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This report has been prepared as the final deliverable for Phase II of a project for the California Department of Transportation to develop a combined quantitative and qualitative approach for planning for improved intermodal connectivity at California airports. The objectives of this phase were to further develop the Intermodal Airport Ground Access Planning Tool (IAPT) to improve its functionality, to estimate updated versions of mode choice models for use with the IAPT, to correct errors in the calculation of performance parameters by the IAPT, and to conduct a case study as a test of the IAPT.

The objective of developing the IAPT is to provide a standard, transparent and scientific way for quantitative airport ground access project evaluation at the airport level. A user-friendly graphical interface makes it easy for a user to run the model in the following sequence of steps: (a) to define performance measures and the associated transportation service data variables for the different modes involved; (b) to select an airport or set of airports for inclusion in the analysis; (3) to define projects to be evaluated; (4) to input the air passenger and transportation service data required for the analysis; (5) to define and modify mode choice model coefficients; (6) to choose the performance measures to be used to compare the projects being evaluated; (7) to run the analysis process; (8) to view the output in different ways; and (9) to export the analysis output to text files for further analysis and use in decision making.

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A Combined Quantitative and Qualitative Approach to Planning for Improved Intermodal Connectivity at California Airports

Phase II Final Report

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Key Words

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Abstract

This report has been prepared as the final deliverable for Phase II of a project for the California Department of Transportation to develop a combined quantitative and qualitative approach for planning for improved intermodal connectivity at California airports. The objectives of this phase were to further develop the Intermodal Airport Ground Access Planning Tool (IAPT) to improve its functionality, to estimate updated versions of mode choice models for use with the IAPT, to correct errors in the calculation of performance parameters by the IAPT, and to conduct a case study as a test of the IAPT.

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Acknowledgements

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The guidance and support from Colette Armao and Terry Barrie of the Caltrans Division of Aeronautics and Frank Law, the Project Manager at the Caltrans Division of Research, Innovation, and System Information are gratefully acknowledged.

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List of Acronyms and Abbreviations

ABAG	Association of Bay Area Governments
AirPax	Air passenger (name of IAPT data file containing air party characteristics)
BART	Bay Area Rapid Transit
Caltrans	California Department of Transportation
CO	Carbon monoxide (air pollutant)
CPI	Consumer price index
CSV	Comma-separated value (data file format)
DRI	Division of Research and Innovation (former name of Caltrans division)
DRISI	Division of Research, Innovation and System Information (Caltrans division)
GUI	Graphical user interface
IAPT	Intermodal Airport Ground Access Planning Tool
MTC	Metropolitan Transportation Commission (San Francisco Bay Area)
NOx	Nitrogen oxides (air pollutants)
OAK	Oakland International Airport
PATH	Partners for Advanced Transportation Technology
PM10	Particulate matter of 10 microns or less (air pollutant)
SamTrans	San Mateo County Transit District
SFO	San Francisco International Airport
SJC	San Jose International Airport
TAZ	Travel analysis zone
VHT	Vehicle-hours of travel
VMT	Vehicle-miles of travel
VOC	Volatile organic compounds (air pollutants)
VTA	Valley Transportation Authority (Santa Clara)

Executive Summary

This report describes the work conducted in the past three years for a project for the California Department of Transportation titled *A Combined Quantitative and Qualitative Approach to Planning for Improved Intermodal Connectivity at California Airports*. Work undertaken during this phase of the project included extensive system modeling and analysis, further development of the Intermodal Airport Ground Access Planning Tool (IAPT), use of the IAPT for a case study analysis of an illustrative Bay Area airport ground access project, and demonstration of the IAPT to potential users from the California Department of Transportation, airport authorities, regional agencies, and consulting firms. The IAPT development included the definition and implementation of improvements to the functionality of various sub-modules, the overall program structure, internal data tables and data flow, and the Graphical User Interface (GUI). The IAPT has been developed using Microsoft Visual Studio.Net. It is designed to facilitate the evaluation of airport ground access projects intended to improve intermodal connectivity and system performance.

Airport ground access and egress trips use a wide range of modes, including taxis, shared-ride vans, rental cars, and scheduled airport bus services. Furthermore the characteristics of air passenger trips are significantly different from most other urban trips. Airport ground access projects are equally diverse, ranging from large intermodal centers constructed at or adjacent to airports, such as the Miami Intermodal Center at Miami International Airport, to expansion of airport access roadways and construction of urban rail links to airports, such as the Bay Area Rapid Transit (BART) extension to San Francisco International Airport. Airport operators and regional transportation planning agencies need an efficient and consistent way to analyze the potential effects of such projects for effective decision making regarding project selection and funding.

The IAPT has been designed to provide a user-friendly and consistent approach to analyzing the performance of airport ground access projects, as well as to efficiently manage the large amount of data required to support such analysis. The IAPT provides the capability to define multiple projects and project variants and to compare the relative performance of different projects and project variants, using standard measures of performance generated by the tool, such as passenger trips by mode, vehicle-miles of travel, and vehicle air quality emissions.

Although the current version of the IAPT does not provide the capability to model the allocation of regional air travel demand to airports in a multi-airport region, it does provide the user with the ability to define multiple airports and sets of projects for each airport, and compare the performance of these projects across airports, as well as generate regional totals of the measures of performance for different project scenarios at each airport. It can therefore support the analysis of airport ground access impacts and traffic flows as part of regional airport system planning.

The work described in this report is a continuation of the work undertaken in Phase I of the project that comprised the following activities:

- A literature review
- Identification of opportunities for improving *intermodal connectivity* at California airports
- Initial design and implementation of the IAPT
- Passenger mode choice modeling
- Transportation provider behavior modeling
- Definition of transportation system performance measures
- Guidelines for using the IAPT in airport ground access planning practice
- Description of potential Bay Area case studies to demonstrate the application of the IAPT
- Development of policy recommendations for improving intermodal connectivity at California airports
- Recommendations for future research

The results of the previous phase were documented in the Phase I final report (Lu et al, 2009).

This phase of the project has mainly focused on the following aspects of the IAPT development:

- IAPT functionality improvement
- Performance measure calculations within the IAPT
- Development of mode choice models based on air passenger data from the 2001 Bay Area Airline Passenger Survey at San Francisco International Airport and the 2006 Bay Area Airline Passenger Survey at Oakland International Airport and San Francisco International Airport

- Undertaking a case study application of the IAPT at a Bay Area airport and demonstrating the IAPT to potential users

The need for further development of the IAPT software resulted from two aspects of the initial version of the IAPT developed in the previous phase of the project:

(1) IAPT functionality improvement: the software coding of the prototype version of the IAPT utilized a number of short-cuts in order to develop a version that would run and allow the functionality to be demonstrated. However, aspects of the internal calculations, data input and storage, and data output lacked flexibility, and in some cases further testing showed resulted in incorrect results. Required changes included:
    - Integrating the mode identification number in all calculations and data files generated by the IAPT, rather than assuming a fixed sequence of modes
    - Integrating the project identification number in analysis calculations, display of performance measures, and output data files
    - Replacing the fixed service data variable name mapping between the mode choice model coefficient table and the service data table with the ability for users to specify the service data variable name for use with each mode choice model coefficient

(2) Performance measure calculation within the IAPT: The improvements in this aspect include:
    - Incorporating user-defined base-year airport demand and annual growth factors in the calculation of performance measures
    - Improvements to the calculation of VHT (vehicle-hours traveled), VMT (vehicle-miles traveled), modal revenues, emissions, and connectivity production costs to allow users to specify the relevant service data variables for each performance measure instead of requiring the service data to be organized in a pre-defined way

The technical development of the IAPT addressed three major aspects: the modeling approach, data management, and Graphical User Interface (GUI).

Modeling Approach: The core of the IAPT analysis is an airport ground access mode choice model that predicts how the access modes chosen by air parties will change in response to changes in the service levels of different modes, such as fares, costs or travel times, or to the addition of new modes with defined characteristics. The user can vary the mode choice model coefficients and the variables included in the utility functions for each mode, allowing the mode choice model to be customized for different airports or regions, or revised as new mode choice model estimation results become available. The mode choice model predicts the probability of a given air party with specified characteristics choosing each available mode. Applied to a large sample of air parties with the appropriate distribution of characteristics, typically obtained from an air passenger survey, these probabilities provide an estimate of the number of air parties (and air passengers) using each mode. Air party origin (grouped by travel analysis zone) is used both to determine the relevant travel times and costs for each mode in the mode choice model, as well as to calculate that party's contribution to the overall measures of ground access system performance.

Data Management: A key capability of the IAPT is to manage the large and diverse sets of data required for effective airport ground access planning through its user interface. The IAPT provides the capability to allow the user to identify the various data files required for a given analysis run. Project definitions and other data entered through the user interface, as well as the output of IAPT runs, are stored as text files on the computer hard disk and can be accessed following an analysis run for use in other applications.

User interface: The user interacts with the IAPT using a graphical user interface that provides an intuitive way to define airports to be included in the analysis and specify projects at each airport. From the initial screen, the user can select index tabs that open a sequence of screens that allow different types of data to be entered or supporting data files to be selected. Before performing an analysis run the user selects the projects to be included and the measures of performance to be calculated in the run, as well as the year for which the analysis is desired. The user then runs the IAPT on the selected projects by clicking on a button on the "Run Model" screen and can view the resulting performance measures and other data generated by the run by selecting the "View Output" screen. Resulting data calculated in a model run can be exported in comma-separated value format and opened in Microsoft Excel or other spreadsheet or database management programs.

The current version of the IAPT provides the user with the ability to define multiple airports and sets of projects for each airport, and compare the performance of these projects across airports, as well as generate regional totals of the measures of performance for different project scenarios at each airport. It therefore can support the analysis of airport ground access impacts and traffic flows as part of regional airport system planning. It could be used by airport, local and state transportation planning agencies to support planning for projects that have the potential to change the airport ground access mode use patterns.

The project resulted in a software tool that simplifies and standardizes the process of analyzing airport ground access projects by planners working for airport authorities, as well as local and state transportation planning agencies. In addition to facilitating the management of the extensive data required for such analysis, use of the IAPT will not only reduce the work involved in analyzing airport ground access projects, allowing more project scenarios to be evaluated, but should result in more consistent analysis of different projects, potentially leading to better project design and selection decisions.

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Chapter 1. Introduction

This research report documents the work performed under California Department of Transportation contract 65A0421 for the project titled *A Combined Quantitative and Qualitative Approach to Planning for Improved Intermodal Connectivity at California Airports – Phase II*. The project was sponsored by the California Department of Transportation (Caltrans) and undertaken by the California Partners for Advanced Transportation Technology (PATH). The project duration was from 7/15/2011 to 5/15/2013.

1.1 Brief Review of Phase I Project

Phase I of the project developed a combined quantitative and qualitative approach to planning for improved intermodal connectivity at California airports. The quantitative approach involved the development of a prototype Intermodal Airport Ground Access Planning Tool (IAPT) which allows planners to evaluate the relative performance of project alternatives in intermodal airport ground access planning. This is a quantitative analysis procedure that combines transportation system performance measurement, an air passenger mode choice model, and a model of transportation provider behavior, and is designed to interface with a traffic network analysis model through the use of data files that provide information on highway travel times and airport ground access vehicle trips. The qualitative approach is intended to complement the quantitative analysis by accounting for factors that are difficult to quantify, and was addressed through a set of policy recommendations and planning guidelines.

The major components and data flows of the IAPT are shown in Figure 1-1

The work undertaken during Phase I of the project is summarized as follows:

Literature Review: An extensive literature review was conducted and opportunities for improving California airport intermodal ground access were identified.

Air Passenger Mode Choice Model: Modeling of air passenger mode choice was undertaken using a multinomial logit model. A preliminary model was estimated for Oakland International Airport (OAK) using 2001 air passenger survey data and implemented in the IAPT. However, refinement of the OAK model and model development for the other two primary Bay Area airports (San Francisco International Airport and San Jose International Airport) and implementation in the IAPT required further work beyond the resources of the first phase of the project.

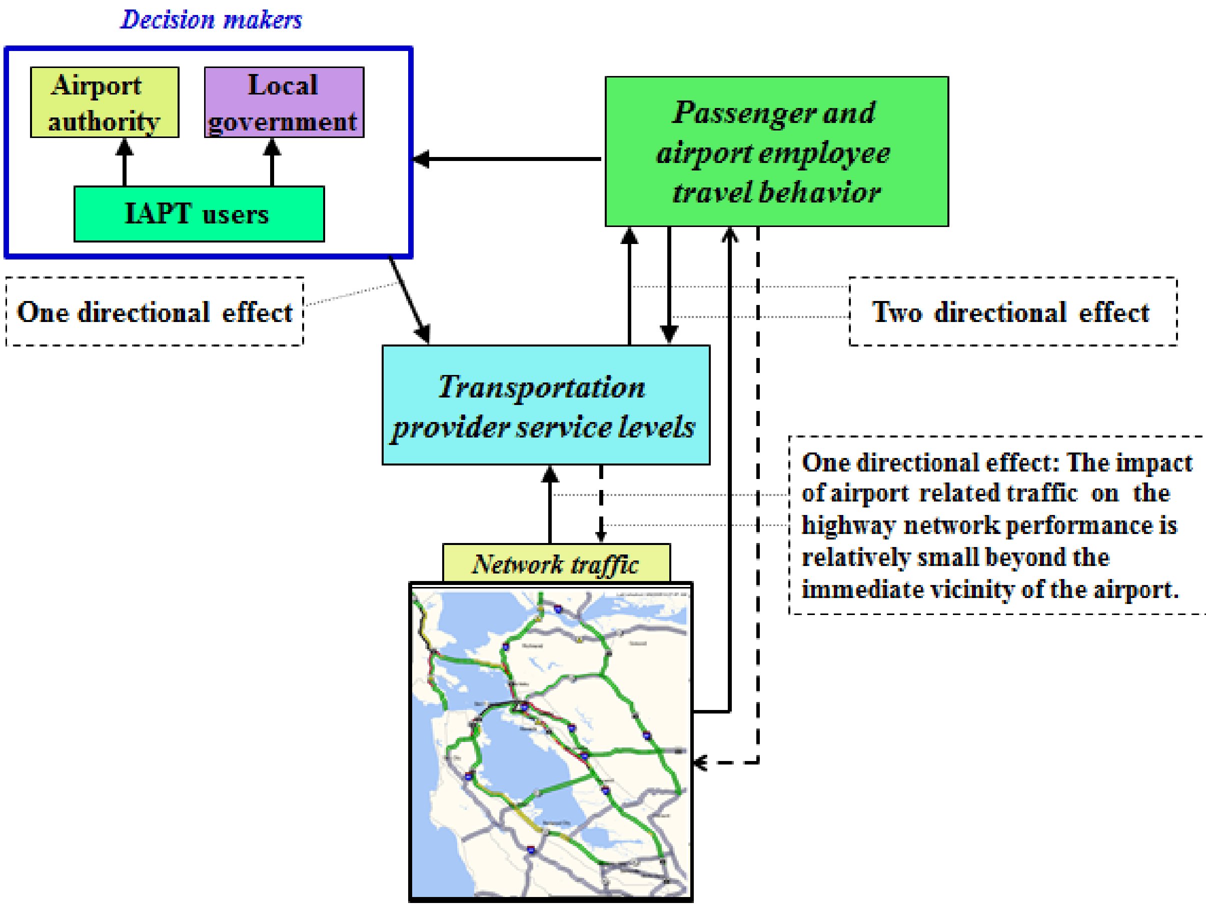


Figure 1-1: Major Components of the IAPT

(Dotted lines mean that the effect is relatively small)

Transportation Provider Behavior Model: This model attempts to predict how airport ground access transportation providers vary their fares and service levels in response to the introduction of a new service or a significant change in the service level of a given mode. The current version of the model only considers competition between modes rather than between transportation providers within each mode. Thus this attempts to predict the collective response of the various providers within a given mode to any given change. While in practice different transportation providers within a mode may respond differently to a given change, since they are often in competition with each other as well as with other modes, the IAPT only models air passenger ridership and calculates the associated transportation performance measures for each mode in total, not for individual providers within a mode, which requires this simplification in modeling the transportation provider behavior. A preliminary version of this model was implemented in the IAPT, although further development of the model is necessary since the initial version does not always converge to a solution.

Network Model: This involves two aspects: the air passenger access paths including the modes involved, and the relevant transportation network service levels, including travel times, distances and costs. For the later, the Metropolitan Transportation Commission (MTC) regional transportation network model based on a 1,454 travel analysis zone (TAZ) system has been used for the initial IAPT implementation. Data from this model was used to obtain travel distances from each TAZ to the three primary Bay Area airports and AM peak, midday, PM peak and off-peak highway travel times to those airports respectively. The impact of airport traffic on general network traffic has been ignored in this version of the IAPT since this impact is small outside the immediate vicinity of the airport.

Performance Measures: They are typically the most interesting aspects of the output of the analysis procedure to planners. A range of performance measures have been defined, which include system performance measures such as vehicle-hours of travel (VHT), vehicle-miles of travel (VMT), revenues, and emissions, and measures of the *connectivity* performance of the transportation system. These performance measures have been expressed as mathematical relationships involving the relevant transportation service levels and mode use travel volumes and implemented in the IAPT analysis.

IAPT Implementation: The IAPT software was designed to allow users to define projects for evaluation, including selection of the airport in question, the years for analysis, the modes involved, project alternatives, and the performance measures to be calculated. A prototype version of the IAPT software was programmed and demonstrated to the Caltrans project manager in the Division of Research and Innovation (DRI) and staff from the Caltrans Aeronautics Division.

Potential Case Studies: A number of potential airport ground access projects were identified at each of the three major Bay Area airports (San Francisco International Airport, Oakland International Airport, and San Jose International Airport) that would improve intermodal connectivity and could serve as case studies to demonstrate the application of the IAPT to evaluate opportunities to improve intermodal connectivity at California airports.

Policy Recommendations: Preliminary policy recommendations to encourage and support enhanced intermodal connectivity at California airports were developed as part of the qualitative approach to planning for improved intermodal airport connectivity identified in the project.

1.2 Remaining Problems with the Initial Version of the IAPT

The implementation of the initial prototype version of the IAPT had not been subject to a detailed quality control evaluation. Significant efforts were spent during the current phase to carefully review the program code, including the overall software structure, the relationships between the program modules, the data flow, the use of external files for reading and saving data, the functionality of each component, compatibility, etc. This process identified many problems with the previous version of the IAPT.

In the initial version of the IAPT, the Graphical User Interface (GUI) framework and the underlying software routines were implemented in a way that made extensive use of short-cuts to simplify how the calculations were performed and the results displayed, so that the full functionality of the IAPT could be demonstrated within the resource constraints of the first phase of the project. However, this resulted in a lack of flexibility in the way that the calculations and data flows – input, storage, use in calculations, and output – were implemented, and in some cases the calculations were incorrect. The problems with the implementation included the following:

(a) Most changes to the input data or data inputs made using the GUI were only stored temporarily in memory instead of being saved in a file or database. After closing the IAPT, the changes made would be gone.
   - Data added or modified in the process of using the IAPT would therefore not be available for subsequent runs. For example, changes in the airport demand growth factors were effective only for the current run(s).

(b) The format of the data in input data files could not be changed by users. For example, the mode choice model coefficients had to be put in a file in a specified format. Furthermore, users could not input values for the model coefficients from the GUI.

(c) Users did not have the ability to change which modes were excluded from the mode choice calculations and considered captive modes (the users of which continue to use the same mode irrespective of changes in the other modes). For example, visitors using rental car were assumed to do so to meet their local transportation needs during their visit and therefore would not consider using a different mode for their airport access trip.

(d) The airport demand growth factor was not properly integrated in the performance calculations.

(e) Changes in the service data variables for the mode choice calculations, such as fare, travel time, wait time, and access time, could be input from the GUI for use in specific project(s), but they were not in fact applied in the subsequent mode use calculations.

1.3 Objectives of Phase II

The objectives of this phase of the project were to implement an improved version of the Intermodal Airport Ground Access Planning Tool that could be used by agencies for regional airport ground access planning, although it was anticipated that further modeling and refining would most likely be needed on the basis of the initial user experience. One objective of this phase of the research was to ensure that the modeling components within the IAPT generate valid results. Due to the funding limitations in the previous phase of the project, the modeling components had not been fully tested. Therefore, further testing and refinement of the IAPT analysis procedures was the main task for this phase. The IAPT refinement focused on the following components: air party mode choice modeling, transportation provider behavior modeling, the calculation of system performance measures, and the supporting functions, including setting analysis parameters and display of the performance analysis results.

1.4 Scope of this Report

This report describes the tasks accomplished in this phase of the project, which include:

- IAPT functionality improvements that allow the user to input data, modify default data, and make changes in model parameters to generate and analyze different scenarios

- Mode choice model estimation for San Francisco International Airport (SFO) and OAK using 2006 air passenger survey data
- Improvements to the consistency, correctness, and generality of the performance measure calculations
- Development of a case study analysis of a major intermodal airport ground access project at one of the Bay Area airports, in order to demonstrate the potential role of the IAPT for analyzing such projects
- Demonstration of the IAPT to potential users

Chapter 2. IAPT Functionality Improvement

Functionality improvements to the IAPT addressed two separate aspects of the tool: the Microsoft Windows-Based Graphical User Interface (GUI) and the performance analysis performed by the tool. The GUI provides an intuitive way to define the airports to be included in the analysis and specify projects at each airport. Index tabs displayed on each screen open a sequence of screens that allow different types of data to be entered or supporting data files to be selected. Before performing a specific analysis run the user selects the projects to be included and the measures of performance to be calculated in the run, as well as the year for which the analysis is desired. The user then performs the analysis of the selected projects by clicking a button on the “Run Model” screen and can view the resulting performance measures and other data generated by the run by selecting the “View Output” screen. Resulting data calculated in a model run can be exported in comma-separated value format and opened in Microsoft Excel or other spreadsheet or database management programs for further analysis or incorporation in reports.

2.1 Data Input Improvement

Data input functionality improvements addressed several issues which are described briefly below, in the sequence of running the IAPT.

2.1.1 Define Performance Measures

Performance measures are the most important output of the IAPT. A screen allows users to define performance measures to be used to evaluate alternative projects by selecting a specific output measure, such as the number of passengers using each mode or the resulting VMT for that mode, and the modes for which that output measure is to be aggregated for that performance measure. On this screen (Figure 2-1), we have added a Cancel button in case the user needs to cancel the editing.

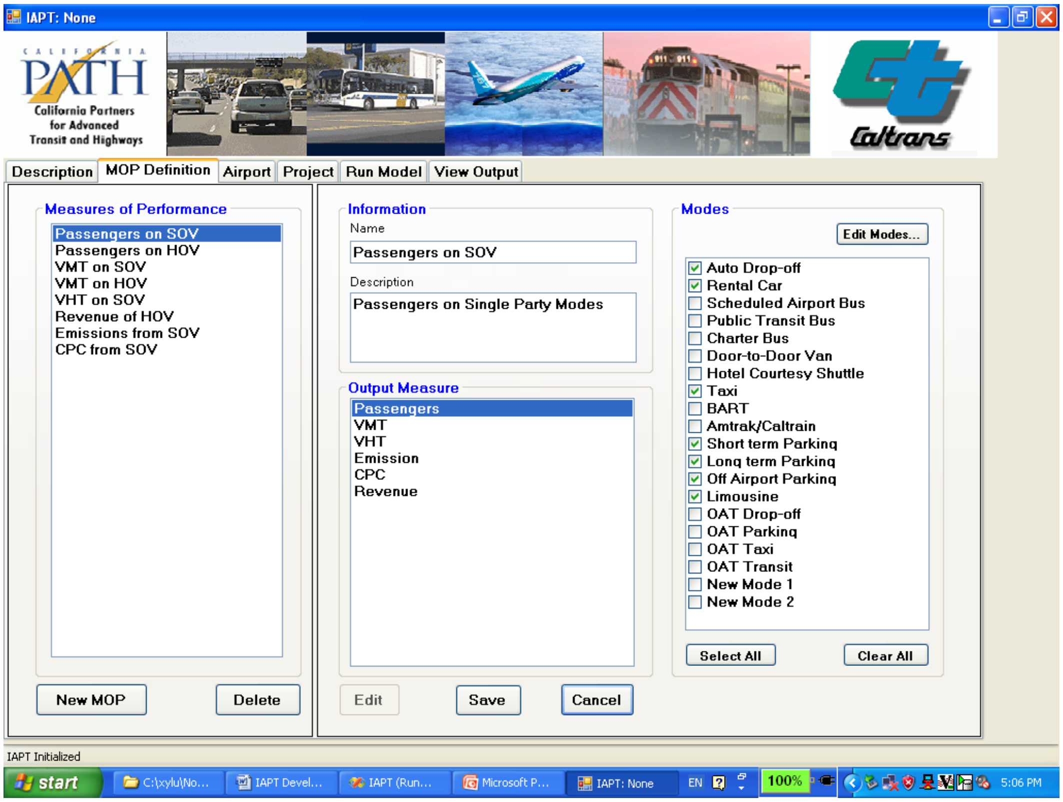


Figure 2-1: Link Measures of Performance to Relevant Modes

2.1.2 Define System of Airports for Analysis

The IAPT is designed to analyze projects at multiple airports in a region. The access trips to those airports will all utilize the regional transportation network although air passenger from different locations traveling to the same or different airports may take different routes. The current version of the IAPT has three default airports coded for the San Francisco Bay Area: SFO, OAK, and San Jose International (SJC). The user can input a new airport for analysis. We have added two more airport alternatives for the convenience of project comparison: OKA (an alternative for OAK) and SFA (an alternative for SFO). For example, the latter has been used in the case study comparison of two scenarios for SFO described in Chapter 4 of this report. Since the current version of the IAPT allows a user to specify only one mode choice model for each airport, if a particular analysis scenario requires a different mode choice model specification for different projects at the same airport, it will be necessary to define two or more alternative configurations for that airport, each with its own mode choice model, and assign the different projects to the appropriate airport. The detailed procedure to define a new airport in the IAPT using the GUI is documented in the IAPT User Manual, and is not repeated here.

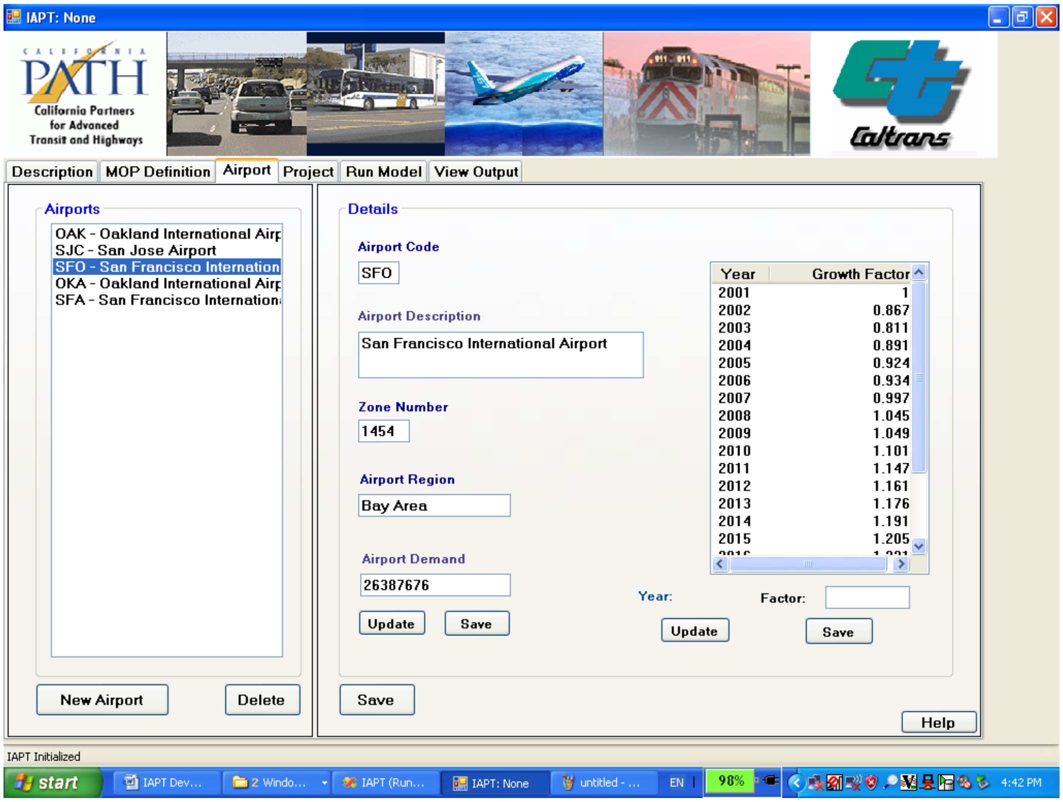


Figure 2-2: Define Airports in a Region and Input Relevant Data

The following functionality for defining airport attributes has been enhanced in the current version of IAPT compared to the initial version developed in Phase I of the project:

- Airport total demand can be input and changed on the screen, which was not possible in the previous version; after editing the value, the user can update the change in memory and save it permanently to file.
- A user can edit the airport demand growth factors for each airport and save the changes permanently as the default for subsequent model runs. This capability was not available in the previous version.

2.1.3 Define Project

Only projects with names specified on the Define Project screen are available for evaluation later on. However, each project needs to be defined by specifying appropriate values for project parameters in subsequent screens. If the project parameters are not edited, the default parameters and data will be used for performance calculation. A project can be a baseline project or a child project of a previously defined project, defined using the screen shown in Figure 2-3. In the latter case, all the regional transportation network data, airport demand values, etc. will be inherited from the parent project.

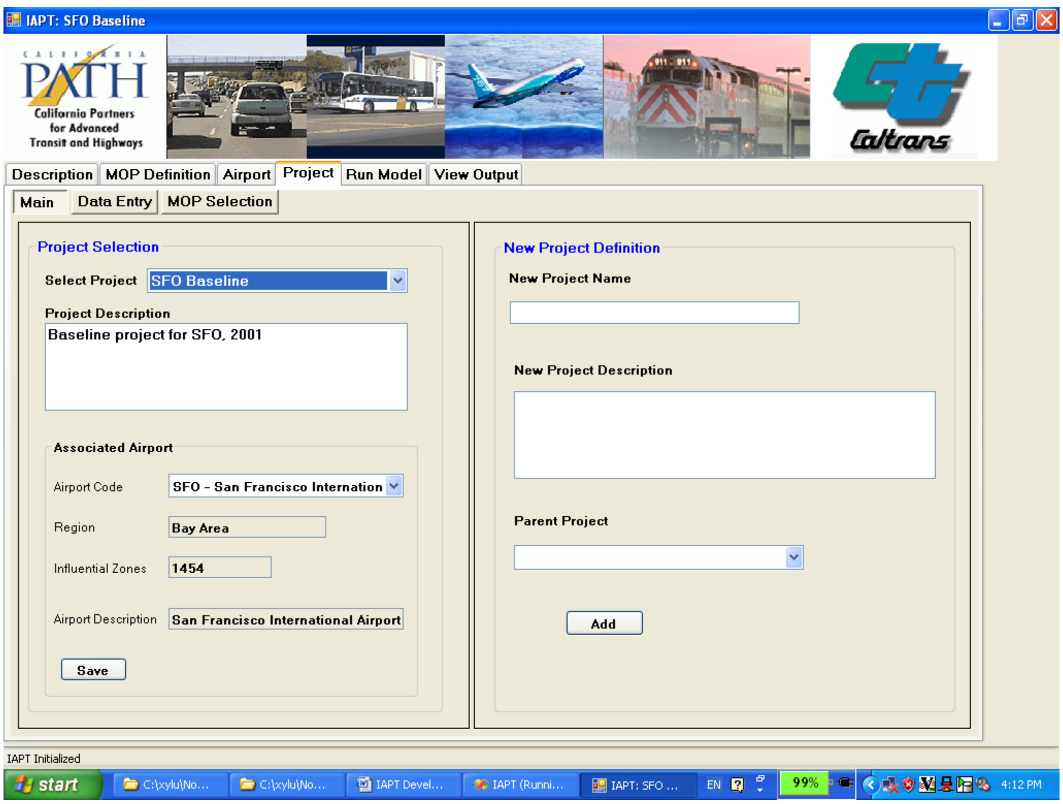


Figure 2-3: Project Definition Based on a Default Baseline Project

The principal change for the project definition function is that the option to change the fares and other modal costs associated with a child project has been removed. This option was redundant since once a child project has been defined and saved, it will become available in the project list. All the projects in the list can have their project parameters modified in subsequent screens, including changes in fares and other modal costs. Allowing users to change fares and other modal costs when defining a child project, but not change other project attributes, could potentially confuse users and complicated the calculation of the mode use and performance measures.

Project parameters need to be input in several steps. Once a new project has been defined, it can be selected for parameter input using the Data Entry tab. There are four data entry sub-tabs under Data Entry (as shown in Figure 2-4): Regional Data, Project Data, Service Data, and Model Data. The Regional Data sub-tab allows the user to selected four data files to be used for regional data, transit system data, highway data, and transportation service data for other modes. The first three are regional data files required for analysis. Users may not need to change them. However, the transportation service data file describes the travel times and user costs for each airport ground access mode. Changes to those values will affect the air passenger mode choice and therefore the performance measures for each project. Changes to the fare or cost for each mode, or changes to travel time components, for a given project can be performed using the Project Data or Service Data sub-tabs shown in Figures 2-5 and 2-6.

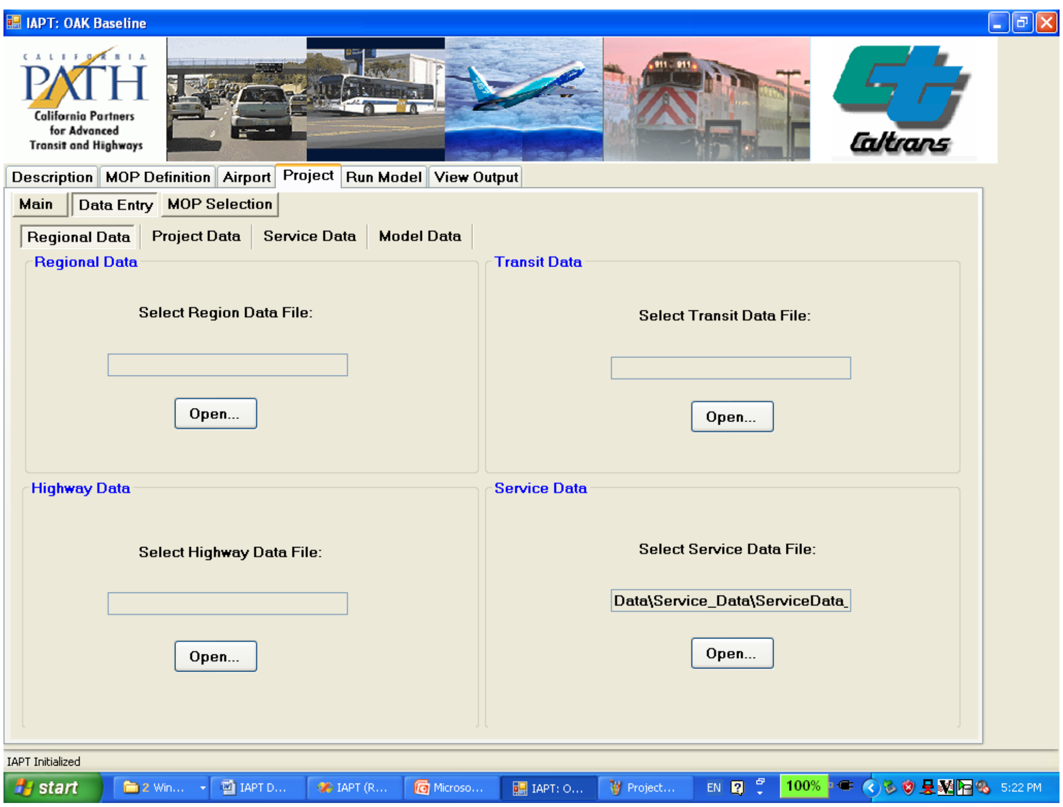


Figure 2-4: Select Regional Data Files

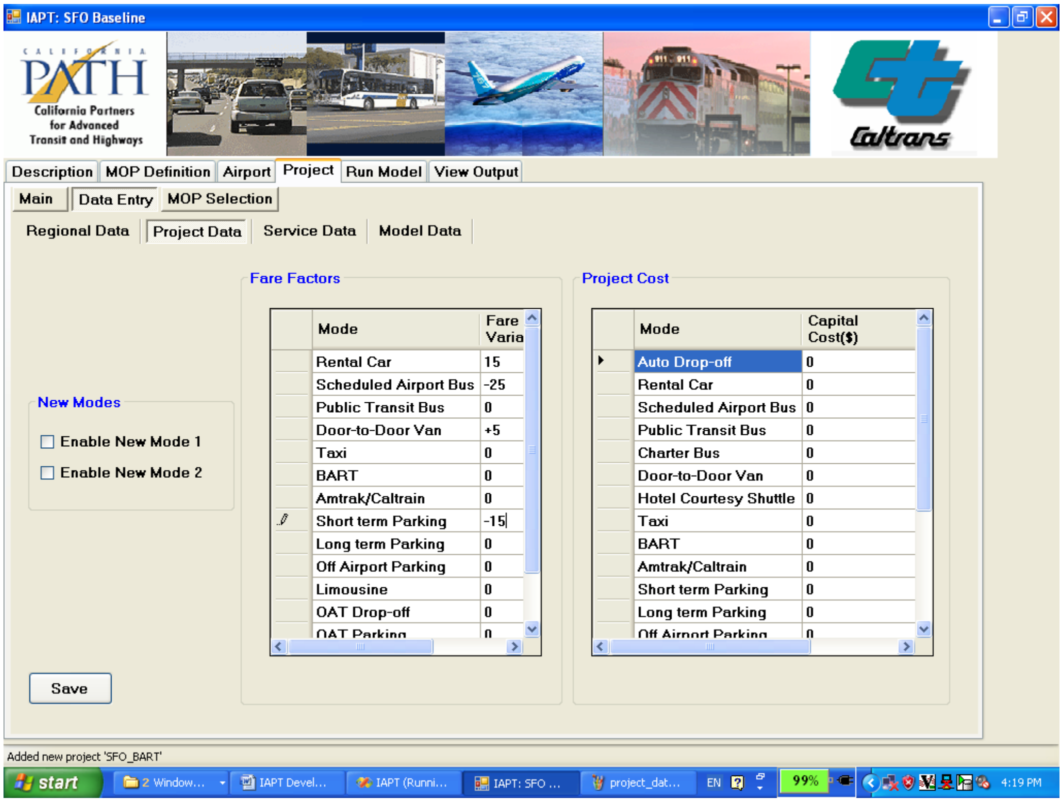


Figure 2-5: Specify Changes in Mode Fares and Costs

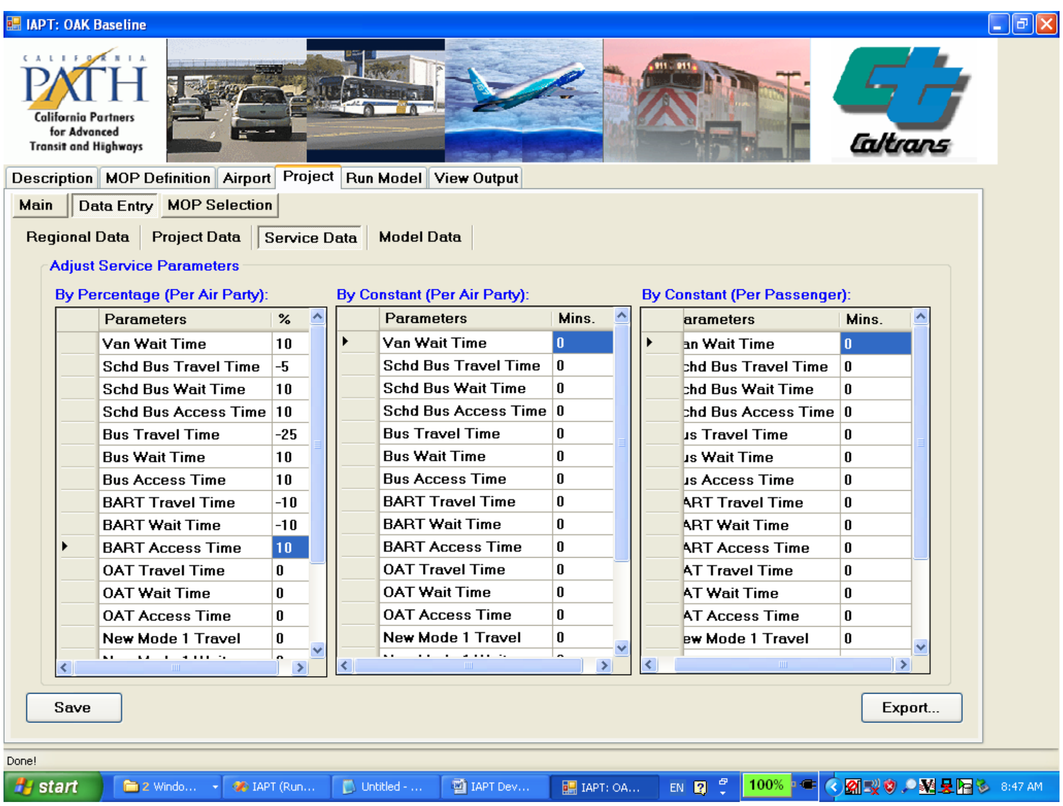


Figure 2-6: Specify Changes in Travel Time Components for Shared-Ride Modes

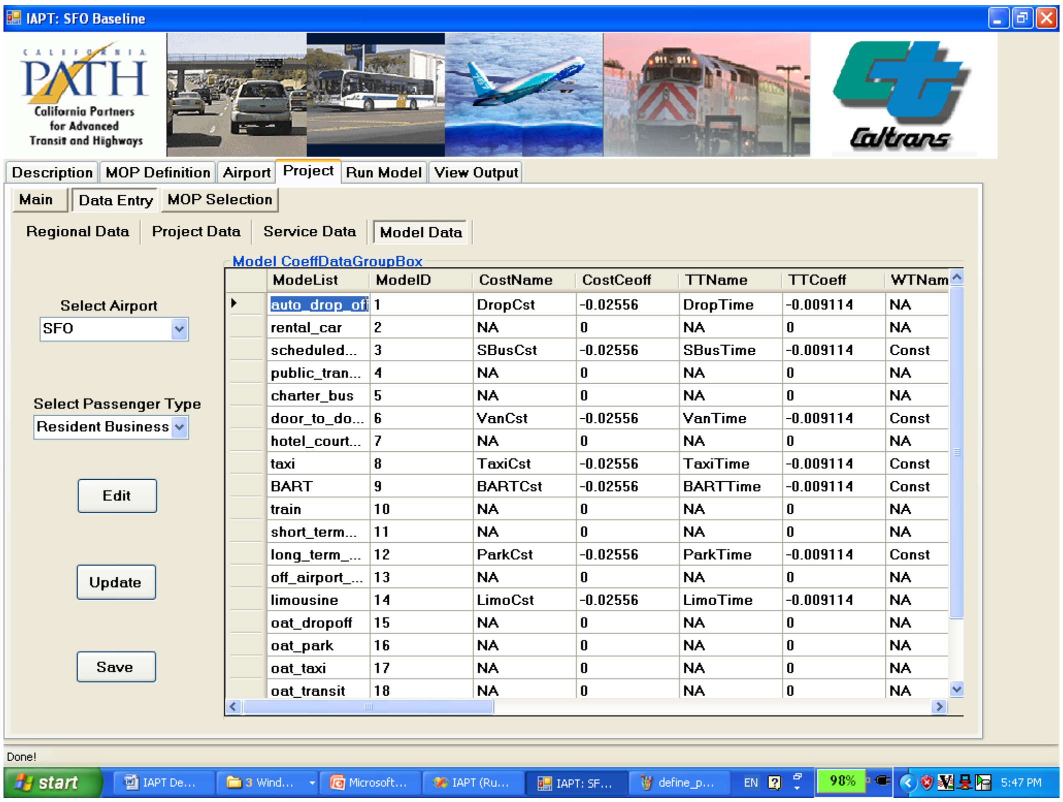
The Project Data screen was modified to remove the year selection dropdown list that appeared on the previous version of the screen. This was redundant because the fare and cost changes were not for a specific year but would apply to any years selected for evaluation and the actual year selected for evaluation is specified on the Run Model screen.

The changes to the time components for shared-ride modes from the default values in the transportation service data file can be performed in one of three ways on the Service Data screen under the Data Entry tab: by a percentage change in the travel times for each air party using a given mode, by constant amount for each air party using a given mode, and by a constant amount for each air passenger using a given mode. In the previous version of the IAPT, it turned out that these changes did not link to the calculation and therefore had no effect. This version of the IAPT has integrated all the three types of changes into the mode choice and performance measure calculations. Normally, the users would only need to make one of the three types of changes, although they may use a different type of change for different modes.

2.1.4 Modifying Mode Choice Model Coefficients

The mode choice model coefficients are estimated outside the IAPT and read in as a data file. The previous version of the IAPT used five terms in the model choice utility function, with a predefined attribute for each term, linked to a specific variable in the transportation service data file. This version of the IAPT has added a new functionality that allows the user to specify which service data variables are to be used for each term in the mode choice model utility functions with a new screen named Model Data. This is implemented as a Data Grid View in Microsoft Visual Studio. The user can select an airport and then select any of the four passenger trip types (Resident Business, Resident Personal, Visitor Business, and Visitor Personal) to display and modify the mode choice model coefficients and associated service data variables.

Figure 2-7 shows the screen displaying the mode choice model coefficients and variables for SFO Resident Business trips. In the table, “NA” means not applicable (either that mode was not included in the mode choice model or that term was not used in the utility function for that mode), “DropCst” is the variable name in the service data file for the air party cost for being dropped off by private vehicle, “SBusCst” is the variable name for the air party cost for using scheduled airport bus, and so forth. The variable names must be the same as the corresponding column headings in the service data file. The values shown on the screen display can be modified by clicking the "Edit" button, then the table can be updated in memory with the "Update" button and saved to file with the "Save" button.



ModelList	ModelID	CostName	CostCeoff	TTName	TTCoeff	WTNam
auto_drop_of	1	DropCst	-0.02556	DropTime	-0.009114	NA
rental_car	2	NA	0	NA	0	NA
scheduled...	3	SBusCst	-0.02556	SBusTime	-0.009114	Const
public_tran...	4	NA	0	NA	0	NA
charter_bus	5	NA	0	NA	0	NA
door_to_do...	6	VanCst	-0.02556	VanTime	-0.009114	Const
hotel_court...	7	NA	0	NA	0	NA
taxi	8	TaxiCst	-0.02556	TaxiTime	-0.009114	Const
BART	9	BARTCst	-0.02556	BARTTime	-0.009114	Const
train	10	NA	0	NA	0	NA
short_term...	11	NA	0	NA	0	NA
long_term_...	12	ParkCst	-0.02556	ParkTime	-0.009114	Const
off_airport_...	13	NA	0	NA	0	NA
limousine	14	LimoCst	-0.02556	LimoTime	-0.009114	NA
oat_dropoff	15	NA	0	NA	0	NA
oat_park	16	NA	0	NA	0	NA
oat_taxi	17	NA	0	NA	0	NA
oat_transit	18	NA	0	NA	0	NA

Figure 2-7: Edit Mode Choice Model Coefficients

Although the various terms in the mode choice model utility functions shown in the screen display in Figure 2-7 have column headings in the data grid view that imply that each term has a specific meaning, this is simply a legacy of the names for each term used in the previous version of the software and imposes no restriction on the service data variable and associated model coefficient used in that position. However, to avoid confusion and mistakes in pairing up the service data variables and model coefficients, it is suggested that users put the relevant variable and coefficient in the data grid position indicated by the column heading.

In addition to the flexibility provided by the revised approach, the number of allowable terms in the mode choice model utility function was increased from five to seven plus a constant term (and displayed in the data grid view by scrolling to the right, as shown in Figure 2-8). This allows more complex utility functions to be specified.

2.1.5 Captive Modes

The mode choice model specification screen includes a column designated as a Captive Mode Flag, which did not exist in the previous version of the IAPT mode choice model specification. This allows users to designate any given mode as a captive mode, the users of which are assumed to continue to use that mode irrespective of service changes to other modes. For example, visitors staying in an airport hotel who used a hotel courtesy shuttle to access the airport could be considered a captive mode, since they would be unlikely to choose any other way to reach the airport, no matter what changes are made to the fares or travel times of those modes. If an air party in the air passenger survey data used for the IAPT analysis used a captive mode, then the probability of that air party using that mode will be set to 1 in the mode choice model and the probability of choosing any other mode will be set to zero. However, for air parties using non-captive modes, the probability of choosing a given mode is determined by the mode choice model.

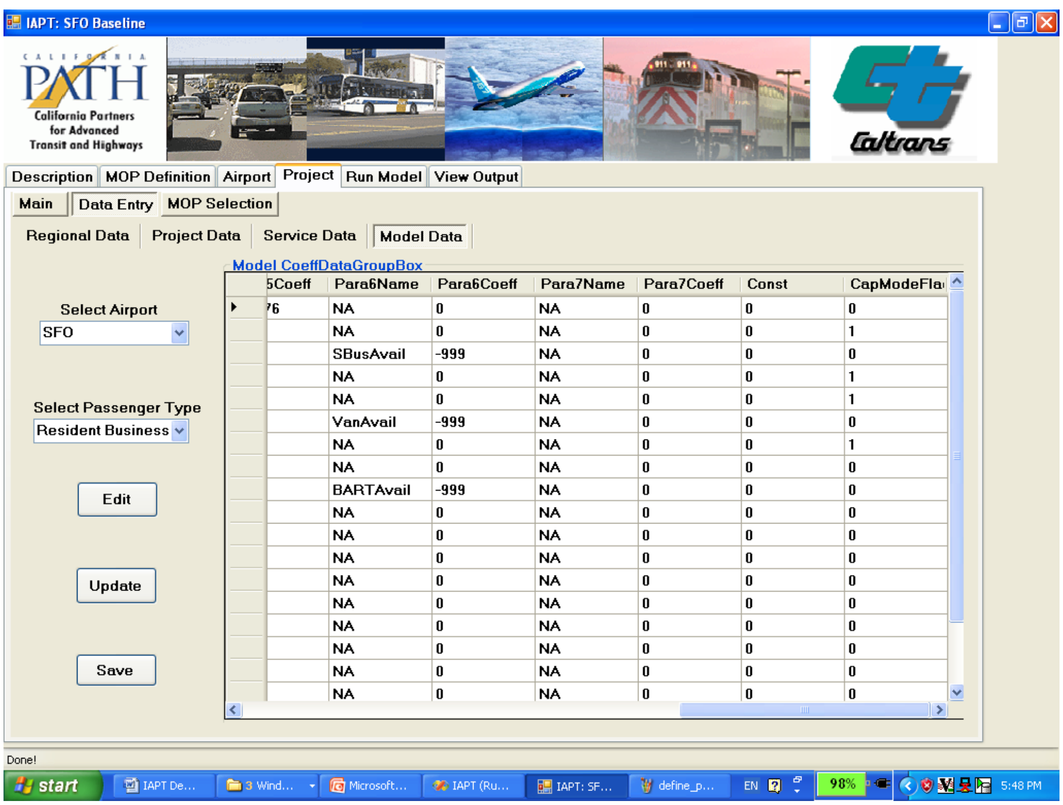


Figure 2-8: Captive Mode Flag in Mode Choice Model Coefficient Table

2.1.6 Improvement in the Display of Analysis Results and Model Output

Several improvements have been made in this function. The first was the addition of a dropdown list of years from which to select the year for evaluation, as shown in Figure 2-9. This option was not available in the previous version of the IAPT.

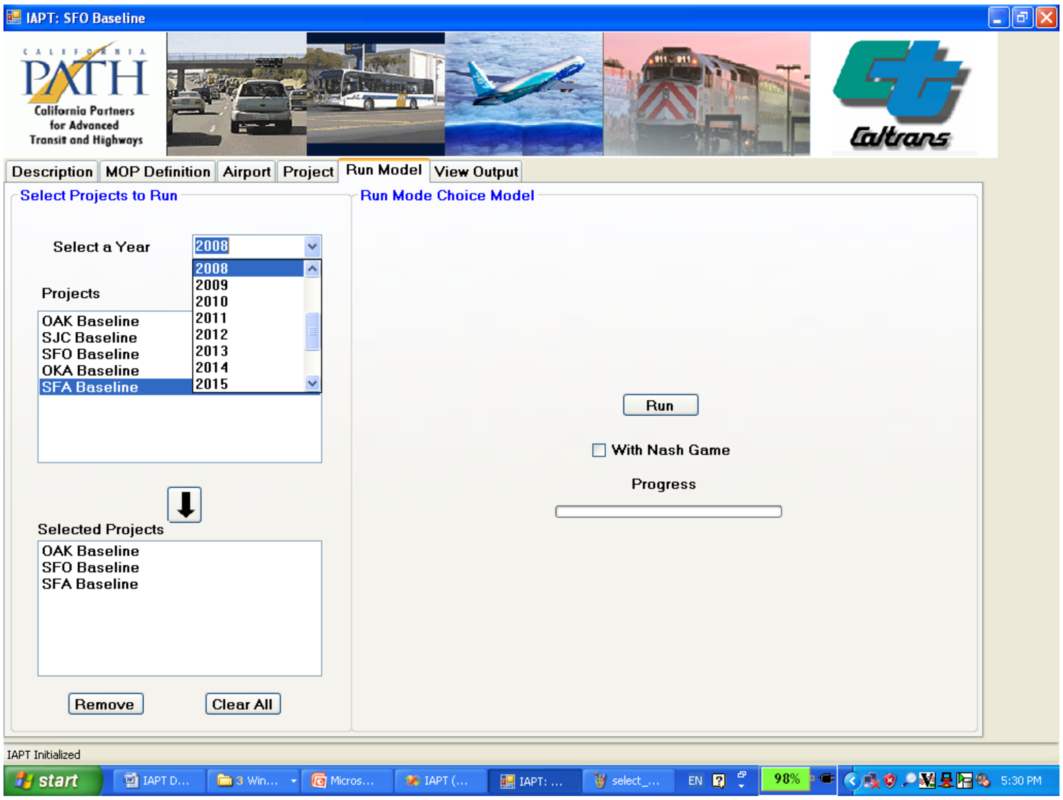
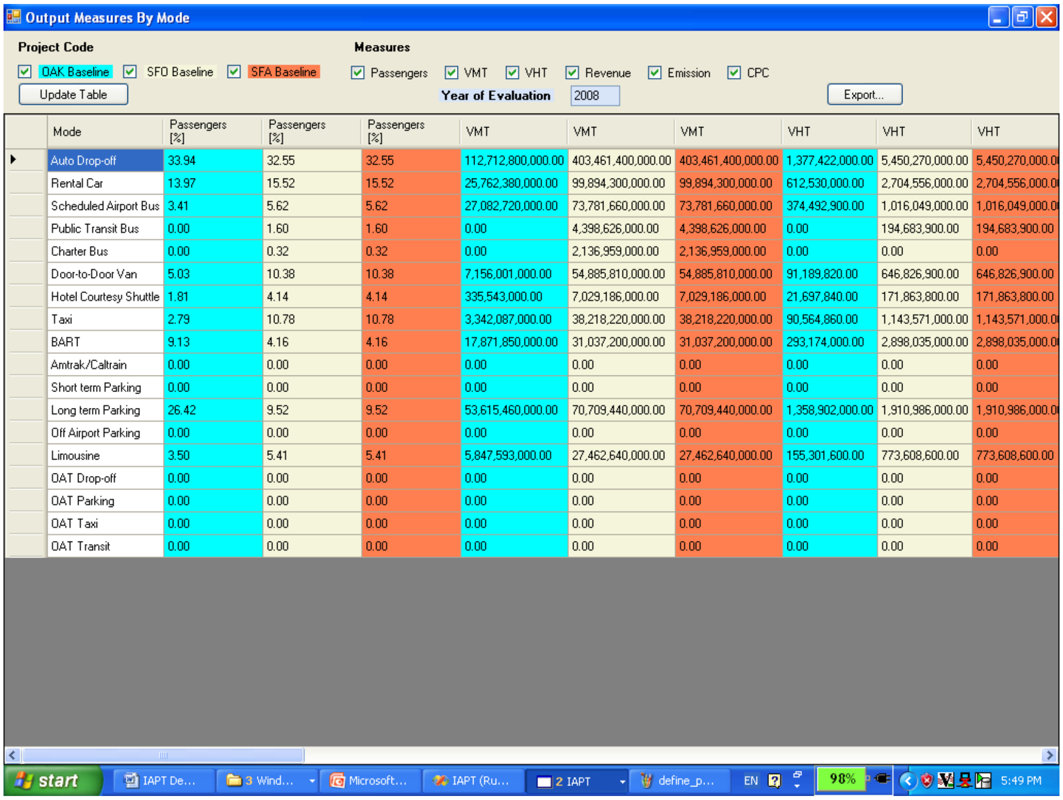


Figure 2-9: Select Analysis Year from Dropdown List

The selected analysis year will be displayed in the upper panel of the performance evaluation results tables, as shown in the Performance Evaluation by Mode screen (Figure 2-10).

Figure 2-10 shows the performance evaluation results for three projects that have been analyzed in a run. The screen displays the performance measures for each mode, with the results for each project color-coded. Additional performance measures can be viewed by scrolling the display to the right. Checking or unchecking the projects or performance measures in the upper panel of the screen adds or removes the corresponding projects or performance measures to or from the display. The screen also includes a button to export the results to a data file.



Mode	Passengers [%]	Passengers [%]	Passengers [%]	VMT	VMT	VMT	VHT	VHT	VHT
Auto Drop-off	33.94	32.55	32.55	112,712,800,000.00	403,461,400,000.00	403,461,400,000.00	1,377,422,000.00	5,450,270,000.00	5,450,270,000.0
Rental Car	13.97	15.52	15.52	25,762,380,000.00	99,894,300,000.00	99,894,300,000.00	612,530,000.00	2,704,556,000.00	2,704,556,000.0
Scheduled Airport Bus	3.41	5.62	5.62	27,082,720,000.00	73,781,660,000.00	73,781,660,000.00	374,492,900.00	1,016,049,000.00	1,016,049,000.0
Public Transit Bus	0.00	1.60	1.60	0.00	4,398,626,000.00	4,398,626,000.00	0.00	194,683,900.00	194,683,900.00
Charter Bus	0.00	0.32	0.32	0.00	2,136,959,000.00	2,136,959,000.00	0.00	0.00	0.00
Door-to-Door Van	5.03	10.38	10.38	7,156,001,000.00	54,885,810,000.00	54,885,810,000.00	91,189,820.00	646,826,900.00	646,826,900.00
Hotel Courtesy Shuttle	1.81	4.14	4.14	335,543,000.00	7,029,186,000.00	7,029,186,000.00	21,697,840.00	171,863,800.00	171,863,800.00
Taxi	2.79	10.78	10.78	3,342,087,000.00	38,218,220,000.00	38,218,220,000.00	90,564,860.00	1,143,571,000.00	1,143,571,000.0
BART	9.13	4.16	4.16	17,871,850,000.00	31,037,200,000.00	31,037,200,000.00	293,174,000.00	2,898,035,000.00	2,898,035,000.0
Amtrak/Caltrain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Short term Parking	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long term Parking	26.42	9.52	9.52	53,615,460,000.00	70,709,440,000.00	70,709,440,000.00	1,358,902,000.00	1,910,986,000.00	1,910,986,000.0
Off Airport Parking	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Limousine	3.50	5.41	5.41	5,847,593,000.00	27,462,640,000.00	27,462,640,000.00	155,301,600.00	773,608,600.00	773,608,600.00
OAT Drop-off	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OAT Parking	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OAT Taxi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OAT Transit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 2-10: Performance Evaluation by Mode

A major addition to the IAPT functionality was the addition of the capability to display and export the mode choice probabilities for each air party in the air passenger data file used for the analysis, as shown in Figures 2-11 and 2-12. This capability was not available in the previous version of the IAPT. Figure 2-11 illustrates the format of the display, which shows the probability of each air party choosing a given mode, as calculated by the mode choice model. Figure 2-12 shows the file name and location selection window used to export the mode use probabilities to a data file. Although a transportation planner may not be interested in such a detailed view of the mode choice model results, model developers may find this capability useful for validation of new or updated mode choice models, such as those described in Chapter 3. This capability may also be useful for analyzing the results of an IAPT run at a finer level of detail that provided by the standard output displays or data files. Since the table includes the air party identification number (Party ID), the detailed probabilities can be aggregated by air party characteristics from the air party data file, such as the geographic origin of the ground access trips.

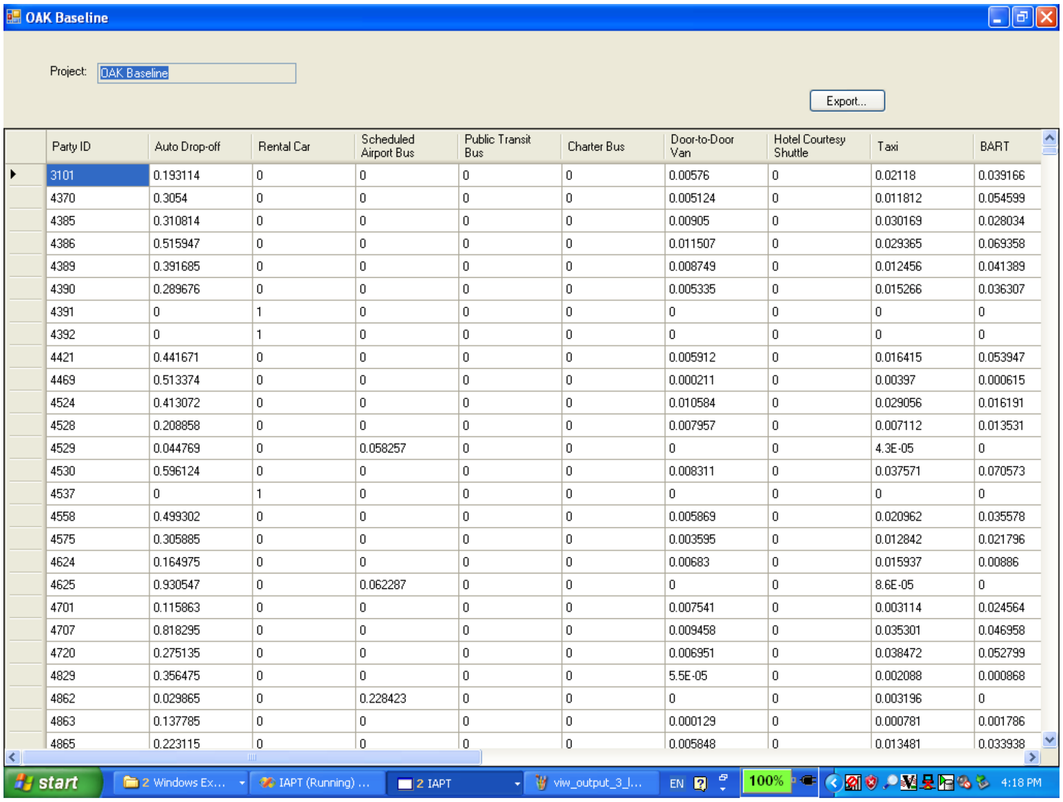


Figure 2-11: Display Air Party Mode Use Probabilities

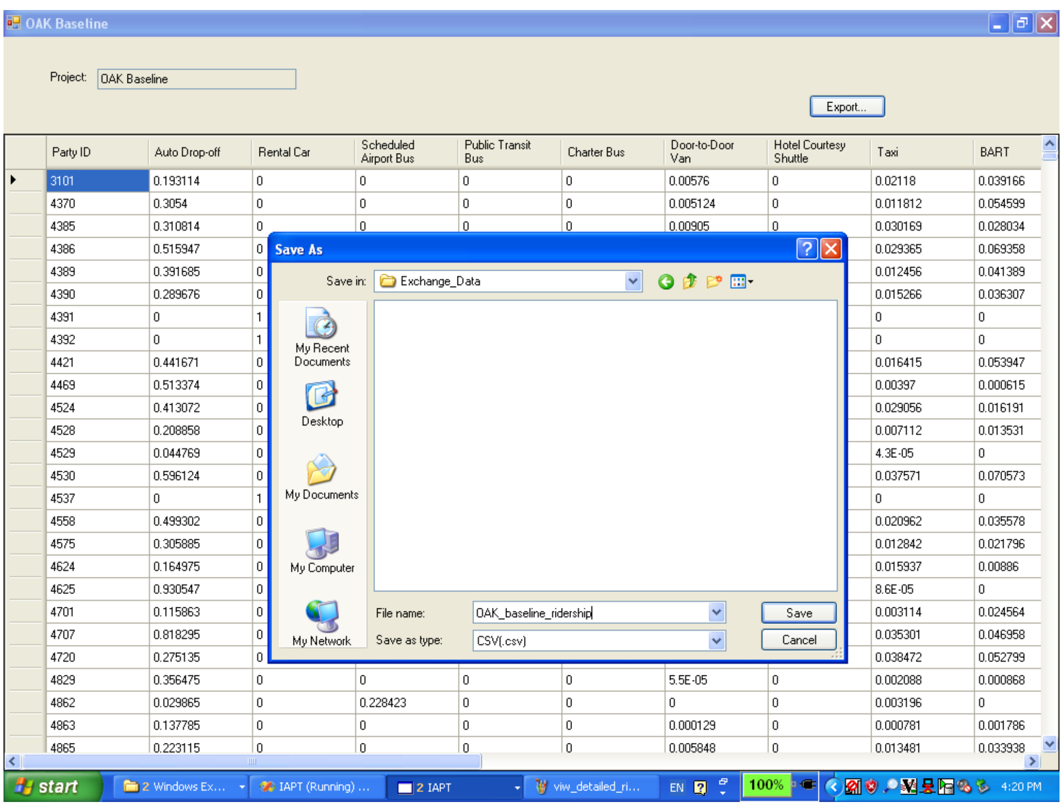


Figure 2-12: Save Air Party Mode Use Probabilities to File for Further Analysis

2.2 Data Management

A key capability of the IAPT is to provide a standardized user interface to managing the large and diverse sets of data required to perform airport ground access analysis. Because of the size of these datasets (for example a typical air passenger survey will have several thousand air party records with multiple attributes for each air party), it is generally not practical to enter these data manually. Instead, they will typically be prepared as large spreadsheet or database files, with each field (column) identified with a unique field name (or column label). The IAPT GUI provides the capability to locate the relevant files on the computer hard disk to be used for a given model run. It also allows the user to specify which fields are to be used for a given variable in the mode choice model or for the transportation service data values (e.g. highway travel time or driving distance to the airport) to be used in the performance measure calculations. This allows the supporting data files for multiple analysis projects to be organized in a logical structure in file folders, assigned user-definable names, and linked to specific projects being analyzed with the IAPT.

Project definitions and other data entered through the user interface are stored as text files on the computer hard disk and can be accessed following an analysis run for use in other applications. This also allows data to be saved from session to session. These data consist of six types which are briefly described below:

- Airport Data
  - Air passenger survey data, such as the MTC Airline Passenger Surveys from 2001 (SFO, OAK, SJC) and 2006 (SFO, OAK)
  - Airport forecast demand
- Highway Travel Time and Distance
  - Highway travel times and distances from each regional TAZ to each airport, as well as from relevant TAZs to rail stations or other locations required for the IAPT analysis, typically obtained from regional travel demand model data, such as the MTC highway network data files
  - Different highway travel times and distances are typically defined for different periods during the day, such as AM peak and off-peak conditions, reflecting varying highway congestion levels typically experienced over the day

- Regional Transit Network
  - Travel times and fares on the regional transit network from each TAZ to each airport or from relevant TAZs to rail stations or other locations required for IAPT analysis, typically obtained from regional travel demand model data, such as the MTC regional transit network data files
- Transportation Provider Service Data
  - Public transportation providers, such as BART, Caltrain, and local transit bus services
  - Private transportation providers, including:
    - Shared ride vans, scheduled airport buses (sometimes termed Airporter services)
    - Taxis, limousines
    - Rental cars
- Performance Data
  - Data used for performance measure calculation, such as vehicle emission factors
  - Performance measures calculated by the IAPT for each project, either in total for each airport or separately for each mode
- Exchange Data
  - Intermediate data calculated in the course of an analysis run, including intermediate parameters used for display, data exchanged between sub-modules, and specific values saved for debugging purposes
  - These are primarily of interest to system developers, and are of limited interest to general users

2.3 Improvement to Performance Measure Calculations

The current version of the IAPT calculates the following performance measures:

- System Performance by Mode
  - Number of passengers
  - Number of air parties
  - Vehicle trips
  - Vehicle-miles of travel (VMT)

    - Vehicle-hours of travel (VHT)
    - Emissions: carbon monoxide (CO), nitrogen oxides (NOx), volatile organic compounds (VOC), and particulate matter of 10 microns or less (PM10)
- Operator Performance (by mode)
    - Passengers/vehicle trip
    - Passenger-miles/vehicle-mile (load factor)
    - Revenue/vehicle-hour
    - Revenue/passenger
- Connectivity Performance by Mode
    - Passenger waiting times
    - Passenger transfers
    - Relative accessibility
        - Weighted travel time by high occupancy modes to travel time by private vehicle
    - Connectivity Production Cost
        - Weighted aggregate measure of performance of the intermodal transportation system taking into account:
            - Travel time
            - Waiting time
            - Access time
            - Number of transfers

The validity of the calculation of the performance measures is clearly critical to the value of the IAPT. Testing revealed that the previous version of the IAPT had the following problems with the calculation of performance measures:

- It only considered the 12 modes that were initially included in the mode choice model
- The calculations of the probability of choosing a particular mode made use of utility equations that were defined individually for each mode using specific service data variables rather than using a generic format with user-defined service data variables, which limited the ability to revise the formulation of the mode choice model

- Some parameters that were used in different places in the program code were not defined globally, which complicated making changes and could lead to multiple values being used if some required changes were overlooked
- In some cases, values that should have been user-definable were hard-coded in the software, preventing the IAPT from being used in different situations
- Many procedures for reading input data and storing values in memory were not implemented in a consistent way, which complicated changes to the program code and increased the risk of errors

To avoid those problems, the following techniques have been used in programming the latest version of the tool:

(1) All the global variables are defined in a single file and used consistently throughout the IAPT. These parameters include:
   - Airport ID codes
   - Future growth in demand for each airport

(2) A maximum of 20 modes are now allowed in the IAPT, which covers the likely range of possible modes that air passengers could use for airport access, including use of off-airport terminals and different types of parking facilities, as shown in Table 2-1. This makes it possible for all the airports in a region to use the same Mode ID for each mode, even if they have different sets of available modes. Two undefined modes are included to allow users to define new modes for inclusion in the analysis where necessary.

(3) Some major data tables have been reorganized, principally the transportation service data table. Since all the transportation service values for each mode that are used in the mode choice and performance measure calculations are obtained from the service data table, the format of the table and the way in which the service data is stored in the IAPT has been modified. The revised approach allows users to place variables in any column in the file, and designate the variable by the column heading in the first row of the table. This approach has brought several advantages:
   - It allows the user to change the variables included in the mode choice model and performance measure calculations and simplifies future development of the IAPT
   - By eliminating the need to provide the service data in a fixed sequence of columns in the file with the data in a defined format for each variable, the user

can more easily update the information and reduces the likelihood of errors in data preparation

- It makes the calculation of mode choice probabilities and performance measures more flexible and simplifies the programming involved in making enhancements to the IAPT

Since the service data table may include different variables for each airport, a performance measure specification table has been created for each airport, which is initially input as a data file and can be edited by the user. This table defines the service data variables to be used for each term in the performance measure calculations.

Table 2-1 Mode ID Number and Mode Names Used Throughout the IAPT

Mode ID	Mode Name	Comment
1	Auto Drop-off	
2	Rental Car	
3	Scheduled Airport Bus	
4	Public Transit Bus	
5	Charter Bus	
6	Door-to-Door Van	
7	Hotel Courtesy Shuttle	
8	Taxi	
9	BART	
10	Amtrak/Caltrain	
11	Short-term Parking	
12	Long-term Parking	
13	Off-Airport Parking	
14	Limousine	
15	OAT Drop-off	Off-Airport Terminal with
16	OAT Parking	access modes indicated
17	OAT Taxi	
18	OAT Transit	
19	New Mode 1	User-defined
20	New Mode 2	User-defined

(4) The utility functions in the mode choice model have been revised to allow a more flexible approach to specifying the variables in the model. In the previous version of the IAPT, only four terms were used in the utility functions and each had a specific interpretation.

In order to reflect differences in mode choice model specification from mode to mode and from airport to airport it was often necessary to combine different attributes into a single variable and modify the definition of the variable to correspond to the value of the model coefficient for that term. The revised version of the IAPT allows up to eight terms to be included in the utility specification, which should be enough to accommodate the differences likely to arise in different model specifications. These terms are designated:

- Travel cost
- Travel time
- Wait time
- Access time
- Service availability
- User–defined parameter 1
- User–defined parameter 2
- Constant

The mode choice model coefficients are defined for each term to correspond with the relevant service data variable. As noted above, the labels for the first five terms are only provided for convenience and are largely a legacy of the previous version of the model choice model implementation. For example, there is no particular reason that the first term has to refer to the travel cost, since both the service data variable and the model coefficient can be defined by the user, so this term could be used to account for any attribute of the mode. However, to avoid confusion, it is suggested that users generally try to reflect the labels for each term in deciding which variable to specify for each term. These changes also simplified the programming of the mode choice probability calculations. In the previous version of the IAPT, over 600 lines of codes were used to calculate the mode choice probabilities for each mode and airport. In the revised version, only 70 lines of code were needed to achieve the same purpose with greatly increased flexibility and much better robustness.

Chapter 3. Development of Updated Mode Choice Models

Since the initial development of the IAPT in Phase I of the current project, more recent air passenger survey data has become available for Oakland International Airport (OAK) and San Francisco International Airport (SFO) from the 2006 Airline Passenger Survey undertaken by the Metropolitan Transportation Commission (MTC) with the support and financial assistance of the two airports. This survey took place in two waves between August 16 and October 7, 2006 (JD Franz Research, 2008) and collected 3,587 responses at OAK and 4,628 responses at SFO, where each survey response represents one air party.

The availability of the survey data allowed the development of updated air passenger ground access mode choice models based on the ground access modes chosen by the survey respondents and the associated characteristics of each air party. This required the preparation of updated transportation service data for each of the airport ground transportation modes, reflecting the transportation service levels faced by each of the air parties in the 2006 survey.

Although Phase I of the project included the development of data files of air party characteristics from each of the three primary commercial service airports in the Bay Area (OAK, SFO and San Jose International Airport) based on an air passenger survey performed by the MTC in 2001 at all three airports, together with the corresponding transportation service data for 2001, an air passenger ground access mode choice model was only estimated for OAK as part of that phase. In order to be able to compare the mode choice models developed from the 2006 data with models developed from the earlier data, and for use in the case study analysis described in the following chapter, an air passenger mode choice model was estimated for SFO using the 2001 data as part of the current phase of the project.

3.1 Data Preparation

The data preparation needed to estimate updated air passenger mode choice models for OAK and SFO using the results of the 2006 MTC Air Passenger Survey involved two steps. The first consisted of creating air passenger (AirPax) data files that contained variables with the relevant air party characteristics for each of the air parties responding to the survey. The second step consisted of creating the corresponding transportation service data (ServiceData) files that contained variables with the values of the travel times, costs, and other service attributes faced by each air party for each available ground access mode considering the trip origin location for the air party. This was accomplished by creating a data file with the relevant transportation service values for each travel analysis zone (TAZ) and then using this file to assign the appropriate values of the service data variables to each air party in the AirPax file, considering such factors as the size of the air party and duration of the air trip.

3.1.1 Air Party Data

In principle, developing the air party data file for each airport simply involved selecting the variables to be included and transferring the relevant values from the survey response data for the 2006 MTC air passenger survey. A number of responses were dropped from the data files if some of the key information (such as the trip purpose or trip origin TAZ) was not available from the survey response data or could not be determined from the information provided by the respondent.

However, in the course of assembling the air party data files it was discovered that some of the air party trip origins had been incorrectly geocoded to TAZs when the original geocoding had been performed following the air passenger survey. In many cases this appears to have resulted from misinterpretation of the trip origin address or location information provided by the survey respondent. Since the trip origin TAZ is used to assign the transportation service data to each air party, any error in the TAZ would result in the air party being assigned incorrect values of the service data for each mode, which could potentially distort the estimated values of the mode choice model coefficients and certainly result in a much poorer fit of the model to the data. Therefore it was necessary to correct these TAZs based on a careful review of the trip origin location information and other relevant information in the air passenger survey data for that air party. This proved a rather time-consuming but essential process to ensure reasonable results for the mode choice model estimation.

3.1.2 Highway Travel Times and Distances

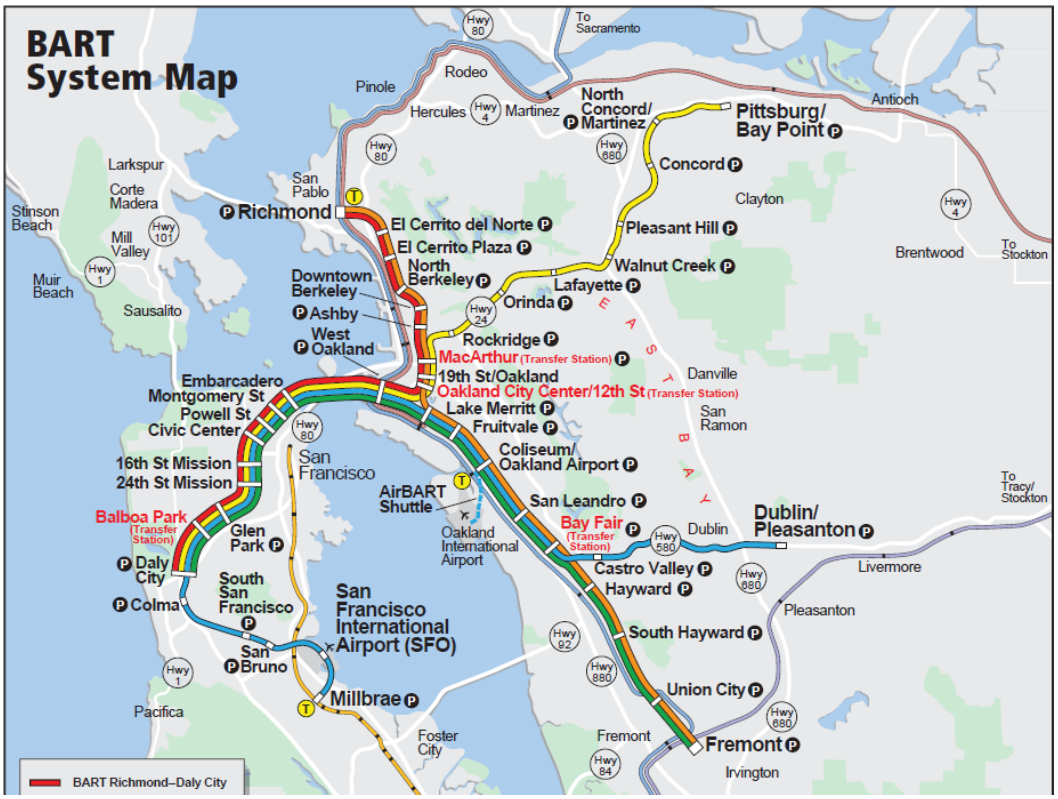
Highway travel times and distances for 2006 were provided by MTC in the form of TAZ to TAZ matrices from the regional travel model network skim files. However, unlike the year 2000 highway network data that was used for the 2001 service data files and which provided travel times and distances for four time periods in the day (AM peak, midday, PM peak, and late evening), the 2006 highway data only provided data for two highway congestions conditions:

AM peak and free-flow. Therefore 2006 travel times for midday and the PM peak were estimated by adjusting the corresponding 2000 travel times in proportion to the change in the AM peak travel times from 2000 to 2006. The late evening travel times were assumed to be free-flow. The PM peak distance was assumed to be the same as the AM peak distance, while the midday and late evening distances were assumed to be the same as the free-flow distance. The highway distance for a given TAZ pair often varied across the time periods reflecting different routes for the quickest time path due to differences in the congestion pattern during each time period.

3.1.3 BART Service Data

By 2006, BART had been extended from Colma to Millbrae, with a station at SFO. The airport station was located adjacent to the International Terminal, with an automated people-mover, termed AirTrain, that links the BART station to the domestic terminals. The AirTrain also provides inter-terminal transportation as well as connecting the passenger terminals to a consolidated rental car center. It is also feasible to walk to any of the terminals from the BART station. In 2006, the extension from Daly City to SFO was served by trains on the Dublin/Pleasanton to Millbrae line, which traveled between San Bruno and Millbrae via the airport, as shown in Figure 3-1. This required passengers using BART to access the airport from East Bay stations on the other lines to change to the Dublin/Pleasanton to Millbrae line at one of common stations (BART information generally advised changing at Balboa Park). In the case of passengers on the Richmond to Fremont line from stations between Richmond and MacArthur, there was a timed, cross-platform transfer at MacArthur station to trains on the Pittsburg/Bay Point to Daly City line. While passengers could take an earlier train on the Richmond to Daly City line (at those times when this line was in operation) and change at one of the stations served by trains on both the Richmond to Daly City and Dublin/Pleasanton to Millbrae lines, there was no travel time advantage to doing so, since they would end up waiting for the same Dublin/Pleasanton to Millbrae train that they would have transferred to from the Pittsburg/Bay Point to Daly City train that they would have taken from MacArthur station.

In 2006 BART operated trains on the same headway on each line to facilitate connections and sequence trains on common sections of track, although the headways varied between the daytime schedule and evening schedule on weekdays and between weekdays and weekends. Two lines (Richmond to Daly City and Fremont to Daly City) only operated during the daytime schedule. Therefore BART travel and waiting times varied by time of day and day of the week. For simplicity, it was assumed that the change of schedule from the daytime to evening schedule occurred at the same time as the transition from the PM peak highway travel times to the late evening travel times. While not strictly correct, since it is not known which BART train the survey respondents using BART actually took, or which train those not using BART would have taken had they used BART, it was assumed that any errors introduced by this simplification would be fairly minor.



Source: BART

Figure 3-1: BART Service to SFO in 2006

3.1.4 Caltrain Service Data

By 2006, the Caltrain schedule had become fairly complicated, particularly on weekdays, with the so-called "Baby Bullet" (limited stop) trains interleaved with express trains that did not stop at all stations and local trains that did. Furthermore, the Baby Bullet and express trains did not all skip the same stations, but successive trains stopped at different stations (although all trains stopped at some stations, including the Millbrae station) in order to provide a similar level of service at those stations that were skipped by some trains. A few stations were only served by local trains.

Therefore, airport travelers from trip origins served by Caltrain would not necessarily use the closest Caltrain station, but could save time by traveling further to a different station that had an earlier Baby Bullet or express train, depending on the time of day they were making the trip. If they were dropped off at the station by private vehicle or drove and parked at or near the station, the additional time involved would be fairly small compared to the time saved by taking a faster or earlier train. If they accessed the station by bus, the tradeoffs became more complicated, and whether using a more distant station would actually save any time would depend on the bus routes involved and the bus schedule.

In principle, the station access times, travel times on Caltrain, and waiting times involved for any given air party could have been determined from a timed network, by assuming a desired arrival time at the airport based on the departure time of the air party's flight. However, this would have required a lot of work to develop, and was deemed to be beyond the resources of this phase of the project. Instead, average station access times, travel times on Caltrain and the BART connection from Millbrae station to SFO, and the waiting times involved were determined for each TAZ and each of the four time periods used in the analysis by using average station to station travel times and waiting times, and average station access times for the closest three stations based on an analysis of the station access modes used by those air parties that actually used Caltrain.

3.1.5 Transit Bus Service Data

Transit level of service data for 2006 was provided by MTC in the form of TAZ to TAZ matrices from the regional travel model transit network skim files. For each TAZ pair, the file provided waiting time, ride time, and fare, with different values for some TAZ pairs depending whether transit was accessed by walking or private vehicle, since the transit services used could be different in the two cases.

However, these values were obtained by assuming that travelers took the shortest time path through the transit network, and thus for many trips assumed that at least part of the trip was taken on BART or Caltrain. Since the IAPT mode choice treated transit bus trips as a separate mode, the MTC network data gave incorrect values for longer trips. This was a particular problem in the U.S. 101 corridor from San Francisco to Palo Alto, which was served by the

SamTrans Route FX freeway express bus that served SFO from downtown San Francisco and selected communities in the U.S. 101 corridor south of the airport. It appears from an analysis of the trip origins of air parties reporting the use of transit bus to access the airport that the majority of such air parties in fact used the FX bus. Therefore the transit bus level of service from each TAZ in San Francisco and San Mateo County was calculated through a combination of the MTC transit network data and the schedule and fares for the SamTrans FX bus, determined from the SamTrans website at the time on the Internet archive (www.archive.org).

For access trips to scheduled modes, such as BART or scheduled airport bus, the values given by the MTC transit network data are probably reasonable, since those shorter trips would not have made use of the heavy rail modes (BART or Caltrain). Light rail modes, such as the Muni streetcar lines in San Francisco or the Valley Transportation Authority (VTA) light rail lines in Santa Clara County, were not modeled separately by the IAPT but included in public transit bus.

3.1.6 Scheduled Airport Bus Service Data

Scheduled airport bus travel times, waiting times, and fares from each stop on the routes operated by the different scheduled airport bus operators were determined from a search of the Internet archive for the websites for each operator at the time. By 2006 the only scheduled airport bus services in the region were from the North Bay (Marin, Sonoma, and Napa counties). Access times, costs, and driving distance to reach the closest bus stop from each TAZ in these counties were based on an analysis of the access modes to the bus stop reported by those survey respondents who used scheduled airport bus to access the airport.

3.1.7 Shared-Ride Van Service Data

Representative shared ride van fares for different geographic zones within the region were determined from a search of the Internet archive for the websites of selected shared-ride van operators. The website of the largest operator, SuperShuttle, contained a fare query capability that was linked to a database that has since been updated, so it is not possible to use this to determine the fares offered in 2006. However some of the other operators displayed fares on their websites in a fixed format that has remained accessible through the archive. It was assumed that the highly competitive nature of the shared-ride van industry is such that the fares of each operator from a given service area were similar. In any case, since the air passenger survey does not indicate which shared-ride van operator was used by those air parties that in fact used a shared-ride van to access the airport, even if different operators had somewhat different fares, it would not be possible to know which of these fares would have been paid by those using shared-ride vans, or would have been paid by others had they used shared-ride van.

A second issue that arises in the case of share-ride van service is the additional time spent on the van while other parties are picked up, if the air party is not the last one to be picked up before the van heads to the airport. Whether an air party from a given TAZ is the last travel party to be picked up, and the additional time involved in picking up subsequent parties if the air party is not the last to be picked up, is likely to vary from air party to air party from a given TAZ, depending on other reservations at the time. Therefore an estimate was made of the average additional time involved for each TAZ, based on an analysis of the reported access times by those survey respondents that used shared-ride van, assuming that the minimum reported time represented the travel time of the last party to be picked up by the van in which they rode.

3.1.8 Taxi and Limousine Fares

Taxi and limousine fares for 2006 were determined from a search of the Internet archive. Taxi meter rates in effect for the City of Oakland and City of San Francisco at the time were used to calculate fares as a function of highway distance for OAK and SFO respectively. Websites for two limousine operators at the time gave fares from OAK and SFO to different communities (cities or sub-city areas) throughout the region. Each TAZ was assigned to one of these communities and the fare for the TAZ determined. Where a TAZ was not in one of the designated communities, a distance relationship was used based on the fares to nearby communities. Bridge tolls were added to the taxi fare or to the limousine fare if they were not already included in the fare (one of the limousine operators included tolls in the published fare while the other did not). It was assumed that other limousine operators offered similar fares. A tip of 10% was added to calculated taxi fares and a tip of 20% was added to limousine fares, based on the recommended practice indicated on the limousine operator websites.

Travel times for taxi and limousine trips were based on the relevant highway travel time for the time period in question. No allowance was included for waiting time to be picked up, since it was assumed that air parties would be picked up at a pre-arranged time.

3.1.9 Airport Parking Rates

Airport parking rates were determined from a search of the Internet archive. The parking cost for a given trip duration was calculated by determining a cost function based on the proportional use of daily parking, long-term parking, and off-airport parking as a function of trip duration from the parking lot use reported in the air passenger survey by respondents who parked for the duration of their trip.

3.2 Model Estimation

As part of Phase I of the project an air passenger airport ground access mode choice model was estimated for Oakland International Airport, using air party data from the 2001 MTC Airline Passenger Survey (Lu, *et al.*, 2009). During the current phase of the research, mode choice model development was undertaken for SFO using air party data from the 2001 air passenger survey and for both OAK and SFO using the more recent data from the 2006 MTC Airline Passenger Survey.

3.2.1 San Francisco International Airport (2001 Data)

Initial model estimation using the 2001 air passenger survey and transportation service data and a similar utility structure to the model developed in the previous phase for OAK gave the model coefficients shown in Table 3-1. The coefficient values have the expected sign, with one exception (walk time to transit for visitor business trips), and generally reasonable values.

The principal travel time and cost coefficients are all statistically significant. The coefficient for the driver time for drop-off by private vehicle for resident business trips is not statistically significant at the 95% confidence level but has a t-statistic only slightly below the threshold. Many of the alternative-specific constants have very poor statistical significance, but are included in the model in order to ensure that the model maintains the overall mode shares.

The implied private vehicle operating costs are generally reasonable, although the implied value for visitor business trips is very weak. This may be due to the small number of such trips with a trip origin at a private residence, for which drop-off by private vehicle would be an available mode. However, it is not clear why the private vehicle operating costs would be different for different trip types.

Table 3-1: Estimated Air Passenger Mode Choice Model – SFO 2001 Data

	Resident Business		Resident Personal		Visitor Business		Visitor Personal	
Continuous variables		*t-stat*		*t-stat*		*t-stat*		*t-stat*
Travel time (min.)	-0.0091	*(2.07)*	-0.0107	*(1.85)*	-0.0306	*(2.21)*	-0.0129	*(2.07)*
Travel cost / f(Inc) ($)	-0.0256	*(6.81)*	-0.0374	*(9.39)*	-0.0085	*(1.99)*	-0.0220	*(5.06)*
Driver time (drop-off) (min)	*assumed*		-0.0087	*(1.63)*	*assumed*		*assumed*	
Walk time (transit bus) (min)	*no use reported*		-0.0712	*(0.52)*	0.1086	*(0.63)*	-0.5812	*(1.78)*
Alternative-specific constants								
Park	+0.104	*(1.11)*	-0.005	*(0.06)*	*not applicable*		*not applicable*	
BART/Caltrain	-1.959	*(5.83)*	-1.685	*(7.63)*	-2.471	*(4.02)*	-1.470	*(8.12)*
Transit bus	*no use reported*		-0.898	*(0.53)*	-1.773	*(0.84)*	3.071	*(1.22)*
Scheduled airport bus	-0.009	*(0.02)*	-0.013	*(0.02)*	1.698	*(1.54)*	-0.023	*(0.05)*
Taxi	-0.099	*(0.76)*	-0.044	*(0.49)*	-0.164	*(0.66)*	-0.638	*(4.28)*
Limousine	0.0	*fixed*	-0.102	*(0.81)*	-0.691	*(2.30)*	-1.258	*(4.63)*
Shared-ride van	-0.530	*(2.36)*	-0.395	*(1.81)*	0.421	*(0.87)*	-0.443	*(1.93)*
Dummy variable								
Non-home trip origin	-0.528	*(1.94)*	+0.105	*(0.60)*	-0.723	*(2.85)*	-1.119	*(7.42)*
Private vehicle operating cost	55 ¢/mi	*(2.27)*	32 ¢/mi	*(2.34)*	34 ¢/mi	*(0.42)*	40 ¢/mi	*(2.53)*
Travel time assumptions								
Waiting time	2x travel time		2x travel time		2x travel time		2x travel time	
Driver time for drop-off trips	0.5x air pax		*estimated*		0.5x air pax		0.5x air pax	
Implied value of time ($/hr)	21.4		17.2		216		35.2	

Notes:
1. Costs expressed in 2001 dollars.
2. All costs and times computed on an air party basis. Travel times multiplied by air party size.
3. Implied values of time for air travelers with an annual household income of $90,000 in 2000.
4. Alternative specific constants and non-home trip origin dummy variable multiplied by air party size.

The implied values of time seem generally reasonable for resident trips, with a somewhat higher value for business trips than personal trips, as would be expected. For a household income of $90,000 per year with two workers making a similar salary, an implied value of time of $21.4 per hour is equivalent to about 99% of the hourly pay rate, assuming 2,080 paid hours per year. The implied value of time for personal trips under the same assumptions is equivalent to about 80% of the hourly pay rate, which seems reasonable.

The implied value of time for visitor business trips appears unreasonably high, and it is not clear what is causing this. It may be that visitors on business trips tend to use fairly expensive modes, such as taxi and limousine, since these costs can usually be charged to their employers or clients, resulting in a high implied value of time. It is also not clear why visitors on personal trips would have a higher implied value of time than residents on personal trips, although this could be due to a greater use of more expensive modes, such as taxi and shared-ride van, due to a lack of familiarity with less expensive transit options.

Although the estimated model coefficients seem generally reasonable, there are a number of aspects that could benefit from further examination, including the very high implied value of time for visitor business trips and the incorrect sign for the coefficient of walk time to transit for visitor business trips.

3.2.2 Oakland International Airport (2006 Data)

Due to the additional (and unanticipated) work involved in revising the incorrectly geocoded TAZs in the air passenger data file from the 2006 MTC Airline Passenger Survey, the work estimating the mode choice model for OAK for 2006 was not completed at the time this report was prepared. The model estimation results will be reported later in a follow-up technical memorandum or included in a revision to this report.

3.2.3 San Francisco International Airport (2006 Data)

As with the model development work for OAK, due to the additional (and unanticipated) work involved in revising the incorrectly geocoded TAZs in the air passenger data file from the 2006 MTC Airline Passenger Survey, the work estimating the mode choice model for SFO for 2006 was still in progress at the time this report was prepared. The model estimation results will be reported later in a follow-up technical memorandum or included in a revision to this report.

3.3 Further Model Development Needs

While the updated mode choice model estimation results for SFO using 2001 data appear to have generally reasonable coefficient values, with a few exceptions noted in the discussion of the estimation results, they also have a number of structural aspects that could adversely affect their reliability for predicting the effect of changes in the airport ground access system. Those changes could include the introduction of new modes or service, or significant changes in the quality of existing services.

These structural aspects include:

- The use of a multinomial logit choice structure
- The relatively high values of some mode-specific constants
- Omission of variables reflecting air party attributes that could influence ground access mode choice
- Consideration of constraints imposed by the egress trip

Several of these issues were brought up in the discussions following the demonstration of the IAPT to potential users described in chapter 5, and the last three aspects are discussed in more detail in section 5.3.1 below.

The use of a nested logit structure to represent the wide range of ground access modes and sub-modes that are typically encountered in airport ground transportation systems has been widely recognized in the literature on airport ground access mode choice modeling, as discussed by Gosling (2008). However, implementing such a model in the IAPT would require a more flexible approach to representing the air passenger ground access mode choice decision process than the current version of the IAPT. In the case of the multinomial logit model, all that needs to be done in order to incorporate a new variable in the utility function or new estimated coefficient values is to change the coefficient values or the variable names in the mode choice model specification table. However, representing a nested choice structure is more complicated, since in addition to defining the utility function for each mode, the nesting structure of the modes also has to be defined in a way that allows the user to change the structure as necessary to implement new or revised mode choice models. While in principle this is possible, the necessary changes to the program code could not be made and tested within the resource constraints of the current phase of the project.

Chapter 4. Bay Area Case Study Analysis

In order to demonstrate the functionality of the IAPT and to illustrate how the capabilities of the IAPT might be used in practice, a case study application was developed based on the extension of the Bay Area Rapid Transit (BART) system to San Francisco International Airport (SFO), which opened in July 2003 (Freeman, Wei & Gosling, 2012). The case study analysis was designed with the following objective:

- To compare the predicted use of BART in 2006 given by the IAPT based on the air passenger survey data from the Metropolitan Transportation Commission (MTC) 2001 Airline Passenger Survey and the mode choice model developed from that data with the actual BART use determined from the subsequent MTC 2006 Airline Passenger Survey.

The premise underlying the case study is a common situation arising in evaluation of planned intermodal airport ground access improvements, namely the prediction of future use of a planned facility using mode choice models estimated on data collected before the improvement has been implemented. At the time that the 2001 MTC Airline Passenger Survey was performed BART terminated at Colma Station and a San Mateo County Transit District (SamTrans) bus (Route BX) connected the station to the airport. Thus the case study represents an analysis that might have been undertaken (had the IAPT been available) prior to the completion of the extension (or soon after the opening of the extension) to predict the expected use of BART by air travelers departing from SFO after the extension had been in operation for several years.

The year 2006 was selected for the predicted BART use because that is the date of the most recent detailed air passenger survey undertaken at SFO that provides data on actual ground access mode use following the extension of BART to SFO.

In order to undertake the case study analysis, the following assumptions were made:

(1) The composition of the air parties departing from SFO in 2006 remained unchanged from those in 2001. Although it is possible to compare the composition of the air parties in 2001 with the composition in 2006 *ex-post*, this information would not have been available at the time the case study analysis was assumed to have been performed.

(2) The travel times and costs on modes other than BART remained the same as in 2001 in real terms (in other words fares or other costs increased from 2001 to 2006 just enough to keep pace with inflation). While in fact fares and other costs may have increased by more or less than inflation, or have increased in discrete steps every few years, in general the actual values for a given future year would not be known several years in advance. The assumption of constant real costs is commonly made in analysis of the sort being undertaken in the case study. Similarly, highway travel times may well have changed from 2001 to 2006, although the full extent of such change would not be known several years in advance.

(3) BART fares and travel times were assumed to be those in effect in 2006, with the fares adjusted to 2001 dollars. Although BART service to SFO was changed and fares were increased a number of times between the opening of the extension and 2006, which would not have been known several years in advance, this assumption simplifies the comparison between the BART use predicted by the IAPT and the actual use observed in 2006 by eliminating any errors due to the use of incorrect travel time and fare assumptions. In any case, some assumptions for future BART fares and travel times would be necessary and the purpose of the case study analysis is not to examine the sensitivity of BART use by departing air travelers to the service pattern and fares charged for trips to SFO.

(4) Household incomes were assumed to have changed in real terms by the actual change in Bay Area household incomes from 2000 to 2005 (since survey respondents would most likely have reported their household income for the previous year). While the exact change in household incomes would not have been known several years in advance, forecasts of future household income growth are made on a periodic basis by the Association of Bay Area Governments (ABAG). Assuming that these forecasts happened to be correct for 2005 simplifies the comparison between the BART use predicted by the IAPT and the actual use observed in 2006 by eliminating any errors due to the

use of an incorrect forecast of household income growth from 2000 to 2005, a factor which would be outside the control of the IAPT.

(5) The air passenger traffic at SFO in 2006 was assumed to be known from airport traffic forecasts. Although in practice such forecasts rarely correspond to the actual traffic in a given year, this assumption simplifies the comparison between the BART use predicted by the IAPT and the actual use observed in 2006 by eliminating any errors due to the use of an incorrect traffic forecast for 2006, a factor which would be outside the control of the IAPT.

4.1 Data Preparation

The foregoing assumptions required several adjustments to the air party (AirPax) and transportation service data files developed for 2001 conditions before running the IAPT for the assumed 2006 conditions. These data files were originally developed in Phase I of the project for the 2001 baseline conditions and used to estimate the airport access mode choice models, based on the air party data from the 2001 MTC Airline Passenger Survey and the corresponding service levels on the various airport ground access transportation modes at the time.

4.1.1 Air Party Characteristics

The air party (AirPax) data file required one change from the baseline 2001 data file, to adjust the household income values to 2005 levels (in 2001 dollars). According to *ABAG Projections 2009*, mean household income in the Bay Area declined by 6.4% from 2000 to 2005 in real terms.

This approach implies that the proportion of air parties in each income band remained unchanged from 2001 (although the average household income for each band was lower). This also implies that the household income of visitors declined by the same percentage as that of Bay Area residents.

4.1.2 Transportation Service Data

The transportation service data file (ServiceData) required a number of adjustments. The BART travel times and fares for each air party were obtained from an adjusted ***modetaz*** file giving the 2006 BART travel times and fares by travel analysis zone (TAZ) with the fares expressed in 2001 dollars. The Bay Area Consumer Price Index (CPI) increased from 189.9 in 2001 to 209.2 in 2006, requiring BART fares in 2006 dollars to be multiplied by 0.9077 to be expressed in 2001 dollars.

The development of the BART service data for 2006 is described in Section 4.1.3 above.

The other major change from 2001 to 2006 was the ending of the SFO Airporter scheduled bus service to downtown San Francisco hotels on April 30, 2005. This service option was therefore removed from the ServiceData files for 2006, resulting in no availability of scheduled airport bus service for air parties from San Francisco or most of the East Bay. While scheduled airport bus service was available from the North Bay counties in 2006, air parties from San Francisco or the East Bay would be quite unlikely to travel in the wrong direction to make use of these services.

4.1.3 Comparison of Assumed and Actual Highway Travel Times

The case study analysis assumptions for travel times and costs on modes other than BART were that these remained unchanged from 2001 (with costs expressed in 2001 dollars). The assumed values of highway distance and highway travel times for 2006 (the 2001 highway distance and travel times were based on the 2000 MTC highway network data) are compared to the actual 2006 values (from MTC highway network data for 2006) for each TAZ in Figures 4-1 to 4-3.

It can be seen that:

(a) There is little change in the AM peak highway distance for the majority of the TAZs. A few TAZs show a somewhat shorter distance, due to taking a shorter route that takes advantage of reduced travel times.

(b) There is a significant reduction in AM peak highway travel times from many of the TAZs, while there is a slight increase for other TAZs. In general, TAZs in the East and North Bay show a reduction in travel times due to reduced congestion on the Bay Area bridges, while TAZs in San Francisco, the Peninsula, and the South Bay show a slight increase in travel times.

(c) Free flow highway travel times show a slight increase from the majority of TAZs, generally consistent with the increase in AM peak travel times from TAZ in San Francisco, the Peninsula, and the South Bay.

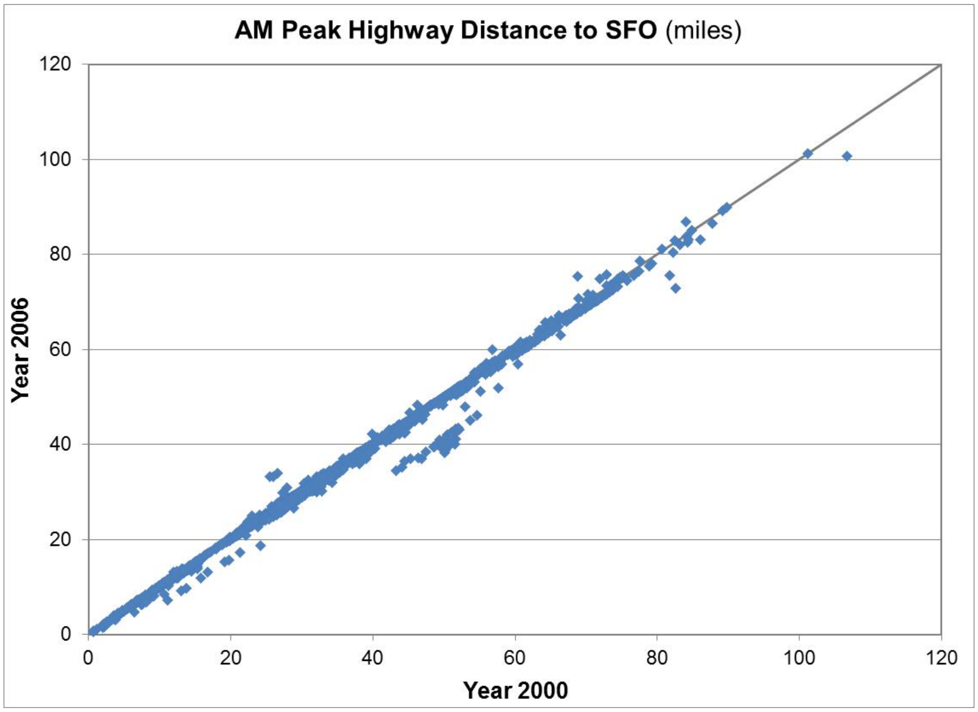


Figure 4-1: Comparison of 2000 and 2006 AM Peak Highway Distance

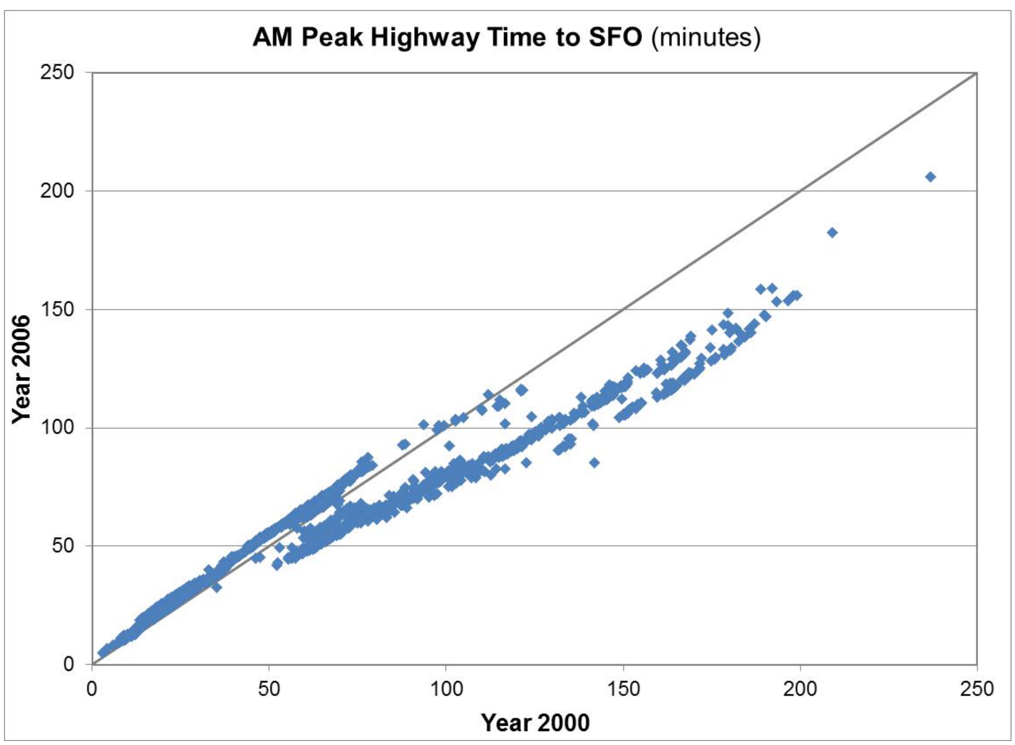


Figure 4-2: Comparison of 2000 and 2006 AM Peak Highway Travel Time

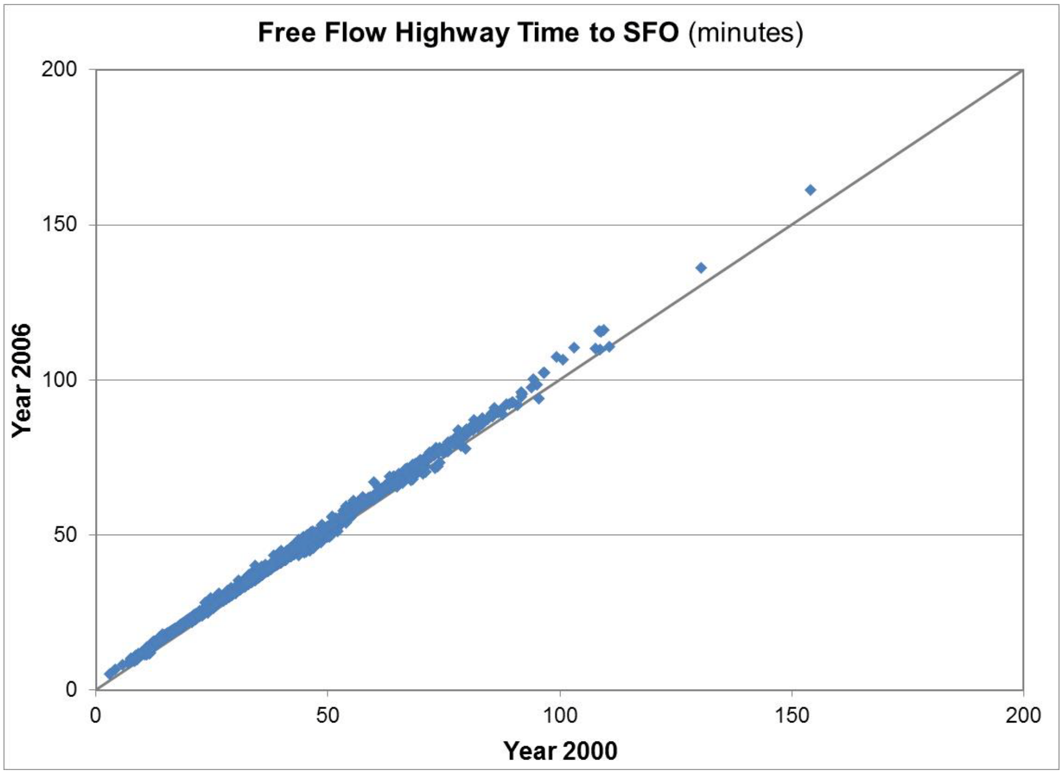


Figure 4-3: Comparison of 2000 and 2006 Free Flow Travel Times

4.2 IAPT Analysis

Two different IAPT transportation service data (ServiceData) files were prepared. The first, representing the no-build scenario, assumed that BART continued to terminate at Colma station, with the SamTrans route BX bus link to SFO. This used the 2006 BART fares, service frequencies, and travel times from each station in the East Bay and San Francisco to Colma to determine the BART service levels to SFO from each TAZ with BART service. The mode availability variable for BART service for TAZs south of Daly City was set to 1 (service not available). The rationale was that air parties from these TAZs would not backtrack to Daly City to ride BART to Colma and then take the BX bus to the airport. Even if they traveled to the Colma station and took the BX bus to the airport, this would not involve riding BART. Most of the TAZs south of the Colma station are closer to the airport than the Colma station anyway, so it would not make sense for air parties from these TAZs to use the BX bus anyway.

The second ServiceData file, representing the BART extension to SFO, used the 2006 BART fares, service frequencies, and travel times corresponding to the service on the

Dublin/Pleasanton to Millbrae line, with allowance for waiting times for transfers from other lines when necessary. It was necessary to estimate highway access times from TAZs south of Colma to the closest station on the extension (the 2001 mode choice model used in the case study analysis assumed that BART passengers were dropped off at the closest BART station by private vehicle).

In addition, for both ServiceData files the scheduled airport bus availability variable was set to 1 for all the TAZs in San Francisco and most of the East Bay, reflecting the elimination of the SFO Airporter service, and the corresponding scheduled airport bus access time, waiting time, ride time, and fare variables for these TAZs were set to zero. While scheduled airport bus service from the North Bay counties continued to be available under this scenario, it was assumed that air parties from San Francisco and those East Bay TAZs that were closer to an SFO Airporter stop in 2001 would not incur the additional access time involved in using one of the North Bay scheduled airport bus services. In most cases, this would have involved a considerable amount of back-tracking or a longer access trip to the nearest scheduled airport bus stop than to the airport.

Other than these changes to the BART and scheduled airport bus service, the service data variables for these two scenarios remained unchanged from the 2001 baseline scenario.

The IAPT required one other change to analyze the two scenarios. In the mode choice model developed for the 2001 baseline scenario, the SamTrans BX bus service from Colma station and the shuttle bus service from the Millbrae Caltrain station operated by SFO were not explicitly included in the times and fares in the ServiceData file, but were accounted for through the mode-specific constant for BART or Caltrain respectively, since each air party would face the same travel time and cost from using these modes. Therefore in modeling the SFO BART Extension scenario, it was necessary to modify the mode-specific constants for the BART and Caltrain modes to account for the elimination of the need to use the SamTrans BX bus in the case of BART and the replacement of the free shuttle bus service from the Millbrae Caltrain station with the BART service between Millbrae and SFO.

Although air parties using Caltrain to access SFO under the 2006 BART Extension scenario would in fact transfer to BART at the Millbrae station, this was treated as a change to the mode-specific constant for Caltrain, rather than as using Caltrain to access BART, since each air party using Caltrain faced an identical travel time and cost for the BART link.

The adjustments to the mode-specific constants were made by estimating the change in waiting time, travel time and cost from the 2001 SamTrans BX and Millbrae station shuttle bus schedules (and fare in the case of the BX bus), and the 2006 BART schedule and fare, and converting these to an equivalent change in mode-specific constant using the mode choice model coefficients for the relevant variables.

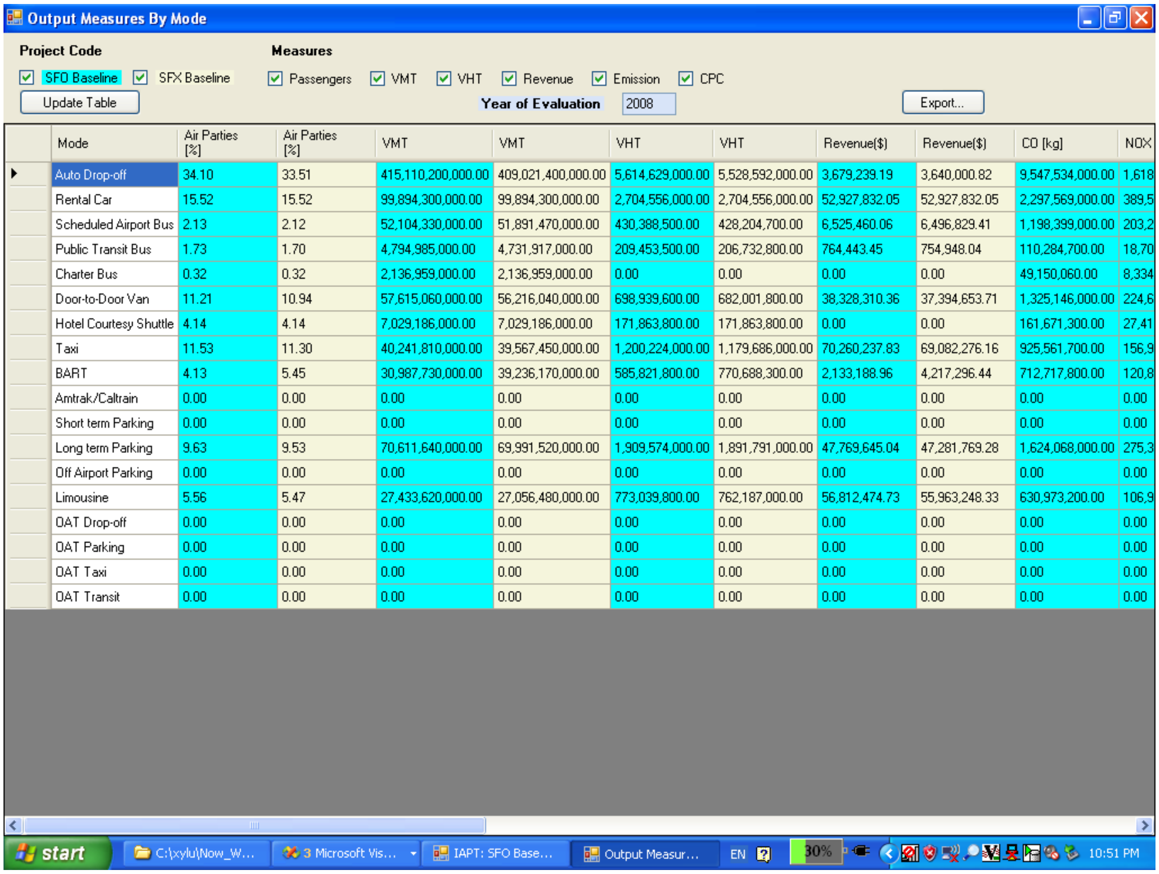
Because the current version of the IAPT does not provide the capability for different scenarios to use different mode choice model coefficients, it was necessary to analyze the two scenarios using separate runs, so that different mode choice model coefficients could be used in each run, reflecting the elimination of the SamTrans BX bus link and the use of the BART connection from Millbrae station to SFO by Caltrain passengers in the BART Extension scenario.

In addition to running the IAPT with the appropriate data files for the 2006 no-build and BART Extension scenarios, the IAPT was also run with the 2001 baseline conditions, in order to assess the change in BART use in the 2006 no-build scenario from the 2001 baseline scenario due to the combined effects of the elimination of the SFO Airport service, the changes in the BART service to Colma from 2001 to 2006, and the assumed changes in household income from 2000 to 2005. The mode use predicted by the IAPT for the two scenarios was also compared to the observed ground access mode use in the 2001 and 2006 MTC Airline Passenger Surveys.

4.3 Analysis Results

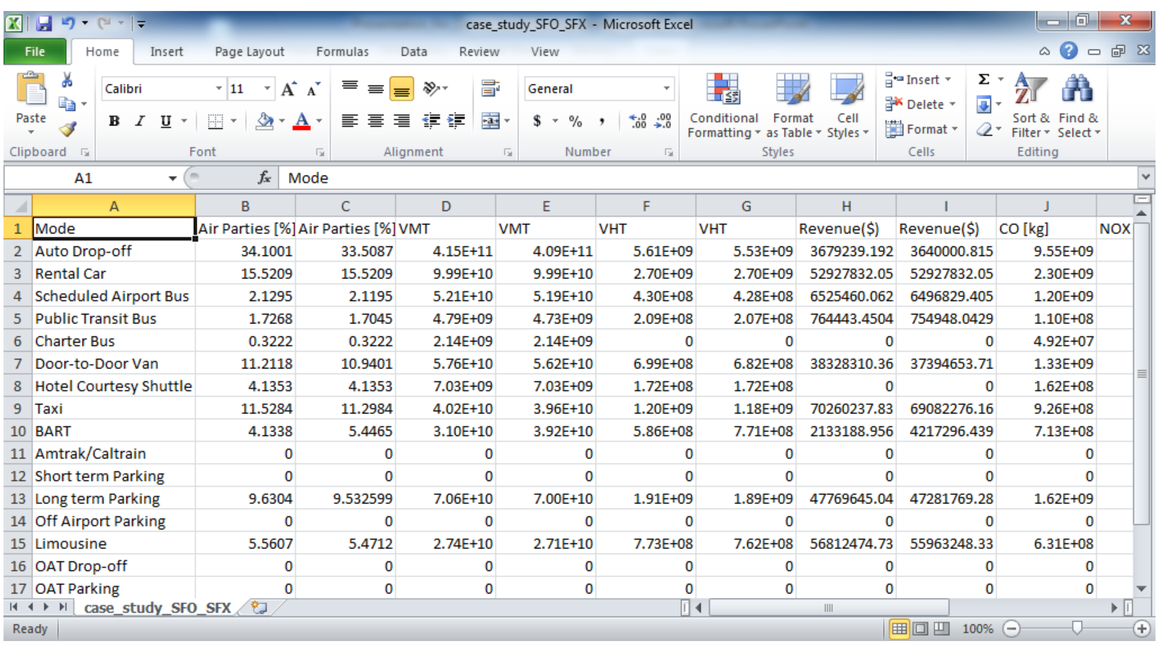
A typical output screen from one of the IAPT runs is shown in Figure 4-4. This shows the various output measures for each ground access mode for two scenarios, the 2001 baseline scenario (termed the SFO Baseline and highlighted in blue on the screen display) and the 2006 no-build scenario (termed the SFX Baseline and shown with a tan background on the screen display). More output measures can be displayed by scrolling to the right, and are not shown in the figure. Although the IAPT display shows separate modes for BART and Amtrak/Caltrain, in the case study analysis BART and Caltrain were treated as a single access mode, with the use depending on the TAZ of the air party trip origin, for reasons discussed below.

The results displayed on the screen were exported to a comma-separated value (CSV) file, which in turn was opened in Microsoft Excel, as shown in Figure 4-5, in order to prepare tables and charts showing the results of the analysis and perform additional analysis.



Mode	Air Parties [%]	Air Parties [%]	VMT	VMT	VHT	VHT	Revenue($)	Revenue($)	CO [kg]	NOX
Auto Drop-off	34.10	33.51	415,110,200,000.00	409,021,400,000.00	5,614,629,000.00	5,528,592,000.00	3,679,239.19	3,640,000.82	9,547,534,000.00	1,618
Rental Car	15.52	15.52	99,894,300,000.00	99,894,300,000.00	2,704,556,000.00	2,704,556,000.00	52,927,832.05	52,927,832.05	2,297,569,000.00	389,5
Scheduled Airport Bus	2.13	2.12	52,104,330,000.00	51,891,470,000.00	430,388,500.00	428,204,700.00	6,525,460.06	6,496,829.41	1,198,399,000.00	203,2
Public Transit Bus	1.73	1.70	4,794,985,000.00	4,731,917,000.00	209,453,500.00	206,732,800.00	764,443.45	754,948.04	110,284,700.00	18,70
Charter Bus	0.32	0.32	2,136,959,000.00	2,136,959,000.00	0.00	0.00	0.00	0.00	49,150,060.00	8,334
Door-to-Door Van	11.21	10.94	57,615,060,000.00	56,216,040,000.00	698,939,600.00	682,001,800.00	38,328,310.36	37,394,653.71	1,325,146,000.00	224,6
Hotel Courtesy Shuttle	4.14	4.14	7,029,186,000.00	7,029,186,000.00	171,863,800.00	171,863,800.00	0.00	0.00	161,671,300.00	27,41
Taxi	11.53	11.30	40,241,810,000.00	39,567,450,000.00	1,200,224,000.00	1,179,686,000.00	70,260,237.83	69,082,276.16	925,561,700.00	156,9
BART	4.13	5.45	30,987,730,000.00	39,236,170,000.00	585,821,800.00	770,688,300.00	2,133,188.96	4,217,296.44	712,717,800.00	120,8
Amtrak/Caltrain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Short term Parking	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long term Parking	9.63	9.53	70,611,640,000.00	69,991,520,000.00	1,909,574,000.00	1,891,791,000.00	47,769,645.04	47,281,769.28	1,624,068,000.00	275,3
Off Airport Parking	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Limousine	5.56	5.47	27,433,620,000.00	27,056,480,000.00	773,039,800.00	762,187,000.00	56,812,474.73	55,963,248.33	630,973,200.00	106,9
OAT Drop-off	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OAT Parking	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OAT Taxi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OAT Transit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 4-4: Output Measure Display Screen for an IAPT Case Study Run



Mode	Air Parties [%]	Air Parties [%]	VMT	VMT	VHT	VHT	Revenue($)	Revenue($)	CO [kg]	NOX
Auto Drop-off	34.1001	33.5087	4.15E+11	4.09E+11	5.61E+09	5.53E+09	3679239.192	3640000.815	9.55E+09	
Rental Car	15.5209	15.5209	9.99E+10	9.99E+10	2.70E+09	2.70E+09	52927832.05	52927832.05	2.30E+09	
Scheduled Airport Bus	2.1295	2.1195	5.21E+10	5.19E+10	4.30E+08	4.28E+08	6525460.062	6496829.405	1.20E+09	
Public Transit Bus	1.7268	1.7045	4.79E+09	4.73E+09	2.09E+08	2.07E+08	764443.4504	754948.0429	1.10E+08	
Charter Bus	0.3222	0.3222	2.14E+09	2.14E+09	0	0	0	0	4.92E+07	
Door-to-Door Van	11.2118	10.9401	5.76E+10	5.62E+10	6.99E+08	6.82E+08	38328310.36	37394653.71	1.33E+09	
Hotel Courtesy Shuttle	4.1353	4.1353	7.03E+09	7.03E+09	1.72E+08	1.72E+08	0	0	1.62E+08	
Taxi	11.5284	11.2984	4.02E+10	3.96E+10	1.20E+09	1.18E+09	70260237.83	69082276.16	9.26E+08	
BART	4.1338	5.4465	3.10E+10	3.92E+10	5.86E+08	7.71E+08	2133188.956	4217296.439	7.13E+08	
Amtrak/Caltrain	0	0	0	0	0	0	0	0	0	
Short term Parking	0	0	0	0	0	0	0	0	0	
Long term Parking	9.6304	9.532599	7.06E+10	7.00E+10	1.91E+09	1.89E+09	47769645.04	47281769.28	1.62E+09	
Off Airport Parking	0	0	0	0	0	0	0	0	0	
Limousine	5.5607	5.4712	2.74E+10	2.71E+10	7.73E+08	7.62E+08	56812474.73	55963248.33	6.31E+08	
OAT Drop-off	0	0	0	0	0	0	0	0	0	
OAT Parking	0	0	0	0	0	0	0	0	0	

Figure 4-5: Output Measures from an IAPT Case Study Run Exported to Excel

The change in mode use across the two scenarios is shown in Table 4-1 and displayed graphically in Figure 4-6. While Figure 4-6 does not add any information to that shown in Table 4-1, it allows the relative changes in the use of the different modes to be more easily appreciated. It can be seen that the use of BART and Caltrain increased from 3.0% of air parties in 2001 to 4.1% in the IAPT results for the 2006 no-build scenario, and 5.4% in the IAPT results for the 2006 BART Extension scenario. However, the actual use of BART and Caltrain in 2006, based on the MTC air passenger survey results, was 10.0%, indicating that the IAPT appears to be significantly under-predicting the increase in the use of BART by air passengers resulting from the opening of the extension to SFO.

Table 4-1: Air Party Mode Use in the Case Study Analysis

Mode	**SFO Actual (2001)** Air Parties (%)	**Predicted No-Build (2006)** Air Parties (%)	**Predicted BART Extension (2006)** Air Parties (%)	**SFO Actual (2006)** Air Parties (%)
Auto Drop-off	35.1	34.1	33.5	29.2
Auto Park (trip duration)	10.3	9.6	9.5	8.1
Rental Car	15.5	15.5	15.5	15.8
Scheduled Airport Bus	5.8	2.1	2.1	1.7
BART/Caltrain	3.0	4.1	5.4	10.0
Public Transit Bus	0.8	1.7	1.7	1.4
Door-to-Door Van	9.9	11.2	10.9	12.1
Taxi	11.4	11.5	11.3	12.4
Limousine	3.7	5.6	5.5	4.6
Hotel Courtesy Shuttle	4.1	4.1	4.1	3.4
Charter Bus	0.3	0.3	0.3	2.3
	100	100	100	100

Note: Highlighted rows are captive modes.

The three modes shown highlighted in blue in Table 4-1 were considered captive modes in the sense that the decision to use those modes was determined by factors other than the relative level of service of the other modes. Those renting cars typically do so to meet their local transportation needs while they are visiting the region, rather than simply for their trip to and from the airport. Since they are renting a car anyway, naturally they use it for their airport access trip. Similarly, users of hotel courtesy shuttles are typically staying in hotels near the airport that provide free transportation to and from the airport, so they would have no reason to use another mode to access the airport, while those using charter bus are usually travelling in an organized group or on a tour that provides bus transportation to the airport as part of their travel arrangements. Therefore the users of these modes in the air passenger survey were excluded from the mode choice model allocation and assumed to continue to use the same mode.

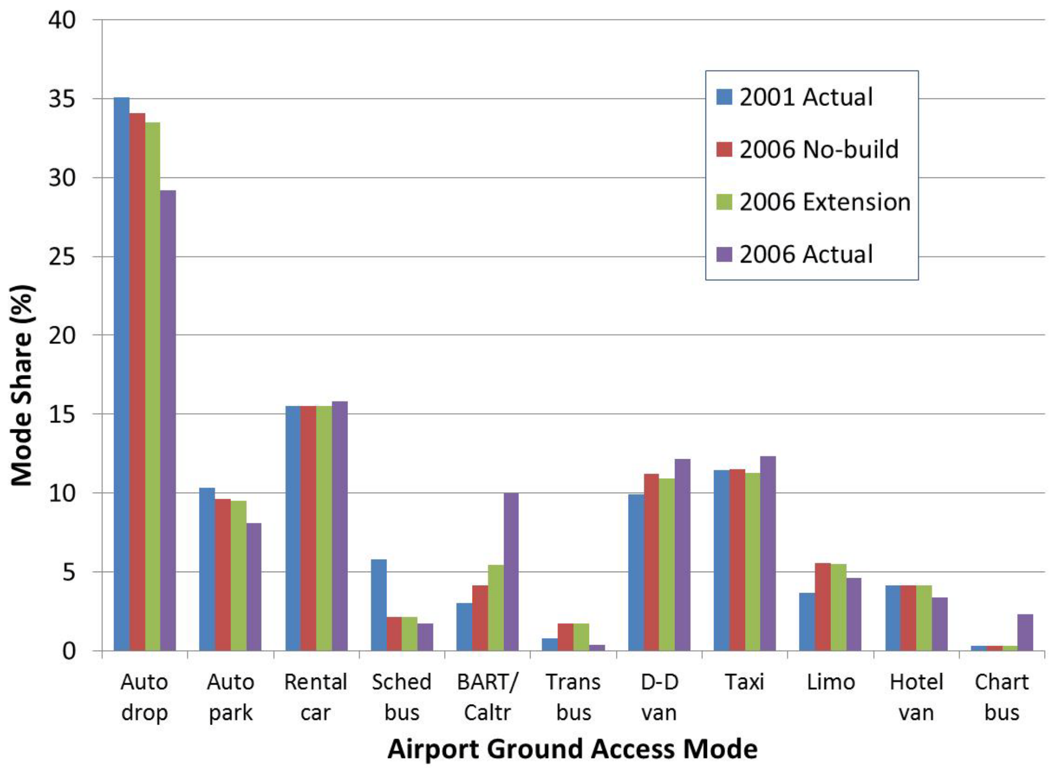


Figure 4-6: Air Party Mode Use in the Case Study Analysis

As expected, the mode share of scheduled airport bus dropped significantly from 2001 to the 2006 under both the no-build and BART Extension scenarios due to the discontinuation of the SFO Airport service. Use of the other public modes increased under the 2006 no-build scenario, while use of private vehicle declined. The decline in private vehicle use is likely to reflect a shift in the composition of the traffic between 2001 and 2006 rather than a result of the discontinuation of SFO Airport service.

The increase in BART and Caltrain use of 1.3% under the BART Extension scenario compared to the no-build scenario resulted in a small reduction in the mode use of all the other non-captive modes (which by definition did not change between the two scenarios). This is a consequence of the mathematical form of the mode choice model, as discussed below, rather than an accurate reflection of how the increase in BART use would be drawn from other modes.

Compared to the actual mode use in 2006, the mode choice model not only under-estimated the use of BART and Caltrain, but also of door-to-door van and taxi, although the under-estimate was not as great. Conversely, it over-estimated the use of private vehicles, scheduled airport bus, public transit bus, and limousine. While the over-estimate of the use of the latter modes is most likely a consequence of under-estimating the magnitude of the shift to BART as a result of the extension, the under-estimate of the use of door-to-door van and taxi is unexpected. The majority of the users of those two modes have trip origins in San Francisco, where the shift to BART might have been expected to be greatest. However, it is possible that this reflects the interaction of two effects: an increase in proportion of visitors with trip origins in San Francisco who may have been less familiar with BART or had baggage that made use of BART inconvenient, and the relative difficulty of accessing BART from many of the hotel districts and residential neighborhoods in San Francisco, which offset the cost advantage of BART. Someone staying in a hotel in San Francisco some distance from the BART stations would be unlikely to take a taxi or ride a transit bus to access BART when the marginal cost of taking a taxi or shared-ride van was fairly small, particularly for an air party of more than one person.

4.4 Discussion and Conclusions

While the case study analysis results show an increase in BART/Caltrain use under the 2006 BART Extension scenario compared to the 2006 no-build scenario of 1.3% of air party trips (from a mode use of 4.1% to a mode use of 5.4%), it appears that this increase is significantly under-estimated compared to the actual mode use in 2006.

This under-estimate could be due to a number of factors, the most important of which are likely to be:

(1) The use of a multinomial logit mode choice model, as currently implemented in the IAPT, has the effect of distributing the trips resulting from the elimination of the SFO Airporter service among the remaining modes in proportion to their mode shares. Thus the majority of these trips would be predicted by the mode choice model to use private vehicles, shared-ride vans, and taxi, rather than BART. However, it seems plausible that air passengers who chose to use the SFO Airporter service were more price-sensitive (since they chose not to use the more expensive shared-ride vans, taxis, or limousines) or they preferred the dependability of a scheduled service. Thus these passengers might be more likely to use BART than the other modes, not less.

(2) The mode choice model estimated on 2001 air party mode use may not adequately reflect the perceived utility of BART service directly into the airport terminal complex. The required transfer to the SamTrans BX bus at the Colma station in 2001 may have had a high perceived disutility not properly reflected in the mode choice model. When the BART mode-specific constant was adjusted to reflect the direct service to SFO in 2006, it was assumed that the effect of the bus link on the mode-specific constant was equivalent to the waiting time and ride time involved, valued at the same disutility per minute as waiting time and travel time on BART. However, it is quite likely that air passengers perceived this link as having a much higher disutility than this, in part due to differences in ride quality between a bus and BART, and in part due to the additional uncertainty of the delay involved in making the connection, or even a lack of awareness of how frequently the bus ran. Even if air passengers knew the headway of the bus, they may have planned on the worst-case assumption that they would just miss a bus and have to wait for the full headway. In contrast, the waiting times for BART connections were highly reliable because of the way that BART scheduled the different lines and the fact that BART trains generally run to schedule.

> There is also the potential factor that air passengers, particularly visitors to the region, may not have been aware that there *was* a bus connection to SFO from Colma station. In 2001 the BART system map did not show the bus connection, so someone not familiar with the system might reasonably have assumed that there was no easy way to get from Colma station to the airport. Even if they decided to use BART to get to San Francisco from the East Bay, they might have chosen to transfer to the SFO Airporter bus at Embarcadero station, where there was an Airporter stop on Market Street next to the station exit, with a direct ride to the airport, mostly on the U.S. 101 freeway. Such air passengers would have been recorded in the air passenger survey as SFO Airporter riders, not BART riders, unless they considered the SFO Airporter service a "shuttle bus from BART" and selected that option for their ground access mode.

It is also possible that the media attention that was given to the construction and opening of the BART extension to SFO and Millbrae caused air travelers to become more aware of the option of taking BART to the airport. This explanation is supported by the fact that BART ridership to the airport steadily increased in the years following the opening of the extension.

In any case, the shortfall in the prediction of BART ridership in 2006 is worth further study in order to better understand the factors behind this. While ridership analysis is commonly performed during the planning for major intermodal projects, including projects to improve airport access, and these ridership estimates necessarily rely on mode choice modeling to some extent, there are relatively few cases in which an *ex-post* analysis has been undertaken after the project has been completed and operating for a few years in order to determine how well the mode choice model predicted the change in mode use that was actually experienced, and the reasons for any discrepancies.

Chapter 5. Demonstration of the IAPT to Potential Users

In order to inform potential users of the IAPT about the existence and capabilities of the tool and to help assess the level of interest in future use of the tool, two demonstration meetings were held at the following locations:

- The Caltrans Division of Research, Innovation, and System Information (DRISI) main office in Sacramento on the afternoon of April 10, 2013
- The Metropolitan Transportation Commission offices at MetroCenter in Oakland on the morning of April 15, 2013

The meeting in Sacramento was primarily intended for Caltrans staff, but also included participants from a consulting firm and the regional Metropolitan Planning Organization. The meeting in the Bay Area included representatives of two of the region's commercial service airports, regional planning agencies, and consulting firms. The Caltrans offices, agencies, and organizations represented at the two meetings are shown in Table 5-1. A webex (online meeting) link was provided at both meetings that allowed participants to view the presentation slides on their own computers as they were being shown in the meeting, and listen to the presenter and ask questions or make comments over a telephone link. Several invitees participated via the online meeting.

A list of potential users of the IAPT was assembled several weeks in advance of the meetings. Key staff members at each organization were contacted to determine their likely availability and the meetings were scheduled to allow as many as possible of those who expressed an interest in attending to participate. Formal invitations were distributed by e-mail two weeks before the meetings and included instructions on how to participate via the online meeting for those who were not able to attend in person.

The meetings provided a demonstration of the functionality of the IAPT and a case study example of its application, presented by the PATH research team, together with an opportunity to discuss potential applications of the tool, availability of the software, and interest in potential future enhancements to the capabilities of the tool. The case study example was based on an analysis of the BART Extension to San Francisco International Airport, described in chapter 5.

Table 5-1: Organizations Participating in the Demonstration Meetings

Sacramento Meeting	Oakland Meeting
Caltrans DRISI Caltrans Division of Aeronautics Caltrans Division of Transportation Planning Sacramento Area Council of Governments	Caltrans DRISI Caltrans Division of Aeronautics Metropolitan Transportation Commission San Francisco Bay Conservation and Development Commission Port of Oakland San Francisco International Airport Cambridge Systematics Fehr & Peers

5.1 Informal Feedback from the Demonstration Meetings

In the course of the demonstrations at the two meetings and in the discussion following the demonstrations, participants raised a number of issues and concerns. These included:

- The influence of the amount of baggage an air party has on ground access mode choice
- Constraints imposed on resident air party ground access mode choice by the need to consider the available egress modes for the return trip
- The ease with which new or revised transportation network travel times, costs, and distances for a specific year can be input into the IAPT
- The need to consider airport employee trips in estimating the use of airport ground access modes or the number of ground access vehicle trips

In addition to comments from those who were able to attend the meetings, valuable feedback was obtained from a former Planning Manager at MTC who had extensive experience with regional airport system planning in the Bay Area and who had served as the Project Manager for the most recent update of the Bay Area Regional Airport System Plan Analysis, based on a review of the presentation slides from the meetings.

5.2 Survey of Potential Users

In order to obtain more detailed feedback after the attendees had an opportunity to reflect on the information that had been presented at the meeting they had attended a questionnaire was distributed to each participant after the meeting by e-mail that solicited their response to several questions. These questions comprised:

- Whether the general functionality of the IAPT appears potentially useful for the respondent's organization
- Which other analysis tools (if any) are used to analyze airport ground access mode choice by the respondent's organization
- Whether the respondent's organization has any airport ground access analysis needs that are not met by the current tools that it is using
- How the IAPT might supplement or enhance the analysis capabilities of the respondent's organization
- The types of analysis that the respondent envisages the IAPT might be used for by his or her organization
- Whether there is any additional functionality that could be added to the IAPT that would be useful to the respondent's organization
- If future enhancements to IAPT would increase its usefulness to the respondent's organization, whether the respondent thinks that the organization might be willing to share in the cost of developing those capabilities

A separate questionnaire was prepared for participants from Caltrans other than DRISI or the Division of Aeronautics that asked a subset of the above questions that addressed whether the IAPT appears potentially useful to the respondent's division or office within Caltrans. The questions include the types of application for which it might be used, how this would supplement or enhance existing analysis capabilities, and whether there is any additional functionality that would be useful to the respondent's division or office if it could be added to the tool.

The questionnaires are attached as Appendix A.

5.2.1 Survey Responses

By the time that this report was finalized, responses to the survey had been received from one Caltrans attendee at the demonstration in Sacramento, and five attendees from the demonstration at MTC, three from the two Bay Area airports, one from MTC, and one from one of the consulting firms.

The respondent from Caltrans felt that the general functionality of the IAPT appeared possibly useful to his organization. He thought that the tool could be used to explore additional opportunities for improving intermodal connectivity at airports in order to reduce the volume of highway traffic generated by airport use and facilitating the ability of airport travelers to sue multi-modal high-occupancy modes. From a planning and operational perspective, he suggested that the tool could help Caltrans optimize the performance of the overall system, at the local as well as the regional geographic levels, by evaluating the benefits of specific intermodal projects as a way to implement the policies and strategies that have been identified at the strategic planning level.

Of the three respondents from the two airports, one definitely felt that the IAPT could be useful to the airport authority, while the other two felt that it could possibly be useful. The respondents from one airport mentioned the use of simulation software for roadway capacity analysis and ground access modeling, while the respondent from the other airport indicated that the airport authority does not have any existing tools to analyze ground access mode choice. One respondent stated that ground access analysis needs were currently being met through the use of consultants, although the IAPT could be helpful to assess project alternatives during early development stages that may not necessitate retaining consultants. The other two respondents identified ground access analysis needs that were not being met by the currently available tools, namely:

- Focused research on specific corridors, market segments, and motivational factors to highlight improvements that would increase the percentage of passengers using shared-ride modes
- Calculation of carbon emissions from specific modes and determination of emission reductions from achieving milestones in shared-ride usage for both passengers and employees
- The effects of replacing connecting buses with a people-mover, changing parking rates, or potential changes to door-to-door van fleets

One respondent suggested that the IAPT would appear to allow the airport to analyze the effects of growth in traffic or potential projects more quickly and accurately than can be done at present. It was also pointed out that with the evolving situation regarding charges for checked baggage on flights and in some cases even carry-on baggage, as well as baggage restrictions on some ground access modes, it would be useful to address the role of baggage in airport ground access mode choice and include this in the IAPT analysis. Potential applications for the IAPT envisaged by the respondents included marketing, analysis of the carbon footprint of airport ground access travel, analysis of the curb space requirements for ground transportation services, and roadway planning and congestion analysis both on and off the airport.

The respondent from MTC felt that the functionality of the IAPT was possibly useful to the agency, since they did not have any existing tools to analyze airport ground access mode choice and would like to be better able to predict air passenger ground access and airport choice. The respondent suggested that the IAPT appeared to have the potential to be integrated with the regional travel model and envisaged that it could be used for predicting air passenger ground access mode choice in regional planning studies. He suggested that there is a need for broader and deeper thinking about what motivates airport ground access mode choice decisions and how these decisions can be better predicted. It would be useful if the ability to model airport choice could be added to the IAPT.

The respondent from one of the consulting firms also felt that the functionality of the IAPT was possibly useful to the firm. The firm currently uses regional travel models developed by metropolitan planning organizations and direct demand models to analyze airport ground access mode choice, together with the use of origin-destination trip data derived from cell phone signals. The respondent felt that the IAPT potentially offered an improvement over other means of estimating modal use for airport ground access trips. He envisaged that the tool could be used for impact analysis for airport expansion projects and evaluating proposed airport ground access investments. It would be very useful if the IAPT could be extended to cover other regions beyond the Bay Area.

The five respondents from organizations other than Caltrans thought that it was possible that their organization might be willing to share in the cost of developing future enhancements to the IAPT that would increase its usefulness to their organizations.

5.3 Conclusions for Future Development Needs

The suggestions for further development of the IAPT fall into two categories. The first covers enhancements that can be made with a fairly modest level of effort that does not require substantive changes to the structure of the IAPT. These include:

- Assigning projected vehicle trips to the highway and local street networks within some distance of the airport (*e.g.* 5 miles). This would require the development of an ancillary data file that would indicate which segments of the highway and local street system would be used by vehicle trips from each TAZ. Then the vehicle trips from that TAZ could be assigned to the relevant segments of the network. The segment assignment file could be extracted from a skim tree of the regional highway and local street network or developed by inspection, since generally it is obvious which route trips from a given TAZ would take to get to the airport.
- Calculating daily and peak month vehicle and transit trips. While the underlying air party data on which the mode use calculations are based are only for the period during which the air passenger survey was performed, the expansion of these results to annual totals assumes that these characteristics and representative of the remainder of the year. Calculating average daily trips is simply a matter of dividing annual totals by the number of days in the year. Calculating peak month trips would require a factor giving the ratio of peak month local air passenger traffic (i.e. those starting or ending their trips at the airport) to annual local air passenger traffic. This could be entered in the IAPT at the same time as the annual growth factor for airport passenger traffic.
- Adding CO_2 emissions to the air quality performance measures. This would simply require incorporation of emission factors that give the CO_2 emissions per vehicle-mile traveled.

The second category of suggestions for additional capabilities involve those that would require significant changes to the IAPT structure or program code, or further research to develop the necessary information or models to implement the suggested capabilities. These include:

- Improvements to the air party airport ground access mode choice model
- Incorporation of airport employee trips in the IAPT
- Provision of the capability to model air passenger airport choice

5.3.1 Improvements to the Air Party Airport Ground Access Mode Choice Model

While the air party ground access mode choice models developed in the course of the project appear to provide a reasonable representation of air passenger ground access mode choice decisions, there are a number of factors that are likely to influence air passenger ground access mode choice that are not currently included in the model, in a particular:

- The role of baggage in air passengers' mode choice decisions
- The number of transfers involved in using scheduled public transportation modes, over and above the waiting time involved
- Constraints imposed by the availability or convenience of different modes for the egress trip from the airport to the final destination in the region

It seems likely that resident travelers consider the factors that will affect the round trip to and from the airport from their trip origin. For visitors, their ground destination would be considered as the main factor. When making their airport access mode choice decisions, there has been no known work to develop an airport ground access/egress mode choice model on a round-trip basis. This is largely because the principal source of data on air passenger ground access/egress mode use consists of air passenger surveys performed at the airport, which naturally focus on how the passengers got *to* the airport and rarely ask about egress travel *from* the airport. Furthermore, apart from those parking a vehicle at the airport for the duration of their trip (for whom the egress mode is obviously predetermined), resident air passengers departing on a trip may not yet have made a decision on how to return home (or another destination in the region) at the end of their air trip.

The availability or convenience of different egress modes is likely to vary considerably by the time of day of the return trip. Those returning late in the evening may arrive after public transportation services have stopped operating, or may be concerned that any flight delays may result in this situation. On the other hand, those departing or arriving during the day may not have family members or friends available to drop them off or pick them up if those people are working. While the availability of someone to drop off or pick up an air party at the airport or public transportation stop or station will vary from air party to air party, there may be systematic patterns by time of day or different air party characteristics that could be incorporated in a mode choice model.

Beyond these specific issues, there are at least three broader issues affecting the reliability of airport ground access mode choice models that are not well understood and deserving of further research:

- The large values of the mode-specific constants that are typically found in airport ground access mode choice models suggest that there are aspects to the perceived utility of different modes that are not explicitly incorporated in the model variables. These are likely to include the availability of information on different modes, as well as the perceived reliability of different modes. Since at least some of these factors are potentially changeable, or may be perceived differently for a proposed airport access improvement project, not explicitly including these factors in the model prevents it from appropriately accounting for changes in the factors when evaluating specific projects.

- Small changes in travel time may be perceived differently from larger changes. This can become important in evaluating projects that provide a relatively small change in total travel time. Model coefficients for travel time that have been estimated on relatively large differences in travel time between different modes may not be appropriate for estimating the effect of relatively small changes in travel time within a mode.

- Mode choice models that have been estimated on data from a specific point in time may not adequately reflect air traveler behavior in the future. This could arise from at least two reasons. The first is that traveler behavior may change over time. For example, traveler perceptions of the reliability of different modes may change, or traveler attitudes to using public transportation may change. The second reason is that the mode choice model may not have been correctly specified, so that the importance assigned to different factors by the estimated model coefficients (so that the model fits the data) may be distorted from the true effect of those factors on air passenger mode choice decisions. Thus if the relative values of those factors change in the future (for example if costs change differently from travel times), the model will not correctly represent the effect of those changes on air passenger ground access mode use.

Since the ability to model air passenger airport ground access mode choice is central to any evaluation of projects designed to improve access to airports, improvements in the accuracy and reliability of airport ground access mode choice models will in turn improve the accuracy and reliability of the evaluation of such projects, with potentially very large cost savings through ensuring that those projects are designed appropriately for the type and level of use that they will attract and through avoiding costly mistakes from over-estimating the use or ridership that they will attract. Therefore there is an ongoing need for further research into the most appropriate specification and estimation of these models.

5.3.2 Incorporate Airport Employee Trips

In addition to air passenger trips, airport workers generate a significant number of ground access vehicle trips, as well as ridership on public modes. In analyzing airport ground access mode use, particularly the feasibility and effectiveness of strategies to improve intermodal access to airports, it is obviously desirable to include access trips by airport workers (whether employed by the airport itself or one of the many organizations that operate at the airport). Rather than perform the calculation of these trips externally to the IAPT and combining the results with the output of the IAPT, it would be desirable for the IAPT to model airport employee trips as well as air passenger trips. Since airport employees also make airport ground access mode choice decisions (although these decisions are most likely influenced by different factors from air passenger decisions), the basic structure of the IAPT can be expanded to include modeling airport employee ground access trips.

This would require the capability to input data on airport employees, in the same way that the air passenger data (AirPax) file provides data on air party characteristics. These data would need to include the home location and the typical shift pattern worked, including days and times. Where shift patterns for a given employee vary from week to week, it would be sufficient to collect data for a representative week and assume that a similar shift patterns occur in other weeks, although they may be worked by different individual employees.

It would also be necessary to develop an airport employee ground access mode choice model. There has been little work done on modeling airport employee journey-to-work mode choice, as noted by Gosling (2008), so this aspect could require a significant research effort.

The IAPT would need modification to the graphical user interface to provide the capability to define the relevant data files for airport employees, define the airport employee mode choice model, and display the analysis results for air passengers and airport employees separately, as well as the combined mode use and vehicle trips.

5.3.3 Provide the Capability to Model Airport Choice

The current version of the IAPT does not have the capability to model airport choice, although it is recognized that this capability could be very useful for airport system planning studies, or even for individual airports that are interested in analyzing how changes in air service or airport ground access could affect the share of the regional market that they attract. Since the current version of the IAPT includes an airport ground access mode choice model that predicts the airport access mode choice of a defined sample of air parties, it would not be a major change to expand the choice model to include airport choice as well as airport access mode choice. Indeed, since airport accessibility is clearly an important factor in airport choice, airport choice models typically have a nested structure in which the lower levels of the nest predict airport access mode choice. However, to implement such a model in the IAPT would require a more flexible way to specify the structure and coefficients of the choice model than the current multinomial logit choice model incorporated in the IAPT. Aside from allowing the IAPT to model airport choice, such an enhancement would be desirable even for modeling airport access mode choice at a single airport, since it would allow a more flexible (and potentially superior) representation of the access mode choice process.

In addition to the relative accessibility of each airport in the choice set, airport choice is also influenced by the air service available at the alternative airports. Therefore incorporating an airport choice modeling capability in the IAPT would require adding the capability to input the air service characteristics (such as average fare and service frequency) in each destination market at each of the airports. Although this is fairly straightforward in the case of historical data, and can be easily handled by providing the capability to define an air service file that includes air service variables for each market in the same way as the ground access transportation service data files, there are a number of implementation issues that will need to be addressed. These include:

- How to predict future values of the air service variables. Since these are likely to change over time, it may be necessary to define a separate air service data file for each year. While the generation of the appropriate values of the future air service variables can be performed outside the IAPT and simply input as data, this ignores the fact that these values may depend on the allocation of demand in a given market to the various airports serving the region, and this may not be exogenous to the IAPT analysis. It would be both simpler for the users and conceptually more valid to have the future values of the air service variables generated by the IAPT as part of the airport choice modeling process, reflecting the underlying airline economic considerations. However, this would significantly complicate the required analysis within the IAPT, although make the tool considerably more useful.
- In reality most air travelers make not only airport choices but also airline choices. In cases where the market to the traveler's destination is served by different airlines from each of the alternative airports, the choice of airline may predetermine the choice of airport (or *vice versa*). To the extent that different airlines have different air service characteristics in the same market (*e.g.* different frequencies or average fares), ignoring differences in airline service may lead to an inadequate representation of the airport choice process.
- While it is common to use average air fares in a given market as the relevant price variable in modeling airport choice, this overlooks the reality that when air travelers make a reservation, they base their flight choice decisions on the fares available at each airport at the time, which may be significantly different from the average fare determined from the data on fares paid (and hence the average fare) reported by each airline for that market. Unfortunately, most air passenger surveys neither ask about the air fare paid by the respondent nor how far in advance of the trip the reservation was made.

- In many markets, air travelers have a choice between direct (nonstop and multi-stop) flights and connecting through one or more intermediate hubs. In many cases, the choice of airline involves a choice between direct and connecting service, as well as which hub to connect at. While it generally the case that air travelers prefer nonstop service where this is available, and multi-stop service to connecting flights, differences in frequency and available fare between different routes can influence the choice of flight and hence airport.

Thus modeling airport choice is significantly more complicated than modeling airport ground access mode choice (which is itself complicated enough) and therefore developing a suitable airport choice model to incorporate in the IAPT would require a significant research effort.

Chapter 6. Concluding Remarks and Future Work

6.1 Concluding Remarks

The IAPT provides a tool for the quantitative evaluation of projects related to intermodal airport ground access planning. The current phase (Phase II) of the project has been focusing on functionality development and enhancement of the IAPT. A large effort has been spent on code development using Microsoft Visual Studio, revising the data tables to provide more generic calculations, updating the mode choice models using air passenger survey data from the MTC 2006 Airline Passenger Survey, and preparation of a demonstration to potential users. The IAPT program code development tasks included:

- To make global parameters consistent for intermediate parameter and performance parameter calculations
- To make the calculations for each mode more generic to accommodate the differences between the characteristics of up to 20 different modes, which should be adequate for most situations in which the IAPT is applied
- To simplify the programming of parameter calculations
- To make the GUI more user-friendly by permanently saving the data if the user edits data tables from the GUI
- To allow the user to save performance parameters and even intermediate parameters in data files for further analysis

Demonstrations of the IAPT were given to potential users from Caltrans, airport authorities, regional planning agencies, and consulting firms at the Caltrans Division of Research, Innovation and System Information headquarters in Sacramento and Metropolitan Transportation Commission offices in Oakland, which formed a critical milestone of this project.

6.2 Future Research Needs

Although the current versions of the IAPT could be used to analyze projects related to airport ground access planning in the San Francisco Bay Area at the three major airports: SFO, OAK and SJC, it is still a prototype tool. Among the issues that remain to be addressed are:

- How to modify the IAPT for use in other regions such as Southern California

- How to model competition between airports, which determines the distribution of air travel demand between airports serving a region
- How to address access/egress trips of airport employees
- What would be involved in modifying the tool to include air freight movement in planning?

It is proposed that the following topics be considered for future research in this area.

6.2.1 Developing a Generic Mode Choice Model Approach

The mode choice model is the core of the performance parameter calculation of the IAPT. This model is estimated with air passenger data specific to a given airport. Obviously, the mode use at each airport needs to be modeled separately. However, might it be possible to develop a generic mode choice model that can be tailored to apply at different airports rather than having to develop a separate model for each airport? The development of a generic mode choice modeling approach would greatly facilitate adapting the IAPT to other regions than the Bay Area although the necessary research to explore the feasibility of this approach has not yet been conducted.

6.2.2 Development of Air Passenger Airport Choice Models

The current research project does not address the role of the airport ground access system in air passenger choice of airports. However, improvements in intermodal connectivity could influence which airports travelers choose to use, and in fact represent a potential strategy to influence this choice. Improved connections to secondary airports in a multi-airport region could encourage more travelers to use those airports and in turn encourage airlines to expand service at those airports. There have been a number of past studies that have developed airport choice models for different regions, including the San Francisco Bay Area, and for the past few years there has been a study in progress to develop a regional airport demand model for the Southern California region that is planned to include an airport choice component as well as an airport ground access mode choice component. However, many of the past models have significant weaknesses, including an inability to adequately reflect the influence of airfare differences in airport choice and limited representation of the role of airport ground access in the choice process. In particular, the representation of the airport ground access system does not allow a reliable analysis of the contribution of improved intermodal connectivity to the airport choice process. Furthermore, many of the models were developed using air passenger survey data that are now significantly out of date or for regions outside California. Potential future research would review recent developments in modeling air passenger airport choice, including the status of the model development activities for the Southern California region, and develop an airport choice model for the San Francisco Bay Area based on the airport ground access modeling capabilities being developed in the current project.

6.2.3 Airport Employee Access Mode Choice

The current research has focused on air passenger travel. However airport access travel by airport employees forms another important component of airport ground access travel. While surveys have been performed at a number of airports of employee journey to work travel mode, there has been no known attempts to develop specific access mode choice models for this class of traveler. Typically for airport ground transportation planning studies, standard urban travel journey-to-work mode choice models are used for airport employees. However, airport employees have unique constraints and travel patterns, including shift work and multi-day duty periods in the case of airline flight and cabin crew. The research is needed to assemble data on airport employee mode use from prior surveys, develop airport employee mode choice models, and evaluate the reliability and transferability of these models by using them to predict airport employee mode choice at other airports for which suitable data are available, from which the actual mode use can be compared to that predicted by the model.

6.2.3 Air Cargo Truck Activity at Airports

The number of truck trips generated by airports depends on the weight of air cargo handled at the airport as well as the presence at the airport of cargo handling facilities, such as regional sorting centers. However, the relationship between the weight of air cargo handled at the airport and the number of truck trips generated by the cargo handling activities is not well understood. There are also no readily available models to predict the regional origins and destinations of the truck trips generated by the airport. The research is needed to review the available data on air cargo truck movements and previous studies on air cargo activity and truck trips at airports, identify gaps in the available information, and develop a research plan to assemble the necessary data to better understand the volume and pattern of truck traffic generated by air cargo activity.

References

Freeman, Dennis, Wenbin Wei, and Geoffrey D. Gosling, *Case Study Report: San Francisco International Airport BART Extension*, Working Paper, Mineta Transportation Institute, San José State University, San José, California, May 2012.

Gosling, Geoffrey D., *Airport Ground Access Mode Choice Models*, Airport Cooperative Research Program Synthesis 5, Transportation Research Board, Washington, D.C., 2008.

JD Franz Research, Inc., *2006 Airline Passenger Survey: Oakland International Airport and San Francisco International Airport*, Final Report, Prepared for the Metropolitan Transportation Commission, Oakland, California, July 2008.

Lu, Xiao-Yun, Geoffrey D. Gosling, Avi Ceder, Steven Tung, Kristin Tsao, Steven Shladover, Jing Xiong, and Sangwon Yoon, *A Combined Quantitative and Qualitative Approach to Planning for Improved Intermodal Connectivity at California Airports*, Final Report on Task Order 6406, California PATH Research Report UCB-ITS-PRR-2009-27, California Partners for Advanced Transit and Highways, Institute of Transportation Studies, University of California, Berkeley, April 2009.

Appendix: Questionnaires for Surveys of Participants at IAPT Demonstrations to Potential Users

Intermodal Airport Ground Access Planning Tool (IAPT)

Division of Research, Innovation, and System Information (DRISI)
Caltrans

Questionnaire for Potential Users

April 2013

Thank you for participating in the recent demonstrations of the Intermodal Airport Ground Access Planning Tool (IAPT) at the Division of Research, Innovation, and System Information in Sacramento on April 10 or the Metropolitan Transportation Commission on April 15.

Caltrans would like to get your feedback on the information presented in the demonstrations and in particular how you envisage your organization may be able to take advantage of the tool. We would appreciate your response to the following questions. You can enter your responses by clicking the check boxes or entering text where indicated, save the file, and either return it by e-mail or print it and return it by fax or mail, as indicated at the end of the questionnaire.

Name: Click here to enter text.

Organization: Click here to enter text.

1. Does the general functionality of the IAPT appear to be potentially useful to your organization?

   Definitely ☐ Possibly ☐ Unlikely ☐

2. Does your organization currently use other tools to analyze airport ground access mode choice?

   No ☐ Yes ☐ (Please describe)

   Click here to enter text.

3. Does your organization have any airport ground access analysis needs that are not met by your current tools (if any)?

   No ☐ Yes ☐ (Please describe)

   Click here to enter text.

If you do not feel that the IAPT would be potentially useful to your organization, please skip the remaining questions.

4. If you feel that the IAPT would be potentially useful to your organization, how would the IAPT supplement or enhance your existing analysis capabilities?

   Click here to enter text.

5. Based on the information provided in the recent IAPT presentation, what types of analysis do you envisage that your organization could use the IAPT for?

   Click here to enter text.

6. Based on the information provided in the recent IAPT presentation, does it appear that there is additional functionality that would be useful to your organization if it could be added to the tool?

   No ☐ Not Sure ☐ Yes ☐ (Please describe)

   Click here to enter text.

   If No, please skip the next question.

7. If future enhancements to the IAPT would increase its usefulness to your organization, do you think that your organization might be willing to share in the cost of developing those capabilities?

   Yes ☐ Possibly ☐ Unlikely ☐

Thank you for your interest in the IAPT and your time responding to this questionnaire

Please return the questionnaire to:

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Intermodal Airport Ground Access Planning Tool (IAPT)

Division of Research, Innovation, and System Information (DRISI)
Caltrans

Questionnaire for Potential Caltrans Users

April 2013

Thank you for participating in the recent demonstrations of the Intermodal Airport Ground Access Planning Tool (IAPT) at the Division of Research, Innovation, and System Information in Sacramento on April 10 or the Metropolitan Transportation Commission on April 15.

DRISI would like to get your feedback on the information presented in the demonstrations and in particular how you envisage your organization may be able to take advantage of the tool. We would appreciate your response to the following questions. You can enter your responses by clicking the check boxes or entering text where indicated, save the file, and either return it by e-mail or print it and return it by fax or mail, as indicated at the end of the questionnaire.

Name: Click here to enter text.

Division/Office: Click here to enter text.

8. Does the general functionality of the IAPT appear to be potentially useful to your organization?

   Definitely ☐ Possibly ☐ Unlikely ☐

9. For what types of application might your organization be able to use the IAPT?

   Click here to enter text.

If you do not feel that the IAPT would be potentially useful to your organization, please skip the remaining questions.

10. If you feel that the IAPT would be potentially useful to your organization, how would the IAPT supplement or enhance your existing analysis capabilities?

    Click here to enter text.

11. Based on the information provided in the recent IAPT presentation, does it appear that there is additional functionality that would be useful to your organization if it could be added to the tool?

    No ☐ Not Sure ☐ Yes ☐ (Please describe)

    Click here to enter text.

Thank you for your interest in the IAPT and your time responding to this questionnaire

Please return the questionnaire to:

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