized. The activity typology and the overlapping time window concept are explained in the following sections.

The two dimensions of the activity typology represent: (1) The extent of intra-household interactions, and (2) Priority. Along the first dimension, activities and tours are classified as: (1a) Individual activities (generated and scheduled at the individual level), (1b) Allocated activities (generated at the household level, but implemented by a specific individual), and (1c) Joint activities (generated at the household level, and implemented by household members traveling together). Along the second dimension, activities and tours are classified as: (2a) Mandatory activities (including going to work, university, or school), (2b) Maintenance activities (including shopping banking, *etc.*), and (2c) Discretionary activities (including social and recreational activities, eating out, *etc.*). The two activity classifications give rise to nine possible activity types, out of which five combinations cover most of the observed activities and corresponding travel. The five activity type combinations are again given a particular priority ordering. The activity type combinations, in the order of priority and sequence in which they are generated and scheduled, are: (1) Individual mandatory activities, (2) Joint maintenance activities, (3) Joint discretionary activities, (4) Allocated maintenance activities, and (5) Individual discretionary activities.

In MORPC model, the active time window for simulation purposes has been set as between 7AM and 10PM (the full formal time window is set as 5AM to 11PM). The residual time window for a given person represents the extent of active time window that is open for pursuing subsequent activities, after scheduling the mandatory activities for that person. These residual time windows, which are updated after scheduling each mandatory and non-mandatory tour, facilitate the explicit modeling of joint tours between individuals. The residual time window overlap between two individuals serves as an important determinant of the potential for joint travel between two persons.

3.4.3 Data

Development of the MORPC model system required the use of 1999 Household Interview Survey (a household travel survey) conducted in the Columbus region, zone-to-zone travel level-of-service variables, and a zonal-level land-use database with base year attributes of each TAZ. The household travel survey data was augmented with an on-board transit survey for facilitating the estimation of mode choice models with transit alternatives. For transit assignment, each of the 1805 TAZs in the Columbus region was divided into as many as 3 transit-access sub-zones (short walk, long walk, and no access).

The-zonal level attributes included population, number of household, labor force, average household income, employment by category, school enrollment by category, and other data (from various complimentary surveys and other sources) such as area type, average parking rate, parking capacity, and accessibility indices (i.e., the log-sums) similar to that in the SACSIM model.

3.4.4 Calibration and Validation

Calibration and validation of the MORPC model system was carried out in two stages: (1) Preliminary validation of all models with the Household Interview Survey data (including the on-board transit survey data for mode choice models), and (2) Calibration of models for the base year (2000) synthetic population (610,000 households) and validation against the base year synthetic data.

In the preliminary validation stage, all the tour-based model components in the MORPC model system were used to validate against the Household Interview Survey sample of 5,555 households. With the base year synthetic data, the models were applied and were validated against the traffic counts, transit counts and on-board survey, CTPP tables and an expanded Household Interview Survey (HIS) data that was re-weighted across several socio-economic dimensions in order to match the synthetic population. Expanding the HIS data facilitated in correcting the model parameters for under-reporting of certain types of activities, and a better calibration of the mode choice model due to an increase in the number of transit tours in the expanded data.

A pre-specified set of general rules were applied in the calibration procedure. These included: (1) adjustment based on behavioral factors and logical explanation of the discrepancy, (2) adjusting only alternative-specific constants and general scaling parameters in choice models (to preserve the behavioral properties and elasticities of the estimated model system), and (3) iterative adjustments with incremental small shifts at each iteration.

3.4.5 Software

The main MORPC model application package is Cube. The model application code has been developed and implemented within the Common Model Framework (CMF) created by PB Consult, and makes use of the Distributive Applications Framework (DAF) class of procedures that are part of CMF. All the core tour-based choice models are written in JAVA. The model code is designed to implement multi-threading of tasks, accommodate addition of computers in distributive processing frameworks for optimal processing time.

The main model application package in CUBE is supplemented TP+ procedures for assignment, network management and other related processing. The TP+ procedures create the four sets of networks, one for each time period, from the main database at the ODOT. After the networks are generated and all input files are created for a particular scenario, the custom JAVA programs are executed to implement the tour-based microsimulation models. A pre-assignment processor step aggregates the microsimulation results, and integrates the commercial and external models to produce four time period sets for transit and highway vehicle demand matrices. After the final trip tables are generated, vehicles are assigned to the transportation network using a multi-class equilibrium assignment procedure.

The run time of the MORPC model system depends on the number of processors in use. The COTA cluster (in-house (MORPC) computer cluster with 5 computers and 10 processors) takes about 15 hours to complete a 3-full-iteration base year model run.

3.4.6 Application Experience and Sensitivity Tests

The MORPC model system was developed in the period 2002-2004. Since 2004 the model has been in use and, as of January 2007, the tour-based model completely supersedes the use of the prior, conventional model in all projects. Some of the application of the MORPC model includes:

- The North Corridor Transit Project (in forecasting, environmental impact study). The model was used to study trip distribution for work purposes, estimate and graphically present user benefits and other benefits as well as the disbenefits of the project. The project is a candidate for the Federal Transit Administration's (FTA's) New Starts program.
- Regional air quality conformity analysis.
- Several corridor studies for highway extensions.
- Central business district parking study.
- 2030 forecasts produced for alternative transit scenarios (without/with LRT). Changes in VMT, VHT, and speeds were verified for reasonableness.
- Peak hour spreading (from year 2000 to 2030) phenomenon was verified for intuitiveness.
- Tested for a shortened work day (8 hours to 7.5 hours) policy.

3.4.7 Challenges/Lessons Learned

Some of the challenges/lessons learned in the process of the development and implementation of the MORPC model include:

- To avoid model structure compromises, the design of the model system should be completed before undertaking the surveys.
- Particular care should be given to the estimation of the location choice models to ensure that the model system distributes trips to appropriate zones.
- Validating existing (old) model is a good idea as the development of a new model may take much longer than the anticipated timetable.
- Model run time could be a major issue; however, use of multiple processors can reduce the run time significantly.
- Use of third-party software (Excel, ESRI Avenue, assignment software) can cause incompatibility in the future if a later version of the software is used.

3.5 The SACSIM Model

3.5.1 General Background and Overview

The SACSIM tour-based travel demand model system was developed for the Sacramento Council of Governments (SACOG) for regional travel demand modeling purposes in the Sacramento Region. The model development and calibration was carried out for the year 2000, using a household activity diary survey data. An overview of the SACSIM model system is shown in Figure 3.5.

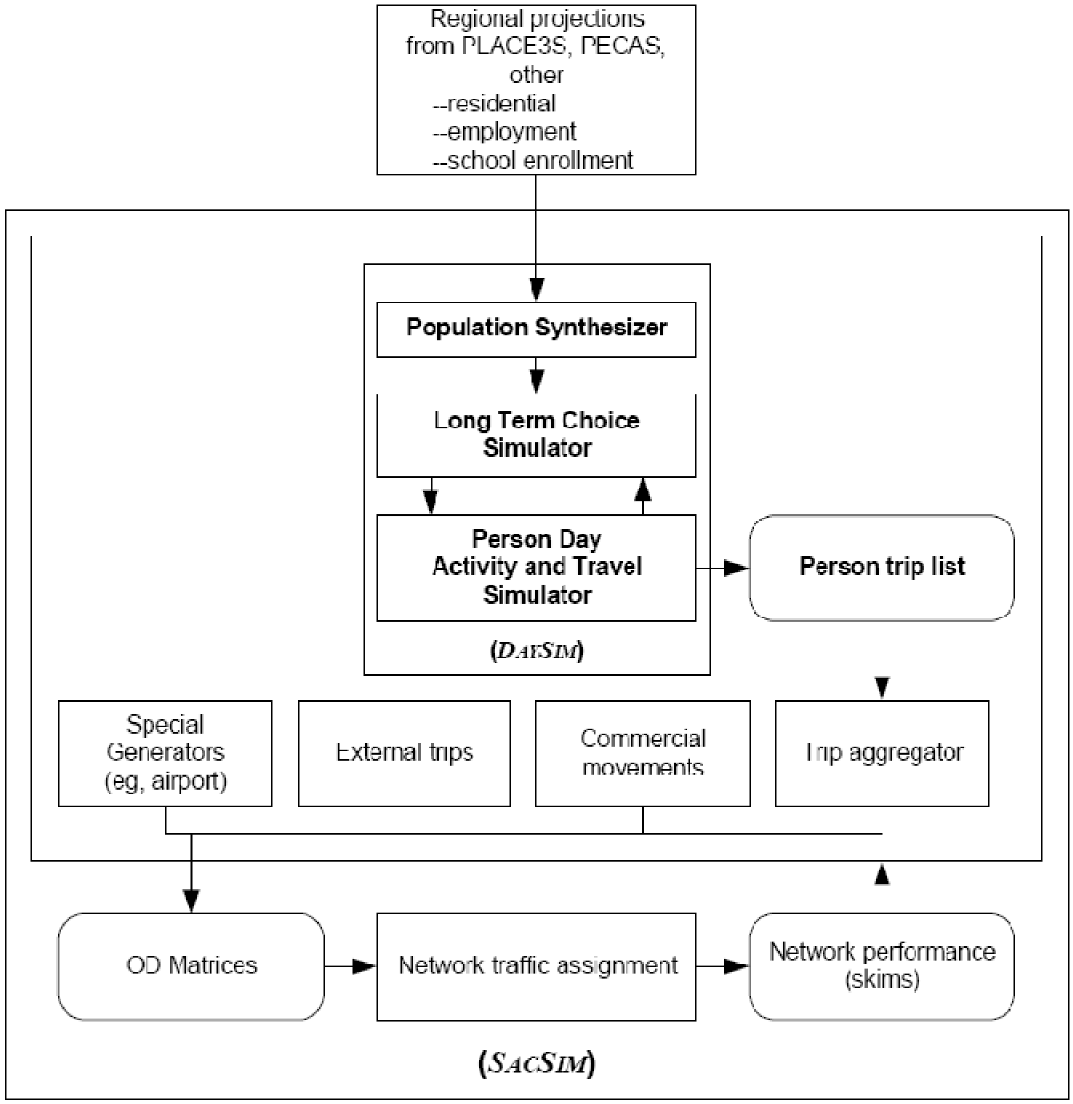

Figure 3.5: The SACSIM Model System (from Bowman and Bradley, 2005)

The SACSIM model starts with a population synthesizer (PopSyn), which takes as inputs the regional projections from land-use models and creates a synthetic population of households drawn from the Public Use Microdata Sample (PUMS) allocated to spatial units known as parcels[8]. The control variables used to create the synthetic population include: household size and composition, number of workers, and income. The PopSyn outcome consists of a list of synthetic households (and individuals) in each parcel with information on all the control variables. Information on other sociodemographics, such as individual age, gender, and employment and student status, is drawn from the PUMS data. After the generation of synthetic population and other sociodemographics, long-term choices (work location zone and parcel, school location zone and parcel, and household auto ownership) are simulated for all synthetic individuals and households in the population. The synthetic households and individuals are now

[8] Parcels are much finer spatial units than TAZs.

ready to be input to the activity-travel simulator DaySim (Daily Activity and Travel Simulator), which creates a one-day activity and travel schedule for each person in the population, including a list of their tours and the trips on each tour. The trips predicted by DaySim are aggregated into OD trip tables by time-of-day and mode and combined with the OD trip tables for special generators, external trips, and commercial traffic. The network traffic assignment models load the trips onto the network. Traffic assignment is iteratively equilibrated with DaySim and the other demand models to obtain a stable set of network traffic volumes.

The DaySim model, which is the core tour-travel microsimulation software of the SACSIM model system, is described in the next section.

3.5.2 Structure of DaySim

The tour-travel forecasting system in SACSIM, labeled as DaySim, includes an integrated econometric microsimulation model that can predict each resident's full-day activity and travel schedule with a highly disaggregate treatment of the activity purpose, time-of-day and location dimensions. The DaySim model follows the full-day activity schedule approach developed by Bowman ad Ben-Akiva (2001). The tour-travel modeling component, DaySim, primarily consists of 3 levels of hierarchy:

(1) Person day-level activity pattern choice models (or pattern-level choice models),

(2) Tour-level choice models, and

(3) Trip-level choice models,

Each of the models in the above mentioned hierarchy consists of a series of econometric choice models, as outlined in Table 3.4. The models are numbered hierarchically in the table to represent the sequence in which the activity-travel decisions are modeled in DaySim. To facilitate readers' comprehension, Figure 3.6 pictorially depicts the sequence in which the activity-travel decisions are modeled.[9] Each step in Figure 3.6 cross-refers to the models identified in Table 3.4. The choice outcomes from models higher in the hierarchy (assumed to be of higher priority to the decision-maker) are treated as known in the lower level models. That is, for example, pattern level choices are known while modeling tour-level choices, and the pattern- and tour-level choices are known while modeling trip-level choices. For all the individual models belonging to the pattern-level, tour-level, and trip-level, Table 3.4 lists the model name and the output of the model, the econometric model structure of the model, the set of choice alternatives, and identifies important policy sensitive variables in the model. As can be observed from the table, each of the activity-travel choices is modeled using either a multinomial logit or a nested logit structure.

Among the models listed in Table 3.4, models 2.1, 2.2, 3.2, and 3.1 together form the activity and travel *generation models*, which provide as outputs a list of all the activities, tours, and trips generated for the person-day. These activities, tours, and trips are scheduled using the other tour-level and trip-level models, which can also be labeled as the *scheduling models*. The

[9]The reader will note here that although DaySim is a hierarchical system since the decisions identified in Table 3.4 modeled sequentially. However, a notable level of integration is achieved in the model system by using log-sums from the lower-level choice models to inform upper-level choice models (discussed later in the section). However, due to the computational infeasibility of implementing a completely joint model, aggregate-level log-sum values are pre-calculated and utilized in the sequential model system.

scheduling models determine the when (time-of-day), where (destination), and how (mode) of the generated activities and travel.

An important aspect of DaySim is the use of accessibility log-sums from the lower-level choice models to inform upper-level choice models. This makes the upper-level choices sensitive to important policy sensitive attributes (travel times and costs) that are known only at the lower-level levels. Log-sum variable at a level is a function of the expected value of the maximum utility of all activity-travel alternatives available at the lower-level. While this is a theoretically appealing approach to integrated lower-level and upper-level decision models, it becomes practically infeasible to implement the approach when there are a large number of alternatives (millions in the case of the entire day tour schedule model) and nests. Hence, aggregated mode-destination log-sums are used for various demographic segments and aggregated alternatives (for examples TAZs instead of parcels) in several models to represent the accessibility (by all modes and all times of day) to various non-work activities. Similarly, aggregate intermediate stop location choice log-sum is used in the activity pattern models, where accessibility for making intermediate stops affects whether the pattern will include intermediate stops on tours, and how many. However, whenever possible, true expected utility log-sums are used. For example, tour mode choice log-sums are used in the tour time of day models.

Table 3.4: List and Sequence of Activity-Travel Choices Modeled in DaySim

Model ID	Model Name and Outcome	Model Structure	Choice Alternatives	Comments/Policy Sensitive Variables
Population synthesizer and Long-term choice models: Generate the disaggregate-level socio-demographic inputs consisting of individual and household records				
1.1	Synthetic population generator: Predicts household size, composition, number of workers, income, person age, gender, employment and student status, along with the parcel-level location of the household	Iterative proportion fitting (IPF)	N/A	Household size, number of workers, and household income, and age of household head are used as the control variables in the IPF procedure.
1.2	Usual work-location: Predicts the usual work location zone and parcel)	Nested logit (NL)	home location in a nest and a sample of other parcels in another nest	The tour-destination models (see rows below) allow the specific work/school tour destination for the day to differ from the person's "usual" work and school location.
1.3	Usual school-location: Predicts the usual school location zone and parcel	Same as above	Same as above	
1.4	Auto availability (or ownership) model: Predicts the number of vehicles available to household drivers	Multinomial Logit (MNL)	0, 1, 2, 3, and 4+	Wok/school mode choice log-sums, mode-destination choice log-sum measuring accessibility from home to non-work activities, distance to nearest transit stop, parking prices, commercial employment
Activity-pattern choice models: Predict the number of home-based tours a person undertakes during a day for seven purposes, and the occurrence of additional stops during the day for the same seven purposes. Purposes: work, school, escort, personal business, shopping, meal, and social/recreational, in that order of priority				
2.1	Daily activity pattern model: Jointly predicts whether or not a person participates in tours and extra stops for 7 activity purposes in a day	MNL	Feasible alternatives of 2080 combinations of 0 or 1+ tours, and 0 or 1+ stops for 7 activity purposes. Base alterative is "Stay at home"	(1) Mode choice to work/school log-sum in tour participation models. (2) Accessibility to retail and service locations on the way to and from work in intermediate stop making models. (3) Residence end density in shopping models (4) Accessibility log-sums by purpose
2.2	Number of tours for each of the 7 activity purposes for which tour making is predicted from the above model	MNL	1,2,or 3 tours for each purpose	
Tour (or subtour or half-tour)-level models: Predict primary destination, mode, and time-of-day, in that order, for all tours. A subtour generation model is also included.				
3.1	Parcel-level tour primary **destination** zone and parcel choice model (for each of the predicted tours) except for school tours since the school location is known at this point. This model is applied for all tours in the order of their priority, with high priority tour-outcomes known at the low-priority tour models.	NL for work-tour, and MNL for non-work and non-school tours	Sample of available parcels (parcel availability based on purpose-specific size and travel time). Work-tour model has usual work location in a nest	(1) Impedance from and to the origin (home or work), (2) destination-specific mode choice log-sum, (3) aggregate mode-destination log-sum at destination, (4) parking & employment mix, (5) zonal-density
3.2	Wok-based sub tour generation model: Predicts the number and purpose of work-based sub tours that originate from each home-based work tour predicted by models 2.1, 2.2, and 3.1. These work-based subtours take priority after home-based work tours	MNL model, applied repeatedly	1 (more) subtour for any of 7 purposes, or No (more) subtours. In application, model is repeated until the 3rd subtour purpose or "No(more) subtour" is predicted	No policy sensitive variables in these models

Model ID	Model Name and Outcome	Model Structure	Choice Alternatives	Comments/Policy Sensitive Variables
3.3	Tour-level main **mode** choice models (by purpose, for all tours): Predicts the tour-level mode choice	NL	Drive-transit-walk, Walk-transit-drive, Walk-transit-walk, School bus, Shared ride 3+, Shared ride2, Drive alone, Bike, Walk	OVTT, coefficients assumed for cost and IVTT, mixed use density and intersection density
3.4	Tour-level **time-of-day** choice models by purpose: Predict half-hour time periods of arrival at and departure from primary destination	MNL	Combinations of all feasible half-hour intervals of arrival and departure = 48x49/2	In- and out-bound auto & transit travel times, presence of transit path in time period, tour mode choice log-sums
4.1	Intermediate stop generation models (predicts the exact number and purpose of stops for the half-tours leading to and from the primary destination of the tour), conditional upon the tour primary destination, mode and arrival and timings, the outcomes of this model for higher priority tours defined by purpose and person type, and the activity purposes that are yet to be undertaken.	MNL model, applied repeatedly for all half-tours	1 (more) stop for any of 7 purposes, or No (more) stops. In application, model is repeated until the 5th stop purpose or No(more) stops is predicted	Aggregate intermediate stop log-sum for auto-based modes, and street network connectivity and commercial employment density for non-auto-based modes
Stop-level models (Stops in half-tour before primary destination are modeled in the reverse chronological order. Location, mode, and 30-minute time period of arrival at location are modeled in that order, and departure time is derived from LOS tables. After the trip chain for the first half-tour is modeled, the trip chain for the second half-tour back to the tour origin is similarly modeled in regular chronological order)				
4.2	Intermediate stop **location:** Predicts the destination zone and parcel of each intermediate stop, conditional on tour origin and primary destination, and location of previous stops.	MNL	Sample of available parcels drawn from an importance sampling procedure at three levels of geography (stratum, TAZ, and parcel). Parcel availability based on purpose-specific size and travel time.	(1) Purpose specific size based on employment by type and other measures, (2) Total generalized detour time based on a sum of all impedance values w.r.t primary destination and tour origin. (3) Distance, (4) travel time as a fraction of available time, (5) proximity to stop origin and tour origin, (6) network connectivity by modes, (7) parking, (8) employment density, (9) land-use mix
4.3	Trip **mode** choice (conditional on main tour mode, the mode of previously modeled adjacent trip, and the specific OD pair anchors)	MNL	Drive to transit, walk to transit, School bus, Shared ride 3+ and 2, Drive alone, Bike, Walk	Generalized cost (travel time and cost variables multiplied by the tour level mode choice coefficients)
4.4	Trip **time-of-day** choice models by purpose: Predict arrival time (departure time) choice for stops in first (second) half tour, conditional on the time windows remaining from previous choices	MNL	Feasible alternatives among the 48 half-hour time period alternatives	Auto travel times, and the presence of transit path in time period
Model ID	**Model Name and Outcome**	**Model Structure**	**Choice Alternatives**	**Comments/Policy Sensitive Variables**
Population synthesizer and Long-term choice models: Generate the disaggregate-level socio-demographic inputs consisting of individual and household records				
1.1	Synthetic population generator: Predicts household size, composition, number of workers, income, person age, gender, employment and student status, along with the parcel-level location of the household	Iterative proportion fitting (IPF)	N/A	Household size, number of workers, and household income, and age of household head are used as the control variables in the IPF procedure.
1.2	Usual work-location: Predicts the usual work location zone and parcel)	Nested logit (NL)	home location in a nest and a sample of other parcels in another nest	The tour-destination models (see rows below) allow the specific work/school tour destination for the day to differ from the person's "usual" work and school location.
1.3	Usual school-location: Predicts the usual school location zone and parcel	Same as above	Same as above	

Model ID	Model Name and Outcome	Model Structure	Choice Alternatives	Comments/Policy Sensitive Variables
1.4	Auto availability (or ownership) model: Predicts the number of vehicles available to household drivers	Multinomial Logit (MNL)	0, 1, 2, 3, and 4+	Wok/school mode choice log-sums, mode-destination choice log-sum measuring accessibility from home to non-work activities, distance to nearest transit stop, parking prices, commercial employment
Activity-pattern choice models: Predict the number of home-based tours a person undertakes during a day for seven purposes, and the occurrence of additional stops during the day for the same seven purposes. Purposes: work, school, escort, personal business, shopping, meal, and social/recreational, in that order of priority				
2.1	Daily activity pattern model: Jointly predicts whether or not a person participates in tours and extra stops for 7 activity purposes in a day	MNL	Feasible alternatives of 2080 combinations of 0 or 1+ tours, and 0 or 1+ stops for 7 activity purposes. Base alterative is "Stay at home"	(1) Mode choice to work/school log-sum in tour participation models. (2) Accessibility to retail and service locations on the way to and from work in intermediate stop making models. (3) Residence end density in shopping models (4) Accessibility log-sums by purpose
2.2	Number of tours for each of the 7 activity purposes for which tour making is predicted from the above model	MNL	1,2,or 3 tours for each purpose	
Tour (or subtour or half-tour)-level models: Predict primary destination, mode, and time-of-day, in that order, for all tours. A subtour generation model is also included.				
3.1	Parcel-level tour primary **destination** zone and parcel choice model (for each of the predicted tours) except for school tours since the school location is known at this point. This model is applied for all tours in the order of their priority, with high priority tour-outcomes known at the low-priority tour models.	NL for work-tour, and MNL for non-work and non-school tours	Sample of available parcels (parcel availability based on purpose-specific size and travel time). Work-tour model has usual work location in a nest	(1) Impedance from and to the origin (home or work), (2) destination-specific mode choice log-sum, (3) aggregate mode-destination log-sum at destination, (4) parking & employment mix, (5) zonal-density
3.2	Wok-based sub tour generation model: Predicts the number and purpose of work-based sub tours that originate from each home-based work tour predicted by models 2.1, 2.2, and 3.1. These work-based subtours take priority after home-based work tours	MNL model, applied repeatedly	1 (more) subtour for any of 7 purposes, or No (more) subtours. In application, model is repeated until the 3rd subtour purpose or "No(more) subtour" is predicted	No policy sensitive variables in these models
3.3	Tour-level main **mode** choice models (by purpose, for all tours): Predicts the tour-level mode choice	NL	Drive-transit-walk, Walk-transit-drive, Walk-transit-walk, School bus, Shared ride 3+, Shared ride2, Drive alone, Bike, Walk	OVTT, coefficients assumed for cost and IVTT, mixed use density and intersection density
3.4	Tour-level **time-of-day** choice models by purpose: Predict half-hour time periods of arrival at and departure from primary destination	MNL	Combinations of all feasible half-hour intervals of arrival and departure = 48x49/2	In- and out-bound auto & transit travel times, presence of transit path in time period, tour mode choice log-sums
4.1	Intermediate stop generation models (predicts the exact number and purpose of stops for the half-tours leading to and from the primary destination of the tour), conditional upon the tour primary destination, mode and arrival and timings, the outcomes of this model for higher priority tours defined by purpose and person type, and the activity purposes that are yet to be undertaken.	MNL model, applied repeatedly for all half-tours	1 (more) stop for any of 7 purposes, or No (more) stops. In application, model is repeated until the 5th stop purpose or No(more) stops is predicted	Aggregate intermediate stop log-sum for auto-based modes, and street network connectivity and commercial employment density for non-auto-based modes

Model ID	Model Name and Outcome	Model Structure	Choice Alternatives	Comments/Policy Sensitive Variables
Stop-level models (Stops in half-tour before primary destination are modeled in the reverse chronological order. Location, mode, and 30-minute time period of arrival at location are modeled in that order, and departure time is derived from LOS tables. After the trip chain for the first half-tour is modeled, the trip chain for the second half-tour back to the tour origin is similarly modeled in regular chronological order)				
4.2	Intermediate stop **location:** Predicts the destination zone and parcel of each intermediate stop, conditional on tour origin and primary destination, and location of previous stops.	MNL	Sample of available parcels drawn from an importance sampling procedure at three levels of geography (stratum, TAZ, and parcel). Parcel availability based on purpose-specific size and travel time.	(1) Purpose specific size based on employment by type and other measures, (2) Total generalized detour time based on a sum of all impedance values w.r.t primary destination and tour origin. (3) Distance, (4) travel time as a fraction of available time, (5) proximity to stop origin and tour origin, (6) network connectivity by modes, (7) parking, (8) employment density, (9) land-use mix
4.3	Trip **mode** choice (conditional on main tour mode, the mode of previously modeled adjacent trip, and the specific OD pair anchors)	MNL	Drive to transit, walk to transit, School bus, Shared ride 3+ and 2, Drive alone, Bike, Walk	Generalized cost (travel time and cost variables multiplied by the tour level mode choice coefficients)
4.4	Trip **time-of-day** choice models by purpose: Predict arrival time (departure time) choice for stops in first (second) half tour, conditional on the time windows remaining from previous choices	MNL	Feasible alternatives among the 48 half-hour time period alternatives	Auto travel times, and the presence of transit path in time period

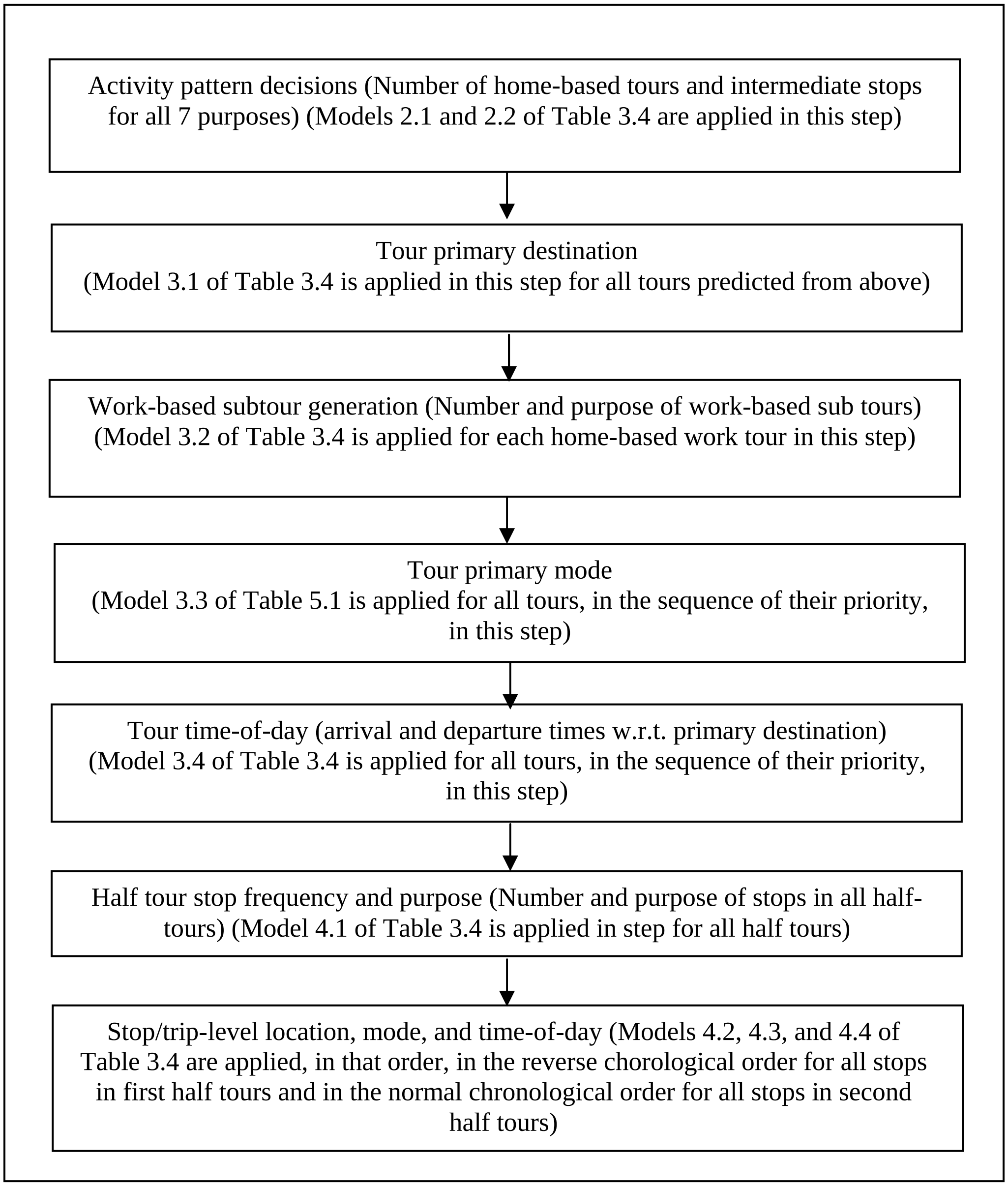

Figure 3.6: Tour-Travel Forecasting Sequence of DaySIM

3.5.3 Data

The development of the DaySim model system required the use of a household travel-diary survey, zone-to-zone travel level-of-service variables skimmed from the base-year transport network, and a parcel database with base year attributes of each parcel, including employment and school enrollment by type, number of households, parking availability and price, and information about the transport network surrounding the parcel.

The inputs for DaySim are the detailed sociodemographics, zone-to-zone travel level-of-service variables, and the parcel-level land-use data-base. The detailed sociodemographics are generated using the PopSyn and the Long-Term Choice Modules, while the zone-to-zone travel level-of-service and the parcel-level land-use data were obtained from SACOG.

The major challenge associated with the development of the SACSIM model was with the preparation of parcel level land-use data. A much bigger challenge was the development of parcel level data for forecast years. A GIS-based land-use scenario generator, labeled as Place3s was used to forecast dwelling units and employment type (for 9 sectors) at parcel level. However, several other land-use and demographic forecasts were not available as outputs from Place3s. The unavailable variables included: K12 schools, colleges, universities, some employment sectors, parking facilities, transit stops, and street pattern variables (number of intersections of different types, *etc*.). Thus, the future year control totals required for population synthesis were obtained from other secondary sources and through the use of a number of heuristics and judgment calls. Each data issue required significant effort and time to address.

3.5.4 Calibration and Validation

The calibration and validation exercises with SACSIM were undertaken in three steps: (1) preliminary validation, (2) base year calibration, and (3) forecast year validation.

Preliminary validation involved comparing estimated model predictions on the household survey sample to the observed activity-travel patterns in the same sample. Each model component, after estimation, was applied to the household survey data and verified for major discrepancies in aggregate predictions. Aggregate results for various subpopulations and model sensitivities were checked to detect and correct deficiencies in the model specifications. Further, after each model was implemented in the application software, the software predictions were compared with the survey sample to find and fix software bugs.

Base-year validation involved running the year 2000 synthetic population of the Sacramento area through the entire model system, and comparing the aggregate results to available external information on actual base year characteristics. The external data was obtained from census data, transit on-board surveys, and screen line and other counts. The model system was calibrated sequentially from top to bottom of the model hierarchy, assuming that the adjustments to the upper level models tend to impact lower level models more than vice versa. Examples of the performed calibrations include the following:

(1) Distribution of workers by work location TAZ was validated against the total employment in the zone, and the work distance distribution was matched with that in the census data. To match the zonal-employment levels, the model was applied in a constrained mode. Also, the work location model was re-estimated with piecewise linear auto distance coefficients so as to match the work distance distribution with that in census data.

(2) Vehicle ownership model was validated against the census data and calibrated by adjusting selected constants and sensitivities.

(3) Person-day activity-travel pattern models were validated by comparing the outputs with the screen line vehicle counts by time period, and transit OD matrices from the transit on-board surveys.

The forecast year validation involved comparing SACSIM forecasts for the year 2005 with the actual 2005 transportation system performance (i.e., traffic counts). Further, it involved aggregate-level and disaggregate-level scenario tests such as cordon pricing, and increased transportation connectivity. An important feature of the SACSIM modeling system is its ability to evaluate the policy impacts at the individual-level. This is enabled by using the same set of random numbers to predict the outputs of each model for each individual across policy scenarios.

Such a random seed coordination method minimizes the random simulation error to enable individual-level policy analysis and to provide more accurate forecasts of aggregate-level policy impacts.

3.5.5 Software

The custom software for applying the SACSIM model system was written in Pascal code. This software has three main modules: (1) Population Synthesizer, (2) Accessibility Calculator, and (3) Activity-Travel Simulator (DaySim). The synthetic population from the Population Synthesizer and the zonal-level accessibility measures (or log-sums) from the Accessibility Calculator, the zonal-level and parcel-level socioeconomic and land-use data, and the zone-to-zone level-of-service data are fed as inputs to DaySim. DaySim provides as output the full-day activity-travel patterns of all synthetic individuals in the study area. Subsequently, a CUBE application framework converts the outputs into trip tables and uses them for highway and transit assignment. The auto and transit skims generated in the CUBE application framework are fed back into the Accessibility Calculator and DaySim. This procedure is continued until a stable set of traffic flows is obtained. CUBE functions as a shell to run the post activity-travel modeling programs, calling the activity-travel microsimulation executable program (DaySim) when needed.

3.5.6 Application Experience and Sensitivity Tests

The SACOG model was developed in the period 2005-2006. Since its development, the model has been used to assess and evaluate a number of projects, including:

- Sacramento State BRT project (used SACOG model to simulate campus arrivals and departures in half hour increment to evaluate parking and transit plan for Sacramento State University).
- Regional air quality conformity analysis.
- A “New Starts” LRT investment study.
- A “4 D’s” study (density, destination, design, diversity).
- Integration with PECAS land use microsimulation model.
- 2005 forecasts were validated, scenario testing and 2032 forecasting work is underway.
- Cordon pricing and increased network connectivity scenario tests were carried out. Simulation error was controlled during the sensitivity tests.
- Plans to compare tour based and trip-based models with respect to trip-level outputs, and undertake sensitivity tests.

3.5.7 Challenges/Lessons Learned

Some of the challenges/lessons learned in the process of the development and implementation of the SACOG model include:

- When using parcel-level data, do not use explanatory variables that may be impractical/impossible to forecast.
- Use of parcel-level data in synthetic population generation requires a lot of consideration and planning.
- Make sure the synthetic population generator produces representative university students in terms of the number and location.
- Improve assignment (highway and transit) module to fully employ the model capability.
- Design transit assignment and the interface better so that fare by person type can be used as a policy variable in the mode choice model.
- Do not implement the new model system during any major statutory function, such as Metropolitan Transportation Plan (MTP).

3.6 The NYBPM Model

3.6.1 General Background and Overview

The NYBPM (New York Best Practice Model) tour-based travel demand model system was developed for the New York Metropolitan Transportation Council (NYMTC) to predict and forecast travel demand for the New York Metropolitan Region (the New York Metropolitan Region includes 28 counties in New York, Connecticut, and New Jersey). A difference between the NYBPM "tour-based" model and the other three tour-based models discussed in sections 3, 4, and 5 is that the NYBPM model uses "journeys" as the basic unit for modeling travel as opposed to "tours." A journey is a chain of trips connecting the main origin and destination and can have intermediate stops. Like tours, journeys can be home-based and non-home-based (*e.g.*, at work).

Figure 3.7 outlines the sequence in which travel decisions are modeled in the NYBPM system. The system has four major modules: tour generation, tour mode and destination choice, time of day choice, and traffic and transit simulation. The first three modules are implemented in a microsimulation framework, while the final module employs a zone-to-zone level aggregate assignment algorithm. The model was developed and calibrated for the base year 1998 using data from the 1997/98 Regional Travel—Household Interview Survey (RT-HIS) undertaken out in 28 counties of the study area.

3.6.2 Structure of the Travel Model System

The <u>first</u> module of the NYBPM system, *tour generation*, starts with a population synthesizer (referred as household synthesis model) that takes the zonal-level socioeconomic and land-use data (total population, number of households, average household income and, total labor force participation) as inputs, and creates a synthetic population of households drawn from PUMS allocated to TAZs. The control variables used to create the synthetic population include: household size, number of workers per household, and income. The outcome consists of a list of synthetic households (and individuals) in each TAZ with information on the control variables. Information on other sociodemographics, such as number of non-working adults, number of children, and household income group is obtained by matching each of the synthetic households to similar households from PUMS. The synthetic households and individuals are then ready to be input to the subsequent models. The next model in the tour generation module is an auto-ownership model, which is applied to each synthetic household to generate the number of cars in the household. Details of the auto ownership model, including the model structure, choice alternatives and the policy sensitive variables in the specification, are provided in Table 3.5 (see row labeled 1.2). The output from the auto ownership model is later used as one of the household explanatory attributes further down in the model system. The final model applied in the tour generation module is the journey frequency model. There are three person types (workers, non-workers, and children) and six journey purposes (five home-based journey purposes: to work, to school, to university, for household maintenance and for discretionary purposes; and one non-home-based journey purpose at work). There are a total of thirteen journey-frequency sub-models. The journey-frequency sub-models are ordered and linked in such a way that intra-household interaction and time-space constraints of each individual in the household are taken into account. Details of the journey-frequency sub-models are provided in Table 3.5 (see rows labeled 2.1 to 2.13). The models are run sequentially for each person in the household and the outputs, number of different types of journeys made by each individual, are used as independent variables for the subsequent models.

The second module, *journey mode and destination choice*, starts with a pre-mode choice model where each journey is assigned to either motorized (ten modes: drive alone, shared ride with 1 passenger, shared ride with 2 passengers, shared ride with 3 or more passengers, transit (including bus, subway and ferry) with walk access, transit with drive access, commuter rail (with transit feeder lines) with walk access, commuter rail with drive access, taxi, and school bus) or non–motorized mode (a combined mode of bicycle and walking) of travel. If the non-motorized mode is selected then the non-motorized destination choice model is used in which the chosen destinations can only be within 3 miles from the origin. If a motorized mode is chosen, first the primary destination and mode for the entire journey are modeled, and then the intermediate stop frequency and stop location(s) (if any) are modeled. Details of the journey mode and destination module are given in rows 3.1 through 3.6 of Table 3.5.

The third module starts with the time of day model, which has a simple structure based on a set of observed time of day distributions segmented by travel purpose, mode, and destination (see row 4.1 in Table 3.5). In conjunction with a pre-assignment processing procedure, the microsimulated records are aggregated to produce a set of time period specific Origin-Destination (O-D) trip tables. These O-D tables are combined with other O-D tables, such as truck and other commercial vehicle O-D tables. The fourth module assigns the combined trip tables to the traffic network (highway and transit assignments are carried out separately) using TransCAD software. The outputs from the network assignment procedure provide traffic link volumes by mode and time-of-day.

An important aspect of this model system is the use of log-sums from the journey-level mode choice models (i.e., the sum of the exponents of the individual modal utilities) to inform primary destination choices. The log-sums are also used from stop location choice model to update the stop frequency. The use of log-sum variables enhances the sensitivity of location choices to level-of-service attributes. Other salient feature of the model includes implementation of intra-household interaction that captures time-space constraint.

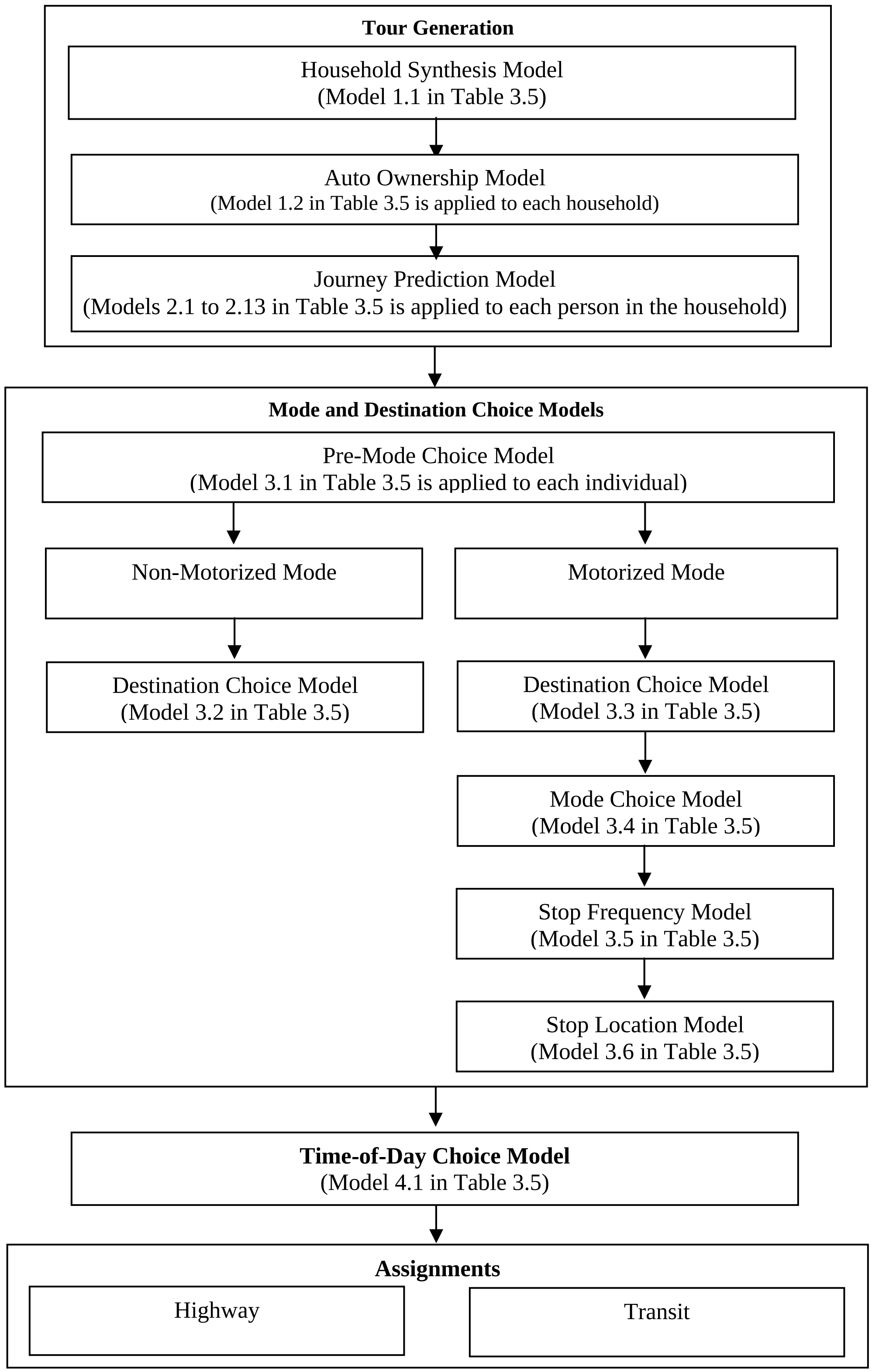

Figure 3.7: Structure of the NYBPM System

Table 3.5: List and Sequence of Activity-Travel Choices Modeled in the NYBPM

Model ID	Model Name and Outcome	Model Structure	Choice Alternatives	Comments/Policy Sensitive Variables
Household synthesis and auto ownership models: Generate the disaggregate-level socio-demographic and auto ownership levels input consisting of individual and household records.				
1.1	Household synthesis: Predicts household size, household income group, number of workers, number of non-working adults, and number of children	Iterative proportion fitting (IPF)	N/A	Average zonal household size, household income, number of workers per household are used as control variables in the IPF procedure
1.2	Auto ownership model: Predicts the number of vehicles available to household drivers	MNL	0, 1, 2, 3+	Household car-sufficiency relative to its size and composition, income, residential urban environment, and auto, transit and walk accessibility
Journey production model: Predicts, for each person, the number of journeys of different types on a day. Journey types are: home-based to work, home-based to school, home-based to university, home-based to maintenance purposes, home-based to discretionary purposes, and at-work journeys. Models are estimated and applied separately for 3 person types: children, workers, and non-workers.				
2.1	Journeys to school for children	Binary logit	0, 1+	Number of workers, number of children, income group, and residential zone area-type identifiers
2.2	Journeys to school for non-workers	Binary logit	0, 1+	A child going to school (creates linkage to model 2.1), and the number of workers in the household
2.3	Journeys to school for workers	Binary logit	0, 1+	A child going to school (creates linkage to model 2.1), low income, and the number of workers in the household
2.4	Journeys to university for non-workers	Binary logit	0, 1+	Presence of workers and residential zone area-type identifiers
2.5	Journeys to university for workers	Binary logit	0, 1+	Child staying at home alone (creates linkage to models 2.1 and, 2.2), low income, and presence of a second worker
2.6	Journey to work	MNL	0, 1, 2+	Child staying at home alone (creates linkage to models 2.1 and, 2.2), making a school/university journey by the model worker (creates linkage to model 2.3), and low income
2.7	Maintenance journeys for non-workers	MNL	0, 1, 2, 3+	Presence of a worker not going to work (creates linkage to model 2.6), making a school/university journey by the modeled non-worker (creates linkage to models 2.2 and, 2.4), car sufficiency, presence of children, presence of more than one non-workers, and walk accessibility to employment
2.8	Journeys at work	Binary logit	0, 1+	Workplace location, low income, presence of non-worker, and presence of more than one worker
2.9	Maintenance journeys for workers	MNL	0, 1, 2, 3+	Making school/university and work journeys by the modeled worker (creates linkage to models 2.3, 2.5 and, 2.6), presence of children, presence of more than one workers and no non-worker, and suburban residential area indicator

Model ID	Model Name and Outcome	Model Structure	Choice Alternatives	Comments/Policy Sensitive Variables
2.10	Maintenance journeys for children	MNL	0, 1, 2+	Making school journey by the modeled child (creates linkage to model 2.1), making maintenance journeys by non-workers, and workers (creates linkage to models 2.7 and 2.9)
2.11	Discretionary journeys for non-workers	Binary logit	0, 1+	Car sufficiency, transit accessibility, presence of exactly one worker, presence of more than one non-worker, and income group
2.12	Discretionary journeys for workers	Binary logit	0, 1+	Making work and maintenance journeys by the modeled worker (creates linkage to models 2.6 and, 2.9), making discretionary journeys by non-workers (creates linkage to model 2.11), and presence of no non-worker
2.13	Discretionary journeys for children	Binary logit	0, 1+	Making school and maintenance journeys by the same child (creates linkage to models 2.1 and, 2.10), maintenance journeys made by non-workers and discretionary journeys made by workers (creates linkage to models 2.7 and, 2.12), and suburban residential area type
Journey mode and destination choice model: Predicts mode, primary destination, intermediate stop frequency and location for each journey				
3.1	Pre-mode choice model: Predicts mode of travel (either motorized or non-motorized mode) for each journey.	Binary logit	Motorized (drive alone, shared ride with 1 passenger (SR2), SR3, SR4+, commuter rail and any additional transit modes (CR) with walk access, CR with drive access, other transit (bus, subway, ferry) (OT) with walk access, OT with drive access, taxi cab, and school bus) and non-motorized mode (bicycle and walking combined)	Logsum from the subsequent destination-choice model for non-motorized travel in a 3-mile radius around the origin is used as density of attractions. Additional variables include income, car sufficiency, transit accessibility, and origin area-type identifiers
3.2	Destination choice (for non-motorized)	MNL	Choice alternatives selected within 3 miles radius of origin	Density of attractions measure, impedance (distance), and intra-school district dummy
3.3	Primary destination choice (for motorized): Predicts the principal destination for each journey. In total, there are eight fully segmented primary destination choice models: six original purposes with additional subdivision of journeys to work by three income groups (low, medium, and high)	MNL	Each TAZ is divided into two sub-zones – accessible by transit and not accessible by any of the transit modes. In total, 7172 (3586*2) choice alternatives	Mode-choice logsum, log of zonal attraction-size variable (based on land use variables such as total employment, retail employment, school enrollment, *etc*), river-crossing dummies, and intra-county dummy
3.4	Motorized mode choice models: Predicts motorized mode for each journey purposes using one of the six models (fully segmented by journey types)	NL	Ten alternatives (not all modes are available for all purposes, for example, school bus is not available for journey to work) : drive alone, shared ride with 1 passenger (SR2), SR3, SR4+, commuter rail and any additional transit modes (CR) with walk access, CR with drive access, other transit (bus, subway, ferry) (OT) with walk access, OT with drive access, taxi cab, and school bus	Travel time, travel cost (including parking cost), distance for commuter rail, car sufficiency, income group, Manhattan-destination dummy, and informal parking lot dummy

Model ID	Model Name and Outcome	Model Structure	Choice Alternatives	Comments/Policy Sensitive Variables
3.5	Stop frequency (for motorized): Predicts number of stops for the entire paired journey	MNL	Four choice alternatives: no stops on outbound or return leg, only one stop on the outbound leg, only one stop on the inbound leg, and one stop on each leg.	Logsum stop density measure (from the stop location model), income, car sufficiency, journey distance and time, household composition, and other journeys (made by the same person and by other members of the household)
3.6	Stop location (for motorized): Predicts the location of the intermediate stop(s) for each journey (i.e., outbound and inbound) separately	MNL	Choice alternatives based on estimated travel time	Stop-density zonal size variable (based on land use variables such as total employment, retail employment, school enrollment, *etc*), relative route deviation, aggregate travel modes (drive alone, shared ride, and transit)
Time of day model: Predicts arrival time for each trip in a journey				
4.1	Time of day choice model: Predicts arrival time for each trip	A look-up table based on observed arrival time and duration distribution	48 possible time choice (half-hour resolution) for arrival time for each trip which is subsequently aggregated by four time of day periods: AM peak (6-9:30 am), midday off-peak (10-3:30 pm), PM peak (4-7:30 pm), and night period (8-5:30 am)	The lookup table is stratified by journey purpose, mode, and some aggregate spatial categories.

3.6.3 Data

The NYBPM model development and calibration was carried out for the base year 1996 using the Regional Travel—Household Interview Survey (RT-HIS) data. The survey was undertaken in 1997/98 for the New York Metropolitan Transportation Council (NYMTC) and the North Jersey Transportation Planning Authority (NJTPA) in New York (12 counties), New Jersey (14 counties), and parts of Connecticut (2 counties). New Jersey Transit also participated in the RT-HIS. The survey was conducted in a diary type format, in which detailed travel information for each member of participating households was collected during an entire weekday. The final sample consisted of 27,369 individuals of 11,263 households.

Other data sources used in model development and application included the (1) external auto cordon survey, (2) highway counts, and (3) travel time and speed data. In 1998, the NYMTC conducted an external cordon origin-destination (O-D) survey (automobile drivers only) to obtain information on external travel patterns for an average weekday, and the collected information was used in the development of the BPM external travel demand forecasting sub-model. In addition to the O-D survey, Automatic Traffic Recorder (ATR) counts, sample vehicle classification counts, and sample vehicle occupancy counts were collected in hourly intervals. The highway counts comprised of hourly directional link count of 2,226 highway network links in the NYMTC area, and all interstate crossings between New York and New Jersey. NYMTC conducted an extensive travel time and speed survey, primarily on principal arterial and above.

In addition to the RT-HIS, external auto cordon survey, highway counts, travel time, and travel speed, the NYBPM also uses the 1990 Census files (STF3A), the Census Transportation Planning Package (CTPP), and socioeconomic employment and land use data.

3.6.4 Calibration and Validation

Calibration and validation of the NYBPM model was undertaken largely using data from the RT-HIS (weighted and expanded to represent aggregate totals for regional households). In addition, the 1990 Census files (STF3A and CTPP), socioeconomic employment and land use data (assembled in Track 8), highway screenline, and transit count data were used to augment the RT-HIS data. It should be noted that, as part of the NYBPM update 2002 process (carried out in 2004), major changes were implemented to the original (1996 base year) calibrated model. Some of these changes were: adjustment to productions by purpose at the district level, use of distance scaling factors in the destination choice model to improve the overall match of the model trip length distribution, application of mode specific constants to specific corridors to try to capture the observed modal shares by purpose.

The travel behavior validation of the NYBPM model was pursued at several levels: (1) validation of the choice models, (2) validation of the highway assignment, and (3) validation of the transit assignment. The choice models were validated across several travel dimensions: (a) journey production, (b) mode, and (c) destination choice. In *journey production*, the outcomes from the journey-frequency model (based on the full synthetic population) were compared with the expanded number of journeys from the survey. The comparison was undertaken at the district level for journey origins by trip purpose. The trip purpose comparison was implemented at two different levels of aggregation: (i) two aggregate travel purposes (work and non-work) and (ii) all eight travel purposes (six original purposes with additional subdivision of work by three income groups). The comparison exercises indicated a reasonable level of closeness between the two outputs by the aggregate trip purposes. At the detailed trip purpose level, the work journeys made by medium income households were higher from the BPM model compared to the work journeys from the expanded survey. For other trip purposes, the BPM model outputs and the RT-HIS expanded survey sample provided similar number of journey predictions. Validation of the *mode choice model* was carried out at three different levels: (i) mode shares by travel purpose (aggregated at region level), (ii) absolute number of journeys by different modes at origin and destination (aggregated at county level), and (iii) the mode shares by journey origin and destination (aggregated at county level). The validation across these three dimensions indicated a very reasonable match between the model outputs and the expanded RT-HIS travel data. Validation of the *destination choice model* was achieved by comparing two aggregate statistics: (i) absolute number of journey attractions at destination county level (district) by travel purpose (estimated for two aggregate and eight detailed travel purposes), and (ii) average journey length and journey length distribution by travel purpose (estimated only for eight detailed travel purposes). The computed statistics were found to be a reasonably good match to the expanded RT-HIS data, both at the regional level and district level.

Traffic assignment calibration was pursued separately for highway and transit modes using observed traffic counts and transit boardings, respectively. The highway assignment calibrations were based on a comparison of model flows with respect to two sources of count data—the screenline database and the MATRIX database of counts (developed by the State Route System in the New York counties). The highway assignment results were calibrated at different levels of aggregation: (1) all network links (excludes some minor arterials, collectors, and local streets), (2) State Route System, and (3) screenline data, (4) inter-county screenlines, and (5) major river crossings. In general, the model flows were found to be within reasonable range of the observed flow. The percent RMSE was about 45%. The NYBPM transit assignment (commuter rail, subway, ferry, and bus) validation considered only the AM peak period. The validation compared the BPM outputs with 1995 and 1997 transit counts available from the Metropolitan Transportation Authority (MTA), along with the model volumes from the 2001 Version of the MTA's Long Range Forecasting model. The percentage differences in the predicted and observed area wide trips were reported for different transit modes. The assignment model is expected to be reviewed and enhanced in the next update to the BPM model

3.6.5 Software

The core NYBPM system is developed using C/C++, Xbase, or Fortran programs. MATRIX.dll access is used to read and write TransCAD matrix data and a pre-assignment processor step is used to aggregate the microsimulation results, and convert them into "trip tables." Assignment of the trip tables (including truck and other commercial vehicle) is carried out in TransCAD (TransCAD 4.0) using a multi-class technique. The CENTRAL program is used to design and support the Graphical User Interface (GUI). The run time of the NYBPM is approximately 4 days.

3.6.6 Application Experience and Sensitivity Tests

The NYBPM model was developed in the period 2000-2002. However, data collection and preparation of the network started in 1994. Since its development, the model has been used to assess and evaluate traffic planning studies for over 30 local agencies and projects, including:

- Several feasibility and pricing studies for major bridges and tunnels (Tappan Zee Bridge/I-270 Alternatives Analysis and Kosciuszko Bridge)

- Major multi-modal corridor study (West Hudson)
- Major investment studies on the Gowanus Expressway and the Bruckner Sheriden Expressway.
- The Long Island East Side study, the Canal Area Transportation study, the Southern Brooklyn Transportation study, the Bronx Arterial Needs study, and the Regional Freight Plan study.
- Manhattan area pricing study (in progress), including extensive social equity analysis
- Studies involving the Hackensack Meadowland Development Corporation and the Lower Manhattan Development Corporation.
- The model has been applied to forecast mobile source emissions and air quality analysis for the year 2020. The forecasted travel characteristics include daily vehicle miles of travel (DVMT) at the county level. The DVMT measures for each county are computed by roadway functional class and compared to the base year results.

3.6.7 Challenges/Lessons Learned

Some of the challenges/lessons learned in the process of the development and implementation of the NYBPM model include:

- Develop a good user interface, online help tools, and structured documentation for the model user.
- Formal training for model users, as well as stakeholders and decision makers is an on-going requirement.
- Model run time could be a major issue though the use of multiple processors can reduce the run time significantly.
- Storage of huge data files can be problematic. The journey production files are over 500 megabytes, the mode destination choice output files are over 300 megabytes.
- Use of different version of TransCAD (version after 4.0) can cause a problem for users with newer version of the software.

3.7 Summary of the Chapter

This section summarizes the report by discussing the various aspects of the four tour-based model systems discussed so far. The aspects include: (1) General features, (2) Overall structure, (3) Calibration and Validation, (4) Software, (5) Data, and (6) Challenges/lessons learned.

3.7.1 General Features of Tour-based Models

The tour-based model systems described in this report are different from the conventional trip-based model systems in three major aspects: (1) Tour-based approach to modeling travel, (2) Tour-based to modeling time of day choice, and (3) Microsimulation approach to implementing the model systems.

All the model systems described in the report are based on a tour-based approach, which uses tour as the basic unit to represent and model travel patterns. Tours are defined as chains of trips beginning and ending at a same location, say, home or work. Such a representation captures the interdependency (and consistency) of the modeled choice attributes among the trips of a same tour.

The tour-based approach employs advanced duration/scheduling models with enhanced temporal resolution. The use of enhanced temporal resolution opens a way to track available time windows after scheduling each tour for a person, and employs the residual time window as an important variable for generation and scheduling of the subsequent tours. Thus tours, trips, and corresponding activities are scheduled in a consistent manner for each individual in a tour-based model.

All systems simulate the activity-travel patterns of each (and every) individual of the study area. Such a microsimulation implementation provides activity-travel outputs that look similar to survey data and can allow analysis of a wide range of policies on specific sociodemographic segments.

3.7.2 Overall Structure of Tour-based Models

All the model systems described in this report share a similar overall structure, although there are variations on the basic structure. The basic structure can be viewed as a hierarchy consisting of the following components:

1. Population synthesis
2. Long-term choice models
3. Person-day models or pattern-level models or activity-travel generation models
4. Tour-level models
5. Trip-level models

Tour-based model systems require the information on each (and every) individual and household of the population of the study area as inputs, because the systems simulate the activity-travel patterns of every individual in the study area. Such disaggregate-level sociodemographic inputs are generated by synthesizing a prototypical sample of the population of the study area. The synthetic sample is generated by using zonal-level (or other levels of geography such as block-level and parcel-level) sociodemographic data and forecasts of sociodemographic control variables (such as household size, structure, income, *etc*.) for sampling households from the PUMS data. The population synthesis procedure provides a synthetic sample of all households and individuals in the study area with the information on their residential locations and the control variables used in the synthesis procedure. Several other socioeconomic attributes (which are not used as control variables) required by the tour-based travel models are either directly borrowed from the matching (in terms of controlled variables) households in the PUMS data, or generated by a separate set of disaggregate models. The use of separate disaggregate models has the advantage that it provides natural variation in the predicted socioeconomic attributes, rather than “replicating” PUMS individuals and households.

After the population synthesis, the longer-term decisions such as auto ownership, work and school locations are determined. All model systems, except the MORPC model, recognize that auto ownership is a longer term decisions that are not adjusted on a daily basis. Further, SF-CHAMP and SACSIM consider work location as a longer term decision. In addition, SACSIM, and MORPC recognize that individuals may travel to locations that are not the “usual” work places for work purpose. For school locations, SACSIM model the choice as a longer-term choice, while MORPC and SF-CHAMP model it as a daily-level choice. The work and school locations are not modeled explicitly in NYBPM model. After the determination of long-term choices, the synthetic population is ready to go through a variety of activity-travel choice models. All the models simulate the entire set of a full-day’s activity-travel choices for all individuals in the population one (individual) by one (individual). Each model system assumes a particular hierarchy in which the decisions are made and simulates the decisions in a corresponding sequence. Overall, the sequence can be viewed as a 3-level hierarchy consisting of pattern-level choices, tour-level choices, and trip-level choices.

At the end of all the activity-travel model components in each model system, the activity-travel information is output. These activity-travel outputs comprise all the activities, tours and trips undertaken on a day, along with the mode, time-of-day, and destinations visited on the day for each (and every) individual in the synthetic population. The outputs are similar in format and content to a household travel survey data and can be used for a variety of policy analyses. These outputs are utilized to form the trip tables for input into standard traffic assignment modules available with the MPOs. Thus, the tour-based models replace the trip generation, trip-distribution, and mode split steps of the four-step trip-based models.

3.7.3 Data

All four tour-based model systems discussed in the report use household travel surveys as the primary sources of data for the estimation of activity-travel choice model components. Along with the household travel surveys, zonal-level (or parcel-level in the case of SACSIM) socioeconomic and land-use data, and the transportation network level-of-service characteristics are used in model estimation. It is important to note here that the data sources used in the development of tour-based models are not any different from those collected and used by regional MPOs for their trip-based model development and calibration. Thus the notion that tour-based models are hungry is not necessarily true. However, as one desires to incorporate more joint activity and interpersonal interactions in the system, tour-based models do require a reasonably large sample size to reflect adequate numbers of different interpersonal interactions (for example, between adults or between an adult and a child) in different kinds of households.

3.7.4 Calibration and Validation

For the model systems discussed in this report, the calibration and validation process for the base year are undertaken in two broad steps: (1) Preliminary validation, and (2) base year validation and calibration.

For preliminary validation, the models are used to predict the activity-travel patterns of a household survey sample (which was typically used for the model estimation and development). The model-predicted outputs for the individuals in the survey sample are compared with the observed activity-travel patterns in the survey data to validate and calibrate the models. At the preliminary validation stage, each model component, after estimation, is applied to the household survey data and verified for major discrepancies with the observed patterns in aggregate predictions. Further, after each model is implemented in the application software, the software predictions of each model component are compared with the observed patterns in the survey sample to find and fix software bugs, and carry out re-estimations or make required adjustments to model parameters.

The base-year validation and calibration involves running the synthetic population of the base year through the entire model system, along with the traffic assignment procedure, and comparing the aggregate results to available external information about actual base year characteristics. The external data is obtained from census data, transit on-board surveys, and screen line and other traffic counts.

The model systems are calibrated sequentially from top to bottom of the model hierarchy, assuming that the adjustments to the upper level models tend to impact lower level models more than vice versa. Any calibrative adjustments are made based on specific rules such as: (1) adjustment based on behavioral factors and logical explanation of the discrepancy, (2) adjusting only alternative-specific constants and general scaling parameters in choice models (to preserve the behavioral properties and elasticities of the estimated model system).

In addition to the base year calibration, several policy scenario tests are undertaken to assess the policy sensitivity of the model systems. Some model systems are also subject to forecast year validations by validating the model predictions for an “existing” forecast year with that of the observed transportation system performance and travel patterns. In addition to validating and calibrating the activity-travel modeling component of the model systems, the population synthesizer outputs, and the longer-term choice model outputs (work locations and auto ownership levels) are validated against observed data such as census journey to work data, and other census data.

Table 3.6 provides a concise summary of information on calibrations/validations and policy tests undertaken using the four model systems discussed in this report.

Table 3.6: Calibration/Validation and Policy Tests undertaken using Tour-based Travel Demand Models

SF-CHAMP Model
Calibration/Validation 1. 1990 and 1996 household survey, and 1990 Census data were used for validation and calibration 2. Department of Motor Vehicle (DMV) registrations were used to validate vehicle ownership predictions 3. Highway and transit assignment results validated against traffic counts, transit onboard survey 4. Other validation criteria include: district to district trip distributions, and employment attracted to each zone
Sensitivity tests and project level applications 1. New Central Subway light rail transit project and an alternatives analysis for the Geary Study 2. County long range transportation plan (used in an equity analysis) 3. Corridor, neighborhood level analysis, with detailed transit assignment, traffic simulation. 4. Environmental Justice (EJ) analysis. 5. Downtown cordon/area time-of-day pricing analysis (in progress). 6. Base year comparison with trip based model did not show many differences as both models were calibrated to base year 7. 2030 forecasts compared with the trip based forecasts
MORPC Model
Calibration/Validation 1. Individual model components validated against observed patterns in survey data (HIS) 2. Base year (2000) predictions validated against traffic counts, transit onboard survey, and CTPP tables. Extensive validation of highway and transit assignment results was carried out by facility type, screen lines, and district level 3. Survey data expanded to match synthetic population totals and predictions were validated as above
Sensitivity tests and project level applications 1. The North Corridor Transit Project (in forecasting, environmental impact study). The model was used to study trip distribution for work purposes, estimate and graphically present user benefits and other benefits and disbenefits of the project. The project is a likely candidate for the Federal Transit Administration's (FTA's) New Starts program. 2. Regional air quality conformity analysis. 3. Several corridor studies for highway extensions. 4. Central business district parking study. 5. 2030 forecasts produced for alternative transit scenarios (w/o LRT and w/LRT). Changes in VMT, VHT, and speeds were verified for reasonableness 6. Peak hour spreading (from year 2000 to 2030) phenomenon verified for intuitiveness 7. Tested for a shortened work day (8 hours to 7.5 hours) policy
SACSIM Model
Calibration/Validation 1. Calibrated for an equilibrated state and tested for a base year of 2000 against Census data, transit on-board surveys, screen line and other counts
Sensitivity tests and project level applications 1. Sacramento State BRT project 2. Regional air quality conformity analysis.

3. A “New Starts” LRT investment study. 4. A “4 D’s” study (density, destination, design, diversity). 5. Integration with PECAS land use microsimulation model. 6. 2005 forecasts were validated, scenario testing and 2032 forecasting work is underway 7. Cordon pricing and increased network connectivity scenario tests were carried out. Simulation error was controlled during the sensitivity tests *8.* Plans to compare tour based and trip-based models with respect to trip-level outputs, and undertake sensitivity tests
NYBPM Model
Calibration/Validation 1. 1997/98 household survey, and 1990 Census data were used for validation and calibration *2.* Highway and transit assignment results validated against traffic and transit counts
Sensitivity tests and project level applications 1. Several feasibility and pricing studies for major bridges and tunnels (Tappan Zee Bridge/I-270 Alternatives Analysis and Kosciuszko Bridge) 2. Major multi-modal corridor study (West Hudson) 3. Major investment studies on the Gowanus Expressway and the Bruckner Sheriden Expressway 4. The Long Island East Side study, the Canal Area Transportation study, the Southern Brooklyn Transportation study, the Bronx Arterial Needs study, and the Regional Freight Plan study. 5. Manhattan area pricing study (in progress), including extensive social equity analysis 6. Studies involving the Hackensack Meadowland Development Corporation and the Lower Manhattan Development Corporation. *7.* The model was applied to forecast mobile source emissions and air quality analysis for the year 2020. The forecasted travel characteristics included daily vehicle miles of travel (DVMT) at the county level. The DVMT measures for each county were computed by roadway functional class and compared to the base year results.

3.7.5 Software

At present, there are no readily available standard software packages to apply tour-based models. Each of the model systems discussed in the report was developed and implemented as customized stand-alone software, and then integrated with other pre-existing application package (such as TP+ and CUBE) modules for land-use modeling and/or traffic assignment. The SF-CHAMP model system is coded as a series of C^{++} programs, the SACSIM model system is coded using the Pascal programming language, and the MORPC tour-based models are coded in Java, and the NYBPM is coded in C/$C^{++,}$ Xbase, or Fortran programs. While it is possible to implement tour-based models in standardized software application packages (such as TransCAD, TP+, and CUBE), such standardization may "*freeze*" the possibility of innovation in developing tour-based travel modeling systems.

3.7.6 Challenges/Lessons Learned

The development of tour-based models requires careful and extensive data preparation procedures to construct entire "sequences" of activities and "tours" of travel. Further, as aforementioned, tour-based model development is associated with an initial overhead of data preparation, model estimation, calibration and validation, and the process of "*putting it all together*" into customized software. However, once the model system is developed, the system can be packaged as user-friendly travel demand modeling and policy analysis software. Further, the software can be sufficiently generic to allow its use in any study area, provided the model parameters for that area are available.

The implementation of tour-based models (for either the base year or for future years) requires the end-user to be well aware of the details of the system. Another implementation challenge is the significant amount of runtime, because tour-based models simulate the activity-travel patterns of each (and every) individual of a study area. However, it appears that the run times can be significantly reduced by simulating the activity-travel patterns of a small sample of the population without compromising the accuracy of the aggregate-level outputs and/or using efficient computing strategies such as data caching and multi-threading.

The implementation challenges associated with tour-based models appear to be higher for the forecast year implementation rather than for the base year implementation. This is primarily because of the need to generate detailed socioeconomic input data for the forecast years.

Finally, while the required technical background, the resource requirements for development and maintenance, and the implementation challenges, and the institutional issues associated with ownership are immediately evident, the potential practical benefits of tour-based models need to be thoroughly assessed and documented. Thus, though the conceptual appeal and the behavioral realism make the tour-based models theoretically superior, a clear assessment and documentation of their benefits vis-à-vis their costs would be helpful.

Chapter 4. Model Design Recommendations for TxDOT and Data Needs

4.1 Overview

This chapter consists of two parts. The first part (Section 4.2) provides design recommendations for implementing tour-based travel demand model systems for TxDOT. Two model design options are considered. For each option, the discussion includes the conceptual framework, the sequence in which travel patterns are modeled, possible analytical methods to model travel patterns, the temporal and spatial resolution, and the application method. The second part of the report (Section 4.3) identifies: (a) the data needs for implementing the proposed tour-based travel demand model designs, and (b) additional data that may be considered for collection in future survey efforts.

4.2 Model Design Recommendations

This section begins with a brief discussion and comparison of trip-based and tour-based models (Section 4.2.1). Subsequently, model design recommendations are provided in Sections 4.2.2 and 4.2.3.

4.2.1 Trip-based and Tour-based Models

The traditional trip-based approach to travel demand modeling uses individual trips as the unit of analysis and usually comprises four sequential steps in travel dimensions: trip generation, trip distribution, modal split, and traffic assignment. Tour-based models, on the other hand, use "tours" as the basic elements to represent and model travel patterns. A tour is a chain of trips beginning and ending at the same location. Using a tour as the base unit of modeling overcomes several limitations of the trip-based approach. First, the trip-based approach treats travel as a collection of independent "trips," and ignores the inter-relationship among the attributes (such as mode, destination, and time-of-day) of different trips within a tour. As a result, the trip-based approach can lead to illogical trip chain predictions and imprecise estimates of the overall travel demand forecasts. In contrast, the tour-based representation helps maintain consistency across, and captures the interdependency of the modeled choice attributes among, the trips of the same tour. Thus, the travel attributes (mode, destination, and time-of-day) related to non-home-based travel can be properly linked to the corresponding home-based travel. Second, in the trip-based approach, the time-of-day choice is usually either completely ignored, or is modeled after one of the first three steps (trip generation, trip distribution, and model choice) in a relatively straightforward manner through the application of fixed time-of-day factors. That is, the proportion of trips made in each time period—typically AM peak, PM peak, and off-peak period—is treated as being fixed. Such fixed time factors do not allow the assessment of time-of-day specific policy measures such as peak period pricing, high occupancy vehicle lane designation during peak periods, and flexible work schedules. In contrast, tour-based approaches usually allow the analyst to employ models with a high level of temporal resolution (such as 30 minutes or 1 hour time periods), with temporal modeling of tours and trips within tours. Third, the trip-based models are typically applied at the aggregate level of traffic analysis zones (or TAZs). The tour-based model, on the other hand, is used to predict travel patterns at the individual and household levels at which decisions are actually made. Thus, the impact of policies can be assessed by predicting individual-level behavioral responses instead of employing trip-based statistical averages that are aggregated over coarsely defined demographic segments. Further, even from a long-term forecasting point of view, the cross-classification techniques that are at the core of the application of trip-based methods employ statistical averages over highly aggregated socio-demographic segments. The tour-based model, on the other hand, has the ability to relatively easily accommodate virtually any number of decision factors related to the socio-demographic characteristics of the individuals, and the travel service characteristics of the surrounding environment. Thus, the tour-based models are better equipped to forecast the longer-term changes in travel demand in response to the changes in the socio-demographic composition and the travel environment of urban areas.

4.2.2 Recommendations for TxDOT

Figure 4.1 provides the research team's recommendations for the design and implementation of advanced travel-demand model systems. As a first step, and based on discussions with the project committee and the synthesis of the literature on tour-based models (work conducted for Task 1 of the project), the research team recommends the development of a tour-based model with no explicit recognition of interactions among tours (such a model system will be referred to as a simple tour-based model system). The reader will note here that, although the proposed model system is relatively simple compared to a number of other tour-based model systems currently in use (for example, all four models—the SF-CHAMP model, the MORPC model, the SACSIM model, and the NYBPM model—reviewed in the previous report), the tour-based approach itself represents a significant improvement (over the trip-based four-step approach) in the representation and modeling of travel patterns, as briefly discussed in Section 4.2.1. In the recommended tour-based approach, the linkages among the trips within a tour are explicitly recognized even if different tours of a person are treated independently of each other. The medium-term recommendation is to consider a tour-based model system with explicit recognition of the interactions among tours (such a model system will be referred as an advanced tour-based model system).

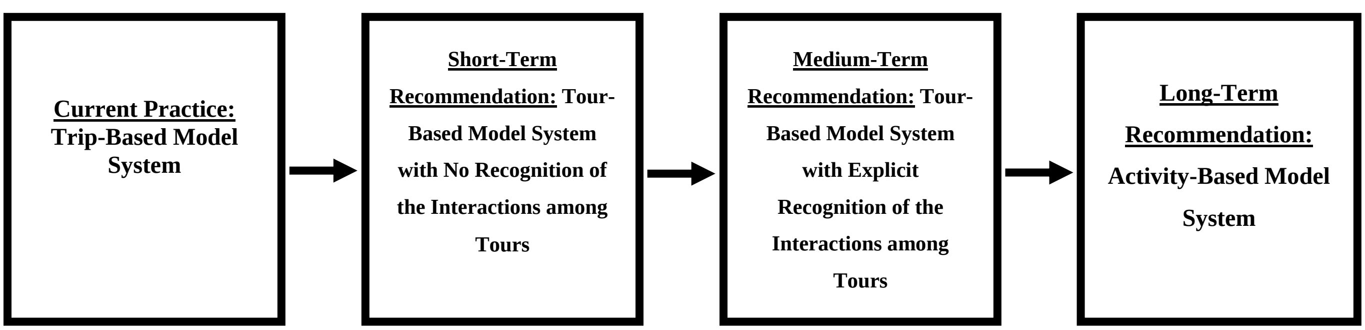

Figure 4.1: Recommended Advanced Travel-Demand Model System Development Phases

Finally, for the most advanced enhancement, the research team recommends the use of an activity-based model system, such as the Comprehensive Econometric Model of Daily Activity-Travel Patterns (CEMDAP). In comparison with the tour-based approach, the activity-based approach represents an advanced framework to model travel demand, and is grounded in a more behaviorally oriented activity participation theory. The activity-based approach to modeling travel demand views travel as derived from the need to pursue activities in time and space. It fundamentally focuses on "activity participation behavior," including activity participation, activity durations, and time-use behavior. Further, by placing primary emphasis on activity participation and focusing on sequences or patterns of activity participation and travel behavior (using the whole day or longer periods of time as the unit of analysis) rather than travel, the approach recognizes the spatial and temporal linkages among the various activity-travel decisions of an individual, as well as the linkages between the activity-travel patterns of different individuals within a household.

Table 4.1 provides recommendations for various design aspects associated with the trip-based model system, the simple tour-based system, the advanced tour-based system, and the activity-based model system.

As a first step towards travel model improvement, in the following section, we provide two design recommendations for a simple tour-based model system.

Table 4.1: Short-Term, Medium-Term and Long-Term Advanced Model Design Recommendations for TxDOT

	Trip-based Model System	Tour-based Model System		Activity-based Model System
Design Aspects	**Current Practice**	**Simple System**	**Advanced System**	**Long-term Recommendation**
Basic Aspects				
Primary units of analysis	TAZs	Individuals and households	Individuals and households	Individuals and households
Prediction methods used	Aggregate methods	Microsimulation	Microsimulation	Microsimulation
Space and Time				
Spatial representation and resolution of the input land-use and level-of-service (LOS) data	TAZs for both land-use and LOS	TAZs for both land-use and LOS	TAZs for both land-use and LOS	TAZs for both land-use and LOS. Could be further enhanced to include parcels for land use
Spatial resolution of travel predictions	TAZ	TAZ	TAZ	TAZs, could be further enhanced to parcels
Temporal resolution of the input transportation level-of-service data	3 to 5 time periods per day	5 time periods	5 to 10 time periods per day (depending on empirical tests and data availability) (finer resolution for dynamic LOS inputs)	5 to 10 time periods per day (depending on empirical tests and data availability) (finer resolution for dynamic LOS inputs)
Temporal resolution of travel predictions	3 to 5 time periods per day	1 hour intervals	30 minute intervals, with 5 to 15 minute intervals in peak periods	Continuous time
Activity Participation Behavior				
Out-of-home activities	No	Partial (as detailed tour/trip purposes)	Partial (as detailed tour/trip purposes)	Yes (detailed activity participation as the basis for travel)
Time-use behavior	No	No	No	Yes
Modeling Methods Used	Cross Classification, gravity methods, and logit	Discrete choice models	Discrete choice models	Discrete/Continuous models
Children's Travel and Household-level Interactions				
Children's activity-travel behavior	No	No	Yes (Partially)	Yes (Completely)
Household-level interactions	No	No	No	Yes
Joint activity/travel	No	No	No	Yes
Allocation of responsibilities	No	No	No	Yes
Allocation of vehicles	No	No	No	No, but could be included later

	Trip-based Model System	Tour-based Model System		Activity-based Model System
Design Aspects	**Current Practice**	**Simple System**	**Advanced System**	**Current Practice**
Other Aspects				
Explicit modeling of work arrangements	No	No	Yes	Yes
Explicit modeling of parking choice	No	No	Yes	No, but can be included later
Effect of climate and seasons	No	No	Yes	No, but can be included later
The time frame of analysis	1 weekday	1 week day	1 weekday and 1 weekend day	1 week day, could be further enhanced to accommodate 1 weekday and 1 weekend day, or a whole week
Traffic Assignment	Equilibration with static traffic assignment	Iterative equilibration with static traffic assignment	Equilibration with dynamic traffic assignment	Iterative equilibration with static traffic assignment. Could be further enhanced to accommodate equilibration with dynamic traffic assignment
Integration with Land-Use Model	No	No	No	No, but can be incorporated later

4.2.3 Model Design Recommendations

4.2.3.1 Design Option # 1

The first design option is based on the design structure of the New Hampshire Statewide Travel Model System (NHSTMS), though several additional desirable features are included to enhance behavioral realism and policy sensitivity. For example, the NHSTMS is implemented using sample enumeration, but we propose the use of a microsimulation method in implementation. This will enable the analyst to undertake disaggregate-level policy analysis and focus on specific demographic segments of the population.

Figure 4.2 depicts the sequence in which travel decisions may be modeled. The model system starts with a population synthesizer, taking as input the U.S. Census Public Use Microdata Sample (PUMS), the population and employment data and other socioeconomic data that may be developed/available for the region. The control variables required for synthetic population can include variables such as household size and composition, number of workers, and household income. The population synthesizer will be used to create a synthetic population of households drawn from the PUMS and allocated to the Traffic Analysis Zones (TAZs). Information on other sociodemographics, such as individuals' age, gender, and employment and student status, may be drawn from the PUMS data by matching each synthetic household to similar households from the PUMS. After the generation of the synthetic population and other sociodemographics, long-term choices such as work location zone and household auto ownership are simulated for all synthetic individuals and households in the population. The details of the long-term choice models, including the model structure, choice alternatives, and possible policy sensitive variables in the specification are provided in Table 4.2 (see rows labeled 1.1 and 1.2).

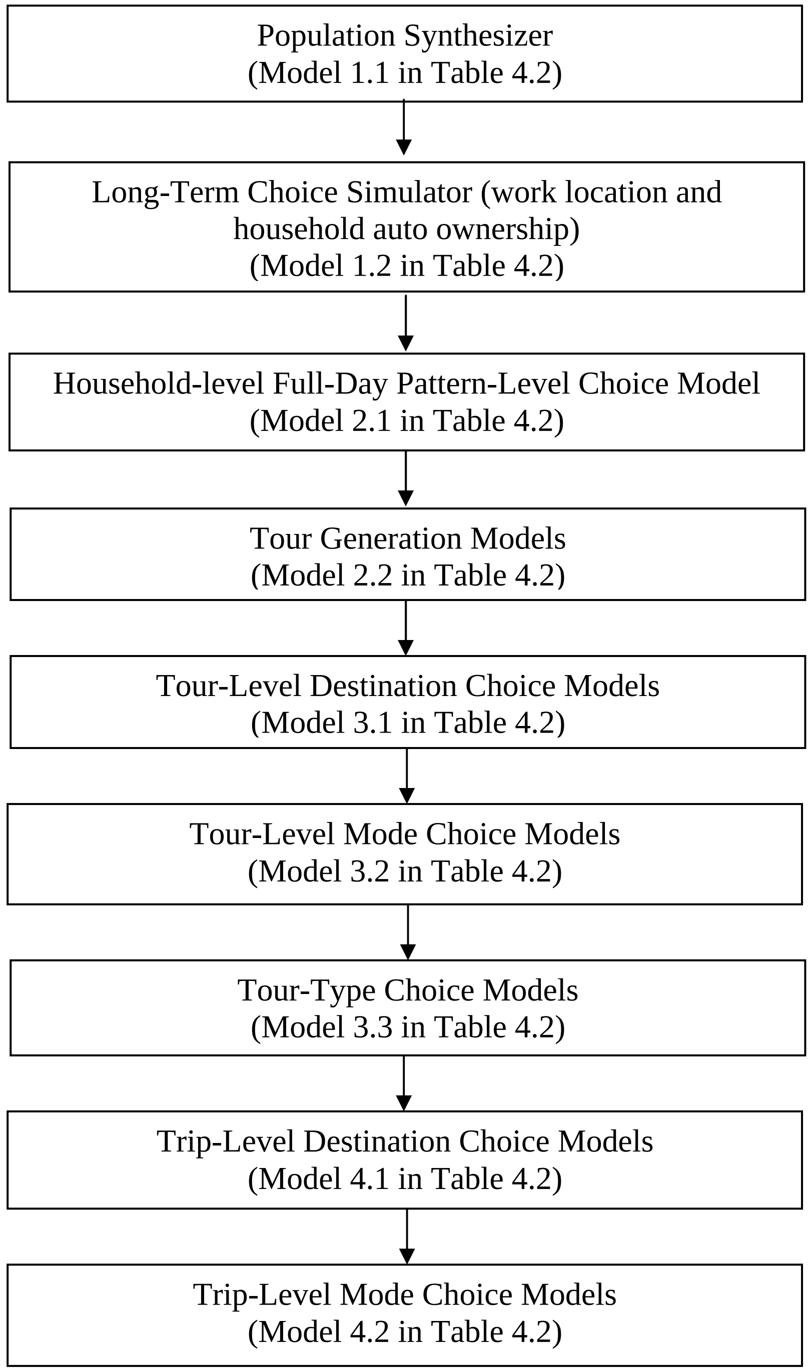

Figure 4.2: Structure of the Design Option # 1 Model System

Table 4.2: List and Sequence of Activity-Travel Choices that may be Modeled in Design Option # 1

Model ID	Model Name and Outcome	Model Structure	Choice Alternatives	Comments/Policy Sensitive Variables
Population synthesizer and Long-term choice models: Generate the disaggregate-level socio-demographic inputs consisting of individual and household records				
1.1	Synthetic population generator: Predicts household size, composition, number of workers, income, person age, gender, employment and student status, along with the TAZ level location of the household	Iterative proportion fitting (IPF)	N/A	Possible control variables: Household size and composition, number of workers, and household income.
1.2	Long-Term Choice Simulator (work location and household auto ownership)	Multinomial Logit (MNL)	Work locations: residence zones; auto ownership: 0, 1, 2, 3, and 4+	Possible control variables: land use variables, travel cost/time variables
Pattern-level choice models: Predict the number of tours generated by a household during a day for six purposes. Hierarchy of purposes: work, school, other (personal business, meal, *etc*), shopping, social/recreational, and drop off/pickup.				
2.1	Daily tour pattern choice model: Predicts whether or not a household generates tours for 6 activity purposes in a day	Binary Logit (BL)	0 or 1+ tours for each activity purpose estimated sequentially based on purpose hierarchy	Possible control variables: Household (HH) size, HH structure, number of workers, income, number of vehicles, seasonal variable, residential location variable, and tour frequencies of purposes higher up in the hierarchy, *etc*.
2.2	Tour generation models: Predicts the number of tours for each of the 6 activity purposes for which tour making is predicted from the above model	MNL	1,2,3 or 4+ tours for each purpose	
Tour-level models: Predict primary destination, number of stops, and mode for all tours.				
3.1	Tour primary destination choice model: Predicts tour destination zone except for work tours (since the work location is already known at this time point). This model is applied for all tours in the order of their priority, with high priority tour-outcomes known at the low-priority tour models.	MNL	Sample of available TAZs (TAZs availability based on purpose-specific size and travel time).	Possible control variables: Travel time, travel cost, socio-demographics of destination zone including population density, parking & employment mix, and CBD indicator, *etc*.
3.2	Tour-level main mode choice models: Predicts the tour-level mode choice (by purpose, for all tours)	Nested Logit (NL)	Drive alone, shared ride, transit, bike, and walk	Possible control variables: Out-of-vehicle travel time , in-vehicle travel time, travel cost, parking cost, number of transfer, built environment factors of tour origin and primary destination, *etc*.

Model ID	Model Name and Outcome	Model Structure	Choice Alternatives	Comments/Policy Sensitive Variables
3.3	Tour type models: Predicts the number of stops on a tour for all tour purposes and whether or not a tour has a sub-tour (modeled only for work tours)	MNL	1 (more) stop for any of 6 purposes, or no (more) stops. In application, model may be repeated until the 5^{th} stop purpose or no (more) stop is predicted. For work-based sub-tour the alternatives are 0 or 1+.	Possible control variables: Number of workers, income, number of vehicle, number of tours of purposes higher in the hierarchy, *etc.*
Trip-level models: Predict stop locations and trip modes (stops before the primary destination are modeled in the reverse chronological order).				
4.1	Secondary destination choice models**:** Predicts the destination zone of each intermediate stop, conditional on tour origin and primary destination, and location of previous stops	MNL	Sample of available TAZs (TAZs availability based on purpose-specific size and travel time).	Possible control variables: Total generalized detour time based on a sum of all impedance values w.r.t primary destination and tour origin, distance, travel time as a fraction of available time, proximity to stop origin and tour origin, network connectivity by modes, parking, employment density, land-use mix, *etc.*
4.2	Trip mode choice models: Predicts trip mode choice (conditional on main tour mode, the mode of previously modeled adjacent trip, and the specific OD pair anchors)	MNL	Drive alone, shared ride, transit, bike, and walk	Possible control variables: Generalized cost (travel time and cost variables multiplied by the tour level mode choice coefficients).

Next, the synthetic households and individuals are taken through three sets of subsequent models:

(1) Pattern-level choice models—Models 2.1 and 2.2 in Figure 4.2/Table 4.2

(2) Tour-level choice models—Models 3.1, 3.2 and 3.3 in Figure 4.2/Table 4.2

(3) Trip-level choice models—Models 4.1 and 4.2 in Figure 4.2/Table 4.2

Each set of models consists of a series of econometric choice models. The choice outcomes from models higher in the hierarchy (assumed to be of higher priority to the decision-maker) are treated as known in the lower level models. That is, for example, pattern level choices are considered exogenous while modeling tour-level choices, and the pattern- and tour-level choices are considered exogenous while modeling trip-level choices. For all the individual models belonging to the pattern-level, tour-level, and trip-level, Table 4.2 lists the model name and the output of the model, the econometric model structure of the model, the set of choice alternatives, and identifies important policy sensitive variables in the model. As can be observed from the table, each of the activity-travel choices is modeled using either a multinomial logit or a nested logit structure.

Among the models listed in Table 4.2, models 2.1, 2.2, and 3.3 together form the activity and travel *generation models*, which provide as outputs a list of all the activities, tours, and trips generated for the person-day. These activities, tours, and trips are scheduled using the other tour-level and trip-level models (models 3.1, 3.2, 4.1 and 4.2), which can also be labeled as the *scheduling models*. The scheduling models determine the where (destination) and how (mode) of the generated activities and travel. Then, the predicted trips can be aggregated into Origin-Destination (OD) trip tables, and combined with other OD trip tables such as external trips and commercial traffic. A set of predetermined factors are used to divide the daily trip tables into trip tables for different time periods (for example, AM peak, midday, PM peak, and evening off-peak). Finally, the network traffic assignment models (such as using TransCAD) can be used to load the trips onto the network. Traffic assignment will need to be iteratively equilibrated with the travel-demand models to obtain a stable set of network traffic volumes.

An important aspect of this model system is the use of tour frequencies higher up in the hierarchy as explanatory variables to inform the subsequent tour type models. This ensures consistency and behaviorally more realistic trip generation. Another feature of this model is the simplicity of the design structure, which makes it more readily transferable from a trip-based to a tour-based approach.

4.2.3.2 Design Option # 2

The second design option presents a behaviorally and conceptually more realistic (and more complex) model structure compared to the first one. This design option includes several desirable features for enhanced behavioral realism in addition to all the features included in Design Option # 1. For example, in addition to work location and household auto ownership, school location is also considered as a long term choice. Further, all the individuals are divided into three person types (children, workers, and non-workers), and all the home-based tours are divided into six purposes (school, work, university, maintenance, discretionary, and others (personal business, drop off/pick up, *etc*)). To reflect general priority of individuals and corresponding activities within the household as well as the logical causality in the intra-household group-decision-making, the tours in the model are generated in a particular order (see

Section 4.2.3.1 for details). In addition, instead of using predetermined time-of-day specific factors, time-of-day choice for tours and trips within a tour (if any) is modeled by purpose. Further, log-sums from tour-level mode choice models and stop location choice models are used in the primary destination choices and the frequency of stop models, respectively. The use of log-sum variables enhances the sensitivity of location choices to level-of-service attributes. Similar to the previous design option, explicit interactions among tours are not incorporated in the proposed model structure.

Figure 4.3 outlines the model system of Design Option # 2. The system comprises of a population synthesizer, a long-term choice simulator, pattern level choice models, tour-level choice models, and trip level choice models. Details of each model, including the model structure, choice alternatives, and the possible control variables/policy sensitivity variables in the specification are presented in Table 4.3. The model system starts with a population synthesizer, which takes the same form as already discussed under Design Option # 1.

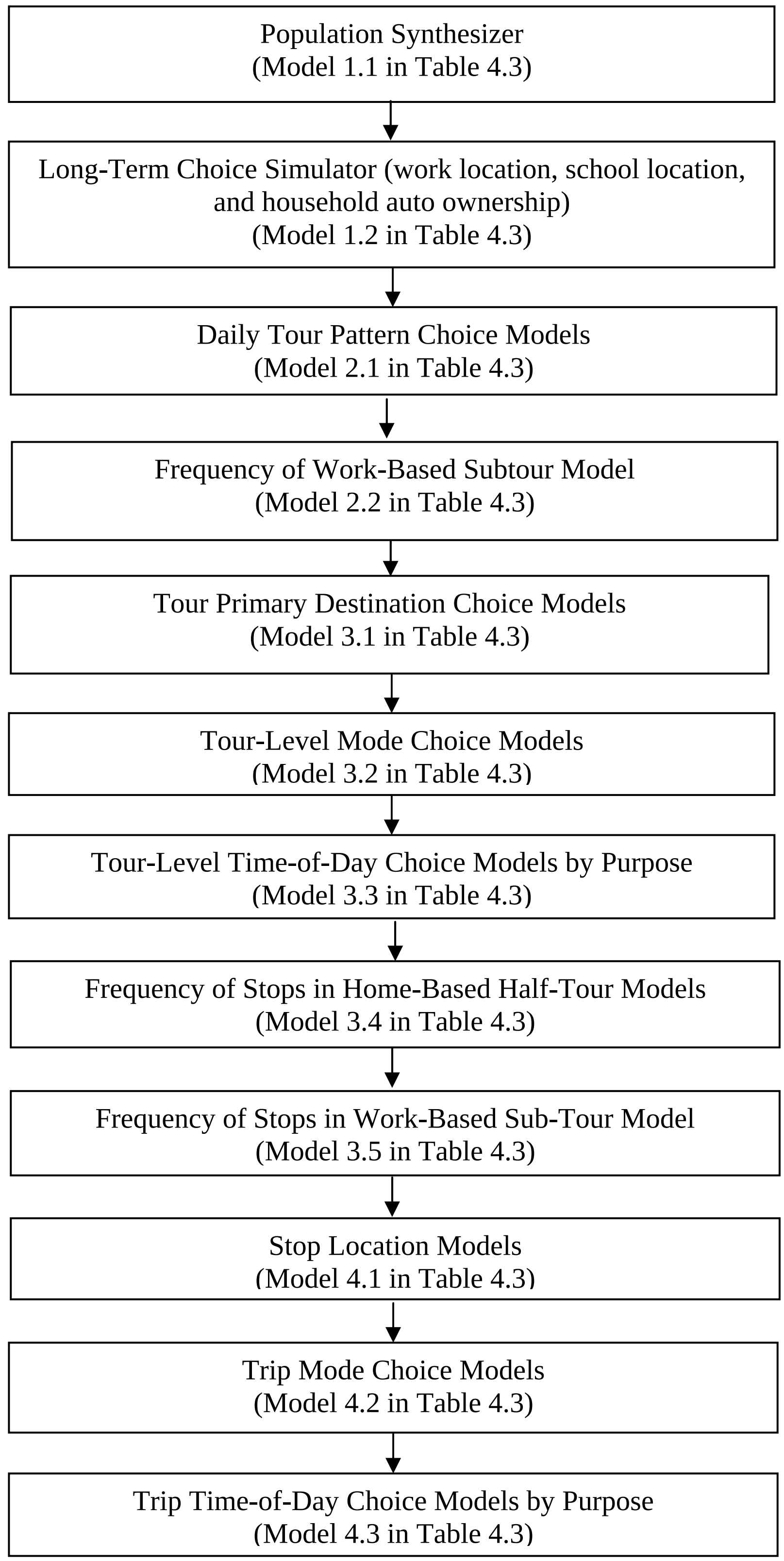

Figure 4.3: Structure of the Design Option # 2 Model System

Table 4.3: List and Sequence of Activity-Travel Choices that may be Modeled in Design Option # 2

Model ID	Model Name	Model Structure	Choice Alternatives	Comments/Control Variables/Policy Sensitive Variables
Population synthesizer and Long-term choice models: Generate the disaggregate-level socio-demographic inputs consisting of individual and household records				
1.1	Synthetic population generator: Predicts household size, composition, number of workers, income, person age, gender, employment and student status, along with the TAZ level location of the household	Iterative proportion fitting (IPF)	N/A	Possible control variables: household size and composition, number of workers, and household income.
1.2	Long-Term Choice Simulator (work location, school location, and household auto ownership)	MNL	Work and school locations: residence zones; auto ownership: 0, 1, 2, 3, and 4+	Possible control variables: land use variables, travel cost/time variables
Pattern-level choice models: Predicts, for each person, the number of tours of different types on a day and the number of trip segments within each tour. Tour types are: home-based school, home-based work, home-based university, home-based maintenance, home-based discretionary, home-based other, and work-based. Models are estimated and applied separately for 3 person types: children, working adults, and non-working adults.				
2.1	Daily tour pattern choice models (segmented by person type: children, working adults, and non-working adults): Jointly predict whether or not a person undertakes tours for 6 activity purposes in a day, the number of tours for each activity purpose, and whether or not work-based sub tours are made	MNL/NL	Home-based tour: feasible combinations of school/work/university/maintenance/discretionary/other tours; work-based tours: 0 or 1+; base alternative is "Stay at home"	Possible control variables: number of vehicles, number of workers, number of children, income, accessibility to transit, accessibility to retail and service locations from home and work, etc.
2.2	Frequency of work-based subtours	Probability model based on observed distributions	1, 2, 3, or 4	Probability model as a function of tour trip chain type
Tour -level models: Predict primary destination, number of stops, mode, and time-of-day for all tours.				
3.1	Tour primary destination choice model: Predicts tour destination zone except for work and school tours. This model is applied for all tours and work-based subtour, in the order of their priority, with high priority tour-outcomes known at the low-priority tour models.	MNL	A sample of TAZs stratified according to importance from all TAZs in the study region	Possible policy sensitive variables: Area type, level-of-service, and zonal employment by types, school/college enrollment of potential destination zones, area size, tour mode choice log-sums to potential destinations

Model ID	Model Name	Model Structure	Choice Alternatives	Comments/Control Variables/Policy Sensitive Variables
3.2	Tour-level mode choice models: Predict the primary mode for the tour	NL	Drive alone, shared ride 2, shared ride 3+, walk, bike, and transit	Possible policy sensitive variables: Level-of-service and built environment factors of tour origin and primary destination. number of transfers, number of stops, parking cost, and transit cost
3.3	Tour-level time-of-day choice models by purpose: Predict half-hour time periods of arrival at and departure from the primary destination	MNL	Combinations of all feasible half-hour intervals of arrival and departure from the primary destination	Auto and transit travel times, network accessibility to employment, service, and retail by auto and transit
3.4	Frequency of stops in home-based half-tour models: Predict the number of stops for each home-based half-tour type	MNL	0, 1, 2, 3, 4+ stops	Possible policy sensitive variables: Logsum stop density measure (from the stop location model), income, number of car, journey distance and time
3.5	Frequency of stops in work-based sub-tour model: Predicts the number of stops in work-based subtour	MNL	Four choice alternatives: no stops on outbound or return leg, only one stop on the outbound leg, only one stop on the inbound leg, and one stop on each leg.	Possible policy sensitive variables: Logsum stop density measure (from the stop location model), income, number of car, journey distance and time
Trip-level models: Predict stop locations, trip modes, and trip time-of-day choice. Stops before the primary destination, location, and time-of-day are modeled in the reverse chronological order. The second half-tour back to the origin are modeled in the regular chronological order.				
4.1	Stop location models**:** Predicts the destination zone of each intermediate stop, conditional on tour origin and primary destination, and location of previous stops.	MNL	A sample of TAZs stratified according to importance from all TAZs in the study region	Possible policy sensitive variables: Stop-density zonal size variable (based on land use variables such as total employment, retail employment, school enrollment, etc), relative route deviation, aggregate travel modes (drive alone, shared ride, and transit)
4.2	Trip mode choice models: Predicts trip mode choice (conditional on main tour mode, the mode of previously modeled adjacent trip, and the specific OD pair anchors)	MNL	Drive alone, shared ride 2, shared ride 3+, walk, bike, and transit	Possible policy sensitive variables: Travel time, travel cost (including parking cost), income, number of car, journey distance and time

Model ID	Model Name	Model Structure	Choice Alternatives	Comments/Control Variables/Policy Sensitive Variables
4.3	Trip time-of-day choice models by purpose: Predict arrival time (departure time) choice for stops in first (second) half tour, conditional on the time windows remaining from previous choices	MNL	Feasible alternatives among the 48 half-hour time period alternatives	Auto and transit travel times, the presence of transit path in time period

The next set of models (models 2.1 and 2.2 in Figure 4.3/Table 4.3) predicts each person's full-day activity and travel patterns. In particular, the *daily tour pattern generation* and *frequency of work-based subtours* models are used to predict the main dimensions of a person's travel across the day. For this, all the individuals are divided into three person types (children, workers, and non-workers), and all the home-based tours are divided into six purposes (school, work, university, maintenance, discretionary, and others (could include personal business, drop off/pick up, etc)). In addition, tours undertaken from work (work-based subtours) are considered. To ensure consistency, the tours in the model are generated in the following order:

1. Home-based school tour – for children,
2. Home-based school tour – for non-workers,
3. Home-based school tour – for workers,
4. Home-based work tour – for workers,
5. Home-based university tour – for non-workers,
6. Home-based university tour – for workers,
7. Work-based subtour – for workers,
8. Home-based maintenance tour – for non-workers,
9. Home-based maintenance tour – for workers,
10. Home-based maintenance tour – for children,
11. Home-based discretionary tour – for non-workers,
12. Home-based discretionary tour – for workers,
13. Home-based discretionary tour – for children,
14. Home-based other tour – for non-workers,
15. Home-based other tour – for workers, and
16. Home-based other tour – for children.

Next, the tour-level destination, frequency of stops in each tour, mode choice, and time-of-day choice models by purpose (see models 3.1 to 3.5 of Figure 4.3/Table 4.3) are used to determine the primary destinations of all home-based non-work/non-school tours, the number of stops made, the primary modes used to travel, and time-of-day for all work and non-work tours, respectively. Subsequently, the trip-level destination, mode choice models, and time-of-day choice models (models 4.1 to 4.3 of Figure 4.3/Table 4.3) are used to determine the locations, modes, and time-of-day of intermediate stops in all the tours, conditional upon the tour-level attributes. The tour-travel model system is applied, in succession, to each (and every) synthetic household to obtain the full-day travel information for all individuals in the population. The final output is a list of all the trips undertaken by all individuals in the synthetic population. This output can be aggregated by time-of-day and mode into trip tables for highway and transit assignment, and can also be combined with other O-D tables, such as truck and other commercial vehicle O-D tables. The combined trip tables can be assigned to the traffic network using TransCAD software and iteratively equilibrated with Design Option # 2 model to obtain stable network traffic volumes.[10]

An important aspect of this model system is the use of log-sums from tour-level mode choice models (i.e., the sum of the exponents of the individual modal utilities) to inform primary

[10] As stated before, instead of using predetermined time-of-day factors, time of day choice for tours is modeled in the second design option. However, since the design structure does not include interactions among tours, one should ensure that there is no overlap in tours. One way of achieving this might be not to allow decision makers to make more than one tour within each time-of-day choice segment.

destination choices. The log-sums are also used from stop location choice model to update the stop frequency. The use of log-sum variables enhances the sensitivity of location choices to level-of-service attributes.

4.3 Data Needs and Recommendations

This section discusses the data needs for estimation, calibration, validation, and application of the tour-based travel demand model for current and future years. The section also discusses any additional data that may be considered for collection in future survey efforts.

4.3.1 Data Needs for Tour-Based Model Implementation

The primary sources of data for the estimation of tour-based models are household activity and/or travel surveys. Data on transportation system networks and regional land-use are also used in model estimation. In addition to these data for the estimation of tour-based models, additional data are required for model calibration and validation, and highly detailed sociodemographic information is required for the application of the models to a study area.

4.3.1.1 Household Activity and/or Travel Survey Data

As the term "household activity and/or travel surveys" suggests, the surveys can be either travel surveys (that collect information on out-of-home travel undertaken by the household members) or activity-travel surveys (that collect information on both in-home and out-of-home activities and associated travel). Both the surveys collect information on: (1) the household-level characteristics, (2) the individual-level characteristics, and (3) the travel undertaken by the individuals, which includes how, why, when, and where they traveled. The development of several advanced travel demand models to date has involved the use of household travel survey data that is not any different from those collected and used by regional MPOs for their trip-based model development and calibration. For example, the activity-based model CEMDAP for the DFW area employed the 1996 Dallas Fort-Worth Household Travel Survey conducted to collect information on out-of-home activities and travel on a weekday for a sample of individuals from about 4000 households. Household-level, person-level, and travel information needed in the development of a tour-based model are listed below:

- Household-level Information: Household-level information includes data on household location, household structure, life cycle stage, income, vehicle ownership, bicycle ownership, housing characteristics, and house ownership.
- Person-level Information: Person-level information includes data on age, gender, race, ethnicity, education, student status and school location, employment status, employment location, work hours, and the ownership of driving license.
- Individual Travel Information: Travel information includes detailed tour-level and trip-level information for all individuals in a household. For each tour, information on the location and purpose of the primary destination, number and location of stops, tour start and end time, mode used, and whether or not the tour began and ended at home. For each trip, information on the origin and destination of the trip, mode(s) used, trip begin/end time, and trip purpose.

4.3.1.2 Land-use Data

Land-use data includes information on the spatial residential characteristics of households, employment locations, and school and other locations at the level of spatial resolution (for example, traffic analysis zones) used in the models. The typical land-use information includes size and density measures, such as number of households, population, area (or size), employment by each category of employment, household density, population density, and employment density for each category of employment.

4.3.1.3 Transportation Network and System Performance Data

Transportation network data typically includes highway network data and transit network data. The highway network data captures information on transportation facilities and system performance (or the level-of-service), including the functional class, distance, direction (one-way or two-way), traffic controls (traffic signals, stop signs, *etc.*), toll cost, number of lanes, hourly capacity, posted speed limit, and uncongested travel speed of each network link, and between each pair of TAZs. Transit network data includes the routes followed by buses and trains, the frequency of service, travel speeds, distance, and travel time between each pair of TAZs.

The transportation system performance data should be of high quality, with time-varying level-of-service (LOS) characteristics (in-vehicle travel time, out-of-vehicle travel time, access, egress, and waiting times) across different time periods, as well as across different location pairs. In fact, moving toward a finer temporal resolution requires LOS data that varies across finer time periods in the day (as opposed to the typically used 3 to 5 time periods a day). Such time varying LOS data may be available with the Traffic Management Centers, which collect enormous amounts of real-time traffic speed and volume data using loop detectors and other equipment.

4.3.2 Input Data for Model Application

4.3.2.1 Synthetic population

Once the tour-based model has been estimated using the data sources discussed above, the application of the model for a study area requires as inputs the information on all individuals and households of the study area. Synthetic population generation techniques can be adopted for this purpose. These generators utilize aggregate-level regional socioeconomic and land-use projections for a subset of desired socio-demographic attributes (labeled as control variables), and create a synthetic population of households drawn from the Public Use Microdata Sample (PUMS).[11] These individuals and households are allocated appropriately to spatial units (such as (TAZs or parcels). The output from the population synthesizer comprises a list of synthetic households (and individuals) in each spatial unit with information on all the control variables. Information on other sociodemographics such as work flexibility and weekly work hours may be obtained by matching each of the synthetic households to similar households from the PUMS, as discussed previously. Subsequently, work location, school location, and household auto ownership are simulated for all synthetic individuals and households in the population. The synthetic households and individuals are then ready to be input to tour-based models. (see Guo

[11] The aggregate-level projections need to be in the form of cross-tabulations that describe the one-, two-, or multi-way distributions of some (but not all) of the desired socio-demographic attributes at a finer resolution (such as blocks/block-groups/tracts). Alternatively, the Census summary file SF1 can be used to create these cross-tabulations for Census years.

and Bhat, 2007 for an application and validation of such a population generator for the DFW area).

4.3.2.2 Inputs for forecast years

Tour-based models take as inputs the synthetic population, the land-use data, the transportation level-of-service data, and the estimated model parameters to provide detailed individual-level activity-travel patterns as outputs. Hence, for a future year forecasting exercise, the inputs should consist of the future year synthetic population and land-use and level-of-service data. The detailed input data for future years can be obtained by either using aggregate demographic or land-use projections for future years and applying a synthetic population generator, or by "evolving" the base synthetic population (see Eluru et al., 2008).

4.3.3 Data for Calibration and Validation

In this section, we discuss the data sources that can be used to calibrate and validate tour-based model systems, and identify additional data needs, if required.

4.3.3.1 Validation of input data

- The synthetic population inputs can be validated against the census data.
- To validate the input work locations, the home-work distance distribution can be matched against that in the census data.
- To validate the vehicle ownership inputs, the census data and the Department of Motor Vehicle (DMV) estimates of auto registrations can be used.

4.3.3.2 Calibration and validation of outputs

- Each component of the tour-based model system can be calibrated by comparing its predictions to the observed activity-travel patterns in the household activity-travel survey.
- The commute mode choice model can be validated using the journey to work data.
- The entire model system can be calibrated by comparing the traffic assignment outputs with the observed traffic volumes in the study area.
- Highway traffic assignment validation can be carried out by using observed traffic volumes, while transit traffic assignment validation can be carried out by using transit boardings from an on-board transit survey.

Along with the above identified base year calibrations and validations, it is essential to understand the forecasting ability and the policy sensitivity of advanced models for non-base year conditions.

To test the forecasting ability, the model performance for past years and for existing future years can be compared with the observed patterns in those years. For this purpose, complete input data (including the aggregate socio-demographic variable distributions for synthetic population generation, and the land-use and level-of-service data), observed traffic volumes, household activity and/travel survey data, and the Census data (if available) are required for past years and existing future years. In this regard, it is important that the regional planning agencies store and document the land-use data and transportation network data of past and existing future years.

For a better understanding of the policy sensitivity, it is essential to test the model predictions before- and after- real-life transportation infrastructure investments or policy actions. Hence, it is important to collect the traffic counts and other travel pattern data before- and after- any major transportation infrastructure investments or policy actions.

4.3.4 Data Recommendations for Future Surveys

In this section, we provide several recommendations for future data collection efforts to support the development/enhancement of tour-based travel demand model in Texas. The data recommendations provided here are based on: (1) the research team's experience with tour-based model development, (2) the review of the data sources used in the development of other tour-based models (as part of Task 1), and other previous and ongoing data collection effects such as: (a) The 1996 Dallas Fort-Worth Household Travel Survey, (b) The 2001 National Household Travel Survey (NHTS 2001), (c) Activity-based household travel surveys such as the 2000 San Francisco Bay Area Travel Survey (see MORPACE International Inc, 2000), and (d) The ongoing Chicago Travel Tracker Survey (see Englund et al., 2008) effort in which the PI of this project has been involved.

4.3.4.1 Household Activity and/or Travel Survey Data

4.3.4.1.1 Household-level Information

It would be beneficial to collect household-level information on the following elements: (1) household location information such as length of stay at current location, previous location, and reason for move to current location (for modeling land-use decisions for the development of an integrated land-use travel demand model), (2) household-level transit and walk usage in the week of the survey (Englund *et al*., 2008), (3) parking availability at home and its cost (for better parking scheme policy evaluations), (4) the ownership and use of computers, internet, landline phones, and mobile phones (to understand substitution effects such as internet shopping in place of routine shopping trips), (5) the availability of physically active activity opportunities (such as swimming pool, gym, and tennis courts) in and around the house (for modeling trade-offs of physically active activity participation), (6) the family or non-family nature of household, and (7) the immigration status of the household.

4.3.4.1.2 Person-level Information

To understand individuals' activity-travel patterns better, we recommend the collection of the following additional information elements: (1) usual means of travel to work and/or school, (2) usual location of work (3) physical and health limitations for travel by different modes, (4) detailed work arrangement information, including number of jobs, fulltime/part time status, occupation, length of current employment, daily and weekly work hours, typical timings of daily arrival and departure, work flexibility, telecommuting and other flexible work arrangements, parking availability and cost at work/school, and need of a vehicle for work, (5) information on any previous employment and the reasons for changing jobs, and (6) other information such as the possession of a transit pass (Englund et al., 2008).

We recommend that the information be collected for all members of the household, including children of age greater than 4.

4.3.4.1.3 Activity-travel information

Typical activity-travel surveys collect data on why (purpose), when (timing), how (mode), and where (destination) of travel. In addition to this information, it would be beneficial to collect information on the "with whom" dimension of activities and travel for modeling social context of activity participation and travel. Instead of simply asking how many other people participated in the activity and/or travel, future data collection efforts should elicit information on which household or non-household member participated with the respondent in an activity and/or travel episode, at what point the household or non-household member joined the activity and/or travel, and the extent of preplanning for activity participation and travel. This information will support the modeling of joint activity engagement and travel, and the better incorporation of shared ride travel mode choice. Other useful data would be: (1) travel times (perceived by the individuals) and travel costs including tolls, (2) parking information (such as availability and options, price, and distance from the destination) at trip ends, (3) linkage of auto travel to the particular household vehicle(s) used, (4) complete transit travel pattern information for transit trips, including access/egress modes, transfer points, and precise transit routes used and considered, and (5) travel information for recreation without specific destination (such as walk/bike trips, and pet walks).

4.3.4.1.4 Household vehicle information

Advanced travel demand model development will benefit from the collection of detailed information on the vehicles owned by households. In this regard, the following information would be valuable for each household vehicle: the primary driver, the make, model and year, the fuel type (diesel, gasoline, electricity, natural gas etc), the year and month of purchase, the type of purchase (buy new, buy used, lease, or trade-in), mileage/gallon or fuel efficiency, odometer readings at the beginning/end of the survey day and the time of purchase, and the recent annual mileage. The 2001 National Household Travel Survey, for instance, collects such detailed information on household vehicles.

4.3.4.1.5 Additional recommendations

In this section, we provide additional guidelines for collecting activity/travel data for the purpose of model estimation.

4.3.4.1.5.1 Data quality and quantity

The survey data collected for advanced travel demand model development should be of very high quality. For example, the data of all household members, including employed, unemployed, active adults, children (of age above 4), elderly, and travel-dependent household members should be collected. In addition, data on short-length walk/bike trips should be collected. Further, it is important to elicit complete activity-travel information, so that individuals' daily patterns can be plotted in time and space without any missing links. All the activity locations, including the work and school locations and the household locations, as well as the travel-transfer stops, should be geo-coded. Any missing information for any individual will significantly affect the usability of that individual's and household's data for model development in the tour- and activity-based model frameworks.

Larger data sets and larger amount of information per household can enhance the quality of model estimations, and allow the estimation of a larger number of (as well as advanced versions of) choice models. However, this must be balanced with resource constraint considerations and survey respondent fatigue issues.

4.3.4.1.5.2 Special population segments

Activity-travel needs of special population segments often vary depending on their income and other socio-economic information. For example, low income households typically have lower vehicle ownership levels, and tend to rely on the public transportation system for most of their travel needs. However, they are quite often under-represented in the survey efforts. We recommend that households from special population segments such as low-income households, single female person households, African-American households, and immigrant households be over-sampled.

4.3.4.1.5.3 Transit

Modeling transit use has been a major challenge with the typically collected household survey data. This is primarily because of the lack of adequate episodes of transit travel in the data, especially for non-commute travel. While on-board transit survey data may be used to model transit travel, it is difficult to use this information when generating travel patterns at the household and individual level. Hence, we recommend the oversampling of transit-dependent and transit-friendly households, along with information on transit availability perceptions and use of transit passes. In addition, it would be useful to elicit information on respondents' overall perceptions regarding transit reliability and level-of-service.

4.3.4.1.5.4 Weekends, length of survey period, and seasonality (Englund et al., 2008)

Weekend travel patterns can be substantially different from weekday travel patterns. Also, activity-travel patterns can be better analyzed and modeled using a time-frame that is longer than a day (such as a week). Hence, it would be beneficial to collect data on selected weekdays as well as weekend days, or for an entire week. This can be done for a small sample of households. Also, it may be useful to survey a subset of households on their travel patterns during vacations, holidays, and special event days.

4.3.4.2 Land-use Data

The following land-use data are recommended to be collected and used to enhance the behavior realism of advanced travel demand model: (1) land-use structure information, such as the percentage of commercial, residential, other, and open areas, percentage of water coverage, and the land-use mix, (3) sociodemographic characteristics, such as average household size, median household income, ethnic composition, housing characteristics such as median housing value, and housing type measures (single family and multiple family dwelling units)[12], and (4) activity opportunity measures such as activity center intensity/density (i.e., the number of business establishments per square mile) for each of the following activity types: (a)

[12] Such sociodemographic and housing data can be obtained from the Census 2000 population and housing data summary file (SF1).

maintenance (grocery stores, gas stations, food stores, car wash, automotive businesses, banks, medical facilities, *etc.*), (b) physically active recreation (fitness centers, sports centers, dance and yoga studios, parks, gardens, *etc.*), (c) physically inactive recreation (theatres, amusement centers, arcades, *etc.*), and (d) restaurants and eateries[13], and (6) transportation network and system performance measures such as highway density (miles of highway facilities per square mile), bikeway density, local street block density, availability of and accessibility to transit, the density of transit stops, density of intersections, local traffic volumes, speed limits, and the number of parking lots and average parking costs.

It should be noted here that it is preferable to collect and develop the above identified land-use data elements for smaller scales of geography (such as parcels) for future (i.e., long-term) model development efforts.

4.3.4.3 Transportation Network and System Performance Data

The non-motorized mode of travel has received scant attention in travel demand modeling, mainly due to the lack of adequate data. To overcome this, it would be beneficial to include bicycle network level-of-service and walk level-of-service attributes (such as availability of, and the length of, the route between two locations) in the survey.

4.4 Summary

This chapter consists of two parts. The first part of the chapter provides design recommendations to implement a tour-based travel demand model system. As a first step towards model improvement, this chapter presents design options for two tour-based model structures with no recognition of interactions among tours. The first design option (referred as design option # 1) is based on the framework of the New Hampshire Statewide Travel Model System (NHSTMS). The NHSTMS is one of the first tour-based travel demand model system developed in the U.S., and has been in use since its development. The reader will note that, although the design structure of option # 1 is similar to the NHSTMS model system, several additional desirable features are included to enhance the behavioral realism and policy sensitivity of the model design option. For example, design option # 1 recommends the use of microsimulation instead of sample enumeration method to implement the model system and modeling of work location as a long-term choice.

The model system in design option # 1 starts with a population synthesizer, which uses population, employment and other sociodemographic variables as input and generates synthetic population and households that are allocated to the TAZs. The synthetic households and individuals are taken through a set of models, which are divided into 3 levels of hierarchy:

(1) Pattern-level choice models,

(2) Tour-level choice models, and

(3) Trip-level choice models.

At the end of the trip-level models, the output consists of predicted trips for each synthetic individuals which are then aggregated into OD trip tables, and combined with other OD trip tables such as external trips and commercial traffic. The traffic assignment is carried out

[13] Activity opportunity variables can be extracted from the InfoUSA business establishments data.

outside the tour-based model system. For this, a set of predetermined factors are used to divide the daily trip tables into trip tables for different time periods (AM peak, PM peak, off-peak, *etc*.). Software package such as TransCAD can be used to load the trips onto the network.

An important aspect of this model system is the use of tour frequencies higher up in the hierarchy as explanatory variables to inform the subsequent tour type models. This ensures consistency and behaviorally more realistic trip generation. Another feature of this model is the simplicity of the design structure, which makes it more readily transferable from a trip-based to a tour-based approach. As a result, the model will require relatively less effort and fewer resources to implement. However, a less complex model comes with a reduction in behavioral realism. As a compromise between design option # 1 and a more advanced tour-based model (i.e., a model with explicit recognition of the interactions among tours), the research team offers another design structure—design option # 2. In addition to all the features included in option 1, this second design option includes several additional desirable features for enhanced behavioral realism and conceptually more realistic travel demand prediction.

The second part of the chapter identifies the data needs for implementing the proposed advanced travel demand model design, and, in turn, recommends data collection components. The primary sources/data used for the estimation of tour-based models are household activity and/or travel surveys, transportation system network and system performance data, and regional land-use data. In addition to these data needed for the estimation of tour-based models, regional socioeconomic and land-use projection data are needed for the generation of synthetic population. Further, model calibration and validation requires additional data. For example, commute mode choice model validation requires the journey to work data while network flow validation requires data on observed traffic volumes. In addition to all the data/sources listed above, the research team also identified additional data needs, and provides recommendations for consideration in future survey efforts.

Chapter 5. Data Availability for Transportation Modeling

5.1 Introduction

The principle objective of this report is the identification and delineation of data availability for transportation model development. In the context of this report available data is viewed as the data that the Texas Department of Transportation (TxDOT) traditionally uses to support model development and thus is readily available to also support the development of advanced models. The available data includes the following:

- Travel survey data
- Texas Workforce Commission (TWC) employment data
- Census data

By outlining in detail the elements comprising each of the available data sets it offers an opportunity to specify what exact data is accessible to support the development of an advanced model structure. Thus, each of the three data sets is discussed in the following report sections.

5.2 Travel Survey Data

TxDOT has a comprehensive on-going travel survey program that supports the travel demand models being developed for transportation planning efforts in urban areas throughout Texas. Data from these surveys serve as inputs to the travel demand models to ensure that the travel models adequately reflect regional travel behavior. Texas urban area comprehensive travel surveys may include any or all of the following surveys:

- Household survey
- Workplace survey
- External station survey
- Commercial vehicle survey
- Special generator survey
- On-board public transit survey

5.2.1 Household Survey Data

In this type of survey, households are randomly selected to participate in the household travel survey program. As a part of the process, interviewers ask people who agree to participate to record in a travel diary the activities and travel by each person over the age of five years during a 24-hour period. For each trip, interviewers ask participants to record the time, activity, place the trip began and ended, mode of travel, number of passengers, purpose of the trip, and other descriptive information. In addition to the data on travel, participants record characteristics of the household such as number and age of persons in the household, number of household members employed, household income, and number of vehicles available. The data collected from the household survey is tabulated in four separate files:

- Record Type 1 – Household Information
- Record Type 2 – Person Information
- Record Type 3 – Vehicle Information
- Record Type 4 – Trip Information

Following is a complete listing of the data associated with each file type.

5.2.1.1 Record Type 1 – Household Information

The Record Type 1 Household Information file contains the household information collected for each household in the first part of the travel diary. The Record Type 1 file consists of 39 data items that are coded in the following format:

1. Record Type - Code indicating type of record, which is a "1."
2. Sample Number - Unique non-zero number assigned to each household that participated in the survey.
3. Phone - Phone number of household.
4. Month - Month of travel day.
5. Day - Day of the month of travel.
6. Day of Week - Day of the week travel was recorded and coded as: 1-Monday, 2-Tuesday, 3-Wednesday, 4-Thursday, and 5-Friday.
7. Advance Letter - Code indicating if household received advance letter; 1-Yes, 2-No, 98-Don't Know, and 99-Refused.
8. Address - Street address or nearest cross streets of household.
9. City - City where household is located.
10. Zip Code - Zip code of household address.
11. Household County - Code indicating county in which household is located; for example: 1- Bastrop, 2- Caldwell, 3- Hays, 4- Travis, 5- Williamson, 6- Bexar, 7- Comal, 8- Guadalupe, 9- Kendall, 10- Wilson, 98 – Don't Know, 99- Refused
12. Household Study Area - Code indicating study area in which household address or traffic analysis zone (TAZ) is located. For example: 'A' is coded if the zone is in the Austin study area and 'S' if the zone is in the San Antonio study area. Field is left blank if the location is not within one of those two Metropolitan Planning Organization (MPO) study areas.
13. Household Zone – TAZ number where household is located. The household address must be coded to a zone in one of the MPO modeling areas. Unknown zones should be coded 88888.
14. Longitude - Longitude of household address. If unknown, it should be coded as 888.8888.
15. Latitude - Latitude of household address. If unknown, it should be coded as 888.8888.
16. Number Persons - Number of persons living in the residence.
17. Number Employed - Number of persons in household that are employed either full or part time.

18. Vehicles Available - Number of cars, vans, light trucks, motorcycles available for use by the household; 98-don’t know, 99-refused.
19. Vehicles Owned or Leased - Combined number of cars, vans, light trucks, motorcycles owned or leased by members of the household; 98-don’t know, 99-refused.
20. Bikes - Number of working bicycles available for use by members of household; 98-don’t know, 99-refused.
21. Residence - Code indicating the type of residence (see below for code definitions).
22. Other Residence - If residence is coded as “other,” this field contains a description of the type of residence.
23. Tenure - Code indicating number of years at residence; 0-less than 1year, 1-one year, 2-two years, 3-three years, 4-four years, 5-five or more years, 98-don’t know and 99-refused.
24. Previous Residence - If tenure was less than five years, this code indicates if previous residence was in one of the modeling area counties; 1-Yes, 2-No, 8-don’t know, and 9-refused.
25. Previous Zip Code - If tenure was less than five years, this is the zip code of the previous residence.
26. Household Factors - Code indicating factors that influenced their decision to locate in their current household. If more than one, separate code numbers by comma (see code definitions below).
27. Other Factors - Other factors influencing their decision to locate in their current household.
28. Income - Code indicating combined annual income of all household members (see codes below).
29. Sample Household Income - Household income stratification for sampling quota. 1-less than $20,000; 2=$20,000 - less than $35,000; 3=$35,000 - less than $50,000; 4=$50,000 - less than $75000; 5= $75,000 or more.
30. Day Visitors - Number of non-family persons that stopped at this residence for any reason on the travel day; 98-Don’t Know, 99-Refused.
31. Overnight Visitors - Number of overnight visitors at this residence during their travel day. 98-don’t know, 99-refused.
32. Delivery Vehicle - Code indicating if someone in household drives a form of delivery vehicle; 1-yes, 2-no, 8-don’t know, 9-refused.
33. Number Delivery Driver - Number of persons in household that are delivery drivers or travel within study area as part of their work.
34. Phone Service - Number of times within past 12 months household was without telephone service.
35. Time Without - Code indicating the average length of time household was without phone service (see code definitions below).
36. Household Vehicle Use by Non-household Member - Code indicating if one or more of the household vehicles were used by a non-household member on the travel day. 1-yes, 2-no, 3-zero vehicle household, 98-don’t know, 99-refused.

37. Share Phone - Number of households that share a phone line with this household.
38. Geographic Positioning System (GPS) House - Code indicating if household vehicles had GPS equipment installed for GPS survey; 1-yes, 2-no.
39. Total Household Trips - The total combined number of all trips made by all persons in the household on the assigned travel day.

The residence codes for item 21 are:

1. Unattached Single Family Home
2. Condo
3. Duplex
4. Apartment
5. Mobile Home
6. Other
7. Don't Know
8. Refused

The household factors for item 26 are:

1. Price of Property
2. Taxes
3. Proximity to Work
4. School District
5. Proximity to School
6. Character of Neighborhood or Area
7. Access to Public Transportation
8. Security / Safety
9. Other

98. Don't Know
99. Refused

The household income codes for item 28 are:

1. Less than $5,000
2. $5,000 to $9,999
3. $10,000 to $14,999
4. $15,000 to $19,999
5. $20,000 to $24,999
6. $25,000 to $29,999
7. $30,000 to $34,999
8. $35,000 to $39,999
9. $40,000 to $49,999
10. $50,000 to $59,999

11. $60,000 to $74,999
12. $75,000 to $99,999
13. $100,000 to $124,999
14. $125,000 to $149,999
15. $150,000 or more
98. Don’t Know
99. Refused

The time without phone service codes for item 35 are as follows:

1. Less than one week
2. One week to less than two weeks
3. Two weeks to less than three month
4. One month to less than four months
5. Three months to less than six months
6. Six months to less than one year
7. One year or more
98. Don’t know
99. Refused

5.2.1.2 Record Type 2 – Person Information

The Record Type 2 Person Information file contains the information for each person in the household from the travel diary. Record Type 2 is comprised of 57 data items and is coded as follows:

1. Record Type - Code indicating type of record; coded as a “2.”
2. Sample Number - Unique non-zero number assigned to each household participating in survey. This number should match the sample number for Record Type 1.
3. Person Number - Number assigned to each person in the household with 0 assumed to be the head of household.
4. Relationship - Code indicating relationship of person to the head of household (see code definitions below).
5. Head of household - Code indicating the person number in the household considered to be the head of household
6. Sex - Sex of person; 1-male, 2-female, 98- don’t know, 99-refused.
7. Ethnicity - Race or ethnicity of person (see code definitions below).
8. Ethnicity Other - Description of other ethnicity which is not included in code definitions.
9. Age - Age of person; 998-don’t know, 999-refused.
10. Licensed Driver - Code indicating if person is a licensed driver; 1-yes, 2-no, 98-don’t know, 99-refused.
11. Employment Code indicating if person is employed in a paying or volunteer job; 1-yes, 2-no, 98-don’t know, 99-refused.

12. Employment Status - If person is employed, this is a code number indicating the person's employment status (see code definitions below).
13. Hours - On average, the number of hours worked per week; 998-don't know, 999-varies from week to week.
14. Not Employed - Code indicating current status if person is not employed (see code definitions below).
15. Not Employed Other - Description of employment status if none of the options in the employment status code is applicable.
16. Delivery - Code indicating if person is a delivery driver or not; 1-yes, 2-no, 98-don't know, 99-refused.
17. Transporting Cargo - Code indicating if vehicle is transporting cargo; 1-yes, 2-no, 98-don't know, 99-refused.
18. Commercial Service - Code indicating if vehicle is for commercial service; 1-yes, 2-no, 98-don't Know, 99-refused
19. Flex Time - Code indicating if person's employer allows them to work flexible hours or the hours are fixed; 1-flexible/variable, 2-fixed/unchanging, 98-don't know, 99-refused.
20. Job - Code indicating if person has more than one paying job; 1-yes, 2-no, 98-don't know, 99-refused.
21. Employer Name - Name of person's primary employer.
22. Workplace Type - Code indicating type of workplace where person is employed (see code definitions below).
23. Other Workplace - Description of workplace type if "other" is coded.
24. Home Office - Code indicating if workplace is a home office or business operated out of the home; 1-yes, 2-no, 98-don't know, 99-refused.
25. Telecommute - If employed 30 or more hours per week, code indicating if person works from home or telecommutes on a regular basis; 1-yes, 2-no, 98-don't know, 99-refused.
26. Workplace Address - Street address of workplace or nearest intersecting street names.
27. Workplace City - City where workplace is located.
28. Workplace County - Code indicating county in which household is located (codes are unique for each survey); for example: 1- Bastrop, 2- Caldwell, 3- Hays, 4- Travis, 5- Williamson, 6- Bexar, 7- Comal, 8- Guadalupe, 9- Kendall, 10- Wilson, 96-Other, 98 – Unknown, 99- Refused
29. Zip Code - Zip code or workplace address.
30. Work Study Area - Code indicating study area in which work address and TAZ is located. For example, 'A' if zone is in the Austin study area, and 'S' if the zone is in the San Antonio study area. Field is left blank if location is not within one of those two MPO study areas.
31. Work Zone - Zone where workplace is located. Those in one of the MPO modeling area counties should be coded to an urban or rural TAZ. If unknown but in one of the modeling area counties it should be coded 08888. Locations outside of either of the two modeling areas but within Texas should be coded using the Statewide Zone System. Unknown locations outside of the modeling area counties but within Texas should be

coded 6666. Addresses in Mexico should be coded 07777. Addresses outside of Texas and Mexico should be coded using 09999.

32. Longitude - Longitude of workplace location. If within either of the modeling area counties, but unknown it should be coded 888.8888. If outside either of the modeling area counties but within Texas and unknown it should be coded as 6666. Locations in Mexico should be coded 777.7777 and addresses outside of Texas and Mexico should be coded 999.9999.
33. Latitude - Latitude of workplace location. If within either of the modeling area counties, but unknown it should be coded 888.8888. If outside the modeling area counties, but within Texas and unknown it should be coded as 6666. Locations in Mexico should be coded 777.7777 and addresses outside of Texas and Mexico should be coded 999.9999.
34. Days Worked - Number of days per week person typically works; 98-don’t know, 99-refused.
35. Work at Home Out of the Last Seven Days - The number of days worked at home instead of going to work; valid responses: 0-7, 98-don’t know, 99-refused.
36. Second Job Type - Code indicating type of workplace where person works at second job (see code definitions below).
37. Second Job Other - Description of workplace type for second job if “other” is coded.
38. Second Job Employment Status - If person is employed in a second job, this is a code number indicating the person’s employment status related to the second job (see code definitions below).
39. Total Hours - Total hours on average person works per week at all jobs; 888-don’t know, 999-refused.
40. Primary Occupation - Code indicating the type of occupation for primary job (see code definitions below).
41. Primary Industry - Code indicating the type of industry worked in for primary job (see code definition below).
42. Secondary Occupation - Code indicating the type of occupation for secondary job (see code definitions below).
43. Secondary Industry - Code indicating the type of industry worked in for secondary job (see code definition below).
44. Student Status - Code indicating if person is enrolled in any type of school; 1-yes, 2-no, 98-don’t know, 99-refused.
45. School Type - Code indicating type of school attended (see code definitions below).
46. School Type Other - Description of ‘other’ if other is coded as school type.
47. Hours Enrolled - If person is enrolled in a college, trade school, etc., code indicates if person is enrolled for 12 or more hours; 1-yes, 2-no, 98-don’t know, 99-refused.
48. Bike Use - Number of days person rode bike in last seven days; 98-don’t know, 99-refused.
49. Bike Purpose - Code indicating the most common trip purpose for person’s bike trips (see code definitions below).

50. Disability - Code indicating if person has transportation disability; 1-yes, 2-no, 98-don't know, 99-refused.
51. Travel - Code indicating if person traveled on the designated travel day; 1-yes, 2-no, 96-indication person was out of town or away from the residence for the entire day and night of their travel day.
52. Person trips - The total number of trips the person made on his/her travel day.
53. Why No Travel - Description of why the person did not make any trips on the travel day.
54. Diary Use - Code indicating if person used diary or if information is based on memory or provided by a proxy; 1-yes, used diary; 2-no, did not use diary; 3-did not receive diary; 98-don't know; 99-refused
55. Data Retrieval Method - Code indicating how data was retrieved: 01-respondent, 02-proxy, 03-mailed diary, 04-internet, 98-don't know; 99-refused
56. Proxy ID - This item identifies the person by person number who provided the information by proxy. 98-don't know; 99-refused.
57. Data Retrieval Date - The month and day the data was retrieved. All months are recorded as 2 digits and all days as 2 digits with the month preceding the day; for example: April 1st should be coded as 0401.

The relationship codes for Item 4 are as follows:

1. Husband / Wife / Unmarried Partner
2. Mother / Father / In-law
3. Brother / Sister / In-law
4. Grandfather / Grandmother
5. Grandson / Granddaughter
6. Son / Daughter / In-law
7. Aunt / Uncle
8. Other Relative
9. Other Non-Relative
10. Household Help
98. Don't Know / Refused
99. Refused

Item 7 ethnicity codes are as follows:

1. Black / African American
2. Hispanic / Mexican American
3. Asian / Pacific Islander
4. Native American
5. White / Caucasian
6. Other Group
98. Don't Know
99. Refused

Employment status codes for Items 12 and 38 are the following:

1. Employed full time 30 or more hours per week
2. Employed part time less than 30 hours per week
3. Self employed full time 30 or more hours per week
4. Self employed part time less than 30 hours per week

98. Don’t Know
99. Refused

Item 14 not employed codes are the following:

1. Retired
2. Disability Status
3. Homemaker
4. Looking for Work
5. Not Looking for Work
6. Student
7. Other

98. Don’t Know
99. Refused

The work place codes for Item 20 and Item 36 are:

1. Office (Non-government)
2. Office (Government)
3. Retail/Shopping/Gas
4. Industrial/Manufacturing/Warehouse
5. Medical
6. Education – Day Care/K-12
7. Education – College, trade school, other
8. Residential
9. Airport
10. Eating Establishment

96. Other
98. Don’t Know
99. Refused

The occupation codes for Items 38 and 40 are:

1. Management, professional, and related occupations
2. Service occupations
3. Sales and office occupations
4. Farming, fishing, and forestry occupations

5. Construction, extraction, and maintenance occupations
6. Production, transportation, and material moving occupations
96. Not applicable (unemployed / student / retired)
98. Don't know
99. Refused

The industry codes for Items 39 and 41 are:

1. Agriculture, forestry, fishing and hunting, mining
2. Construction
3. Manufacturing
4. Wholesale trade
5. Retail trade
6. Transportation, warehousing, utilities
7. Information
8. Finance, insurance, real estate, rental and leasing
9. Professional, scientific, management, administrative and waste management services
10. Education, health, and social services
11. Arts, entertainment, recreation, accommodation, and food services
12. Other services (except public administration)
13. Public Administration
96. Not Applicable – (unemployed, student, retired)
98. Don't Know
99. Refused

The school type codes for Item 43 are:

1. Day Care / Pre-School
2. K-12th
3. Post Secondary, College, Trade
4. Other
98. Don't Know
99. Refused

Item 47, bike trip purpose codes are as follows:

1. Work
2. School
3. Shopping
4. Visiting
5. Recreation / Exercise
6. Other

96. Child
98. Don’t Know
99. Refused

5.2.1.3 Record Type 3 - Vehicle Information

This file contains the information for each vehicle available to members in each household. Each vehicle has a data record. The seventeen items comprising Record Type 3 are coded as follows:

1. Record Type - Code indicating type of record; coded as a “3.”
2. Sample Number - Unique non-zero number assigned to each household participating in survey.
3. Vehicle Number - Unique non-zero number assigned to vehicle.
4. Type of Vehicle - Code indicating type of vehicle (see code definitions below).
5. Other Vehicle Type - Other vehicle type not listed in vehicle code below.
6. Year - Year vehicle was manufactured; 9998-don’t know, 9999-refused.
7. Make - Make of vehicle (see vehicle make codes below).
8. Other Make - Specify other make of vehicle if not included in vehicle make code below.
9. Model - Model of vehicle.
10. Type of Fuel - Type of fuel used by vehicle; 1-gasoline, 2-diesel, 3- propane, 4-natural gas, 5-electricity, 6-other, 7-hybrid, 8-don’t know, 9-refused.
11. Other Fuel Type - Other type of fuel specified.
12. Commercial Use - Code indicating if vehicle is used for commercial purposes; 1-yes, 2-no, 98-don’t know, 99-refused.
13. Odometer Reading - Odometer reading on vehicle at beginning of travel day; doesn’t know is 99999998 and refused is 99999999.
14. Ownership - Code indicating ownership of this vehicle; 1-Owned or leased by household or member of household, 2-owned or leased by another person, 98-don’t know, 99-refused
15. Non-household Vehicle Number - If one or more household vehicles used by non-household member, this is the number of the vehicle that was used.
16. Non-household Use - Code indicating if vehicle was used by a non-household member on the travel day; 1-yes, 2-no, 8-don’t know, 9-refused.
17. Lighter Working - Code Indicating if the lighter in the vehicle is working; 1-yes, 2-no, 8-don’t know, 9-refused.

The vehicle type codes for Item 4 are as follows:

1. Motorcycle (includes mopeds)
2. Car (includes station wagons)
3. Van (mini and passenger)
4. Sport Utility Vehicle
5. Pickup Truck
6. Cargo Transport

7. Commercial or Service Vehicle
8. Other
98. Don't Know
99. Refused

The vehicle make codes for Item 7 are:

01 – Acura	29 – Plymouth	57 – Gillig
02 – Audi	30 – Pontiac	58 – Grumman
03 – BMW	31 – Porsche	59 – Imperial
04 – Buick	32 – Range/Land Rover	60 – International Harvester/Navistar
05 – Cadillac	33 – Saab	61 – Iveco / Magirus
06 – Chevrolet	34 – Saturn	62 – Kenworth
07 – Chrysler	35 – Subaru	63 – Lancia
08 – Dodge	36 – Suzuki	64 – Mack
09 – Ford	37 – Toyota	65 – MCI
10 – Geo	38 – Volkswagen	66 – Merkur
11 – GMC	39 – Volvo	67 – MG
12 – Harley Davidson	40 – Yamaha	68 – Moto-Guzzi
13 – Honda	41 – Daewoo	69 – Norton
14 – Hyundai	42 – Alfa Romeo	70 – Peterbuilt
15 – Infiniti	43 – AM General	71 – Peugeot
16 – Isuzu	44 – AMC	72 – Renault
17 – Jaguar	45 – Austin / Austin Healey	73 – Sterling
18 – Jeep	46 – Bluebird	74 – Thomas Built
19 – Kawasaki	47 – Brockway	75 – Triumph
20 – KIA	48 – BSA	76 – White / Autocar-White GMC
21 – Lexus	49 – Daihatsu	77 – Yugo
22 – Lincoln	50 – Diamond Reo / Reo	78 – Other Make Moped
23 – Mazda	51 – Ducati	79 – Other Make Motorcycle
24 – Mercury	52 – Eagle	97 – Other (specify)
25 – Mercedes-Benz	53 – Eagle Coach	98 – Don't Know
26 – Mitsubishi	54 – Fiat	99 – Refused
27 – Nissan/Datsun	55 – Freightliner	
28 – Oldsmobile	56 – FWD	

5.2.1.4 Record Type 4 - Trip Information

The Record Type 4 file contains the trip or activity information for each person in each household. There are 49 data items that comprise Record Type 4; they are coded in the following format:

1. Record Type - Code indicating type of record; coded as a “4.”
2. Sample Number - Unique non-zero number assigned to each household participating in survey. This number must match the number used for the same household and recorded in the Household Data File.
3. Month - Month of survey day.
4. Day - Day of the month of the survey.
5. Person Number - Number assigned to the person doing this activity.
6. Activity/Trip Number - The first trip/activity for each person will be recorded as 0 for where their day began. Each subsequent trip/activity should be numbered sequentially as 1, 2, 3, etc.
7. Activity Type Code - Code indicating the type of activity (see activity codes below). For activity 0 (where day began), this should be coded as a 1 if it began at home, 4 if day began at work, or as 20 if it began at another location. If this is coded as 20, the activity description should be included in item 8.
8. Activity Description - Description of Activity.
9. Location - Name of location where activity took place.
10. Location Address - Street address of location or name of nearest intersecting streets.
11. Location City - Name of city where location is.
12. Location County - Code indicating county where location is; codes are specific to each survey, for example: 1- Bastrop, 2- Caldwell, 3- Hays, 4- Travis, 5- Williamson, 6- Bexar, 7-Comal, 8-Guadalupe, 9-Kendall, 10-Wilson, 98-unknown, 99-refused
13. Zip Code - Zip code of location address.
14. Exit Route Name - If location is outside of the modeling area, this is the name of the highway/route/road used to exit the applicable study area.
15. Exit Route Zip Code - Zip code for route exiting the study area.
16. Study Area - Code indicating study area in which activity address/TAZ is located. For example, ‘A’ if zone is in the Austin study area, and ‘S’ if the zone is in the San Antonio study area. Field should be left blank if location is not within one of those two MPO study areas.
17. Zone Number - Zone number of location address. If in a modeling area county but location unknown, it should be coded 08888. Locations in Mexico should be coded 07777 and addresses outside of the modeling area counties, but within Texas should be coded using the Statewide Zone System. Unknown locations outside of the modeling area counties but within the state of Texas should be coded 06666. Addresses outside of Texas and Mexico should be coded using 09999.
18. Longitude - Longitude of location. If within the modeling area counties, but unknown it should be coded 888.8888. If outside the modeling area counties but within Texas and unknown it should be coded as 6666. Locations in Mexico should be coded 777.7777 and addresses outside of Texas and Mexico should be coded 999.9999.
19. Latitude - Latitude of location. If within the modeling area counties, but unknown it should be coded 888.8888. If outside the modeling area counties but within Texas and unknown it should be coded as 6666. Locations in Mexico should be coded 777.7777 and addresses outside of Texas and Mexico should be coded 999.9999.
20. Type of Place - Code indicating the type of place at this location. If coded as “other,” specified in the next field (see code definitions below).
21. Other Place - Description of “other” type of place where activity occurred.

22. Purpose - Purpose of trip, developed based on the activity type in Item 7 (see code definitions below).
23. Mode of Travel - Code indicating mode of travel used in traveling to this location (see travel mode code definitions below).
24. Other Mode - If "other" is coded in mode of travel, this is the description of the "other" mode.
25. Number of People - If travel was by private vehicle, this is the number of persons in the vehicle, including the person driving. Non-private vehicle modes should be coded 96.
26. Household Members - Of those in the vehicle, how many were household members.
27. Persons on Trip - The household members traveling with driver; person numbers code are separated by commas.
28. Non-household Members - Compute non-household members using information from items 24 and 25.
29. Household Vehicle - Was a household vehicle used to make this trip? 1-yes, 2-no, 98-don't know, 99-refused.
30. Vehicle Used - If household vehicle was used for travel, this is the vehicle number (must correspond with vehicle number in household record). If other vehicle is used, this should be coded as 99.
31. Body Type - See code set for body type.
32. Other Body Type - If body type is not in code set, describe body type.
33. Other Vehicle Year - Year of "other" vehicle used for trip; 9998-Don't Know, 9999-Refused.
34. Other Vehicle Make - Make of "other" vehicle used for trip (see code set).
35. Other Vehicle Make Description - If make of other vehicle is coded as other, this field contains a description of the vehicle make
36. Other Vehicle Model - Model of "other" vehicle used for trip.
37. Other Vehicle Fuel - Code indicating type of fuel used by "other" vehicle; 1-gasoline, 2-diesel, 3-propane, 4-natural Gas, 5-electricity, 6-other, 7-hybrid, 98-don't know, 99-refused.
38. Other Fuel - Description of "other" fuel for "other" vehicle, if not in fuel code above.
39. Other Vehicle Commercial Use - Code indicating if "other" vehicle used for commercial purposes; 1-yes, 2-no, 98-don't know, 99-refused.
40. To Bus Stop - Code indicating if they walked more than one block to get to bus stop; 1-yes, 2-no, 98-don't know, 99-refused.
41. To Activity - Code indicating if they parked or got off bus more than one block from this activity; 1-yes, 2-no, 98-don't know, 99-refused.
42. Off Bus Location - Street address or nearest intersecting streets where person got off of bus.
43. Parking Location - Street address of nearest intersecting streets where vehicle was parked.
44. Parking Cost - Amount paid for parking.
45. Payment Method - Time period for parking cost payment; 1-hourly, 2-daily, 3-weekly, 4-monthly, 5-annually, 98-other, 99-don't know/refused.
46. Arrival Hour - Hour that person arrived at this location and is coded in terms of military time. If this is activity 0, this should be blank since this is where they began their day.

47. Arrival Minute - Minute that person arrived at this location. If this is activity 0, this should be blank since this is where they began their day.
48. Departure Hour - Hour that person departed this location coded in terms of military time. If this is the last activity, this should be blank.
49. Departure Minute - Minute that person departed this location. If this is the last activity for this person, this should be blank.

Activity type codes for Item 7 are as follows:

1. At Home; primary job related
2. At Home; other
3. At Home; job and non-job related
4. Work
5. Work Related
6. School; post secondary, college, trade
7. School; secondary-day care, kindergarten, elementary, middle, high
8. Incidental Shopping; gas, groceries, etc.
9. Major Shopping; clothes, appliances, etc.
10. Banking
11. Personal Business; laundry, dry cleaning, barber, medical, etc
12. Other Services
13. Social / Recreational
14. Eat Out
15. Civic Activities (including church)
16. Pick-up / Drop-off Person at Work
17. Pick-up / Drop-off Person at School / Day Care
18. Pick-up / Drop-off Person at Other
19. Change Mode of Travel
20. Other Activity (specify)
98. Don't Know
99. Refused

Item 20, type of place codes are as follows:

1. Residential
2. Residential type workplace
3. Construction site
4. Transportation stop (Bus, Train)
5. Automotive dealer/Repair
6. Bank / Financial institution
7. Barber/Beauty/Nail salon
8. Bookstore/Newsstand
9. Convenience / Drug Store
10. Government/City/County/State/Federal Offices
11. Offices (Non-Government)
12. Grocery
13. Health club
14. Medical facility/Hospital

15. Movie theater/Cinema
16. Restaurant/Fast Food, Bar and Grill
17. Educational – 12th Grade or lower
18. Educational – College, trade, etc.
19. Shopping mall / Department store.
20. Gas station
21. Airport
22. Other
98. Don't Know
99. Refused

Trip purpose codes for Item 22 are:

1. Home (Activity Codes 1,2,3)
2. Meal/Eat (14)
3. Work (Activity Codes 4)
4. Work Related (Activity Code 5)
5. School; K thru 12 (Activity Codes 7)
6. School; Post Secondary (Activity Code 6)
7. Shopping (Activity Codes 8,9)
8. Personal (Activity Codes 10,11,12,15)
9. Social / Recreation (Activity Codes 13,)
10. Pick-up Drop-off Other (Activity Code 16,17,18)
11. Change Mode (Activity Code 19)
12. Other (Activity Code 20)
98. Don't Know
99. Refused

Item 23, mode of travel codes are:

1. Walk
2. Auto / Van / Truck Driver
3. Auto / Van / Truck Passenger
4. Carpool Driver
5. Carpool Passenger
6. Vanpool Driver
7. Vanpool Passenger
8. Commercial Vehicle Driver
9. Commercial Vehicle Passenger
10. Bus
11. School Bus
12. Taxi / Paid Limo
13. Bicycle
14. Motorcycle / Moped
15. Other
98. Don't Know
99. Refused

5.2.2 Workplace Survey

A workplace survey collects information on travel at the destination end of trips. This type of survey consists of two primary components: one part designed to collect travel information and household characteristics (such as income, vehicle availability by type/make of vehicle, household size, etc.) of employees at the work sites, and one designed to collect travel data on visitors (non-employees) traveling to and from the workplace during the day. For the workplace survey, TxDOT-TPP cross-classifies employment establishments by employment type (basic, service, retail or education), area type, and freestanding or non-freestanding business. Interviewers provide employees at participating workplaces with a survey and ask them to record all of their trips on a specified day. Collected data include the origin and destination for each trip, trip arrival and departure times, travel mode, reason for trip (trip purpose), vehicle occupancy, vehicle make/model/year, and parking costs. Interviews are also conducted with randomly selected non-employees arriving at the workplace during the survey day. The data collected from non-employees includes trip origin, trip purpose, mode of travel, vehicle occupancy and arrival/departure times. The workplace survey collected data is tabulated in nine separate files:

- Workplace Establishment General Information, Form A
- Workplace Employee Survey, Form B Part 1
- Workplace Employee Survey, Form B Part 1 – Vehicle Information
- Workplace Employee Survey, Form B Part 2
- Visitor Survey Freestanding Workplace, Form C
- Visitor Survey Non-Freestanding Workplace, Form D
- Workplace Delivery Vehicle Survey, Form E
- Workplace Vehicles Owned/Leased Survey – Vehicle Information
- Workplace Vehicles Owned/Leased Survey – Trip Information

Following is a complete listing of the data associated with each file type.

5.2.2.1 Workplace Establishment General Information Survey, Form A

This file contains the general information data pertinent to the surveyed workplace establishment. There are 39 data items comprising Form A; the data is coded as follows:

1. Record Type - Code indicating type of record; coded as a “9.”
2. Month - Month establishment was surveyed.
3. Day - Day of month establishment was surveyed.
4. Site Number - Unique non-zero number assigned to each establishment.
5. NAICS Code - North American Industry Classification System (NAICS) code of the establishment.
6. Survey Code - Code indicating type of survey done; 1-full survey and 2-partial survey.
7. Establishment Type - Code indicating the type of establishment; 1-free standing, 2-non-free standing.
8. Area Type - Code indicating the area type where the establishment is located.

9. Employment Type - Code indicating the type of employment at the establishment (see code descriptions below).
10. Employment Type Other - If employment type is coded as other, this field should contain a description of the type of employment at the establishment.
11. Name - Name of establishment.
12. Address - Address of establishment.
13. City - City where establishment is located.
14. Zip Code - Zip code for establishment’s location.
15. Longitude - Longitude of establishment’s address; if unknown, it should be coded as 888.8888.
16. Latitude - Latitude of establishment’s address; if unknown, it should be coded as 888.8888.
17. Zone - Zone where establishment is located.
18. Hours of Operation - Number of hours in operation during a normal weekday.
19. Number of Vehicles - Total number of vehicles entering and exiting the establishment during the 24 hours the travel survey was conducted.
20. Number of Persons - Total number of persons counted entering and exiting the establishment during the 24 hours the travel survey was conducted.
21. Cargo Transport Vehicles - Total number of commercial cargo transport vehicles counted entering and exiting the establishment during the 24 hours the travel survey was conducted.
22. Service Vehicles - Total number of commercial service vehicles counted entering and exiting the establishment during the 24 hours the travel survey was conducted.
23. Total Employment - Total number of persons (full and part time) employed at the establishment.
24. Employees at Work - Total number of employees at work on day the travel survey was conducted.
25. Number of Shifts - Number of work shifts at establishment.
26. Employees per Shift - Number of employees per work shift.
27. Parking Spaces - Number of parking spaces.
28. Parking Cost - Cost per hour of parking.
29. Loading Docks - Number of loading docks at establishment.
30. Deliveries - Number of deliveries to establishment on day of travel survey.
31. Delivery Hours - Hours allowed for deliveries.
32. Bus Routes - Number of bus routes serving the establishment.
33. Number of Bus Stops - Number of bus stops serving the establishment.
34. Cars Owned/Leased - Number of cars owned or leased by establishment for business purposes
35. Vans Owned/Leased - Number of vans owned or leased by establishment for business purposes
36. SUV’s Owned/Leased - Number of sport utility vehicles (SUVs) owned or leased by establishment for business purposes.
37. Pickup Trucks Owned/Leased - Number of pickup trucks owned or leased by establishment for business purposes
38. Cargo Transport Vehicles Owned/Leased - Number of cargo transport vehicles owned or leased by establishment for business purposes

39. Service Vehicles Owned/Leased - Number of service vehicles owned or leased by establishment for business purposes

Employment type codes for Item 9 are the following:

1. Office (Non Government)
2. Retail / Restaurant
3. Industrial / Manufacturing
4. Medical
5. Education – Day Care / K-12th
6. Education – College, trade, other
7. Government
8. Not used
9. Other
99. Unknown/Refused

5.2.2.2 Workplace Employee Survey, Form B, Part 1

The Form B, Part 1 file contains the household/individual information data collected for each surveyed employee at the surveyed workplace establishment. Nineteen data items are coded in a data file as follows:

1. Record Type - Code indicating type of record; coded as a "5."
2. Month - Month of travel day.
3. Day - Day of the month of travel.
4. Site Number - Unique non-zero number assigned to the workplace where this employee works.
5. Sample Number - Unique non-zero number assigned to this sample (i.e. employee). This number will be assigned to the form handed out to the employee to complete and return.
6. Address – Home street address of the employee.
7. City - City where employee lives.
8. Study Area County - Code indicating study area county where employee lives; for example: 1- Bexar, 2- Comal, 3- Guadalupe, 4- Kendall, 5- Wilson, 6- Travis, 7- Hays, 8- Williamson, 9- Bastrop, 10- Caldwell, 98-other and 99-refused.
9. Other County - If county of residence is coded as other in item 8, this field should contain the name of the county the person lives in.
10. Zip Code - Zip code where employee lives.
11. Study Zone ID. - Code indicating study area employee lives; for example: 'A'-employee lives in Austin Study area and 'S'-employee lives in San Antonio study area. A 'T' is coded if employee lives in a county that is not in the study area, but within Texas. A '9' indicates employee lives outside Texas.
12. Zone - Zone where employee lives. Unknown zone numbers in a study area county should be coded 8888. Mexico locations should be coded as 7777. External locations outside of a study area county but within Texas should be coded to the state zone number. External locations outside the study area but within Texas that are unknown should be coded 6666. External locations outside Texas and Mexico should be coded 9999.

13. Longitude - Longitude of employee's home address. If address is in Mexico, this should be coded as 777.7777. If address is outside Texas and not in Mexico, this should be coded 999.9999. If unknown but in the study area, it should be coded 888.8888. If unknown but in Texas, it should be coded 666.6666.
14. Latitude - Latitude of employee's home address. If address is in Mexico, this should be coded as 777.7777. If address is outside Texas and not in Mexico, this should be coded 999.9999. If unknown but in the study area, it should be coded 888.8888. If unknown but in Texas, it should be coded 666.6666.
15. Number of Persons - Number of persons residing at employee's home address.
16. Number Employed - Number of persons residing at employee's home address that are employed (including the person completing the form).
17. Blank - This field is blank.
18. Vehicles - Number of vehicles available for use by members of employee's household.
19. Income Code - Indicating the combined annual household income of all members of this household (see code definitions below).

    The income codes for Item 19 are:
    1. Less than $5,000
    2. $5,000 to $9,999
    3. $10,000 to $14,999
    4. $15,000 to $19,999
    5. $20,000 to $24,999
    6. $25,000 to $29,999
    7. $30,000 to $34,999
    8. $35,000 to $39,999
    9. $40,000 to $49,999
    10. $50,000 to $59,999
    11. $60,000 to $74,999
    12. $75,000 to $99,999
    13. $100,000 to $124,999
    14. $125,000 to $149,999
    15. $150,000 or more
    98. Don't Know
    99. Refused

5.2.2.3 Workplace Employee Survey, Form B, Part 1 – Vehicle Information

The Form B, Part 1 file is followed by records containing the vehicle information completed by the surveyed employee. The data file contains 14 data items coded as follows:

1. Record Type - Code indicating type of record; coded as a "6."
2. Blank - This field should be blank.
3. Site Number - Unique non-zero number assigned to the workplace where this employee works (same as above).

4. Sample Number - Unique non-zero number assigned to this sample (i.e. employee). This number will be assigned to the form handed out to the employee to complete and return (same as above).
5. Vehicle Number - Unique non-zero number assigned to the vehicle.
6. Year - Year vehicle was manufactured.
7. Make - Make of vehicle used for trip.
8. Model - Model of vehicle used for trip.
9. Fuel Type - Code indicating type of fuel used by vehicle; 1-diesel, 2-gas, 3-other, 4-no response or unknown.
10. Other Description - Description of fuel used by vehicle if fuel type is coded as "other."
11. Vehicle Type - Code indicating the type of vehicle (see code definitions below).
12. Other Vehicle Type - If vehicle type is coded as other, this field should contain the description of the vehicle type
13. Beginning Mileage - Odometer reading on vehicle at beginning of travel day.
14. Ending Mileage - Odometer reading on vehicle at end of travel day.

Vehicle type codes for Item 11 are:

1. Motorcycle
2. Car
3. Van
4. Sport Utility Vehicle
5. Pickup Truck
6. Commercial Vehicle
7. Other
99. Refused/Unknown

5.2.2.4 Workplace Employee Survey Form B, Part 2

This file contains the travel information for employees surveyed in the workplace survey. The data file format is as follows:

1. Record Type - Code indicating type of record; coded as a "7."
2. Month - Month that travel occurred.
3. Day - Day of the month that travel occurred.
4. Site Number - Unique non-zero number assigned to the establishment where this employee works.
5. Sample Number - Unique non-zero number assigned to this sample (i.e. employee). This number will be assigned to the form handed out to the employee to complete and return.
6. Trip Number - Trip number; beginning trip will be recorded as 0 with each subsequent trip numbered sequentially as 1, 2, 3, etc.
7. Location - Description of location. This field contains the name or description of the location. For example, if this is the beginning of the trip and the location was home, this would have "home" data entered.
8. Address - Street address of location.
9. City - City where location is.
10. Zip Code - Zip code for location.

11. Longitude - Longitude of location. If address is outside study area but in Texas, this should be coded 666.6666. If unknown but in study area, it should be coded 888.8888. If outside Texas but not Mexico, it should be coded 999.9999. If in Mexico, it should be coded 777.7777.
12. Latitude - Latitude of location. If address is outside study area but in Texas, this should be coded 666.6666. If unknown but in study area, it should be coded 888.8888. If outside Texas but not Mexico, it should be coded 999.9999. If in Mexico, it should be coded 777.7777.
13. Study Zone ID - Code indicating study area location is in; for example, 'A'-in Austin study area, 'S'-in San Antonio study area, 'T'-in county that is not in the study area, but within Texas and '9' indicates outside Texas.
14. Zone Number - Zone number of location. Locations in Mexico should be coded 7777. Locations outside of study area county but within Texas should be coded to the state zone system. Unknown zone numbers within a study area county should be coded as 8888. Unknown zone numbers outside of a study area county but within Texas should be coded as 6666. Locations outside Texas and not in Mexico should be coded as 9999.
15. Road - If location is outside of study area county, this is the name of the street/highway/bridge the person was on when they entered/left the study area.
16. Work Location - Code indicating if this location is where person normally works at or out of; 1-yes, 2-no, 99-unknown or no response.
17. Arrival Hour - Hour that employee arrived at this location coded in terms of military time. If this is trip number 0, this field should be blank.
18. Arrival Minute - Minute that employee arrived at this location. If this is trip number 0, this field should be blank.
19. Departure Hour - Hour that employee departed this location coded in terms of military time. If this is the last location (i.e. trip), this field should be blank.
20. Departure Minute - Minute that employee departed this location. If this is the last location (i.e. trip), this field should be blank.
21. Activity Type - Type of activity at this location: 0-residential, 1-basic, 2-retail, 3-eervices, and 4-other.
22. Other Activity - Description of activity at location if activity type is coded as 4-other.
23. Trip Purpose - Code indicating purpose of trip (see definitions below). For trip number 0, this should be coded as 1 if it began at home, 2 if it began at work, or as 99 if it began at another location.
24. Other Purpose - Description of trip purpose if purpose code is "other."
25. Mode - Code indicating mode of travel used in traveling to this location (see travel mode code definitions below).
26. Other Mode - Description of mode of travel if mode is coded as "other."
27. Number People - If mode of travel was driver, passenger, taxi, commercial vehicle, or motorcycle, this is the number of persons in the vehicle, including the person completing the form. A zero or blank should be recorded for all other modes of travel.
28. Vehicle Year - If mode was driver, passenger, or commercial vehicle, this is the year vehicle was manufactured. The information may come from record type 6 of employee survey.
29. Vehicle Make - Make of vehicle used for trip.
30. Vehicle Model - Model of vehicle used for trip.

31. Parking Cost - Cost of parking if parking was paid.
32. Cost Basis - Code indicating basis for parking cost; 1-hourly, 2-daily, 3-monthly, 4-unknown or no response.
33. Bus Fare - Bus fare cost if trip was by bus.
34. Arrival Mode - Code indicating the mode used by the person to get to the location where they boarded the bus. This should be zero or blank for all modes of travel except bus (see code definitions below).
35. Other Arrival Mode - Description of arrival mode of travel if arrival is coded as "other."

Trip purpose codes for Item 23 are:

1. Leave / Return Home
2. Go to Work
3. Work Related
4. School
5. Social / Recreation
6. Eat Out
7. Shop
8. Pick up / Drop off Passenger
9. Change Travel Mode
10. Personal Business
11. Other
99. No Response

Mode of transportation codes for Item 25 are the following:

1. Driver (car/truck/van)
2. Passenger (car/truck/van)
3. Walk
4. Bicycle
5. Bus / Public Transportation
6. School Bus
7. Taxi / Limo
8. Commercial Cargo Transport Vehicle
9. Commercial Service Vehicle
10. Motorcycle
11. Other
99. No Response

Item 34, arrival mode codes are:

1. Drove Auto and Parked
2. Dropped Off
3. Walked
4. Carpooled
5. Other

5.2.2.5 Visitor Survey, Free Standing Workplace Survey Form C

This file contains the travel data for non-employees (visitors) at surveyed free-standing work establishments. The data is coded in the following format:

1. Record Type - Code which indicates the type of record; coded as an “8.”
2. Month - Month workplace was surveyed.
3. Day - Day of the month workplace was surveyed.
4. Site Number - Unique non-zero number assigned to the establishment where these interviews were conducted.
5. Person Number - Number of person being interviewed. This corresponds to the column number on the interview form.
6. Residence - Name of city, county, or country where person lives.
7. Residence Code - Code indicating if residence is not located within a county in the study area: 1-yes, 2-no, 99-refused or unknown.
8. Overnight Stay - If residence code is 1, this field entry is a code indicating if person stayed overnight in the study area; 1-yes, 2-no, 99-refused or unknown. If residence code is 2, this field should be blank.
9. Place Stayed - If person stayed overnight, this field contains the name of the place the person stayed. If person did not stay overnight, this field should be blank.
10. Entry Road - If person did not stay overnight, this field should contain the name of the street/highway/bridge the person was on when they entered the study area. If person stayed overnight, this field should be blank. Note that airport is a valid entry.
11. Home Address - Address where person lives. If person gives nearest intersecting streets, this should be the first street name.
12. Intersecting Street - If person gave nearest intersecting streets for their home address, this field should have the second street name, otherwise it is blank.
13. Longitude - Longitude of person’s home address. If address is in Mexico, this should be coded 777.7777. If address is outside Texas this should be coded 999.9999. If unknown but in study area, it should be coded 888.8888. If unknown but in Texas, it should be coded as 666.6666.
14. Latitude - Latitude of person’s home address. If address is in Mexico, this should be coded 777.7777. If address is outside Texas, this should be coded 999.9999. If unknown but in study area, it should be coded 888.8888. If unknown but in Texas, it should be coded as 666.6666.
15. Study Zone ID - Code indicating study area home is in; for example, ‘A’-in Austin Study area, ‘S’-in San Antonio study area, ‘T’-in county that is not in the study area, but within Texas and ‘9’ – outside Texas
16. Zone - Zone number where person lives. Locations in Mexico should be coded 7777. Locations outside of the study area but within Texas should be coded to the state zone system. Unknown zone numbers within a study area should be coded as 8888. Unknown zone numbers outside of the study area but within Texas should be coded as 6666. Locations outside Texas and not in Mexico should be coded as 9999.
17. Origin Code - Code indicating origin of trip; 1-home, 2-other.
18. Origin Location - Location that trip originated from (i.e. name, address, etc).
19. Longitude - Longitude of location trip originated from. If location is in Mexico, this should be coded 777.7777. If location is outside Texas, this should be coded 999.9999. If

unknown but in study area, it should be coded 888.8888. If unknown but in Texas, it should be coded as 666.6666.

20. Latitude - Latitude of location trip originated from. If location is in Mexico, this should be coded 777.7777. If location is outside Texas, this should be coded 999.9999. If unknown but in study area, it should be coded 888.8888. If unknown but in Texas, it should be coded as 666.6666.
21. Study Zone ID - Code indicating study area location is in; for example 'A'-in Austin Study area, 'S'-in San Antonio study area, 'T'-in county that is not in the study area, but within Texas and '9'-outside Texas.
22. Origin Zone - Zone where trip originated. Locations in Mexico should be coded 7777. Locations outside of the study area, but within Texas should be coded to the state zone system. Unknown zone numbers in a study area county should be coded as 8888. Unknown zone numbers outside of the study area but within Texas should be coded as 6666. Locations outside Texas and not in Mexico should be coded as 9999.
23. Entry Facility - If origin is outside of a study area county, this field should contain the name of the bridge, street, or highway used to enter the study area.
24. Entry External Zone - If origin is outside of the study area, this field should contain the external station number associated with the bridge, street, or highway used to enter the study area.
25. Arrival Hour - Hour person arrived at this site coded in terms of military time.
26. Arrival Minute - Minute person arrived at this site.
27. Mode - Code indicating mode of travel to this location (see definitions below).
28. Other Mode - If mode is coded "other," this field should contain a description of the mode given.
29. Number of Persons - If mode of travel was driver, passenger, taxi, commercial vehicle, or motorcycle, this is the number of persons in the vehicle including the person being interviewed. This field is blank for all other modes.
30. Bus Fare - If mode of travel was bus, this is the bus fare paid.
31. Trip Purpose - Code indicating purpose of trip (see code definitions below).
32. Other Purpose - If purpose is coded as "other," this contains description of purpose given.
33. Depart Destination - Code indicating destination when person departs from this site; 1-home, 2-other.
34. Destination Location - Location of destination person is going.
35. Destination Longitude - Longitude of destination location. If location is in Mexico, this should be coded 777.7777; if location is outside Texas, it should be coded as 999.9999. If unknown but in study area, it should be coded as 888.8888 and if unknown but in Texas, it should be coded as 666.6666.
36. Destination Latitude - Latitude of destination location. If address is in Mexico, it should be coded 777.7777. If address is outside Texas, it should be coded as 999.9999 and if unknown but in study area, it should be coded as 888.8888. If unknown but in Texas, it should be coded as 666.6666.
37. Study Zone ID - Code indicating study area destination is in. For example, 'A'-in Austin Study area, 'S'-in San Antonio study area, 'T' – in county that is not in the study area, but within Texas and '9' – outside Texas.
38. Destination Zone - Zone where individual is going when they leave this location. Locations in Mexico should be coded 7777. Locations not in a study area county, but

within Texas should be coded to the state zone system. Unknown zone numbers in a study area county should be coded as 8888. Unknown zone numbers not in a study area county but within Texas should be coded as 6666. Locations outside Texas and not in Mexico should be coded as 9999.

39. Exit Facility - If destination is outside of the study area, this field should contain the name of the bridge, street, or highway used to enter the study area.
40. Exit External Zone - If destination is outside of a study area county this field should contain the external station number associated with the bridge, street, or highway used to enter the study area.
41. Household Size - Number of persons living at person's home address.
42. Vehicles Available - Number of vehicles available to persons in household.
43. Income - Code indicating household income (see code definitions below).
44. Form Number - Survey form number which contains raw survey data.

Modes of transportation codes for Item 27 are the following:

1. Driver (car/truck/van)
2. Passenger (car/truck/van)
3. Walk
4. Bicycle
5. Bus / Public Transportation
6. School Bus
7. Taxi / Limo
8. Commercial Cargo Transport Vehicle
9. Commercial Service Vehicle
10. Motorcycle
11. Other
99. No Response

Trip purpose codes for Item 31 are as follows:

1. Work Related
2. School Related
3. Social / Recreational / Visit
4. Shop
5. Eat Out
6. Pick Up / Drop Off Passenger
7. Change Travel Mode
8. Delivery – Pick Up / Drop Off
9. Other
10. Non-Response

The income codes for Item 43 are:

1. Less than $5,000
2. $5,000 to $9,999
3. $10,000 to $14,999
4. $15,000 to $19,999
5. $20,000 to $24,999

6. $25,000 to $29,999
7. $30,000 to $34,999
8. $35,000 to $39,999
9. $40,000 to $49,999
10. $50,000 to $59,999
11. $60,000 to $74,999
12. $75,000 to $99,999
13. $100,000 to $124,999
14. $125,000 to $149,999
15. $150,000 or more
98. Don’t Know
99. Refused

5.2.2.6 Visitor Survey, Non-Free Standing Workplace Survey Form D

This file contains the travel data for non-employees (visitors) at surveyed non-free standing work establishments. The data is coded as follows:

1. Record Type - Code which indicates the type of record; coded as “11.”
2. Month - Month workplace was surveyed.
3. Day - Day of the month workplace was surveyed.
4. Site Number - Unique non-zero number assigned to the establishment where these interviews were conducted.
5. Person Number - Number of person being interviewed. This corresponds to the column number on the interview form.
6. Residence - Name of city, county, or country where person lives.
7. Residence Code - Code indicating if residence is outside study area; 1-yes, 2-no, 99-refused or unknown.
8. Overnight Stay - If residence code is 1, this field entry is a code indicating if person stayed overnight in the study area; 1-yes, 2-no, 99-refused or unknown. If residence code is 2, this field should be blank.
9. Place Stayed - If person stayed overnight, this field contains the name of the place the person stayed. If person did not stay overnight, this field should be blank.
10. Entry Road - If person did not stay overnight, this field should contain the name of the street/highway/bridge the person was on when they entered the study area. If person stayed overnight, this field should be blank. Note that airport is a valid entry.
11. Home Address - Address where person lives. If person gives nearest intersecting streets, this should be the first street name.
12. Intersecting Street - If person gave nearest intersecting streets for their home address, this field should have the second street name, otherwise it is blank.
13. Longitude - Longitude of person’s home address. If address is in Mexico, this should be coded 777.7777. If address is outside Texas, this should be coded 999.9999. If unknown but in study area, it should be coded 888.8888. If unknown but in Texas, it should be coded as 666.6666.
14. Latitude - Latitude of person’s home address. If address is in Mexico, this should be coded 777.7777. If address is outside Texas, this should be coded 999.9999. If unknown

but in study area, it should be coded 888.8888. If unknown but in Texas, it should be coded as 666.6666.

15. Study Zone ID - Code indicating study area location is in; for example, ‘A’-in Austin Study area, ‘S’-in San Antonio study area, ‘T’-in county that is not in the study area, but within Texas and ‘9’-outside Texas.
16. Zone - Zone number where person lives. Locations in Mexico should be coded 7777. Locations not in a study area county, but within Texas should be coded to the state zone system. Unknown zone numbers in a study area county should be coded as 8888. Unknown zone numbers outside of the study area, but within Texas should be coded as 6666. Locations outside Texas and not in Mexico should be coded as 9999.
17. Origin Code - Code indicating origin of trip: 1-home and 2-other.
18. Origin Location - Location that trip originated from (i.e. name, address, etc).
19. Longitude - Longitude of location trip originated from. If location is in Mexico, this should be coded 777.7777. If location is outside Texas, this should be coded 999.9999. If unknown but in study area, it should be coded 888.8888. If unknown but in Texas, it should be coded as 666.6666.
20. Latitude - Latitude of location trip originated from. If location is in Mexico, this should be coded 777.7777. If location is outside Texas, this should be coded 999.9999. If unknown but in study area, it should be coded 888.8888. If unknown but in Texas, it should be coded as 666.6666.
21. Study Zone ID - Code indicating study area origin is in; for example, ‘A’-in Austin Study area, ‘S’- in San Antonio study area, ‘T’-in county that is not in the study area, but within Texas and ‘9’-outside Texas.
22. Origin Zone - Zone where trip originated. Locations in Mexico should be coded 7777. Locations outside of Cameron or Hidalgo County but within Texas should be coded to the state zone system. Unknown zone numbers in a study area county should be coded as 8888. Unknown zone numbers not in a study area county but within Texas should be coded as 6666. Locations outside Texas and not in Mexico should be coded as 9999.
23. Entry Facility - If origin is outside the study area, this field should contain the name of the bridge, street, or highway used to enter the study area.
24. Entry External Zone - If origin is not in a study area county this field should contain the external station number associated with the bridge, street, or highway used to enter the study area.
25. Arrival Hour - Hour person arrived at this site coded in terms of military time.
26. Arrival Minute - Minute person arrived at this site.
27. Mode - Code indicating mode of travel to this location (see definitions below).
28. Other Mode - If mode is coded “other,” this field should contain a description of the mode given.
29. Number Persons - If mode of travel was driver, passenger, taxi, commercial vehicle, or motorcycle, this is the number of persons in the vehicle including the person being interviewed. This field is blank for all other modes.
30. Bus Fare - If mode of travel was bus, this is the bus fare paid.
31. Trip Purpose - Code indicating purpose of trip (see code definitions below).
32. Other Purpose - If purpose is coded as “other,” this contains description of purpose given.
33. First Store - Code indicating if this store/establishment is the first visited in the center since arriving; 1-yes, 2-no, 99-refused or unknown.

34. Number Visited - Number of stores/establishments visited in this center.
35. More Visits - Number of stores/establishments in this center person plans on visiting during this trip.
36. Depart Destination - Code indicating destination when person departs from this site; 1-home, 2-other.
37. Destination Location - Location of destination person is going.
38. Destination Longitude - Longitude of destination location. If location is in Mexico, this should be coded 777.7777. If location is outside Texas, this should be coded 999.9999. If unknown but in study area, it should be coded 888.8888. If unknown but in Texas, it should be coded as 666.6666.
39. Destination Latitude - Latitude of destination location. If address is in Mexico, this should be coded 777.7777. If address is outside Texas, this should be coded 999.9999. If unknown but in study area, it should be coded 888.8888. If unknown but in Texas, it should be coded as 666.6666.
40. Study Zone ID - Code indicating study area destination is in; for example, ‘A’- in Austin Study area, ‘S’-in San Antonio study area, ‘T’-in county that is not in the study area, but within Texas and ‘9’-outside Texas.
41. Destination Zone - Zone where individual is going when they leave this location. Locations in Mexico should be coded 7777. Locations outside of the study area but within Texas should be coded to the state zone system. Unknown zone numbers in a study area county should be coded as 8888. Unknown zone numbers outside of the study area but within Texas should be coded as 6666. Locations outside Texas and not in Mexico should be coded as 9999.
42. Exit Facility - If destination is outside of the study area, this field should contain the name of the bridge, street, or highway used to enter the study area
43. Exit External Zone - If destination is outside of a study area county this field should contain the external station number associated with the bridge, street, or highway used to enter the study area.
44. Household Size - Number of persons living at person’s home address.
45. Vehicles Available - Number of vehicles available to persons in household.
46. Income - Code indicating household income (see code definitions below).
47. Form Number - Survey form number which contains raw survey data.

Modes of transportation codes for Item 27 are the following:

1. Driver (car/truck/van)
2. Passenger (car/truck/van)
3. Walk
4. Bicycle
5. Bus / Public Transportation
6. School Bus
7. Taxi / Limo
8. Commercial Cargo Transport Vehicle
9. Commercial Service Vehicle
10. Motorcycle
11. Other
99. No Response

Trip purpose codes for Item 31 are as follows:

1. Work Related
2. School Related
3. Social / Recreational / Visit
4. Shop
5. Eat Out
6. Pick Up / Drop Off Passenger
7. Change Travel Mode
8. Delivery – Pick Up / Drop Off
9. Other

99. Non-Response

The income codes for Item 43 are:

1. Less than $5,000
2. $5,000 to $9,999
3. $10,000 to $14,999
4. $15,000 to $19,999
5. $20,000 to $24,999
6. $25,000 to $29,999
7. $30,000 to $34,999
8. $35,000 to $39,999
9. $40,000 to $49,999
10. $50,000 to $59,999
11. $60,000 to $74,999
12. $75,000 to $99,999
13. $100,000 to $124,999
14. $125,000 to $149,999
15. $150,000 or more

98. Don't Know
99. Refused

5.2.2.7 Workplace Delivery Vehicle Survey, Form E

This file contains the travel data for commercial vehicles surveyed in the workplace survey. The data is coded as an ASCII data file.

1. Record Type - Code which indicates the type of record; coded as "10."
2. Month - Month workplace was surveyed.
3. Day - Day of the month workplace was surveyed.
4. Site Number - Non-zero number assigned to the workplace.
5. Truck Number - Truck number surveyed. This should correspond to the column number of the survey form used to collect the data.
6. Arrival Hour - Hour vehicle arrived at location coded in military time.
7. Arrival Minute - Minute vehicle arrived at location.
8. Occupancy - Number of people in vehicle.

9. Vehicle Classification - Code indicating the classification of the vehicle (see below for code descriptions).
10. Other Classification - If vehicle classification is coded as “other”, this field should contain the description recorded on the survey form for vehicle
11. Type of Vehicle - Code indicating type of commercial vehicle. Use 1 for cargo transport vehicle and 2 for service vehicle (i.e. all others besides cargo transport)
12. Year of Vehicle - Year vehicle was manufactured.
13. Gross Vehicle Weight - Gross (empty) weight of vehicle.
14. Vehicle Fuel Type - Type of fuel used by vehicle: 1-leaded gas, 2-unleaded gas, 3-diesel, 4-propane, and 5-other.
15. Other Fuel - If vehicle fuel type is coded “other,” this field should contain the description recorded on the survey form for the vehicle.
16. Odometer - Odometer mileage on vehicle.
17. Vehicle Cargo - Cargo being carried by vehicle (see code definitions below).
18. Delivery Cargo Weight - Weight in pounds of cargo being delivered
19. Pick Up Cargo Weight - Weight in pounds of cargo being picked up
20. Cargo Origin Country - If cargo originated in Mexico enter 1 for Yes and 2 for No.
21. Trip Purpose - Purpose of trip (see code descriptions below).
22. Other Trip Purpose - If trip purpose is coded as “other,” this is a description of that purpose.
23. Origin Address - City and street address of last place person got into vehicle before traveling to this workplace.
24. Origin Longitude - Longitude of location trip originated from. If location is in Mexico, this should be coded 777.7777. If location is outside Texas, this should be coded 999.9999. If unknown but in study area, it should be coded 888.8888. If unknown but in Texas, it should be coded as 666.6666.
25. Origin Latitude - Latitude of location trip originated from. If location is in Mexico, this should be coded 777.7777. If location is outside Texas, this should be coded 999.9999. If unknown but in study area, it should be coded 888.8888. If unknown but in Texas, it should be coded as 666.6666.
26. Study Zone ID - Code indicating study area origin is in; for example, ‘A’-in Austin Study area, ‘S’-in San Antonio study area, ‘T’-in county that is not in the study area, but within Texas and ‘9’-outside Texas.
27. Origin Zone - Zone where trip originated. Locations in Mexico should be coded 7777. Locations not in a study area county but within Texas should be coded to the state zone system. Unknown zone numbers in the study area should be coded as 8888. Unknown zone numbers not in a study area county but within Texas should be coded as 6666. Locations outside Texas and not in Mexico should be coded as 9999.
28. Entry Facility - If origin is outside of the study area, this field should contain the name of the bridge, street, or highway used to enter the study area.
29. Entry External Zone - If origin is outside the study area, this field should contain the external station number associated with the bridge, street, or highway used to enter the study area.
30. Origin Purpose - Purpose for being at origin address where this trip originated (see code definitions below).

31. Other Origin Purpose - If the origin purpose is coded as “other,” this is a description of that purpose.
32. Hour Departed - Hour vehicle departed from origin address coded in military time.
33. Minute Departed - Minute vehicle departed from origin address.
34. Destination Address - City and street address of location vehicle will be going when they leave this workplace.
35. Longitude - Longitude of destination location. If location is in Mexico, this should be coded 777.7777. If location is outside Texas, this should be coded 999.9999. If unknown but in study area, it should be coded 888.8888. If unknown but in Texas, it should be coded as 666.6666.
36. Latitude - Latitude of destination location. If address is in Mexico, this should be coded 777.7777. If address is outside Texas, this should be coded 999.9999. If unknown but in study area, it should be coded 888.8888. If unknown but in Texas, it should be coded as 666.6666.
37. Study Zone ID - Code indicating study area destination is in; for example, ‘A’-in Austin Study area, ‘S’-in San Antonio study area, ‘T’-in county that is not in the study area, but within Texas and ‘9’-outside Texas.
38. Destination Zone - Zone where individual is going when they leave this location. Locations in Mexico should be coded 7777. Locations outside the study area but within Texas should be coded to the state zone system. Unknown zone numbers in the study area should be coded as 8888. Unknown zone numbers outside the study area but within Texas should be coded as 6666. Locations outside Texas and not in Mexico should be coded as 9999.
39. Exit Facility - If destination is outside the study area, this field should contain the name of the bridge, street, or highway used to enter the study area
40. Exit External Zone - If destination is outside the study area, this field should contain the external station number associated with the bridge, street, or highway used to enter the study area.
41. Destination Purpose - Purpose for traveling to the next destination (see below for code definitions).
42. Other Destination Purpose - If the destination purpose is coded as “other,” this is a description of that purpose.
43. Form Number - Number of survey form.

Item 9, Vehicle classification codes are as follows:

1. Passenger car
2. Pick-up Truck
3. Van (Passenger or Mini)
4. Sport Utility Vehicle (SUV)
5. Single Unit 2-axle (6 wheels)
6. Single Unit 3-axle (10 wheels)
7. Single Unit 4-axle (14 wheels)
8. Semi (all Tractor-Trailer Combinations)
9. Other

Trip purpose options for Items 21, 30 and 41 are:

1. Base location or return to base location
2. Delivery
3. Pick-up
4. Delivery and pick-up
5. Maintenance
6. Driver needs (lunch, etc)
7. Buy gas or fuel
8. Other
99. Refused / Unknown

Vehicle cargo codes are as follows:

1. Farm Products - Livestock, fertilizer, dirt, landscaping, etc.
2. Forest Products - Trees, sod, etc.
3. Marine Products - Fresh fish, seafood, etc.
4. Metals and Minerals - Crude petroleum, natural gas, propane, Metals, gypsum, ores, etc.
5. Food, Health, and Beauty Products - Assorted food products, cosmetics, etc.
6. Tobacco Products - Cigarettes, cigars, and chewing tobacco
7. Textiles - Clothing, linens, etc.
8. Wood Products - Lumber, paper, cardboard, wood pulp, etc.
9. Printed Matter - Newspapers, magazines, books, etc.
10. Chemical Products - Soaps, paints, household or industrial chemicals, etc.
11. Refined Petroleum or Coal Products - Gasoline, etc.
12. Rubber, Plastic, and Styrofoam Products - Finished products of rubber, plastic, or Styrofoam
13. Clay, Concrete, Glass, or Stone - Finished products of clay, concrete, glass, or stone
14. Manufactured Goods/Equip - Miscellaneous products, such as machinery, appliances, furniture, etc.
15. Wastes - Waste products including scrap and recyclable materials
16. Miscellaneous Shipments - U.S. mail, U.P.S., Federal Express, and other mixed cargo
17. Hazardous Materials - Hazardous chemicals and substances
18. Transportation - Automobiles, Heavy Equipment, etc.
19. Unclassified Cargo - Cargo not falling within one of the above categories
20. Driver Refused to Answer - Driver refused to answer
21. Unknown to Driver - Unknown to driver
22. Empty - Empty (including empty shipping containers)

5.2.2.8 Workplace Vehicles Owned/Leased Survey - Vehicle Information (Record Type 20)

This file contains general information for each vehicle included in the vehicle survey. Data for each vehicle surveyed is recorded using the following format:

1. Record Type - Code which indicates the type of record; coded as "20."
2. Vehicle ID Number - Unique identification number assigned to vehicle for survey purposes.

3. Vehicle License Number - License number of the vehicle being surveyed.
4. Month - Month of vehicle travel day.
5. Day - Day of the month of vehicle travel day.
6. Name - Name and address of the person or company to which the vehicle is registered. If space is not sufficient in the current field size, the address should be continued at the end of the record. The field sizes and contents for these continuations should be furnished with the data when submitted.
7. NAICS Code - Four-digit NAICS code of the business at the base location.
8. Study Zone ID - Code indicating study area location is in; for example, 'A'-in Austin Study area, 'S'-in San Antonio study area, 'T'-in county that is not in the study area, but within Texas and '9'-outside Texas
9. Zone - Zone where base is located. Unknown zones should be coded as 8888.
10. Longitude - Longitude of the base location. Unknown longitudes should be coded as 888.8888.
11. Latitude - Latitude of the base location. Unknown latitudes should be coded as 888.8888.
12. Make of Vehicle - Make of vehicle.
13. Model of Vehicle - Model of vehicle
14. Year of Vehicle - Year vehicle was manufactured. Unknown years should be coded as 9999.
15. Vehicle Fuel Type - Type of fuel used by vehicle: 1-leaded gas; 2-unleaded gas; 3-diesel; 4-propane; 5-other.
16. Fuel Type Other - If item 14 is coded as "other," this is a description of the type of fuel; otherwise this field is blank.
17. Vehicle Class - Code indicating the classification of the vehicle (see below for code descriptions).
18. Other Vehicle - If item 16 is coded as "other," this field should contain a description of the vehicle; otherwise this field is blank.
19. Vehicle Type - Code indicating type of commercial vehicle. 1 is used for cargo and/or freight transport and 2 is used for service vehicles.
20. Gross Vehicle Weight - Gross weight of the vehicle or total gross weight of the vehicle/trailer combination.
21. Odometer - Odometer mileage on the vehicle at the beginning of the survey day. Refusals or unknown values should be coded as 9999999.
22. More Trips - Total number of trips made by vehicle on its survey day including any additional trips made but not recorded in diary due to lack of space.

Item 17, Vehicle classification codes are as follows:

1. Passenger car
2. Pick-up Truck
3. Van (Passenger or Mini)
4. Sport Utility Vehicle (SUV)
5. Single Unit 2-axle (6 wheels)
6. Single Unit 3-axle (10 wheels)
7. Single Unit 4-axle (14 wheels)
8. Semi (all Tractor-Trailer Combinations)
9. Other

5.2.2.9 Workplace Vehicles Owned/Leased Survey, Trip Information (Record Type 21)

This file contains trip information for each vehicle included in the commercial vehicle survey. Data for each commercial vehicle surveyed is recorded using the following format:

1. Record Type - Code which indicates the type of record; coded as "21."
2. Vehicle ID Number - Unique identification number assigned to vehicle for survey purposes. Must match the number used in data format for record type 20.
3. Vehicle License Number - License number of the vehicle being surveyed.
4. Trip Number - Trip number; beginning trip will be recorded as 0 with each subsequent trip numbered sequentially as 1, 2, 3, etc.
5. Address Field 1 - Name of location and address of first street name or nearest intersecting streets to the location. If name and address exceed field size it should be continued in item 6.
6. Address Field 2 - Continuation of name of location and address in item 5 or second street name of intersecting streets to the location.
7. Study Zone ID - Code indicating study area location is in; for example, 'A'-in Austin Study area, 'S'-in San Antonio study area, 'T'-in county that is not in the study area, but within Texas and '9'-outside Texas.
8. Zone - Zone number of location. Unknown zones in study area should be coded as 8888. Locations in Mexico should be coded as 7777. Locations outside study area but within Texas should be coded to the state zone system. Locations outside of study area but within Texas that cannot be geocoded should be coded to 6666. Locations outside of Texas should be coded as 9999.
9. Longitude - Longitude of location. Unknown longitudes in study area should be coded as 888.8888. Longitudes for locations in Mexico should be coded as 777.7777. Longitudes for locations outside Texas should be coded 999.9999. Unknown locations outside study area but in Texas should be coded 666.6666.
10. Latitude - Latitude of location. Unknown latitudes in study area should be coded as 888.8888. Latitudes for locations in Mexico should be coded as 777.7777. Latitudes for locations outside Texas should be coded 999.9999. Unknown locations outside study area but in Texas should be coded 666.6666.
11. Work Indicator - Code indicating if this location is base location for the vehicle; 1-yes; 2-no.
12. County Indicator - Code indicating the county the address is located; for example: 1-Bexar, 2-Comal, 3-Guadalupe, 4-Kendall, 5-Wilson, 6-Travis, 7-Hays, 8-Williamson, 9-Bastrop, 10-Caldwell, 98-other and 99-refused
13. Arrival Hour - Hour that the vehicle arrived at this location. This hour should be in military format. For trip 0, this field should be blank.
14. Arrival Minute - Minute that the vehicle arrived at this location. For trip 0, this field should be blank.
15. Odometer - Odometer mileage of the vehicle while stopped at this location.
16. Departure Hour - Hour that the vehicle departed this location. This hour should be in military format. If this is the last trip, this field should be blank.
17. Departure Minute - Minute that the vehicle departed this location. If this is the last trip, this field should be blank.

18. Type of Place/Activity - Code indicating the type of place at this location (see activity code descriptions below).
19. Other Place - If the type of place is coded as “other,” this field should contain the description of the land use activity at this location.
20. Trip Purpose - Code indicating purpose of trip (see definitions below). For place number 0 (first trip), this should be coded as 1 if it began at the base location, 6 if it began at home, or as 7 if it began at another location.
21. Other Purpose - If trip purpose is coded as “other,” this field should contain the description of the trip purpose given.
22. Cargo - Code indicating the cargo picked up or delivered at this location (see cargo classifications provided below). If no cargo was picked up or delivered at this location, code 21 should be entered.
23. Other Cargo - If item 22 is coded as 22, this field should contain a description of the cargo; otherwise this field is blank.
24. Load - Code indicating if vehicle is partially or fully loaded when leaving initial location. Use 1 if fully loaded; 2 if partially loaded; and 3 if empty. This field is coded only for trip 0.
25. Initial cargo weight - Weight of cargo in pounds being carried when leaving initial location. This field is coded only for trip 0.
26. Delivery cargo weight - Weight of cargo in pounds being delivered. This field is blank for trip 0.
27. Pick Up cargo weight - Weight of cargo in pounds being picked up. This field is blank for trip 0.

Activity codes for Item 18 are the following:

1. Office Building (Non Government)
2. Retail / Shopping
3. Industrial / Manufacturing Site
4. Medical / Hospital
5. Educational (12th Grade or less)
6. Educational (College, Trade, etc.)
7. Government Office / Building
8. Residential
9. Airport
10. Intermodal Facility
11. Warehouse
12. Distribution Center
13. Construction Site
14. Other
99. Refused / Unknown

Trip purpose codes for Item 20 are:

1. Base Location / Return to Base Location
2. Delivery
3. Pick-up
4. Delivery and Pick Up

5. Maintenance (fuel, oil, etc.)
6. Driver Needs (lunch, etc.)
7. Service Related
8. Other
99. Refused / Unknown

Vehicle cargo codes are as follows:

1. Farm Products - Livestock, fertilizer, dirt, landscaping, etc.
2. Forest Products - Trees, sod, etc.
3. Marine Products - Fresh fish, seafood, etc.
4. Metals and Minerals - Crude petroleum, natural gas, propane, Metals, gypsum, ores, etc.
5. Food, Health, and Beauty Products - Assorted food products, cosmetics, etc.
6. Tobacco Products - Cigarettes, cigars, and chewing tobacco
7. Textiles - Clothing, linens, etc.
8. Wood Products - Lumber, paper, cardboard, wood pulp, etc.
9. Printed Matter - Newspapers, magazines, books, etc.
10. Chemical Products - Soaps, paints, household or industrial chemicals, etc.
11. Refined Petroleum or Coal Products - Gasoline, etc.
12. Rubber, Plastic, and Styrofoam Products - Finished products of rubber, plastic, or Styrofoam
13. Clay, Concrete, Glass, or Stone - Finished products of clay, concrete, glass, or stone
14. Manufactured Goods/Equip - Miscellaneous products, such as machinery, appliances, furniture, etc.
15. Wastes - Waste products including scrap and recyclable materials
16. Miscellaneous Shipments - U.S. mail, U.P.S., Federal Express, and other mixed cargo
17. Hazardous Materials - Hazardous chemicals and substances
18. Transportation - Automobiles, Heavy Equipment, etc.
19. Unclassified Cargo - Cargo not falling within one of the above categories
20. Driver Refused to Answer - Driver refused to answer
21. Unknown to Driver - Unknown to driver
22. Empty - Empty (including empty shipping containers)

5.2.3 Commercial Vehicle Survey

In some areas, TxDOT conducts a separate commercial truck survey to develop a more comprehensive database of travel patterns, vehicle weights, and fuel types for commercial trucks operating in the urban area. TxDOT-TPP uses information collected from this survey to develop truck trip rates for trip production and in modeling associated with air quality conformity analysis. Participating firms provide data for each trip taken during one day’s travel. Information collected includes departure and arrival times, an address for each destination, truck types, truck weight, fuel type, and truck routes traveled. The commercial vehicle survey data provides an estimated truck trip control total for the truck trip purpose in the trip generation model. The data collected from the commercial vehicle survey is tabulated in two files:

- Commercial Vehicle Information (Record Type 20)
- Commercial Vehicle Information (Record Type 21)

5.2.3.1 Commercial Vehicle Information (Record Type 20)

The Record Type 20 file contains general information for each vehicle included in the commercial vehicle survey. Data for each commercial vehicle surveyed is recorded using the following format:

1. Record Type - Code which indicates the type of record; coded as “20.”
2. Vehicle ID Number - Unique identification number assigned to vehicle for survey purposes.
3. Vehicle License Number - License number of the vehicle being surveyed.
4. Month - Month of vehicle travel day.
5. Day - Day of the month of vehicle travel day.
6. Name - Name and address of the person or company to which the vehicle is registered. If space is not sufficient in the current field size, the address should be continued at the end of the record. The field sizes and contents for these continuations should be furnished with the data when submitted.
7. Type of Place - Type of place vehicle was based at on the beginning of the travel day. See codes below.
8. Type of Place Other - Description of ‘other’ if type of place code is coded as 14 – other.
9. NAICS Code – Four-digit NAICS code of the business at the base location.
10. Study Area Identifier - This field identifies the MPO study area in which the zone in item 11 is located or if the zone is rural. For example, TAZ zones in the Waco study area should be coded as ‘W’ and TAZ zones in the Killeen-Temple study area should be codes as ‘K’.
11. Zone - Zone where base is located. Unknown zones should be coded as 8888.
12. Longitude - Longitude of the base location. Unknown longitudes should be coded as 888.8888.
13. Latitude - Latitude of the base location. Unknown latitudes should be coded as 888.8888.
14. Make of Vehicle - Make of vehicle.
15. Model of Vehicle - Model of vehicle.
16. Year of Vehicle - Year vehicle was manufactured. Unknown years should be coded as 9999.
17. Vehicle Type - Type of commercial vehicle; 1-major cargo or freight transport; 2-local service or delivery.
18. Vehicle Fuel Type - Type of fuel used by vehicle: 1-unleaded gas; 2-diesel; 3-propane; 4-hybrid; 5-other.
19. Fuel Type Other - If item 18 is coded as “other,” this is a description of the type of fuel. Otherwise this field is blank.
20. Vehicle Class - Code indicating the classification of the vehicle (see below for code descriptions).
21. Other Vehicle - If item 20 is coded as “other,” this field should contain a description of the vehicle. Otherwise this field is blank.

22. Gross Vehicle Weight - Gross weight of the vehicle or total gross weight of the vehicle/trailer combination.
23. Odometer - Odometer mileage on the vehicle at the beginning of the survey day. Refusals or unknown values should be coded as 9999999.
24. More Trips - Total number of trips made by vehicle on its survey day including any additional trips made but not recorded in diary due to lack of space.

Type of place codes for Item 7 are the following:

1. Office Building
2. Retail / Shopping
3. Industrial / Manufacturing
4. Medical / Hospital
5. Educational (12th grade or less)
6. Educational (college, trade, etc)
7. Government office/building
8. Residential
9. Airport
10. Intermodal Facility
11. Warehouse
12. Distribution Center
13. Construction Site
14. Other – specify
99. Refused / Unknown

Item 20, Vehicle classification codes are as follows:

1. Passenger car
2. Pick-up Truck
3. Van (Passenger or Mini)
4. Sport Utility Vehicle (SUV)
5. Single Unit 2-axle (6 wheels)
6. Single Unit 3-axle (10 wheels)
7. Single Unit 4-axle (14 wheels)
8. Semi (all Tractor-Trailer Combinations)
9. Other

5.2.3.2 Commercial Vehicle Survey, Trip Information (Record Type 21)

The Record Type 21 file contains trip information for each vehicle included in the commercial vehicle survey. Data for each commercial vehicle surveyed is recorded using the following format:

1. Record Type - Code which indicates the type of record; coded as “21.”
2. Vehicle ID Number - Unique identification number assigned to vehicle for survey purposes that must match the number used in data format for record type 20.
3. Vehicle License Number - License number of the vehicle being surveyed.

4. Trip Number - Trip number; beginning trip will be recorded as 0 with each subsequent trip numbered sequentially as 1, 2, 3, etc.
5. Address Field 1 - Name of location and address of first street name or nearest intersecting streets to the location. If name and address exceed field size it should be continued in item 6.
6. Address Field 2 - Continuation of name of location and address in item 5 or second street name of intersecting streets to the location.
7. State Zone Number - If location is within Texas and geocoded to a state zone, this field should have a 1 in it, otherwise this field is left blank.
8. Zone Identifier - This field identifies the MPO study area in which the zone in item 11 is located or if the zone is rural. For example, TAZ zones in the Waco study area should be coded as ‘W’ and TAZ zones in the Killeen-Temple study area should be codes as ‘K’. The field is left blank if the location is not within these counties.
9. Zone - Zone number of location. Unknown zones should be coded as 8888. Locations in Mexico should be coded as 7777. Locations outside study area but within Texas should be coded to the state zone system. Locations outside of study area but within Texas that cannot be geocoded should be coded to 6666. Locations outside of Texas should be coded as 9999.
10. Longitude - Longitude of location. Unknown longitudes in study area should be coded as 888.8888. Longitudes for locations in Mexico should be coded as 777.7777. Longitudes for locations outside study area should be coded 999.9999.
11. Latitude - Latitude of location. Unknown latitudes in study area should be coded as 888.8888. Latitudes for locations in Mexico should be coded as 777.7777. Latitudes for locations outside study area should be coded 999.9999. External latitudes should be coded as 99.999.
12. Base Indicator - Code indicating if this location is base location for the vehicle; 1-yes; 2-no.
13. Study area Indicator - Code indicating if this location is in one of the study area. 1-yes, 2-no.
14. Facility Used - If item 13 is coded as 2, this field should contain the name of the facility/highway the vehicle was on when it entered or exited the study area. If item 12 is coded as 1, this field should be blank.
15. External Station - If item 13 is coded as 2, this field should contain the external station number for the facility the vehicle was on when it entered or exited the study area. If item 12 is coded as 1, this field should be blank.
16. Begin Load Status - Load status of the vehicle when it left the place its travel began for the day; the status codes are: 1-fully loaded; 2-partially loaded; 3-empty and 4-not applicable.
17. Begin Load Weight - If begin load status coded as 1 or 2, this field contains the weight in pounds of cargo being transported when the vehicle left the location its travel began for the day.
18. Arrival Hour - Hour that the vehicle arrived at this location coded in military format. For trip 0, this field should be blank.
19. Arrival Minute - Minute that the vehicle arrived at this location. For trip 0, this field should be blank.

20. Departure Hour - Hour that the vehicle departed this location coded in military format. If this is the last trip, this field should be blank.
21. Departure Minute - Minute that the vehicle departed this location. If this is the last trip, this field should be blank.
22. Type of Activity - Code indicating the type of activity at this location. See code descriptions below.
23. Other Activity - If the type of activity is coded as “other,” this field should contain the description of the land use activity at this location.
24. Type of Place - Code indicating type of place of this location (see type of place options).
25. Other Type of Place - If type of place is coded as other, this field should contain a description of the type of place given.
26. Cargo - Code indicating the cargo picked up or delivered at this location (see definitions below). If no cargo was picked up or delivered at this location, code 22 should be entered.
27. Other Cargo - If item 26 is coded as 19 (unclassified) this field should contain a description of the cargo, otherwise this field is blank.
28. Cargo Weight Pick-Up - Weight in pounds (lbs.) of the cargo picked-up at this location.
29. Cargo Weight Drop-Off - Weight in pounds (lbs.) of the cargo dropped off at this location
30. Hazardous Placard - If cargo code is 17 (indicating hazardous material), this is the placard number for the hazardous material.

Activity options for Item 22 are the following:

1. Base Location / Return to Base Location
2. Delivery
3. Pick-up
4. Pick-up and Delivery
5. Maintenance (fuel, oil, etc.)
6. Driver Needs (lunch, etc.)
7. Service Related (to job/work site, etc.)
8. Other (specify)
99. Refused / Unknown

The type of place options for Item 24 are:

1. Office Building
2. Retail / Shopping
3. Industrial / Manufacturing
4. Medical / Hospital
5. Educational (12th Grade or less)
6. Educational (College, Trade, etc.)
7. Government office / building
8. Residential
9. Airport
10. Intermodal Facility
11. Warehouse
12. Distribution Center

13. Construction Site
14. Other (specify)
99. Refused / Unknown

Vehicle cargo codes are as follows:

1. Farm Products - Livestock, fertilizer, dirt, landscaping, etc.
2. Forest Products - Trees, sod, etc.
3. Marine Products - Fresh fish, seafood, etc.
4. Metals and Minerals - Crude petroleum, natural gas, propane, Metals, gypsum, ores, etc.
5. Food, Health, and Beauty Products - Assorted food products, cosmetics, etc.
6. Tobacco Products - Cigarettes, cigars, and chewing tobacco
7. Textiles - Clothing, linens, etc.
8. Wood Products - Lumber, paper, cardboard, wood pulp, etc.
9. Printed Matter - Newspapers, magazines, books, etc.
10. Chemical Products - Soaps, paints, household or industrial chemicals, etc.
11. Refined Petroleum or Coal Products - Gasoline, etc.
12. Rubber, Plastic, and Styrofoam Products - Finished products of rubber, plastic, or Styrofoam
13. Clay, Concrete, Glass, or Stone - Finished products of clay, concrete, glass, or stone
14. Manufactured Goods/Equip - Miscellaneous products, such as machinery, appliances, furniture, etc.
15. Wastes - Waste products including scrap and recyclable materials
16. Miscellaneous Shipments - U.S. mail, U.P.S., Federal Express, and other mixed cargo
17. Hazardous Materials - Hazardous chemicals and substances
18. Transportation - Automobiles, Heavy Equipment, etc.
19. Unclassified Cargo - Cargo not falling within one of the above categories
20. Driver Refused to Answer - Driver refused to answer
21. Unknown to Driver - Unknown to driver
22. Empty - Empty (including empty shipping containers)
23.

5.2.4 External Station Survey

At each external survey station location (e.g. a major roadway facility at the model area boundary), surveyors randomly select out-bound vehicles and interview the drivers to determine information on the trip purpose, the trip origin and destination, and the vehicle occupancy. TxDOT-TPP uses this information to estimate the number of trips originating outside the study area and traveling to a point inside the area, the number of trips beginning and ending at a point outside the study area (through trips), and trips originating inside the study area and destined to a point outside the study area. The data collected from the external station survey is tabulated in five separate files:

- External Station Non-Commercial Travel Survey Form A
- External Station Commercial Vehicle Survey Form B

- High Volume Non-Commercial External Station Survey License Plate Data
- High Volume Non-Commercial External Station Survey Form C – Non-Commercial Mail-out Survey
- External Station Commercial Travel Survey Form D – Commercial Vehicle Data

5.2.4.1 External Station Non-Commercial Travel Survey Form A Data File Format

This file contains the survey data collected from non-commercial vehicle respondents at external stations in the outbound direction. The data is coded in the following format:

1. Record Type - Code which indicates the type of record; coded as "A."
2. Month - Month station is being surveyed.
3. Day - Day of the month survey is being conducted.
4. Station Number - Site number of the station being surveyed; these are unique numbers for each urban area survey.
5. Station - Name of station/facility being surveyed.
6. Longitude - Longitude of location being surveyed.
7. Latitude - Latitude of location being surveyed.
8. Name of Interviewer - Name of surveyor conducting interview.
9. Vehicle Number - Vehicle number surveyed (column number on survey form).
10. Survey Begin Time - Hour and minute when survey began coded in military time.
11. Survey End Time - Hour and minute when survey ended coded in military time.
12. Occupancy - Number of people in vehicle.
13. Vehicle Classification - Code indicating the classification of the vehicle (see below for code descriptions).
14. Vehicle Classification Other - If vehicle type is coded as other, this is the description of the vehicle type.
15. Year of Vehicle - Year vehicle was manufactured, 9999 coded for unknown or refused.
16. Vehicle Make - Make of vehicle.
17. Vehicle Model - Model of vehicle.
18. Vehicle Fuel Type - Type of fuel used by vehicle: 1-unleaded gas; 2-diesel; 3-propane; 4-hybrid; 5-other.
19. Fuel Type Other - If type of fuel is coded as "other" this is the description of the type of fuel, otherwise it is left blank.
20. Odometer - Odometer mileage on vehicle with 9999999 is coded for unknown or refused.
21. Residence Status - Code indicating county in which person lives; for example 1-Brazoria, 2-Chambers, 3-Fort Bend, 4-Galveston, 98-unknown and 99-refused.
22. Resident Home Location - This field contains the city and state of their home. This field is blank if item 21 is coded as 3.
23. Home Location (Non-Resident) - For persons not living in the study area, this field contains the city and state where they reside. This field is blank if item 21 is coded 1.
24. Stayed Overnight (Non-Resident) - For persons not living in study area, this field contains code indicating if person stayed overnight in study area; 1-yes; 2-no; 99-unknown or refused. This field is blank if item 21 is coded 1.

25. Stay-over Location (Non-Resident) - For persons not living in study area who indicated they stayed overnight in item 24, this field contains the name and location of where they stayed. This field is blank if item 21 is coded 1 or if item 24 is coded as 2.
26. Number of Nights (Non-Resident) - This field should contain the number of nights non-resident stayed overnight in the study area. This field is blank if item 21 is coded 1.
27. Enter Texas (Non-Resident) - For persons not living in the study area, this field contains the code indicating if person entered Texas on the survey date; 1-yes; 2-no; 99-unknown or refused. This field is blank if item 21 is coded 1.
28. Travel Origin (Non-Resident) - For persons not living in the study area, this field contains the travel origin for persons who entered Texas on the survey day. This field is blank if item 21 is coded 1 or if item 27 is coded as 2.
29. Texas Entry Point (Non-Resident) - For persons not living in the study area who entered Texas on the travel day, this field should state the name of the road or highway they used to enter Texas. This field is blank if item 21 is coded 1 or if item 27 is coded as 2.
30. Texas Entry Zone (Non-Resident) - This field contains the external station zone number of the entry or exit point listed in item 29. This field is blank if item 21 is coded 1 or if item 27 is coded as 2.
31. Origin Field 1 - This is the address of the last place person got into their vehicle or the name of the nearest intersecting streets to that place.
32. Origin Field 2 - This is the second street name of the nearest intersecting streets to the last place person got into their vehicle or a continuation of the address in item 31.
33. Origin Longitude - This is the longitude of the origin address. Unknown or refused origins within the study area should be coded as 888.8888. Unknown external origins outside of the study are but within Texas should be coded as 666.6666. Unknown Mexico external origins should be coded as 777.7777. Unknown out-of-state external origins (non-Mexico) should be coded as 999.9999.
34. Origin Latitude - This is the latitude of the origin address. Unknown or refused origins within the study area should be coded as 888.8888. Unknown external origins outside of the study are but within Texas should be coded as 666.6666. Unknown Mexico external origins should be coded as 777.7777. Unknown out-of-state external origins (non-Mexico) should be coded as 999.9999.
35. Origin Study Area - Code indicating study area origin is located; for example, ‘H’ if zone is in the Houston study area and ‘B’ if the zone is in the Beaumont study area. Field should be left blank if location is not within one of these two MPO study areas.
36. Origin Zone - If the trip origin is within the study area, this is the zone number where the origin is located. Unknown or refused internal locations within the study area should be coded as 8888. If the trip began outside of the study area but within Texas, it should be coded using the statewide zone system (SAM) and preceded by the number 1 in column 431. Unknown or refused external locations within Texas should be coded as 6666. If the origin is in Mexico, this should be the zone number for the international border crossing used to enter Texas. Unknown or refused border crossings from Mexico should be coded as 7777. If the origin is outside of Texas (non-Mexico), this should be the statewide model zone number for the highway used to enter the state. Unknown or refused external locations outside of Texas (non-Mexico) should be coded as 9999.
37. Departure Hour - This is the hour the vehicle departed from the origin location coded in military time.

38. Departure Minute - This is the minute the vehicle departed from the origin location.
39. Origin Type - Code indicating the type of place from which the trip originated (see code definitions below).
40. Origin Type Other - If the origin type is coded as "other" this is the description of the type of place, otherwise it is left blank.
41. Origin Purpose - This is the driver's purpose for being at that location (see code definitions below).
42. Origin Purpose Other - If the origin purpose is coded as "other" this is the description of the purpose, otherwise it is blank.
43. Trip Indicator - Code indicating if the origin address in item 31 or 32 is within the study area; 1-yes, 2-no, 99-unknown or refused.
44. Entry Point - If trip origin is outside the study area (i.e. indicated by a 2 in item 43), then this field states the name of the external highway or bridge at which the vehicle entered the study area. This field is left blank if item 43 is coded as a 1.
45. Entry Zone - If the trip origin is outside the study area (i.e., indicated by a 2 in item 43) this field contains the external station number of the entry point listed in item 44. Unknown should be coded as 99999. This field is blank if item 43 is coded as 1.
46. Destination Field 1 - This is the address of the destination for the person or the name of the nearest intersecting streets to that destination.
47. Destination Field 2 - This is the second street name of the nearest intersecting streets to the destination of the person or a continuation of the address in item 46.
48. Destination Longitude - This is the longitude of the destination address. Unknown or refused internal destinations should be coded as 888.8888. Unknown external destinations within Texas should be coded as 666.6666. Unknown Mexico external destinations should be coded as 777.7777. Unknown out-of-state external destinations (non-Mexico) should be coded as 999.9999.
49. Destination Latitude - This is the latitude of the destination address. Unknown or refused internal destinations should be coded as 888.8888. Unknown external destinations within Texas should be coded as 666.6666. Unknown Mexico external destinations should be coded as 777.7777. Unknown out-of-state external destinations (non-Mexico) should be coded as 999.9999.
50. Destination Study Area - Code indicating study area in which destination is located; for example, 'H' if zone is in the Houston study area and 'B' if the zone is in the Beaumont study area. Field should be left blank if location is not within one of these two MPO study areas.
51. Destination Zone - If the trip destination is within the study area, this is the zone number where the destination is located. Unknown or refused internal locations within the study area should be coded as 8888. If the trip ends outside of the study area but within Texas, it should be coded using the statewide zone system and preceded by the number 1 in column 602. Unknown or refused external locations within Texas should be coded as 6666. If the destination is in Mexico, this should be the zone number for the international border crossing used to exit Texas. Unknown or refused border crossings to Mexico should be coded as 7777. If the destination is outside of Texas (non-Mexico), this should be the statewide zone system zone number for the highway used to exit the state. Unknown or refused external locations outside of Texas (non-Mexico) should be coded as 9999.

52. Trip Purpose - Code indicating purpose of trip to destination (see code definitions below).
53. Trip Purpose Other - If trip purpose in item 52 is coded as “other,” this field should contain the description of that other trip purpose.
54. Destination Indicator - Code indicating if the destination location is outside of Texas; 1-yes, 2-no, 99-unknown or refused.
55. Destination Location - If person is traveling to a location outside of Texas (i.e., indicated by a 1 in item 54), this field should contain the city and state to which the person is traveling. This field is blank if item 54 is coded as 2.
56. Exit Location - If person is traveling to a location outside of Texas (i.e., indicated by a 1 in item 54), this field should state the name of the road or highway where the vehicle will exit this state. This field is blank if item 54 is coded as 2.
57. Exit Zone - If person is traveling to a location outside of Texas (i.e., indicated by a 1 in item 54), this field contains the external station zone number of the exit point listed in item 56. Unknown should be coded as 99999. This field is blank if item 54 is coded as 2.
58. Days Remaining - If person is traveling to a location outside of Texas (i.e., indicated by a 1 in item 54), this field should contain the number of days the person will remain in this state. This field is blank if item 54 is coded as 2.
59. Destination Texas - If person is traveling to a location within Texas (i.e., indicated by a 2 in item 54), this field should contain the city or county to which the person is traveling. This field is blank if item 54 is coded as 1.
60. Beginning Location - Location where person’s first trip began on day of survey. This can be a description or a zone number if location has been geocoded.
61. First Destination - Location of first place person went.
62. Second Destination - Location of second place person went.
63. Third Destination - Location of third place person went.
64. Fourth Destination - Location of fourth place person went.
65. Additional Trips - Number of additional trips/stops person made on day of survey up to the time they were surveyed.
66. Form - Number of survey form where data was recorded.

Item 13, Vehicle classification codes are as follows:

1. Passenger Vehicle (car/truck/van)
2. Bus
3. Taxi/Paid Limo
4. School Bus
5. Commercial Vehicle (Over 1 Ton)
6. Motorcycle
7. Recreational Vehicle
8. Other
99. Unknown/Refused

Trip purpose options are:

1. Home/Return Home
2. Go/Return to Work
3. Work Related
4. School
5. Vacation

6. Visit Friends/Family
7. Eat Out
8. Shop
9. Buy Gas
10. Personal Business
11. Pick Up/Drop-off Passenger
12. Change Travel Mode
13. Delivery
14. Recreation
15. Overnight stay / sleep
16. Other
99. Refused/Do Not Know

Type of place options are:

1. Office Building
2. Retail/Shopping/Gas
3. Industrial/Manufacturing/Warehouse
4. Medical
5. Educational (12th grade or lower)
6. Educational (college, trade. Etc)
7. Government
8. Residential
9. Airport
10. Eating Establishment
11. Hotel/Motel)
12. Other (specify)
99. Refused/Unknown

5.2.4.2 External Station Commercial Vehicle Survey Form B Data File Format

This file contains the survey data collected using Form B in the external station commercial vehicle survey. The data is coded in the following format:

1. Record Type - Code which indicates the type of record; coded as “B.”
2. Month - Month station is being surveyed.
3. Day - Day of the month station is being surveyed.
4. Station Number - Site number of the station being surveyed; these are unique numbers for each urban area survey.
5. Station - Name of station / facility being surveyed.
6. Longitude - Longitude of location being surveyed.
7. Latitude - Latitude of location being surveyed.
8. Name of Interviewer - Name of surveyor conducting interview.
9. Truck Number - Truck number surveyed (column number on survey form).
10. Survey Begin Time - Hour and minute when survey began coded in military time.
11. Survey End Time - Hour and minute when survey ended coded in military time.
12. Occupancy - Number of people in vehicle.

13. Vehicle Classification - Code indicating the classification of the vehicle (see below for code descriptions).
14. Vehicle Classification Other - If vehicle classification is coded as “other” this is the description of the other classification, otherwise it is blank.
15. Vehicle Type/Use - Code indicating if the vehicle is primarily used for major cargo/freight transport or for service: 1-cargo transport and 2-service.
16. Vehicle Cargo - This is a code number indicating the type of cargo being carried by the vehicle (see code definitions).
17. Vehicle Cargo Other - If the cargo type in Item 16 is coded as 19 “Unclassified Cargo” this is the description of the cargo, otherwise it is blank.
18. Last Cargo - If cargo is empty indicated by a 22 in item 16, this is the code number indicating the type of cargo that was last delivered by the vehicle, prior to it being empty (see code definitions). Otherwise it is left blank.
19. Last Cargo Other - If the last cargo type in Item 18 is coded as 19 “Unclassified Cargo” this is the description of the last cargo, otherwise it is blank.
20. Cargo Weight - Code indicating the weight in pounds of the cargo being transported.
21. Multimodal container - Code indicating if cargo is being hauled by a multimodal container/trailer or twenty-foot equivalent unit (TEU): 1-yes, 2-no. This field is blank if item 16 is coded as 22.
22. Container type - If item 21 is coded as 1, this field indicates the type of container; 1-reefer, 2-dry box, 3-neither. Otherwise it is blank.
23. Hazmat Placard - If transportation hazardous materials, this is the hazmat placard number affixed to the sides/rear of the vehicle or trailer.
24. Mexico Cargo - Code indicating if cargo came from or is going to Mexico; 1-yes; 2-no; 99-unknown or refused. This field is blank if item 16 is coded as 22.
25. Pick up Address - Address of location where cargo was picked up. This field is blank if item 16 is coded as 22.
26. Pick up Intermodal - Code indicating if location where cargo was picked up was an interposal transfer or custom brokerage facility; 1-yes; 2-no; 99-unknown or refused. This field is blank if item 16 is coded as 22.
27. Cargo Transfer Type - Code indicating how cargo was transferred (see below for code descriptions). This field is blank if item 16 is coded as 22.
28. Drop off Address - Address of location where cargo will be dropped off. This field is blank if item 16 is coded as 22.
29. Drop off Intermodal - Code indicating if location where cargo will be dropped off is an interposal transfer or custom brokerage facility; 1-yes; 2-no; 99-unknown or refused. This field is blank if item 16 is coded as 22.
30. Cargo Transfer Type - Code indicating how cargo will be transferred at drop off site (see below for code descriptions). This field is blank if item 16 is coded as 22.
31. Year of Vehicle - Year vehicle was manufactured; 9999 is coded for unknown or refused.
32. Gross Weight Rating - Gross weight rating of the vehicle or of the truck/trailer combination.
33. Vehicle Fuel Type - Type of fuel used by vehicle: 1-unleaded gas; 2-diesel; 3-propane; 4-hybrid; 5-other.
34. Fuel Type Other - If type of fuel is coded as “other” this is the description of the type of fuel, otherwise it is blank.

35. Odometer - Odometer mileage on the vehicle. Unknown or refused should be coded as 9999999.
36. General Origin - This is the city or state where the vehicle is coming from. City or state information is required for locations in Mexico.
37. Texas Origin - Code indicating if the location listed in item 36 is located in Texas; 1-yes; 2-no; 99-unknown or refused.
38. Enter Texas - If general origin was not in Texas (indicated by a 2 in item 37), this field contains the code indicating if the person entered or left Texas on the survey date; 1-yes; 2-no; 99-unknown or refused. This field is blank if item 37 is coded as 1.
39. Entry Point - If general origin was not in Texas, this field should state the name of the road or highway at which the person entered or exited Texas. This field is blank if item 37 is coded as 1 or item 38 is coded as 2.
40. Entry State Zone - This field contains the external station zone number of the entry or exit point listed in item 39. This field is blank if item 37 is coded as 1 or if item 38 is coded as 2.
41. Stayed Overnight - This field contains the code indicating if person stayed overnight as part of his/her travel; 1-yes; 2-no; 99-unknown or refused.
42. Stay-Over Location - For persons who indicated they stayed overnight as part of travel (indicated by a 1 in item 41), this field contains the name and location of where they stayed overnight, otherwise this field is blank.
43. Number of Nights - If person stayed overnight (i.e., indicated by a 1 in item 41) this field should contain the number of nights the person stayed overnight, otherwise this field is blank.
44. Origin Field 1 - This is the address of the last place person got into the vehicle or the first street name of the nearest intersecting streets to that location.
45. Origin Field 2 - This is the second street name of the nearest intersecting streets to the originating point or a continuation of the address in item 44.
46. Origin Longitude - This is the longitude of the origin address. Unknown or refused origins within the study area should be coded as 888.8888. Unknown external origins outside of the study area but within Texas should be coded as 666.6666. Unknown Mexico external origins should be coded as 777.7777. Unknown out-of-state external origins (non-Mexico) should be coded as 999.9999.
47. Origin Latitude - This is the latitude of the origin address. Unknown or refused origins within the study area should be coded as 888.8888. Unknown external origins outside of the study area but within Texas should be coded as 666.6666. Unknown Mexico external origins should be coded as 777.7777. Unknown out-of-state external origins (non-Mexico) should be coded as 999.9999.
48. Origin Study Area - Code indicating study area in which origin is located; for example, ‘H’ if zone is in the Houston study area and ‘B’ if the zone is in the Beaumont study area. Field should be left blank if location is not within one of these two MPO study areas.
49. Origin Zone - If the trip origin is within the study area, this is the TAZ number where the origin is located. Unknown or refused locations within the study area should be coded as 8888. If the trip began outside of the study area but within Texas, it should be coded using the statewide zone system and preceded by the number 1 in column 603. Unknown or refused external locations within Texas should be coded as 16666. If the origin is in Mexico, this should be the zone number for the international border crossing used to

enter Texas. Unknown or refused border crossings from Mexico should be coded as 7777. If the origin is outside of Texas (non-Mexico), this should be the statewide zone system zone number for the highway used to enter the state. Unknown or refused external locations outside of Texas (non-Mexico) should be coded as 9999.

50. Departure Hour - This is the hour the vehicle departed from the location listed as "Origin" coded in military time.
51. Departure Minute - This is the minute the vehicle departed from the location listed as "Origin."
52. Origin Type - Code indicating the type of place from which the trip originated (see code descriptions below).
53. Origin Type Other - If the origin type in item 52 is coded as ‘other’ this is the description of the type of place, otherwise it is blank.
54. Origin Purpose - This is the driver's purpose for being at that location (see below for code descriptions).
55. Origin Purpose Other - If trip purpose in item 54 is coded as ‘other’, this field should contain the description of that other trip purpose.
56. Trip Indicator - Code indicating if trip origin is inside the study area; 1-yes; 2-no; 99-unknown or refused.
57. Origin Entry Point - If the trip origin is outside the study area (i.e., indicated by a 2 in item 56), this field should state the name of the road or highway at which the vehicle entered the study area. This field is blank if item 56 is coded as 1.
58. Origin Entry Zone - If the trip origin is outside the study area (i.e., indicated by a 2 in item 56) this field contains the external station number of the entry point listed in item 57. Unknown should be coded as 99999. This field is blank if item 56 is coded as 1.
59. Destination Field 1 - This is the address of the destination for the person or the first street name of the nearest intersecting streets to that location (e.g. place, address, nearest intersection or city).
60. Destination Field 2 - This is the second street name of the nearest intersecting streets to the destination of the person or a continuation of the address in item 59.
61. Destination Longitude - This is the longitude of the destination address. Unknown or refused internal destinations should be coded as 888.8888. Unknown external destinations within Texas should be coded as 666.6666. Unknown Mexico external destinations should be coded as 777.7777. Unknown out-of-state external destinations (non-Mexico) should be coded as 999.9999.
62. Destination Latitude - This is the latitude of the destination address. Unknown or refused internal destinations should be coded as 888.8888. Unknown external destinations within Texas should be coded as 666.6666. Unknown Mexico external destinations should be coded as 777.7777. Unknown out-of-state external destinations (non-Mexico) should be coded as 999.9999.
63. Destination Study Area - Code indicating study area in which destination is located; for example ‘H’ if zone is in the Houston study area and ‘B’ if the zone is in the Beaumont study area. Field should be left blank if location is not within one of these two MPO study areas.
64. Destination Zone - If the trip destination is within the study area, this is the TAZ number where the destination is located. Unknown or refused locations within the study area should be coded as 8888. If the trip ends outside of the study area but within Texas, it

should be coded using the statewide zone system and preceded by the number 1 in column 814. Unknown or refused external locations within Texas should be coded as 6666. If the destination is in Mexico, this should be the zone number for the international border crossing used to exit Texas. Unknown or refused border crossings to Mexico should be coded as 7777. If the destination is outside of Texas (non-Mexico), this should be the statewide zone system zone number for the highway used to exit the state. Unknown or refused external locations outside of Texas (non-Mexico) should be coded as 9999.

65. Trip Purpose - Code indicating purpose of trip to destination (see code definitions below).
66. Trip Purpose Other - If trip purpose in item 65 is coded as “other” this field should contain the description of that other trip purpose.
67. Destination Indicator - Code indicating if the destination location is outside of Texas; 1-yes, 2-no, 99-unknown or refused.
68. Destination Location - If person is traveling to a location outside of Texas (i.e., indicated by a 1 in item 67), this field should contain the city / state to which the person is traveling. This field is blank if item 67 is coded as 2.
69. Exit Location - If person is traveling to a location outside of Texas (i.e., indicated by a 1 in item 67), this field should state the name of the road or highway where the vehicle will exit Texas. This field is blank if item 67 is coded as 2.
70. Exit Zone - This field contains the external station zone number of the exit point listed in item 69. Unknown should be coded as 99999. This field is blank if item 67 is coded as 2.
71. Days Remaining - If person is traveling to a location outside of Texas (i.e., indicated by a 1 in item 67), this field should contain the number of days the person will remain in Texas. This field is blank if item 67 is coded as 2.
72. Destination Texas - If person is traveling to a location inside Texas (i.e., indicated by a 2 in item 65), this field should contain the city or county in Texas to which the person is traveling. This field is blank if item 65 is coded as 1.
73. Beginning Location - Location where person’s first trip began on day of survey; this can be a description or a zone number if location has been geocoded.
74. First Destination - Location of first place person went.
75. Second Destination - Location of second place person went.
76. Third Destination - Location of third place person went.
77. Fourth Destination - Location of fourth place person went.
78. Fifth Destination - Location of fifth place person went.
79. Sixth Destination - Location of sixth place person went.
80. Additional Trips - Number of additional trips/stops person made on day of survey up to the time they were surveyed.
81. Form - Number of survey form where data was recorded.

Item 20, Vehicle classification codes are as follows:

1. Passenger car
2. Pick-up Truck
3. Van (Passenger or Mini)
4. Sport Utility Vehicle (SUV)
5. Single Unit 2-axle (6 wheels)
6. Single Unit 3-axle (10 wheels)

7. Single Unit 4-axle (14 wheels)
8. Semi (all Tractor-Trailer Combinations)
9. Other

Trip purpose options are:
1. Base location/Return to Base location
2. Delivery
3. Pick Up
4. Maintenance
5. Driver Needs (lunch, etc)
6. To Home
7. Buy Fuel
8. Other (specify)
99. Refused/unknown

Cargo transfer codes are the following:
1. Truck-to/from-Truck
2. Rail-to/from-Truck
3. Ship-to/from-Truck
4. Airplane-to/from-Truck
5. Warehouse-to/from-Truck
6. Pipeline-to/from-Tuck
7. Unknown
99. Refused

Options for type of place are the following:
1. Office Building
2. Retail/Shopping/Gas
3. Industrial/Manufacturing/Warehouse
4. Medical
5. Educational (12th grade or lower)
6. Educational (college, trade. Etc)
7. Government
8. Residential
9. Airport
10. Eating Establishment
11. Hotel / Motel
12. Other (specify)
99. Refused/Unknown

Vehicle cargo codes are as follows:
1. Farm Products - Livestock, fertilizer, dirt, landscaping, etc.
2. Forest Products - Trees, sod, etc.
3. Marine Products - Fresh fish, seafood, etc.
4. Metals and Minerals - Crude petroleum, natural gas, propane, Metals, gypsum, ores, etc.

5. Food, Health, and Beauty Products - Assorted food products, cosmetics, etc.
6. Tobacco Products - Cigarettes, cigars, and chewing tobacco
7. Textiles - Clothing, linens, etc.
8. Wood Products - Lumber, paper, cardboard, wood pulp, etc.
9. Printed Matter - Newspapers, magazines, books, etc.
10. Chemical Products - Soaps, paints, household or industrial chemicals, etc.
11. Refined Petroleum or Coal Products - Gasoline, etc.
12. Rubber, Plastic, and Styrofoam Products - Finished products of rubber, plastic, or Styrofoam
13. Clay, Concrete, Glass, or Stone - Finished products of clay, concrete, glass, or stone
14. Manufactured Goods/Equip - Miscellaneous products, such as machinery, appliances, furniture, etc.
15. Wastes - Waste products including scrap and recyclable materials
16. Miscellaneous Shipments - U.S. mail, U.P.S., Federal Express, and other mixed cargo
17. Hazardous Materials - Hazardous chemicals and substances
18. Transportation - Automobiles, Heavy Equipment, etc.
19. Unclassified Cargo - Cargo not falling within one of the above categories
20. Driver Refused to Answer - Driver refused to answer
21. Unknown to Driver - Unknown to driver
22. Empty - Empty (including empty shipping containers)

5.2.4.3 High Volume Non-Commercial External Station Survey License Plate Data File Format

This file contains the license plate data collected at high volume external stations for non-commercial vehicles. The data is coded in the following format:

1. Record Type - Code which indicates the type of record; coded as “LP.”
2. Month - Month station is being surveyed.
3. Day - Day of the month station is being surveyed.
4. Station Number - Site number of the station being surveyed; these are unique numbers for each urban area survey.
5. Station - Name of station / facility being surveyed.
6. Longitude - Longitude of location being surveyed.
7. Latitude - Latitude of location being surveyed.
8. Direction - Code indicating the direction of travel: 0-north; 1-northeast; 2-east; 3-southeast; 4-south; 5-southwest; 6-west; 7-northwest.
9. Dealer Plate - Code indicating if vehicle has a dealer/temporary license plate: 1-yes; 2-no.
10. State - This field contains the State shown on the vehicle license plate. The entry should be abbreviated using all capital letters. This field is left blank if item 9 is coded as 1.
11. License Number - This field contains the license plate number of the vehicle using all capital letters. For partial license plates, a unique symbol shall be used in the position that the letter/number could not be read. This field is left blank if item 9 is coded as 1.
12. Hour - Hour that the vehicle was observed, coded in military time.
13. Minute - Minute that the vehicle was observed.

5.2.4.4 High Volume Non-Commercial External Station Survey Form C – Non-Commercial Mail-out Survey Data File

This file contains the non-commercial vehicle data collected at high volume external stations. The data is coded in the following format:

1. Record Type - Code which indicates the type of record; coded as “C.”
2. Month - Month vehicle was observed.
3. Day - Day of the month vehicle was observed.
4. Direction - Code indicating direction vehicle was moving: 1-outbound; 2-inbound
5. License Number - License number of vehicle.
6. State - State where vehicle was registered.
7. Site Number - Unique non-zero number assigned to the station being surveyed
8. Station - Name of station/facility being surveyed.
9. Longitude - Longitude of location being surveyed. Unknown should be coded as 888.888888.
10. Latitude - Latitude of location being surveyed. Unknown should be coded as 888.888888.
11. Arrival Hour - Hour vehicle was observed coded in military time.
12. Arrival Minute - Minute vehicle observed coded in military time.
13. Origin Activity - Code indicating the type of activity person was engaged at the origin of trip.
14. Other Activity - If the origin purpose is coded as ‘Other’ this is the description of the purpose, otherwise it is blank.
15. Destination Activity - Code indicating the type of activity person was engaged at the destination end of the trip.
16. Other Activity - If the origin purpose is coded as ‘Other’ this is the description of the purpose, otherwise it is blank.
17. Origin Field 1 - This is the address of the last place the person got into their vehicle, or the name of the nearest intersecting streets to that place.
18. Origin Field 2 - This is the second street name of the nearest intersecting streets to the last place the person got into their vehicle or a continuation of the address in the previous field.
19. Origin Study Area - Code indicating study area in which origin is located; for example, ‘H’ if zone is in the Houston study area and ‘B’ if the zone is in the Beaumont study area. Field should be left blank if location is not within one of these two MPO study areas.
20. Origin Zone - If the trip origin is within the study area, this is the TAZ number where the origin is located. Unknown or refused locations within the study area should be coded as 8888. If the trip began outside of the study area but within Texas, it should be coded using the statewide zone system and preceded by the number 1 in column 202. Unknown or refused external locations within Texas should be coded as 6666. If the origin is in Mexico, this should be the zone number for the international border crossing used to enter Texas. Unknown or refused border crossings from Mexico should be coded as 7777. If the origin is outside of Texas (non-Mexico), this should be the statewide zone system zone number for the highway used to enter the state. Unknown or refused external locations outside of Texas (non-Mexico) should be coded as 9999.
21. Origin Longitude - This is the longitude of the origin location. Unknown or refused should be coded as 888.888888

22. Origin Latitude - This is the latitude of the origin location. Unknown or refused should be coded as 888.888888.
23. Destination Field 1 - This is the address of the destination for the person or the name of the nearest intersecting streets to that destination; if unknown, shown as "unknown."
24. Destination Field 2 - This is the second street name of the nearest intersecting streets to the destination of the person or a continuation of the address in destination field 1; if unknown, shown as "unknown."
25. Destination Study Area - Code indicating study area in which destination is located; for example, 'H' if zone is in the Houston study area and 'B' if the zone is in the Beaumont study area. Field should be left blank if location is not within one of these two MPO study areas.
26. Destination Zone - If the trip destination is within the study area, this is the TAZ number where the destination is located. Unknown or refused locations within the study area should be coded as 8888. If the trip ends outside of the study area but within Texas, it should be coded using the statewide zone system and preceded by the number 1 in column 288. Unknown or refused external locations within Texas should be coded as 6666. If the destination is in Mexico, this should be the zone number for the international border crossing used to exit Texas. Unknown or refused border crossings to Mexico should be coded as 7777. If the destination is outside of Texas (non-Mexico), this should be the statewide zone system zone number for the highway used to exit the state. Unknown or refused external locations outside of Texas (non-Mexico) should be coded as 9999.
27. Destination Longitude - This is the longitude of the destination location. Unknown or refused should be coded as 888.888888.
28. Destination Latitude - This is the latitude of the destination location. Unknown or refused should be coded as 888.888888
29. Occupancy - Number of people in vehicle; a non response is coded as 99.
30. Trip Frequency - Code indicating frequency of trip for person (see code definitions below).
31. Form Number - Number of survey form where data was recorded.

Activity codes are:

1. Home/return Home
2. Go/Return to Work
3. Work Related
4. School
5. Vacation
6. Visit Friends/Family
7. Eat out
8. Shop
9. Buy Gas
10. Personal Business
11. Pick/Up Drop Off Passenger
12. Change Travel Mode
13. Pickup and/or Delivery
14. Other

15. Refused/Unknown

Trip frequency codes for Item 30 are the following:

1. Every Week Day
2. 3 to 4 times per week
3. 1 to 2 times per week
4. 1 to 10 times per month
5. More than 10 times per month
6. 1 to 10 times per year
7. More than 10 times per year
8. Other
9. Refused/Unknown

5.2.4.5 External Station Commercial Travel Survey Form D – Commercial Vehicle Data File Format

This file contains the commercial vehicle data collected as part of the external station survey. The data is coded in the following format:

1. Record Type - Code which indicates the type of record; coded as "D."
2. Month - Month station is being surveyed.
3. Day - Day of the month workplace is being surveyed.
4. Site Number - Unique non-zero number assigned to the station being surveyed.
5. Station - Name of station/facility being surveyed.
6. Longitude - Longitude of location being surveyed.
7. Latitude - Latitude of location being surveyed.
8. Interviewer - Name of person conducting interview.
9. Truck Number - Truck number surveyed (column number on survey form).
10. Time Survey Began - Time survey interview began coded in military time.
11. Time Survey Ended - Time survey interview ended coded in military time.
12. Direction Headed - Direction driver will be heading on the high volume facility being surveyed once he/she leaves the high volume site: 1-northbound; 2-eastbound; 3-southbound; 4-westbound.
13. Occupancy - Number of people in vehicle.
14. Vehicle Classification - Code indicating the classification of the vehicle (see below for code descriptions).
15. Other Vehicle Classification - If vehicle classification is coded as 'other', this field contains a description of the vehicle.
16. Vehicle Type - Code indicating the type of vehicle: 1-cargo transport vehicle; 2-commercial service vehicle.
17. Vehicle Cargo - This is a code number indicating the type of cargo being carried by the vehicle (see code definitions below).
18. Previous Cargo - If vehicle cargo is coded as 22, empty, this field should contain the cargo code for the previous cargo transported.
19. Cargo Weight - This field should contain the weight of the cargo being transported in pounds.

20. Multi-Modal or TEU - Code indicating if cargo is being transported using a multi-modal container/trailer or TEU: 1-yes; 2-no.
21. Container Type - If the cargo is being transported using a multi-modal container/trailer or TEU, this field contains a code indicating if it is a reefer or dry box: 1-reefer; 2-dry box.
22. Hazardous Placard - This field contains the placard number for the hazardous material being transported. If the cargo is not a hazardous material, this field is blank.
23. Cargo Origin - This field contains the name of the city, state, and country that was the point of origin for the cargo.
24. To/From Mexico - This field contains a code indicating if the cargo came from or is going to Mexico; 1-yes; 2-no; 99-refused or unknown
25. Pick up Address - Address of location where cargo was picked up.
26. Bridge Used - If cargo was picked up in Mexico, this field contains the name of the international bridge used to bring the cargo into Texas.
27. Entry Point - If cargo was picked up outside Texas and not in Mexico, this field contains the name of the highway/road the vehicle was on when it entered the state of Texas.
28. Statewide Zone System External Station - If cargo was picked up outside Texas, this field contains the statewide zone system external station number associated with the bridge, highway, or road the vehicle was on when it entered Texas.
29. Pick up Location - Code indicating if location where cargo was picked up is an intermodal transfer facility or custom brokerage site; 1-yes, 2-no; 99-refused or don't know.
30. Cargo Transfer Type - Code indicating how cargo was transferred (see below for code descriptions).
31. Drop off Address - Address of location where cargo will be dropped off.
32. Drop off Location - Code indicating if location where cargo will be dropped off is an intermodal transfer facility or custom brokerage site; 1-yes; 2-no; 99-refused or don't know.
33. Cargo Transfer Type - Code indicating how cargo was transferred (see below for code descriptions).
34. Cargo Destination - This field contains the name of the city, state, and country that is the final destination of the cargo being transported.
35. Year of Vehicle - Year vehicle was manufactured.
36. Gross Vehicle Weight - Gross weight of the vehicle or total gross weight of the truck/trailer combination.
37. Vehicle Fuel Type - Type of fuel used by vehicle: 1-unleaded gas; 2-hybrid; 3-diesel; 4-propane; 5-other; 99-refused or unknown.
38. Fuel Type Other - If type of fuel is coded as "other" this is the description of the type of fuel, otherwise it is blank.
39. Odometer - Odometer mileage on the vehicle.
40. Trip Beginning - This field contains the name of the city, state, and country where the vehicle began their travel on the day of the survey.
41. Trip Indicator - Code indicating if the trip is a through trip or trip began in Texas; 1-through; 2-local; 9-unknown or refused.
42. Enter Texas Today - Code indicating if person entered Texas today: 1-yes, 2- no.
43. Entry Highway - Name of highway vehicle was on when it entered Texas.

44. Entry Point - If the trip is a through trip, this should be the number of the station at which the vehicle entered Texas. Unknown should be coded as 99999. If the trip began in Texas, this field should be left blank.
45. Overnight Stay - This code indicates if the driver stayed overnight in Texas; 1-yes; 2-no; 99-refused
46. Place Stayed - If the driver stayed overnight in Texas, this field contains the name of the city stayed.
47. Nights Stayed - If the driver stayed overnight in Texas, this field contains the number of nights they stayed in Texas.
48. Origin Field 1 - This is the address of the last place person got into the vehicle or the first street name of the nearest intersecting streets to that location.
49. Origin Field 2 - This is the second street name of the nearest intersecting streets to the originating point or a continuation of the address in Origin Field 1.
50. Origin Study Area - Code indicating study area in which origin is located, for example, ‘H’ if zone is in the Houston study area and ‘B’ if the zone is in the Beaumont study area. Field should be left blank if location is not within one of these two MPO study areas.
51. Origin Zone - If the trip origin is within the study area, this is the TAZ number where the origin is located. Unknown or refused locations within the study area should be coded as 8888. If the trip began outside of the study area but within Texas, it should be coded using the statewide zone system and preceded by the number 1 in column 764. Unknown or refused external locations within Texas should be coded as 6666. If the origin is in Mexico, this should be the zone number for the international border crossing used to enter Texas. Unknown or refused border crossings from Mexico should be coded as 7777. If the origin is outside of Texas (non-Mexico), this should be the statewide zone system zone number for the highway used to enter the state. Unknown or refused external locations outside of Texas (non-Mexico) should be coded as 9999.
52. Origin Longitude - This is the longitude of the origin location. Unknown or refused should be coded as 888.888888
53. Origin Latitude - This is the latitude of the origin location. Unknown or refused should be coded as 888.888888
54. Departure Hour - This is the hour the vehicle departed from the location listed as "Origin" coded in military time.
55. Departure Minute - This is the minute the vehicle departed from the location listed as "Origin.”
56. Origin Purpose - This is the driver's purpose for being at that location (see below for code descriptions).
57. Origin Purpose Other - If the origin purpose is coded as “other" this is the description of the purpose, otherwise it is blank.
58. Destination Field 1 - This is the address of the destination for the person or the first street name of the nearest intersecting streets to that location.
59. Destination Field 2 - This is the second street name of the nearest intersecting streets to the destination point or a continuation of the address in destination field 1.
60. Destination Study Area - Code indicating study area in which destination is located; for example, ‘H’ if zone is in the Houston study area and ‘B’ if the zone is in the Beaumont study area. Field should be left blank if location is not within one of these two MPO study areas.

61. Destination Zone - If the trip destination is within the study area, this is the TAZ number where the destination is located. Unknown or refused locations within the study area should be coded as 8888. If the trip ends outside of the study area but within Texas, it should be coded using the statewide zone system and preceded by the number 1 in column 874. Unknown or refused external locations within Texas should be coded as 6666. If the destination is in Mexico, this should be the zone number for the international border crossing used to exit Texas. Unknown or refused border crossings to Mexico should be coded as 7777. If the destination is outside of Texas (non-Mexico), this should be the statewide zone system zone number for the highway used to exit the state. Unknown or refused external locations outside of Texas (non-Mexico) should be coded as 9999.
62. Destination Longitude - This is the longitude of the destination location. Unknown or refused should be coded as 999.999999.
63. Destination Latitude - This is the latitude of the destination location. Unknown or refused should be coded as 999.999999.
64. Trip Purpose - Code indicating purpose of trip to destination (see code definitions below).
65. Other Trip Purpose - If trip purpose is coded as "other" this field should contain the description of that other trip purpose.
66. Form - Number of survey form where data was recorded.

Vehicle classification codes are as follows:

1. Passenger car
2. Pick-up Truck
3. Van (Passenger or Mini)
4. Sport Utility Vehicle (SUV)
5. Single Unit 2-axle (6 wheels)
6. Single Unit 3-axle (10 wheels)
7. Single Unit 4-axle (14 wheels)
8. Semi (all Tractor-Trailer Combinations)
9. Other
99. Unknown

The trip purpose options are as follows:

1. Base location/Return to Base location
2. Delivery
3. Pick Up
4. Delivery and Pick-up
5. Maintenance
6. Driver Needs (lunch, etc)
7. To Home
8. Buy Fuel
9. Other
99. Refused/unknown

The cargo transfer codes are:

1. Truck-to-Truck

2. Rail-to-Truck
3. Ship-to-Truck
4. Airplane-to-Truck
5. Warehouse-to-Truck
6. Pipeline-to-Truck
99. Unknown / Refused

Vehicle cargo codes are as follows:

1. Farm Products - Livestock, fertilizer, dirt, landscaping, etc.
2. Forest Products - Trees, sod, etc.
3. Marine Products - Fresh fish, seafood, etc.
4. Metals and Minerals - Crude petroleum, natural gas, propane, Metals, gypsum, ores, etc.
5. Food, Health, and Beauty Products - Assorted food products, cosmetics, etc.
6. Tobacco Products - Cigarettes, cigars, and chewing tobacco
7. Textiles - Clothing, linens, etc.
8. Wood Products - Lumber, paper, cardboard, wood pulp, etc.
9. Printed Matter - Newspapers, magazines, books, etc.
10. Chemical Products - Soaps, paints, household or industrial chemicals, etc.
11. Refined Petroleum or Coal Products - Gasoline, etc.
12. Rubber, Plastic, and Styrofoam Products - Finished products of rubber, plastic, or Styrofoam
13. Clay, Concrete, Glass, or Stone - Finished products of clay, concrete, glass, or stone
14. Manufactured Goods/Equip - Miscellaneous products, such as machinery, appliances, furniture, etc.
15. Wastes - Waste products including scrap and recyclable materials
16. Miscellaneous Shipments - U.S. mail, U.P.S., Federal Express, and other mixed cargo
17. Hazardous Materials - Hazardous chemicals and substances
18. Transportation - Automobiles, Heavy Equipment, etc.
19. Unclassified Cargo - Cargo not falling within one of the above categories
20. Driver Refused to Answer - Driver refused to answer
21. Unknown to Driver - Unknown to driver
22. Empty - Empty (including empty shipping containers)

5.2.5 Special Generator Survey

Special generator surveys collect information on travel patterns for employees and visitors at sites that exhibit special trip generating characteristics. Special generators are unique employment sites that generate or attract lesser or greater amounts of traffic than employment sites within the same employment category (i.e. basic, retail, service or education).

Special generator surveys provide information on those unique land uses having special trip generating characteristics which normal trip attraction rates do not adequately reflect. The special generator survey emphasizes the generating establishment's noteworthy and distinguishing characteristics. The information developed from a special generator survey enables TxDOT-TPP to determine trip attraction rates, both person and vehicular, for internal person, auto-driver, and truck-taxi rates for each surveyed special generator. Typically, special generators are counted at each entrance/exit and the total number of trip ends estimated for a special generator conforms to the count for that particular location. Survey data from special generator surveys are coded like workplace surveys.

5.2.6 On-Board Public Transit Survey

An on-board survey of bus passengers collects information on current bus rider characteristics and to provide data to develop a representative origin-destination trip table for use in the travel demand models. Survey data collected includes trip origins and destinations, mode of travel to/from transit stop, trip purpose, transit routes taken during trip, ridership frequency, transit fare paid and method of payment, and the traveler's household characteristics, such as household vehicle availability, household size, and household income. On-board transit surveys are conducted by the local MPO or transit authority and thus there are no standard coding conventions for the collected data.

5.3 Census Data

Data provided by the U.S. Census Bureau has been used for years as one of the main data sources for transportation planning and modeling. In the past, the decennial census has included 2 forms: a short form sent to every household within the nation and designed to collect population, age, sex, race, and household ownership data; and, a long form sent to one in six households structured to collect a variety of data on such items as income, transportation, housing units, and migration. Beginning with the 2010 census, only the short form will be used. The long form has been replaced by the American Community Survey (ACS) and the data are collected on an annual basis.

The data to be collected by the 2010 short form includes: name, sex, age, relationship, Hispanic origin, race, and home ownership. These data translate into the basic population characteristics which have been available in prior censuses and will be available at every geographic level used by the Census Bureau. The data now collected through the ACS includes most of the data collected in the long form of past censuses. Table 5.1 provides a list of the subject items included in the annual ACS. (A complete list of the ACS survey questions and the data tables available from the base ACS can be found in the NCHRP Report 588, *A Guidebook for Using American Community Survey Data for Transportation Planning*.)

Table 5.1: Subject Items Contained in the American Community Survey

Demographic Characteristics	Social Characteristics	Housing Characteristics
Age	Marital Status/Marital History	Year Structure Built
Sex	Fertility	Units in Structure
Hispanic Origin	Grandparents as Caregivers	Year Moved into Unit
Race	Ancestry	Rooms
Relationship to Householder	Place of Birth/Citizenship/Year of Entry	Bedrooms
		Kitchen Facilities
Economic Characteristics	Language Spoken at Home	Plumbing Facilities
Income	Educational Attainment	Heating Fuel
Labor Force Status	School Enrollment	Telephone Service
Industry/Occupation/Class of Worker	Residence One Year Ago	Farm Residence/Acres/Value of Agriculture Products
	Veteran Status/Period of Military Service/VA Disability	
Place of Work		
Journey to Work	Disability	**Financial Characteristics**
Work Status Last Year		Tenure (Owner/Renter)
Vehicles Available		Housing Value
Health Insurance Coverage		Rent
		Selected Monthly Owner Costs

Source: U.S. Census Bureau

Approximately 250,000 households are surveyed each month for the ACS, a total of 3 million households each year. The response rate however, is only about 60 percent resulting in approximately 2 million completed surveys each year. As a result, multiple years of data are required in order to produce reliable data for small geographic areas (i.e., areas less than 65,000 in population). Areas that are below the 65,000 threshold will be provided in 3-year and 5-year estimates. The schedule for the release of ACS data by geographic area size is provided in Table 5.2. As indicated, it is anticipated that 5-year estimates will be available for areas as small as census tracts and block groups.

Table 5.2: Schedule of Release for ACS Data

		Year of Data Release						
Data	**Population Threshold**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
1-Year Estimates	65,000+	2005	2006	2007	2008	2009	2010	2011
3-Year Estimates	20,000+			2005-2007	2006-2008	2007-2009	2008-2010	2009-2011
5-Year Estimates	All Areas					2005-2009	2006-2010	2007-2011

Source: U.S. Census Bureau

The major issue with the ACS data is the geographic level for which the data will be available. Major geographic areas for which the census anticipates having ACS data is provided in Table 5.3. At this time no data from the ACS is expected to be available at the block level.

And, although the Census Bureau anticipates having data from the five-year estimates for census tracts and block groups, small sample sizes may result in some data for many of these small geographic areas to be suppressed or provided through collapsed tables.

Table 5.3: Geographic Areas and Available Data

Major Type of Geographic Area	Total Number of Areas	Percent of Total Areas Having Data From: 1-year, 3-year & 5-year Estimates	3-year & 5-year Estimates Only	5-Year Estimates Only
State and District of Columbia	51	100.0	0.0	0.0
Congressional Districts	435	100.0	0.0	0.0
Public Use Microdata Areas	2,071	99.9	0.1	0.0
Metropolitan Statistical Areas	363	99.4	0.6	0.0
Micropolitan Statistical Areas	576	24.3	71.2	4.5
Counties and County Equivalents	3,141	25.0	32.8	42.2
Urban Areas	3,607	10.4	12.9	76.7
School Districts	14,120	6.6	17.0	76.4
Places (cities, towns, CDPs)	25,081	2.0	6.2	91.8
Townships and Villages	21,171	0.9	3.8	95.3
Zip Code Tabulation Areas	32,154	0.0	0.0	100.0
Census Tracts	65,442	0.0	0.0	100.0
Block Groups	208,801	0.0	0.0	100.0

Source: U.S. Census Bureau

The Census of Transportation Planning Package (CTPP) will be developed from the ACS 5-year estimates, and is expected to be available in 2012. A preliminary CTPP will be developed using the 2006-2008 3-year ACS data, but the geographic levels will be limited to areas with 20,000+ population. A preliminary list of data tables that will be included in the CTPP has been prepared, but is not available for distribution at this time. One change relative to the CTPP from previous census years is that traffic analysis zones (TAZs) will be developed using census block equivalencies rather than defining TAZ boundaries based on features found in the TIGER database.

Another issue regarding the ACS data is in understanding how to use the data. Decennial census data are for a specific point in time while ACS data are collected on a continuous basis from which the 1-year, 3-year, and 5-year estimates are prepared. Because travel demand models generally use socioeconomic data for a specific point in time, the use of 5-year cumulative averages may pose some problem in calibrating/validating for a specific year. Additionally, the standard error in the ACS is greater than that for the census long form which, in turn, increases the error of the models that use the data.

5.4 Employment Data

The Transportation Planning and Programming (TPP) Division of the Texas Department of Transportation (TxDOT), under an agreement with the Texas Workforce Commission (TWC) receives yearly employment data. The TWC refers to this data as the Enhanced Quarterly U-1 Address File, which contains quarterly and monthly employment data for all of the 254 counties within the state of Texas. The data represent the 3rd month of the 3rd quarter (corresponding to September) of the previous year. TxDOT-TPP post processes the data to remove unnecessary or sensitive information from each release. The appropriate county or counties are grouped to form individual files for each of the 25 urban study areas modeled within the state. The data provided by the TWC are found in Table 5.4.

Table 5.4: Texas Workforce Commission Employment Data

Data Item Code	**Data Definition**
STATE-FIPS	Census identifying number for the State of Texas
YEAR	Year of employment data
QTR	Quarter of the year represented by data (will always be the 3rd quarter)
LEGAL-NAME	The legal name for the business
TRADE-NAME	The trade name for the business. May be different than the legal name.
PL-ADDR1	Business address.
PL-ADDR2	Additional address information.
PL-CITY	City business is located in.
PL-STATE	State business is located in.
EMPL-CODE	Type of employment (Basic, Retail, Service, or Education)
NAICS	North American Industrial Classification Code of business
OWN	Ownership code identifying government and private. 1=Federal government 2=State government 3=Local government 5=Private
MEEI	Multiple Establishment Employment Indicator 1=Single 2=Multi-worksite Master (This is the Parent Company) 3=Worksite Sub (Child of parent company) 4=Known multi-worksite refusing to provide worksite detail 5=Composite worksite (multiple worksites such as county wide 6= Multi-worksite Master treated as single due to less than 10 total employees
CNTY	Census FIPS code for the county the business is located in
MON3-EMPL	Number of employees at the work place
LATTITUDE	Latitude of the work place
LONGITUDE	Longitude of the work place
PLACE-CODE	First 3 digits identify the county in which the community is located. If outside the community, the last two digits are 00, and the third digit will be an odd number except when a community is located in more than one county. In that event, the middle number will be the next even number (higher order) than the county's third normal third digit number.
PLACE-CLASS-CODE	Set at both the place-county level and for the whole place and could vary if a place is in multiple counties.
CENSUS-BLOCK	Census block number for the work place location
CENSUS-TRACT	Census tract number for the work place location

Chapter 6. Implementation Steps for the Recommended Model Design Option

6.1 Overview

This chapter provides the details of implementing a tour-based travel demand model system. Specifically, the implementation steps are provided for the Design Option #1 of the tour-based travel demand model system.[14] This includes discussion on data assembly and data preparation (Section 6.2), model estimation and calibration (validation) (Section 6.3), trip assignment output validation (Section 6.4), and software recommendations and budgetary considerations (Section 6.5).

6.2 Data Development

In the previous chapters, the data needed for the implementation of a tour-based travel demand model system was discussed. In this regard, the main sources of data for the implementation of the tour-based travel demand model system Design Option #1 are the household activity and/or travel survey, land use data, and transportation network and system performance data.

6.2.1 Household Activity and/or Travel Survey Data

Household activity and/or travel surveys record household and individual socio-demographic information and the activity-travel patterns of an individual on the survey day. The participants are asked to maintain a travel diary and record their travel information, including the time, activity type, travel mode, number of passengers, trip purpose, and trip start and end location of each trip. This section describes procedures for forming tours from the travel diaries obtained from the household activity and/or travel survey.

6.2.1.1 Data Screening

The main unit of analysis for tour generation is a person-day. A person-day is included for analysis if the following criteria are met in the travel diary data:

- The origin (destination) of the first (last) trip for the day is home.
- The departure and arrival times for all trips across the day are recorded, and are consistent (that is, they can be arranged in chronological order).
- The origin purpose and location for each trip are the same as the destination purpose and
- location of the previous trip.
- There may be person-days with a single record and no trips. These are valid entries and indicate that the corresponding individuals did not make any trip on the diary day.

[14]In a progress meeting with the project monitoring committee (PMC), it was decided that the preferred tour-based model structure is the Design Option #1.

The data screening listed above will ensure that the entire day of each individual is accounted for and can be plotted in time and space.

6.2.1.2 Forming Tours from Travel Diary Data

The travel diary data should be processed to form tours as follows:

- **Identify the primary workplace:** If there is more than one work trip, the primary work location is defined as the one that is visited most often and/or the time spent most at during the day.
- **Identify home-based work tour, work arrival, and work departure time:** If multiple trips are made from/to home to/from the primary workplace, identify the last/first trips made during the day. This will define the home-based work tour and the work arrival and departure times.
- **Identify work-based subtour:** Any trips made between the first arrival at the work location and last departure from the work location will be classified as work-based subtours.
- **Identify and define home-based non-work tours:** Classify any remaining trips into before and/or after the work tour. A new tour begins when the origin is home and a tour ends when the destination is home (then the tour is home-based). In determining the tour purpose, the following order of the priority should be maintained: school, other (personal business, meals, *etc.*), shopping, social and recreational, and drop off/pickup. In a tour, the trip purpose with the highest priority should determine the tour purpose.
- **Identify the primary and the secondary destinations:** The tour purpose will determine the location of the primary destination. If there is more than one destination with the same purpose, then, the one with the longest duration of stay is the primary destination. The rest of the trip destinations in a tour will be designated as secondary destinations.
- **Identify tour and trip modes:** Accumulate the travel time spent in each type of mode during each tour. The available modes are drive alone (DA), shared ride (SR), transit, bike, and walk. The trip modes in a tour should fall into one of these categories. The tour mode is determined as the mode in which the longest time is spent.

The final tour file should have one record for each tour with detailed tour-level and trip-level information. The relevant household and individual socio-demographic information, land use data and the level of service data should subsequently be appended to the tour file appropriately. In addition, several checks will need to be undertaken to ensure the consistency of the sample data.

6.2.2 Land Use Data

This section describes the steps for preparing the land use data for the tour-based model.

6.2.2.1 Traffic Analysis Zone (TAZ)

To make the transition from the trip-based to the tour-based model easier, the research team recommends that the TAZs as defined for each MPO (and as included in the Texas Package) be maintained in the tour-based modeling approach.

6.2.2.2 Demographic Data

The Texas MPOs, in conjunction with the Transportation Planning and Programming (TP&P) Division of TxDOT, develops the following socioeconomic data for each TAZ in the base year and the forecast year:

- Total population,
- Number of households,
- Median household income,
- Total employment by different categories (basic, retail, service, and education), and
- Special generator (regional mall, airport, hospital, college, *etc.*).

Since the data are already generated at the TAZ level for the Texas Package, no additional data processing is required for the development of the tour-based model system.

6.2.3 Transportation Network and System Performance Data

The MPOs in Texas collect and maintain a transportation network database that lists the physical characteristics of the network, including the number of lanes, posted speed limit, direction (one-way or two-way facility), median access type (divided, undivided or continuous left turn), and functional classification. For each link, the TxDOT-TP&P Division develops additional information including link length, area type, link capacity, and speed. The TransCAD software is used to calculate link length and the travel time matrix between each origin-destination (O-D) pair. The travel time matrix represents the minimum network travel time path for each O-D pair. All the network data mentioned above can be directly incorporated, without any additional data processing, for the development of the tour-based model.

Every year, TxDOT-TPP collects 24-hour saturation counts on a number of urban roadways and state highways. These count data are currently used to validate the travel model in the Texas Package. The count data used for the trip-based model validation can also be used, without any additional processing, for the validation of the tour-based model system.

The Texas urban area comprehensive travel surveys include an on-board public transit survey component. The survey collects information on trip origins and destinations, mode of travel to/from transit stop, trip purpose, transit routes taken during trip, ridership frequency, transit fare paid and method of payment, and the traveler’s household characteristics (such as household vehicle availability, household size and household income). This survey data can be used, with no/very little additional processing, for the calibration and validation of the tour-based mode choice models.

6.3 Model Development

The sequence in which travel decisions are to be modeled in the Design Option #1 is presented in Figure 6.1. For ease of comparison, each model in Figure 6.1 is given the same model number as in the previous report. Based on their functionality (rather than the sequence of application), the models in the Figure 6.1 can be grouped into three categories:

- Models 1.1 and 1.2 generate the synthetic population and the long-term choices.
- Models 2.1, 2.2, and 3.3 together constitute the activity-travel *generation module*, which provide as outputs a list of all the activities, tours, and trips generated for the day.
- Models 3.1, 3.2, 4.1 and 4.2 schedule the generated activities, tours, and trips; these models can be labeled as the *scheduling module*. Models in the scheduling module determine the where (destination) and how (mode) of the generated activities and travel.

6.3.1 Population Synthesizer and the Long-Term Choice Models

The population synthesizer and the long-term choice module of Design Option #1 include three models:

1) Household population synthesizer,
2) Work location choice model, and
3) Household vehicle ownership model.

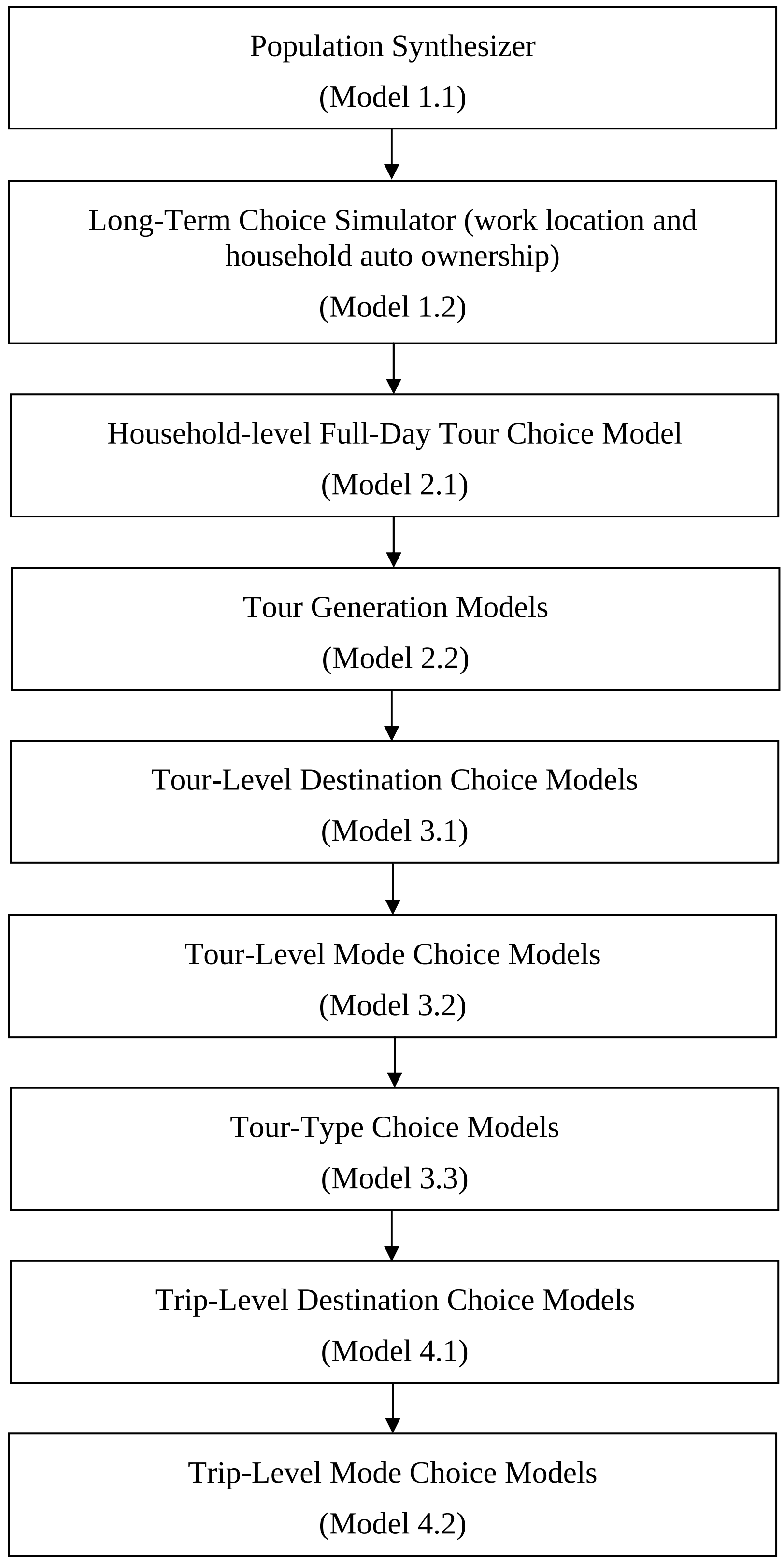

Figure 6.1: Structure of the Design Option # 1 Model System

6.3.1.1 Household Population Synthesizer

The Design Option #1 model system starts with a population synthesizer that is designed to create a list of synthetic households (and individuals) in each TAZ with information on the control variables. The control variables used here include zonal-level values for mean household size, number and age distribution of children, number of workers, and household income. These basic inputs for the control variables can be obtained from a land-use model, or be defined directly by the user from data sources available with the Texas State Data Center.

Next, the control variables are categorized as follows to classify sampling "cells":

- Household (HH) size—1 person HH, 2 persons HH, and 3+ persons HH.
- Number and age group of children—HH with no children, HH with 1 child, and HH with 2 or more children. Each HH is then further classified into one of the three groups depending on the age of the children: HH own children age less than 4 years, HH own children aged between 4 and 10 years, and HH own children between 10 and 15 years.
- Number of workers—0 workers, 1 worker, 2 workers, and 3+ workers.
- HH income—income $<$ 20k, 20k $\leq$ income $<$ 35k, 35k $\leq$ income $<$ 50k, 50k $\leq$ income $<$ 75k, and income $\geq$ 75k.

The categories for household size, number and age group of children, and number of workers were chosen because they distinguish important family lifecycle groups. The breakdown for income was chosen because it is compatible with both the household survey undertaken by TxDOT and the Census tables available in the Census Transportation Planning Package (CTPP) 2000. The combinations of the categories across the four control variables result in 195 (39 x 5) different sampling cells in total.[15]

The population synthesis procedure is implemented for each TAZ, using the seed distribution of households observed in the Public Use Microdata Sample (PUMS). Iterative proportional fitting (IPF) is used to estimate the number of households within each cell in each TAZ. At the end of this procedure, for each cell in each TAZ, the synthesizer will generate a list of households with household size, number and age distribution of children, number of workers, and household income group. Once the number of households for each of the 195 cells is estimated for a given TAZ, PUMS data are used to randomly sample the correct number of households within each cell. Since the PUMS constitutes a 5% sample, each PUMS household will appear in the full sample 20 times for each draw. The resulting sample file will contain the PUMS household ID number, the TAZ number, and the sampling cell number. Using this information, the relevant household and person level data (available in the PUMS records) can be appended to the sample file, which can subsequently be used in the travel demand models. The reader is referred to Guo and Bhat (2007) for technical details of the synthetic population generation procedure that may be employed.

[15]Not each of the 84 (3*7*4) HH size-number and age group of children-number of workers combination is feasible. For example, HH with 1 person will not have any children and can have at most 1 worker. This reduces the number of possible combinations of these three control variables to 39.

6.3.1.2 Workplace Location Choice Model

The work location model is the first component of the model system for application, and hence only variables in the PUMS-based synthetic population can be used to estimate work location choice model. These could include residence location (CBD, urban, suburban, *etc.*), household and individual characteristics (household income, number of workers, presence and age of children, number of licensed drivers, *etc.*), and origin and destination zone characteristics (population, household and employment densities, retail space, same zone indicator, *etc.*). The model will be estimated using a multinomial logit structure where the number of choice alternatives can potentially be equal to the number of TAZs. However, depending on the size of the study area, the estimation process can be made significantly faster and less cumbersome if only a subset of TAZs is considered as being in the choice set for each worker. This can be achieved by classifying the TAZs into a number of ordered categories and sampling from each category according to their importance. A number of criteria can be used to define the importance of a particular category. For example, zonal employment can be used to classify the TAZs into a number of categories.

For model estimation (and validation), data collected by TxDOT as part of the household survey will be used. The estimation data should include only the worker residents (full time or part time) of the study area. To ensure that the origin TAZs are within the proper range, the data sample should be checked for consistency, and, in turn, data with TAZ numbers outside the range, missing TAZ numbers, or work tours that do not originate at home need to be removed.[16] The model is applied to predict the work location for each worker in the sample, which is then used as the primary destination for all work-related tours made by the corresponding individual.

6.3.1.3 Household Vehicle Ownership Model

The number of vehicles available to a household is defined as the number of cars, vans, and light trucks owned/leased by the household members. The vehicle ownership model is a multinomial logit model with the following potential choice alternatives:

- Household with no car,
- Household with one car,
- Household with two cars,
- Household with three cars, and
- Household with four or more cars.

A number of household socio-demographic, residential location and accessibility variables need to be tested for inclusion in the model specification. The household socio-demographic variables may include number of adults, number of workers, number of children, number of licensed drivers, and household income. Residential location variables may include residential density and type of area (CBD, urban, suburban, *etc.*). Accessibility variables may include auto travel time and cost, transit travel time and fare, parking availability, and cost of parking. The final model specification will be based on a systematic process of removing statistically insignificant variables, and combining variables when their effects were not

[16] Since only home-based and work-based tours are modeled, tours that do not originate at either of these two locations are excluded from the model estimation data set.

significantly different. The specification process should also be guided by prior research, intuitiveness/parsimony considerations, and TxDOT suggestions.

The vehicle ownership model may be applied for each synthetic household to calculate the probability of having a certain number of vehicles. The model can be estimated using the available survey data. Depending on the sample size, a subset of the survey data that has not been used in model estimation can be used for validation. In addition, the model prediction can be compared against the Department of Motor Vehicle (DMV) and the Census data. The model prediction can also be validated against aggregate survey data (total number of households with no car, total number of households with one car, *etc.*) as well as data stratified by segments (for example, HH with no workers, single worker HH, and multiple workers HH).

6.3.2 Activity-travel Generation Module

The activity-travel generation module may be considered similar in function to the trip generation step in a four-step trip-based model. This module provides a list of all the activities, tours, and stops generated by a household in a day. As stated before, the activity-travel generation module consists of 3 distinct model categories: 1) Daily tour choice model (Model 2.1 in Figure 6.1), 2) Tour generation models (Model 2.2 in Figure 6.1), and 3) Tour type models (Model 3.3 in Figure 6.1). Note that the former two models together can be referred as the pattern-level models, as discussed in the next section.

6.3.2.1 Pattern-Level Models

As mentioned in the paragraph above, the pattern-level models consist of two model types:

1) Daily tour choice model (Model 2.1 in Figure 6.1), and
2) Tour generation models (Model 2.2 in Figure 6.1).

The daily tour choice model is a binary logit model, and predicts whether or not a household makes tours for a particular activity purpose in a day. The tour generation models then determine the number of tours for each activity purpose made by the household. This may be undertaken within a multinomial logit framework. Depending on the available data, the choice alternatives for each purpose may include 1, 2, 3, and 4+ tours made by a household.

The tours are divided into six purposes and are generated in the following order:

1) Home-based school tours,
2) Home-based work tours,
3) Home-based other tours (includes personal business, meals),
4) Home-based shopping,
5) Home-based social/recreational tours, and
6) Home-based drop off/pickup tours.

All tours are assumed to fit into one of these categories. An advantage of adopting this hierarchy of tour purposes is that all tours generated by a household are interrelated. This is achieved by using tour frequencies of a particular purpose higher up in the model system as explanatory variables in the subsequent tour type models. For illustration, consider a nuclear family household with two working adults and a school-going child. If, due to sickness or some other reason, the child does not go to school and stays at home, then one of the parents is likely to stay at home and take care of the child. The impact on the activity participation pattern of adult household members due to a change in the home-based school tour pattern of young household members can then be incorporated in the model system.

Travel survey data with detailed information on out-of-home activities and travel can be used for model estimation and validation of the daily tour choice and tour generation models. The entire data set may be used to estimate a single model (for a particular purpose), or the data set may be segmented to estimate multiple models. For example, for the home-based work tours, the data set can be segmented into single-individual households, two-individual households, and multiple-individual households to differentiate the distinct work tour frequencies and patterns of households of different sizes. The decision whether to estimate a single model or multiple models will depend on the observed distribution of the tour frequencies.

6.3.2.2 Tour Type Models

Tour type models (Model 3.3 in Figure 6.1) generate the number of stops on a tour for all tour purposes and whether a work tour has a subtour associated with it or not. To increase computational efficiency, the maximum number of stops associated with a tour is limited to five (one stop to the primary destination and four intermediate stops to the secondary destinations).[17] The subtours have work location as origin and destination, and can have only one stop.

The tour type models may be formulated with a multinomial logit structure using travel survey data. The models will be applied to each type of tour after the estimation of tour-level mode choice models (Model 3.2 in Figure 6.1)[18]. This will provide the opportunity to use tour mode as an explanatory variable in the tour type models. In addition, because of ease of travel and flexibility of using personal vehicles, it is likely that tours made by the auto mode have different travel patterns from, for example, tours made by transit. Based on data analysis, tours made by auto and non-auto modes may be modeled separately to yield behaviorally more realistic predictions. Further, the number of stops in a tour and subtour will be generated in the following order: school tours, work-based subtour, other tours, shopping tours, social/recreational tours, and drop off/pickup tours. Additional variables that should be considered for inclusion in the models include household size, number of workers, income, number of tours of purposes higher in the hierarchy, and residential location type.

6.3.3 Scheduling Module

The tours and the stops generated by a household in a day (as discussed in Section 6.3.2) are scheduled using the models discussed in Sections 6.3.3.1 and 6.3.3.2.

6.3.3.1 Location Choice Models

In Design Option #1, two types of location (destination) choice models will be estimated:

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[17] For ease of presentation, the same maximum number of stops is used for all activity purposes here. However, the maximum number of stops associated with a tour can be different for different activity purposes. This can be easily incorporated once the final survey data are made available.

[18] The reader will note that the tour-level mode choice models are part of the Scheduling Module, which is discussed in the next section (Section 6.3.3).

1) Tour primary destination choice model (Model 3.1 in Figure 6.1), and

2) Secondary destination choice model (Model 4.1 in Figure 6.1)

The tour-level model predicts the primary destination of each tour, except for the work tours.[19] The trip level model predicts the location of intermediate stops in a tour. Both models are estimated as multinomial logit models with the possible number of choice alternatives equal to the number of TAZs. As discussed in Section 6.3.1.2, the estimation process can be made more efficient by considering only a subset of TAZs as possible candidates for destination. This can be achieved by adopting a "stratified importance sampling" approach. This is a well established sampling strategy that has been successfully implemented in a number of travel demand model systems, including the Portland Metro Tour-Based Model, the New Hampshire Statewide Travel Model System (NHSTMS) and the San Francisco Travel Demand Forecasting Model. For each tour type, the following criteria may be used to stratify the TAZs:

1) Home-based school tours – Student enrollment and/or travel time from zones with at least one school.

2) Home-based other tours – Area type (CBD, urban, suburban, and rural).

3) Home-based shopping – Area type and/or accessibility index based on retail employment/space.

4) Home-based social/recreational tours – Area type and/or travel time.

5) Home-based drop off/pickup tours – Area type (CBD, urban, suburban, and rural).

The primary destination choice models are applied to all tours (by purpose), while the secondary destination choice models are applied only to tours with more than one stop. The locations of the secondary destinations are conditioned on the location of the tour origin, primary destination, and the previous stop (if any). In the first half of the tour (i.e., from home to primary destination), the secondary destinations will be modeled in the reversed chronological order. In the second half of the tour (i.e., from primary destination to home), the secondary destinations will be modeled in the regular chronological order.

A number of TAZ-level attraction and accessibility variables may be considered for inclusion in the models. The attraction variables may include employment data by industry sector, student enrollment (enrollment in schools, part-time colleges, full-time colleges), number of school buildings/school area, hotel rooms, population and household densities, and existence of specific facilities/attractions (airports, stadiums, parks, *etc.*). The accessibility variables may include the logsum from the mode choice model (the logarithm of the sum of the exponents of the individual modal utilities), and travel time and distance by various modes. In addition, vehicle availability and number of tours for each activity purpose should be included.

The data sets for the primary and the secondary destination choice model estimation may be prepared using the individual tour and trip records from the survey data (see Section 6.2.1.2). For secondary destination choice models, all trips constituting a tour may be used except the trips to the primary destination, home, and work locations. The tour purpose -instead of trip purpose- will be used to group trips together for estimation. For calibration and validation, the model

[19]At this stage of the model system, the primary destination for the home-based work tours is already known (see Section 3.1.2).

prediction can be compared against such observed data as (1) the frequency of the tours and trips by origin and destination area types (for example CBD, urban, suburban, and rural), (2) the percentage by origin (destination) area type within each of the destination (origin) area types, and (3) travel time.

6.3.3.2 Mode Choice Models

Mode choice models perform a similar task as the modal split step in the four-step travel demand models. The design option includes two types of mode choice models:

1) Tour-level mode choice models (Model 3.2 in Figure 6.1), and
2) Trip-level mode choice models (Model 4.2 in Figure 6.1)

The tour mode choice models determine the primary mode for the tour while the trip mode choice models determine the mode for each trip within a tour - condition on the tour mode. Five tour modes are considered here: drive alone, shared ride, transit, bike, and walk. Not all combinations of modes are available for trips. For example, transit as a trip mode is not available for an individual choosing drive alone to make a tour. Table 6.1 summarizes the tour-trip mode combinations that are allowed in the model system.

Table 6.1: The Tour-Trip Mode Combinations to be Modeled in the Design Option #1

Trip Mode	**Tour Mode**				
	Drive alone (DA)	Shared ride (SR)	Transit	Bike	Walk
Drive alone (DA)	√	-	-	-	-
Shared ride (SR)	√	√	√	-	-
Transit	-	-	√	-	-
Bike	-	√	√	√	-
Walk	√	√	√	√	√

The tour-level mode choice models may be estimated using a nested logit structure, while the trip-level mode choice models may use a simpler multinomial logit structure. Two possible nesting structures for tour mode choice models are shown in Figure 6.2. The nesting structure that fits the observed data best should be adopted in the final specification of the models. The explanatory variables to be considered for the tour-level and trip-level mode choice models include household income, number of workers, number of vehicles, travel cost and travel time by different modes, parking availability, parking cost, number of transit transfer, built environment factors of tour origin and primary destination, and the number of stops in the tour and the tour mode (for trip mode choice models only). The tour mode choice model estimation dataset should contain one record for each tour, while the trip mode choice estimation dataset should contain one record per trip. The trip mode choice models will be applied to all the stops in a tour, including the primary destination. Travel survey data with mode information on all the trips in a tour will be used for the estimation. The models can be calibrated (and validated) against (1) the observed number (or percentage) of trips by each mode made by the residents of the study area only, and (2) the observed number (or percentage) of trips by each mode by tour purposes.

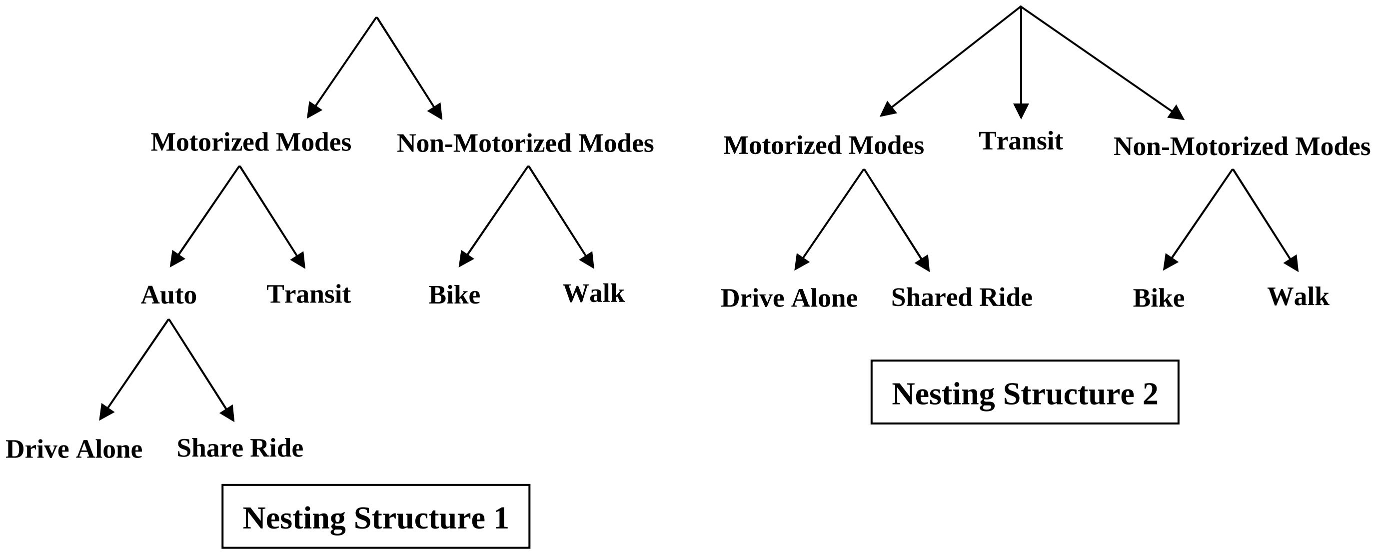

Figure 6.2: Possible Nesting Structure for Tour Mode Choice Models

6.4 Validation

The validation of individual components of the activity-travel system has already been discussed in the previous section. In this section, only the validation of the results at the end of the traffic assignment step is discussed. The reader will note that, once the activity-travel pattern of each individual is obtained from the implementation of the models in Figure 6.1, these patterns can be translated into trip origin-destination matrices by time of day for internal-internal trips. These matrices will need to be updated by adding trip matrices corresponding to external trips and freight-related trips, which have to be obtained externally using procedures already in place by TxDOT. The final origin-destination matrices by time of day may be assigned to obtain link volumes and speeds based on the current static assignment procedure employed by TxDOT.

6.4.1 Highway Assignment

Highway assignments will be primarily validated against observed traffic volumes. The traffic count data are collected as 24-hour counts. Therefore, the highway assignment results will be compared against daily traffic flows. The individual link flows will be aggregated to compare against volumes by corridors and volumes by facility types. For volumes by corridor, a number of screenlines will be defined, and the observed traffic volume and the predicted traffic volume will be compared by screenline. For volume by facility types, the predicted link flows will be aggregated by facility types (freeway, arterial, collector, local, *etc.*), and compared against observed volumes. In addition, predicted network speeds at strategic locations and travel times will be compared against observed data to ensure that these are accurately represented in the models. All of these validation steps are similar to those already being pursued in the context of the trip-based model predictions.

6.4.2 Transit Assignment

The observed transit data are collected by transit on-board surveys. Although the survey data contains detailed information on time period, the proposed model will only be able to predict daily transit boardings. For validation, observed daily transit boardings will be compared against the predicted transit boardings at an aggregate level as well as by individual route (or similar routes grouped together).

6.5 Application Software and Other Implementation Issues

6.5.1 Software System

TxDOT maintains a list of recommended development languages for application software development; these recommended development languages are:

- Visual Basic
- C#
- C++
- J#
- Perl

A permissible alternative development language is Java; however, the use of Java would require that an exception request be submitted to TxDOT's Technology Services Division (TSD). For the proposed tour-based modeling system, it recommended that the core model system be developed using Visual C^{++}, a flexible language that also provides the benefit of relatively easily generating visual interfaces. This should be helpful, among other things, in building a user-friendly interface with the Texas Package and TransCAD.

The application of the tour-based model will require a significant amount of computing resources, as well as careful management of a large number of computer files. Based on past experience, the research team recommends the use of computers with Windows 2000 Professional or XP Operating System and a minimum of a 1 GHZ Processor, 4 GB RAM, and 210 GB Hard Drive. For the software architecture, we propose a streamlined configuration as shown in Figure 6.3. The major components of the model system are the input database, data coordinator, run-time data objects, modeling modules, simulation coordinator, application coordinator, and output files. As mentioned earlier, the simulation of activity-travel patterns is a data intensive exercise. Therefore, we propose the input data to be stored in a relational database management system (DBMS). The reason for choosing a DBMS to store data is to leverage on the last 30 to 40 years of research advances in storage, organization, query, and management of large volumes of data. Next, the data coordinator creates instances of household, person, zone-to-zone, and level-of-service (LOS) entities from the input database. The modeling modules simulate the activity-travel patterns generated by households while the simulation coordinator generates the patterns, tours, and the stops. The run-time data objects act as a cache for the simulation coordinator that frequently accesses data. The application driver starts and runs the application. Finally, the outputs are written using the output files module. The format of the output files can be selected through the Graphical User Interface (GUI). To maintain ease and flexibility, we recommend the outputs be stored in flat-files (plain tabbed formatted files).

As shown in Figure 6.3, we recommend that the model system interact with a relational DBMS through an open database connectivity (ODBC). One of the reasons for this is that ODBC provides a product-independent interface between client applications (Design Option #1 model system, in this case) and database servers, allowing applications to be portable between database servers from different manufacturers. We also recommend employment of several performance enhancement strategies, including multithreading and data caching.

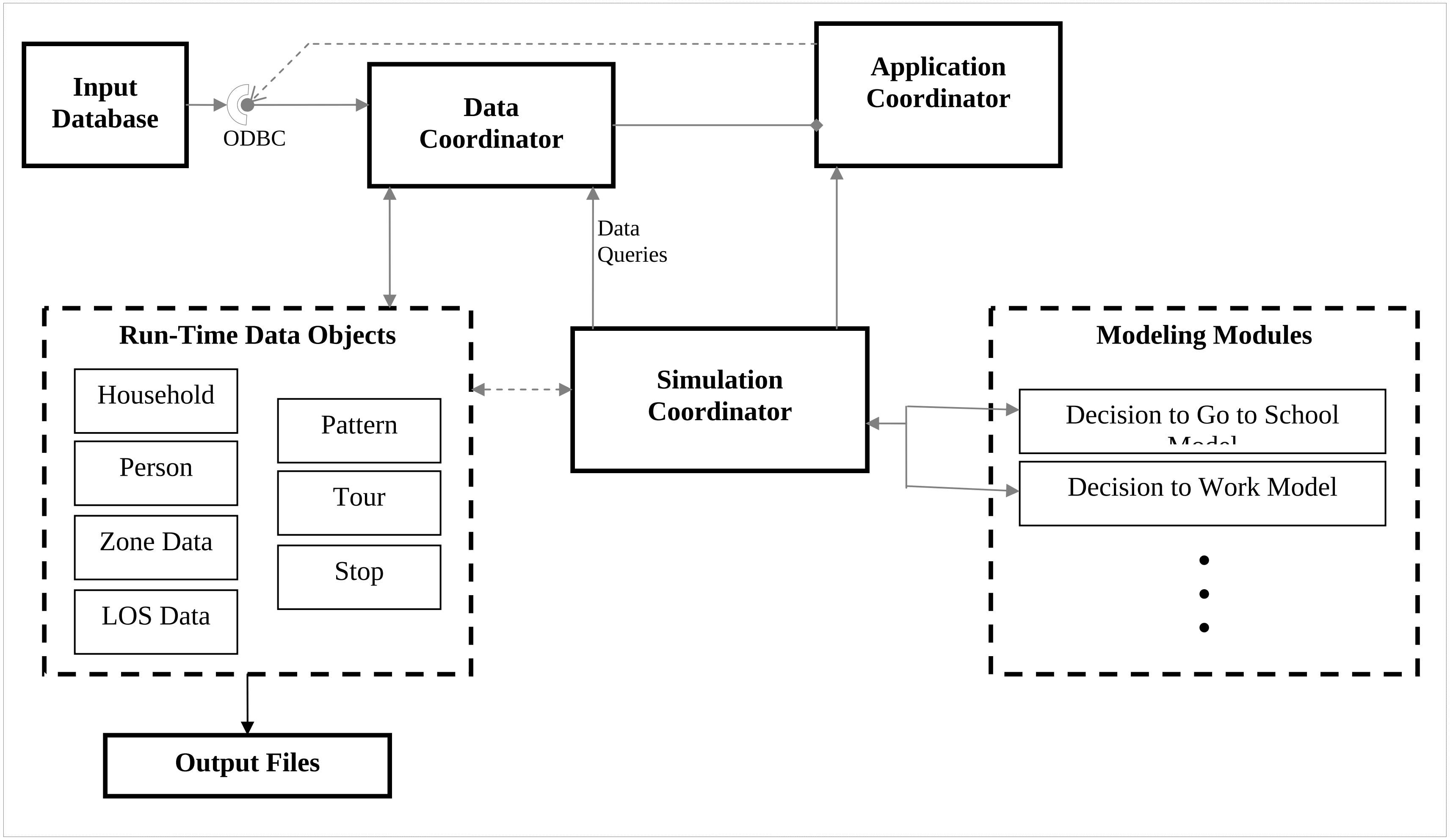

Figure 6.3: Proposed Decomposition Structure of the Software Architecture

6.5.2 Budget and Timeline for Development

An informal investigation of funding needs for the development of a full-fledged activity-based model revealed that, depending on the study area and complexity of the model, the budget resources required for the development of a tour-based model could range from $1 million to $1.4 million (Transportation Research Board of the National Academies (2007) Special Report 288). But, in the case of TP&P, there can be considerable economies of scale since (1) the proposed tour-based model system has a relatively simple structure (i.e., no interaction across tours), (2) the survey data used for the development of the trip-based model can be used with little or no additional processing for the development of the tour-based model, and (3) the system can be applied to multiple urban areas under TP&P's modeling jurisdiction with relatively little overhead to populate the model with local data and parameters.

The team recommends that the entire enterprise of developing a tour-based model be focused on a single case study region to begin with, though the architecture for the model should be developed to be portable and transferable to any metropolitan region. The case study region should represent a "middle of the road" MPO among those whose travel modeling TP&P handles. We recommend that the study region also be chosen based on a metropolitan region that may see relatively substantial land-use and transportation network changes in the near-term, along with changes in demographic characteristics of the resident population. A desire by the MPO to be part of the development of a tour-based modeling framework for its metropolitan region would also be important, as would good GIS experience among the MPO Staff and readily available land-use/transportation network files for the MPO region. For such a pilot case study, the estimated budget would be $650,000 (without considering overhead). Note, however, that this budget does not include extensive validation testing of individual components of the model system and/or validation using before/after or back-casting exercises. Rather, it includes the kind of basic validation that is currently undertaken with trip-based models. Table 6.2 provides a listing of the major tasks for the pilot development within each of three categories: (1) Data preparation ($100,000 estimated budget), (2) Methods and model estimation ($200,000 estimated budget), and (3) Application software development, interfacing with TEXAS and TransCAD, and validation ($300,000 estimated budget). The development timeline would be 24 months. Note that these budgets are for the pilot case study, and should be viewed as best estimates at this point. Once developed for the pilot area, the application of the software to additional metropolitan areas should entail a smaller budget and a much faster turnaround time in terms of application.

Table 6.2: Tentative Cost Estimates for the Development of Design Option #1 for a Pilot Case Study

Major Tasks	Costs
1. Data preparation a. Identify and compile data sources for synthetic population generation b. Assemble and review survey data (including on-board transit survey), generate tours and stops, append land-use and transportation system data c. Identify additional data sources (for example, Department of Motor Vehicle) and assemble available data d. Prepare input tour and trip data files for each model component in Figure 6.1 e. Assemble validation data for basic testing of link volume predictions	$150,000
2. Methods and model estimation a. Design and apply synthetic population generation procedure b. Specify and estimate each model component in Figure 6.1 c. Develop prediction procedures and implementation procedures d. Develop validation procedures and statistics	$200,000
3. Application software development, interfacing with Texas Package and TransCAD, and validation a. Identify software platform and design software architecture b. Write code and routines for seeking/writing data, call models in the appropriate sequence, make predictions, and compile predictions to generate activity-travel patterns for each individual of each household c. Prepare a set of template files defining the input and output interfaces of each model within the model system framework d. Translate activity-travel patterns to origin-destination trip matrices by time-of-day e. Augment trip matrices with external trips and freight-related trips f. Interface with a static traffic assignment model g. Test software functionality and validate model predictions with link volumes from traffic assignment h. Prepare calibration, validation, and other relevant technical documents	$300,000
Total cost	**$650,000**

6.6 Summary

In the previous chapters of this project, the research team recommended two design options for the development of a tour-based travel demand model system: Design Option #1 and Design Option #2. Design Option #1 was chosen by the project monitoring committee (PMC) as the preferred framework for the possible implementation of a tour-based travel demand model system for TxDOT. In this chapter, the details of implementing the Design Option #1 for Texas MPOs are provided.

The main sources of data required for the implementation of the Design Option #1 are household activity and/or travel survey, land use data, and transportation network and system performance data—the same data currently being used for the development and/or updating of the trip-based models. The land use and the transportation network and system performance data require no/very little additional processing to be used in the development of the tour-based model. The household activity and/or travel survey data requires additional processing to form tours from trips recorded in the travel diary. The necessary steps for tour development are outlined in Section 6.2.1 of this chapter.

The models in the Design Option #1 can be grouped into three categories:

(1) Population synthesizer and the long-term choice models,

(2) Activity-travel generation module, and

(3) Scheduling module.

The population synthesizer generates synthetic population and households that are allocated to the TAZs. The long-term choice models include work location choice model and household vehicle ownership model. For each synthetic individual and household, the long-term choice models predict work location and the number of vehicles owned by a household, respectively. The outputs from the population synthesizer and the long-term choice models are used as inputs in the subsequent models.

The activity-travel generation module provides a list of all the activities, tours, and trips generated by a household in a day. The generated tours and trips are scheduled using the scheduling module. For each tour generation and scheduling module, the model development steps are provided, including analytical methods to model travel patterns, econometric framework, choice alternatives, possible explanatory variables, and calibration (and validation) criteria.

The core model system may be developed using software programs such as Visual C^{++}, interfaced with TransCAD and the Texas Package.

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